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The “hidden” Prehistory of European Research Networking

Or

“The sad saga of the obscurantism of some European networking leaders and their influence on European Research Networks”

Olivier H. Martin[1]

Preface

The two last decades of the twentieth century brought about a revolution in computing and telecommunication all over the world. From scattered small test projects that connected a few computers the Internet emerged as a new information and communication infrastructure. During this period, networks evolved from using 9.6 Kb/s links to using 2.5 Gb/s links, an incredible increase by a factor of 250,000.

Email and Web search are now so ubiquitous that *Googling* has become a verb. Few businesses can run without a Web strategy and social structures like YouTube, Facebook and Twitter are part of the daily life of a large percentage of the world population.

Olivier Martin has focused on development in Europe and has described how Universities and Research Institutions led this revolution. In the process there were choices to be taken and the developers and policy makers in Europe were basically in two camps: those who backed *de jure* standards and the OSI development versus those who initially used *ad hoc* solutions and next *de facto* standards for IP. We now know that the latter group prevailed but that was certainly not obvious in the first years and the arguments and fighting were fierce.

The telecommunication monopolies certainly did not make the development easier. On the other hand, when telecommunication liberalization came in the EU an impressive expansion in capacity and user numbers took off.

Ideally, the history of war or competition should not be written by one of the participants. On the other hand Oliver Martin, being part of the development in the whole period, can provide a lot of information as well as his personal assessment of the persons involved. And, as you will see in the literature list, the other party has already written their version of the story.

In addition to writing history, Olivier Martin gives some thought to future developments and, among other things, raises the question whether it will always be optimal to have a special computer network for universities and research institutions. After all, they do not have a special postal service or a special telephony service.

Frode Greisen

[1] Olivier.Martin@ictconsulting.ch

Abstract

The main purpose of this article, that mostly covers the period 1984-1993, is about the history of European Research Networking. In particular, this article strives to throw some light on some lesser known, sometimes forgotten, aspects of the European Research Networking history, as the EARN and EASInet initiatives from IBM but also DEC (EARN/OSI) thanks to which operational pan-European networks were built during the period 1984-1990 thus allowing the starting of operational European academic and research networking services in a very effective and swift manner.

A secondary purpose of this article is to make a critical assessment of the political and technical achievements of the European NRENs and especially those of DANTE, the company setup by these same NRENs to build and operate a pan-European backbone interconnecting their national networking infrastructures as well as establishing international connections to other NRENs worldwide.

Key words: BITNET, CCIRN, DANTE, DECNET, EAN, Ebone, ECFA, EARN, EUnet, EASInet, GÉANT, GIBN, HEPnet, IBM, INTERNET, JANET, NSFNET, RARE, RIPE, SNA, TERENA, USENET, X.25, X.400.

Disclaimer

Although the facts reported in this article occurred while I was in the Communication Systems (CS) group at CERN, the opinions expressed herein, which are sometimes purposely controversial, are mine; therefore, despite my former affiliation with CERN, these do not, by any means, reflect the past and/or the current position of CERN. In addition, as I have lost access to my archives since my retirement from CERN in 2006, the facts reported in this article are the memories I have of that time and are therefore bound to contain inadvertent errors. In addition, like any other human being, I may have some technical as well as political biases that I documented in chapter 16.1 "Am I neutral?"

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1 Introduction

The main purpose of this article, that mostly covers the period 1980-1999, is about the history of European Research Networking.

Having been a witness as well as an actor in the establishment of European Research Networks during the 1984-1999 periods, I believe that relating the facts as I saw them happening could be a valuable contribution to history, instead of the *self-complacent* stories that have now become commonplace; indeed, I do not believe that political correctness or, even worse, sheer *propaganda* is a proper way to write history.

Therefore, this article attempts to throw some light on some lesser known, sometimes hidden, sometimes forgotten, aspects of the European Research Networking history, in particular, I believe that it is indispensable to do justice to initiatives from IBM (EARN [1], EASInet [2]) and DEC (EARN/OSI) through which operational pan-European networks have been launched during the period 1984-1990. Indeed, networking was then still in its *infancy* and the high related expenditures were difficult to justify for new services whose *strategic* importance still needed to be widely recognized. Therefore, the seed-funding from mainly IBM but also from DEC had a tremendous impact, allowing the starting of operational European academic and research networking services in a very effective manner.

Last but not least, I want to take this opportunity to make a critical assessment of the political and technical achievements of the European NRENs[2] and especially those of DANTE[3] [3], the commercial company setup by these same NRENs to build and operate a pan-European backbone interconnecting their national networking infrastructures as well as establishing international connections to other NRENs worldwide.

2 Europe's pre-Internet Computing and Networking Situation

There is no lack of information about this fascinating period which, as stated by John Day [4], an Internet pioneers, in a private email message: "*Though it may be uncomfortable for some people, the politics of the early networking are far more interesting and not what most people think".*

Data networks did not start with the Internet in the late 1980s, however the use of data networks was only prevalent in specific communities (e.g., large multinational corporations, mission oriented communities (e.g. Space, HEP, Magnetic Fusion); this being said, networks in its wider sense have been pervasive in the 20th century, water, telephone, electricity, radio, TV, roads, railways, sewers, etc., therefore many efforts were spent towards reusing existing networks (e.g. ADSL/Telephony) rather than building new expensive ones, e.g. FTTx[4] [5].

The pre-Internet period was therefore extremely challenging with a diversity of:

1. Networking technology, usually proprietary solutions (IBM's NJE[5], SNA[6] and RSCS[7], DECnet, Novell) but also FIDOnet, UUCP, etc.

[2] National Research and Education Networks
[3] Delivery of Advanced Network Technology to Europe
[4] Fiber to the x
[5] Network Job Entry
[6] System Network Architecture
[7] Remote Spooling Communication Subsystem

2. Mail addresses and file transfer protocols, hence the need for translators/gateways in order to interwork, in turn creating electronic mail loops, long communication delays, poor reliability, etc. SPAM [6] only came later.

In short, we now live in a kind of *dream networking world* where Internet access is nearly ubiquitous and *Internetworking* has become so simple, thanks to the use of sophisticated search engines like Google and Web browsers [7], so that few people are even aware of the existence of an underlying network. The only significant problem left, as far as users are concerned, is Quality of Service, especially when watching live audio/video streams.

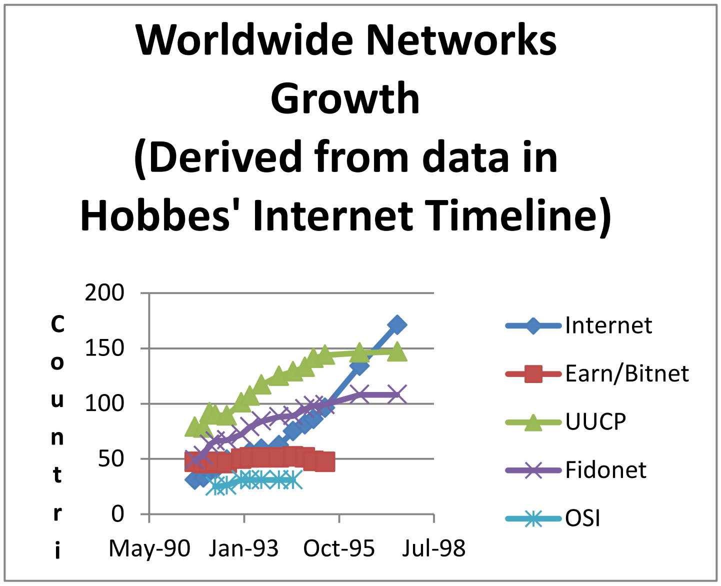

Figure 1 Worldwide Network Growth

The enclosed chart that was extracted from Hobbes' Internet Timeline by Robert Zakon[8] [8] shows very well the exponential growth of the Internet from 1990, the corresponding stagnation and finally the demise of EARN/BITNET in 1995, the *ephemeral* emergence of OSI[9] [9][10] in a few countries and the lasting existence of both Fidonet and UUCP through the 1990s.

I found the following three documents of particular interest:

1. "*Notable computer networks*" [11] by John S. Quarterman [12] and Josiah C. Hoskins (1986)
2. "*European International Academic Networking: A 20 years Perspective"* [13] by Peter T. Kirstein (UCL)
3. Exploring the Internet: "*A Technical Travelogue"* [14] by Carl Malamud [15]

2.1 "*Notable computer networks*"

The network taxonomy used is very unusual as it distinguishes "*Research Networks"* (ARPANET), "*Company Networks*" (Xerox, DEC, IBM, AT&T), "*Cooperative Networks*" (BITNET/EARN, UUCP/USENET), "*Commercial Networks*" (e.g. COMPUSERVE [16], TYMNET [17], TELENET [18], Telephone Networks) and "*Meta-Networks*", i.e. networks attempting to assemble dissimilar networks (in 1986, CSNET was the only operational example, however, NSFNET and RARE are also quoted).

[8] Internet evangelist, MITRE Corporation
[9] Open Systems Interconnection

The article as a whole is extremely informative as it provides information about networks that have long been forgotten already! Figure 2 provides the time lines for development of "*Notable Computer Networks"* during the period 1969 through 1986. Though there may still be some isolated use of DECNET, UUCP and RSCS, it is interesting to note that, off the 10 families of networks considered, only the ARPANET branch survived through NSFnet and what is now known as "*The Internet*", which gives some credibility to Larry Landweber's *very bold* conclusion in his keynote speech [19] at the Euroview 2010 conference titled "*The Future (Inter)Network: challenges and paradigms*" as very realistic: "*in the future, i.e. beyond 2030, world, IP, much like SNA, X.25, etc., will be largely forgotten*". What Larry means, of course, is that the successor of IP will be completely different from IPv4, in other words, he implies that IPv6 may not make it which may or may not turn out to be true. In any case, few people know about IP as such, the only thing they know about is "The Internet" and the Internet will, for sure, survive, as the underlying protocol only matters to the only the Internet architects.

The CYCLADES [20] packet switching network deserves special mention as it is generally considered as having had a profound influence on the design of the second generation ARPANET by moving the reliability of data from the network to the hosts and thus introducing packet numbering and windowing concepts. It is not widely known that there have been two versions of ARPANET, the 1st one based on NCP and IMP, the 2nd one without IMPs and based on TCP/IP, a "*fatal*" mistake according to John Day as "*when NCP was shut down, the internetwork layer got lost and the Internet became a concatenation of IP networks with an end to end transport layer on top.*"

The CYCLADES had influence on the 2nd generation ARPANET that marked the start of the Internet. Further explanations can be found in chapter 19.2.2. CYCLADES was designed by IRIA the predecessor of INRIA [21] under the direction of Louis Pouzin [22] and was considered as a "*renegade*" by the supporters of "*circuit oriented networks*". A continued collaboration between the ARPANET and CYCLADES teams could have changed the course of European Research Networking with increased cooperation between Europe and the USA; unfortunately it did not happen! However, the concepts of CYCLADES and CIGALE, the packet layer, were used in the EIN[10] project [23] [24] led by Derek Barber (NPL[11]), a colleague of Donald Davies that is generally considered as one the three inventors of packet switching.

Although the contributions of Louis Pouzin to the Internet have long been underestimated or even ignored, this unfair situation was corrected in 1997 where the SIGCOMM Award [25] was presented jointly to Jonathan B. Postel of the USC ISI[12], and to Louis Pouzin[13].

During the FIA[14] meeting [26] in Budapest in May 2011, John Day gave an excellent keynote speech titled "*Back to the Future: A Journey from Science to Craft . . . and Back?*" [27], where he relates the ARPANET and CYCLADES work.

Last but not least, the respective roles of Louis Pouzin, Rémi Després and Hubert Zimmermann is clarified by Vint Cerf [28] in Nethistory.info [29]: "*On the design of TCP/IP*", whose excerpts can be found in chapter 19.2.3.1. In particular, the position of Louis Pouzin regarding the

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[10] European Informatics Network

[11] National Physics Laboratory

[12] University of Southern California Information Sciences Institute

[13] "*Louis Pouzin is best known for his work as the inventor and advocate of "Datagrams", later extended and renamed connectionless communication, as the basic mode for the transmission of packets in a network. His ideas in this area paved the way for a new thread of thought on how to manage resources in networks, resulting in several major innovations, including today's ATM networks. During the 1970s, Louis was a strong focal point for cooperation between research and industry, between Europe and North America, and between the computer community, the datacom community and the more traditional telecommunications community.*"

[14] Future Internet Assembly

implementation of virtual circuits/connections at the transport rather than at the network layer is unambiguously described.

There are also three excellent history articles by Valérie Schafer that are apparently not available in English but can, however, be translated from French to English by Google, about:

1.1. The move from mainframes with locally or remotely connected terminals to general purpose networks [30]

1.2. The EIN project [31]; there are *troubling* similarities between EIN and EARN with respect to the position of the CEPT, namely: "*While CEPT recognizes the value and importance of the EIN experiment, it notes that this network should not normally be allowed to grow or even be kept in service, as a private network, beyond the experimental phase of five years under the agreement and the completion of which should normally take place in February 1978.* Also, members of CEPT intend *"to limit the experimental authorization of the circuits designed to provide interconnection between these centers.*"

     In other words, the PTTs firmly intended to keep their monopoly on transmission lines.

1.3. The EURONET project [32] marked the end of the EIN project and the victory of the PTTs with the advent of X.25 [33] based, i.e. virtual circuits, networks.

2.2 "European International Academic Networking: A 20 years Perspective"

Although the article by P. Kirstein is really excellent and provides a wealth of useful references, it is a little too focused on UCL and the UK, but this article is also very focused on CERN as it is preferable to relate the facts to which we have participated!

As rightly pointed out by P. Kirstein, there was a continuous dilemma on both sides of the Atlantic on the "*vexing question*" of "*Networks for researchers versus networks for researchers in networks*". What happened with European NRENs is clearly the former, namely the provision of Internet services with a particular focus on interconnecting Universities[15], while "*the USA always made a fairly sharp separation between academic work in network research and provision of network facilities. This is the reason that DARPA was happy to support SATNET, Packet Radio Net and the Internet in its early stages but then to withdraw from these in favor of NSF who commissioned NSFNET, which was then transitioned into the private sector".* However, as most researchers needed much higher performance facilities than the commercial Internet was then able to provide, the Abilene [34] backbone was deployed by Internet2 "*in order to enable the higher-speed applications to run while also serving as a testbed for the deployment of IPv6, QoS*[16]*, Multicast and many other important functions."*

The above article contains a lot of information about the US connections to Europe, in particular the ARPANET connections through SATNET, as well as the UK networking scene (SERCNET, JANET [130], etc.), other satellite projects such as STELLA [35] and SILK [36], the role of the European Commission (EC) through the various, ACTS[17] [37], COST [38], ESPRIT[18]

[15] Nonetheless, the NRENs feeling was that they had to also get involved in research for networks because of the lack of standards and products but they would claim that the object of the exercise was for the benefit of users. But EARN would demonstrate that the benefit of the users can be trumped by politics, namely the provision of network services with a particular focus on interconnecting Universities

[16] Quality of Service

[17] Advanced Communications and Technology

[18] EU's Information Technology Programme

[39] [40], EUMEDIS [41], PARADISE [42], PHARE [43] [44], RACE[19], SEEREN [45], TEIN[20], 6NET [46] programs and projects.

As noted by P. Kirstein, it is particularly impressive to observe that over a 25 years period the bandwidth increased from 9.6 Kb/s in the early 1980 to 10Gb/s in the mid-2000, i.e. a factor 1,000,000 in less than 25 years!

2.3 Exploring the Internet: "*A Technical Travelogue"*

The narrative style of this book whose electronic copies are freely available is most informative about the atmosphere of the early 1990s. In the preface to the electronic version Carl Malamud starts by writing that "*I didn't censor myself, and wrote a fairly straightforward narrative. I did leave one thing out, though. When I was in Switzerland, I stopped by CERN to learn about X.400 mail gateways, a concept that has become as relevant to today's Internet as the rest of OSI. Brian Carpenter suggested that I stop by a lab and look at a little program running on a NeXT computer. There, I met Tim Berners-Lee who showed me his not-yet-announced concoction, the World Wide Web. Interesting little program, I thought to myself, but not very relevant. My thought, as I walked out of the office was "it won't scale," so I left it out of this book. Every time I hear a pundit with a definite opinion, I remember that experience. We are all still trying to understand the implications of the Internet and anybody who has the answers is asking the wrong questions.*"

The "*Travelogue*" is organized in three successive "Rounds", themselves divided according to the chronological order of the visited cities. I particularly recommend the Amsterdam sections in Round one, which gives some details about the creation of Ebone, and Round two (11th RIPE meeting" where it is written that RIPE "*was formed as a sort of anti-organization, a reaction to the total ineffectiveness of other groups in setting up a pan-European Internet. At the time RIPE was formed, there had been several years of thrashing while people tried to figure out how to make OSI into something real*". But the Amsterdam [47], Berlin, Bonn [48], Geneva and Utrecht sections are well worth reading too; the Geneva sections deal mostly with repeated contacts with Tony Rutkowski (ITU) about standards but also a visit at CERN.

Overall, this book is very refreshing[21] and I was amazed to find that many of the observations made matched my own, despite the fact that I came across that book after having written this article!

The conversation with Klaus Birkenbihl about EARN, EASInet but also AGFnet and WIN is particularly interesting: "*This private network, AGFnet, was not OSI (in fact it was SNA [50]), but at least it contained X.25, the "pathway to OSI," to make it politically palatable to the bureaucracy. What AGFnet did do was prod DFN into action[22], which resulted in a national X.25 network called Wissenschaftsnetz (WIN or "science network")"*

2.4 The European Networking scene

In the 1980-1988 periods, there was a lack of open networking options; indeed, apart from CCITT standards X.25 [33], there was a lack of international standards at layer 3 and above. However, telephony and data transmission standards, such as SONET[23]/SDH[24] [49], were widely used as the need to offer global services was obvious. Therefore, the norm rather than the

[19] Research for Advanced Communications in Europe
[20] Trans-Eurasia Information Network
[21] CERN, an EASInet site, was sometimes referred to as the Center for European Research Networking.
[22] I made a similar comment about the influence of EARN on the creation of RARE elsewhere in this article
[23] Synchronous Optical NETworking
[24] Synchronous Digital Hierarchy

exception was to use proprietary protocols. IBM with SNA [50] and/or RSCS [51], DEC[25] [52] with DECNET [53] were then very popular and were sort of "*de facto*" industry standards with emulation software [54] available on most hardware platforms. However, there was no lack of other proprietary solutions like, HP [55], Apollo [56] with Apollo domain [57], Novell [58] with IPX [59], a protocol actually derived from Xerox XNS [60], NetBIOS [61], Norsk Data [62], SUN [63], Microsoft's NWLink[26] [64] [65], etc.

Unlike other manufacturers and despite some pre-announcement about a worldwide IPX [66] (actually Novell) network, Microsoft finally had the *wisdom* to adopt TCP/IP as its default network protocol.

In some specific cases (e.g., the emerging UNIX and PC worlds) solutions like UUCP [67] or FIDOnet [68] could be used.

It is interesting to note that private "*company networks*"[27], e.g. AT&T, DEC (EASYnet), IBM (VNET) and Xerox, predated by many years the development of academic networks, in contrast to the generally held view that the network development process was entirely controlled by the academic community[28].

Apart from X.25, the glaring lack of open communications standards in the early 1980s created very difficult problems in heterogeneous hardware environments such as CERN; therefore, there were numerous attempts to specify and implement your own protocols and networks, e.g. CERNET.

Otherwise, there were basically three possible choices for deploying "*open networks*":

1) Use the US developed TCP/IP protocols, which was seen by many Europeans as "*anti-patriotic*" (sic) but also *risky,* not being developed according to the regular Standards organizations manner! Furthermore, as the penetration of UNIX, upon which TCP/IP was layered, was very small outside University's Computer Science Departments and the UUCP community, it was basically irrelevant in the early 1980s.
2) Use their UK counterpart the, so called, "*Coloured Book*" [69] that, apart from the "Grey book[29]" (email), were basically orthogonal[30] to TCP/IP making use, in particular, of X.25 at the network layer. However, this was also *risky* as the future of the "*Coloured Book*", that were only meant to be "*interim standards*" was, by definition, very uncertain. According to Paul Bryant "*In very early discussion with Francois Fluckiger there were some hopes that we could get some Coloured book/X25 presence at CERN. Curiously, we were quite reluctant to push our protocols abroad feeling that each country had to find its own salvation. They would sell on their own merits.*"
3) Rely on the emerging ISO/OSI protocol suite that was still in a very *immature* state, to say the least! Thus, although the OSI protocols had undoubtedly a lot of *appeal* in the early 1980s, it was not only unrealistic but also *totally irresponsible* to propose them in the late 1980s as an *operationally viable* solution.

Unfortunately, given the slow pace of development of the ISO/OSI standards making process, the inevitable happened, namely the rapid acceptance of the open TCP/IP protocol suite in the late

[25] Digital Equipment Corporation

[26] Microsoft implementation of Novell's IPX also including NetBIOS

[27] according to the taxonomy used by J. Quarterman in "*Notable Computer Networks*"

[28] This was obviously the case for ARPANET, the UK "Coloured book" and CYCLADES but these were exceptions rather than the rule in the 1970-1985 period.

[29] At the application level only, as it was designed to run on the Yellow Book Transport Service (YBTS)

[30] But they were much more general, as they dealt with the heterogeneity of hardware and operating systems.

1980s thanks to their implementation on diverse hardware and software platforms and despite numerous devious political manipulations to prevent the adoption of US protocols by Europe.

Although, this may appear to be slightly off subject in a chapter dedicated to the European networking scene, it is worth reminding that DARPA had established connections with five European institutions, including UCL (London) that was providing a gateway service to the UK academic community, thus there was good knowledge of the capabilities as well as the lack of maturity of these protocols in the early 1980s. Indeed, the basic DARPA Internet protocols as we know them today, i.e. datagram (i.e. packet) at layer 3 (IP) and end-to-end connection at layer 4 (TCP), were only documented in RFC 791 (IP) [70] and RFC 793 (TCP) [71] in September 1981 and deployed across ARPANET [72] in 1983. However, as observed by P. Kirstein, ARPANET was only one of three networks using the DARPA Internet Protocol suite, the other two being PRNET [73] and SATNET [74] [75]. UCL that was part of SATNET started to run their operational service based on the new TCP/IP specifications[31] as early as 1982, i.e. a year before it went live on ARPANET. Needless to say, as explained by P. Kirstein in his most instructive article "*Early Experiences with the ARPANET and INTERNET in the UK*" [76] he had to face difficult times with the British authorities as well as the academic community that were backing International Standards through BSI[32] participation to CCITT and ISO: "*The British were embarking during this period on their "Coloured Book" protocols; the Europeans (including the UK) were developing different sets under first the EIN [31]and later EURONET [32] projects. The European networks were not really kept going very long, did not have a large set of computers, and did not have long-term funding. As a result the European efforts did not lead to any strong standards - except at Level 2, where they led to the X.25 protocols [33] that became the main European data networks for the next fifteen to twenty years.*" Peter Kirstein's observation about EIN and EURONET is perfectly right, as these networks had few, if any real users and they were mostly used as "*proof of network technology*" real scale test-beds, whereas the strength of ARPANET but also HEPNET, SRCNET, EARN and EUNET is that they were providing real services to users.

As ARPANET had restricted access use, CSNET [77], the Computer Science Network, initiated by Larry Landweber from Wisconsin University in 1980 met rapid acceptance and received NSF funding during the 1981-1984 period. However, despite its fast growing popularity within the US academic computer science community, CSNET, was far from being an undisputed success because of the immaturity of the Internet routing protocols, in particular, and because of the limited bandwidth available (i.e. 56Kb/s and 9.6Kb/s circuits). In 1986 CSNET was funded by the NSFnet Programme as a community network / regional network in the NSFnet's three tier model of campus networks / regional, community and supercomputer centre networks / and the NSFnet backbone. The interim NSFnet backbone went into service in April 1986, and was upgraded in 1987 was replaced in 1989 by NSFNET [78], a 1.5 Mb/s (T1) [79] backbone. The NSFnet Programme, initiated in 1985, was the first general purpose national TCP/IP inter-network and marked the real start of the Internet.

3 CERN

CERN deserves a special chapter given its special, not to say central, role in European networking history, being already one of the main worldwide sources of scientific data in the mid-1970s. As stated by Carl Malamud in [48]: "*CERN was sometimes referred to as the Center for European Research Networking*". The geographical distribution of the CERN user community

[31] These included among other things the concept of windowing which was critical for satellite based communications because of the inherent 500 milliseconds round-trip-time.

[32] British Standards Institute

is inherent to the organizational structure of the laboratory, in which CERN builds and operates the particle accelerators while the collaborating High Energy Physics (HEP) institutes design the detectors, run the experiments and analyze their results. There is a similar style of working in other particle accelerator centers around the world (e.g., Brookhaven [80], Fermilab [81], KEK [82] and SLAC[33] [83]) and there is also a long established tradition within this community to work in a collaborative manner as reported by Paul Kunz (SLAC) in his very informative "*Status of Networking for High Energy Physics in the United States*" report [84].

In order to make this collaboration as effective as possible, the HEP user community as well as other communities, e.g., the Space community with NSI[34] and SPAN (Space Physics Analysis Network), the Astronomers community (JIVE [85]) were early users of advanced telecommunication services, which justified the establishment of mission oriented networks such as MFEnet[35] but also, as described by François Fluckiger in "*HEPnet in Europe: Status and Trends*", HEPNET [86], a star shaped network around CERN, as there was no suitable general purpose network available. HEP and SPAN subsequently agreed to form a single wide area DECNET network *dubbed* HEP/SPAN[36].

It is interesting to note that in the pre-HEPNET and pre-EARN eras (i.e.1980), CERN only had two analog 9.6 Kb/s lines to CEA[37] in Saclay [87] and RAL[38] near Oxford [88], with essentially one full time person to ensure "*stable*" operations (i.e. fixing bugs, liaising with the PTTs in case of line outages, etc.).

A unique aspect of CERN during the 1970-1990 periods was *intellectual freedom* with its corollary of internal ideological battles and the establishment of independently managed "*empires*". Coupled to the fact that the four LEP [89] experiments were both competing[39] between themselves and largely independent of CERN, these were major factors stimulating innovation that, in turn, greatly contributed to the richness and the diversity of the whole environment (e.g., general purpose LAN, dedicated accelerator control network, experiment specific data acquisition and filtering systems, etc.). No wonder therefore that in such a *burgeoning* environment with so many diverse, sometimes conflicting, requirements independently managed LAN *islands* appeared, such as: Ethernet (shared, switched), IBM Token Ring [90], FDDI[40] [91], Ultranet [92], Apollo Domain, Norsk Data, etc. However, the use of Ultranet, a proprietary 1Gb/s interface developed to fill a technological gap above 10Mb/s Ethernet and FDDI (100 Mb/s) in the late 1980s, when 1Gb/s Ethernet interfaces were not yet commercially available, did not bring the expected benefits as Ethernet technology caught up quickly.

The CERN Computer Centre had the same problem with successive generation of computers from IBM, Control Data Corporation [93] (CDC) 6600 then 7600, IBM again quickly complemented by IBM compatible (i.e. Fujitsu/Siemens), then CRAY [94]. Interestingly enough, it is the introduction of a Cray XMP [95] which actually popularized the use of UNIX [96] and later LINUX [97] at CERN.

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[33] Stanford Linear Accelerator Center

[34] NASA Science Internet

[35] Magnetic Fusion Energy Network

[36] Areas 1-46 were reserved for HEP/SPAN, while the remaining areas, 47-63, were replicated throughout the network (i.e. "*hidden areas*" conceptually similar to RFC 1918 "*Address Allocation for Private Internets*").

[37] French Atomic Energy Commission

[38] Rutherford Appleton Laboratory

[39] The competition between the particle physics experiments is about Nobel prizes and other prestigious scientific awards

[40] Fiber Distributed Data Interface

In 1990, the SHIFT (Scalable Heterogeneous Integrated FaciliTy) project [98] marked the start of a new paradigm, namely: moving away from very expensive mainframes towards distributed high performance RISC [99] CPUs with much better price/performance characteristics, thus paving the way to "*Commodity computing* [100]". Subsequently SHIFT received a 21st Century Achievement Award [101] from the Computerworld Honors Program. In 1993, the EC funded BETEL project extended SHIFT to CCPN [102], the IN2P3 [103] computer center in Lyon. In some sense, SHIFT, together with BETEL, can be seen as precursors of the GRID.

"Computing at CERN in the LEP era (May 1983)", better known as the *"Green Book"* [104], was followed in 1988 by the *"MUSCLE"* [105] report which was focused on networking. The presentation made by David Williams during the LEP festivity [106] in 2000 is particularly interesting.

The "*MUSCLE*" report made the case for 2Mb/s circuits between CERN and the main LEP computing centers (IN2P3 (Lyon), CEA, CNAF (Bologna) [107], CASPUR[41] (Roma) [108] , ETH[42] (Zurich) [109], etc. in order to exchange experimental LEP data. In practice, the *"MUSCLE"* recommendations were largely implemented thanks to IBM's EASInet initiative, however, the network could not be used to disseminate the LEP data as originally anticipated given that the available bandwidth between CERN and the main LEP computing centers was far too small (i.e. 2Mb/s at best): so one had to wait 20 more years, i.e. until LHC and the LHCOPN [110], to make this *dream* finally become reality! Indeed, until approximately 2008, the bandwidth available to the HEP community was insufficient to allow the transfer of the LEP experimental data therefore only the calibration and some mini-DSTs could be shipped across the network. However, shipping tapes by postal mail was also expensive, and several studies proved that, under some slightly "*biased*" hypothesis such as "*near real time*" access to experimental LHC data (i.e. 1-2 days), high-speed 10 Gb/s networks were actually cheaper than making massive and regular use of FedEx style services.

CERN was also involved in two high-speed data transmission over satellite projects, namely: STELLA [111] and CHEOPS [112] (using ESA's Olympus Satellite). There is an excellent article by Brian Carpenter [113] describing the purposes and status of CHEOPS.

Although these projects were technically very interesting and successfully demonstrated the feasibility of using satellites for high speed data transmissions before TCP's "*windows scale*" option became available [114], they essentially led nowhere, practically speaking, though they mobilized some of the best European networking experts!

Therefore CERN was to some extent *relieved* when the Olympus [115] satellite disappeared from its orbit as, in exchange for free access to this satellite, CERN had, if not a contractual, at least a moral obligations to make use of Olympus, in order to demonstrate the use of satellite for high-speed transfers of LEP experimental data (Data Summary Tapes), à la STELLA, between CERN and three computing centers located in Finland, Greece and Portugal. However, CERN saved its technical credibility as the feasibility of the project had been demonstrated, whereas the operational phase which was due to last several years never happened for reasons beyond CERN's control.

In the CS group but also within the LEP experiments, there was some dislike of IBM, the "*Big Blue"* [116] company, the "*evil*" monopoly, so to speak, whereas DEC, together with its integrated networking solution, DECNET, was then extremely popular within the LEP [117] experiments with PDP and later VAX "*superminicomputers*" [118], and was therefore perceived as a "*good* company.

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[41] Inter-University Consortium for the Application of Super-Computing for Universities and Research
[42] Swiss Federal Institute of Technology

Indeed, DEC was then a very dynamic and innovative company and was one of the initiators of both distributed computing and Ethernet[43], although the DEC flavor of Ethernet, that was in wide use in University campuses, had a different frame format than the one standardized later by IEEE. Nonetheless, DEC was truly committed to open standards, e.g. DECNET/OSI transition, that actually never happened because of unforeseen technical difficulties and was also instrumental in the support of the EARN/OSI transition plan [119].

3.1 CERNET

Given the lack of open communications standards and the extremely heterogeneous hardware environment at CERN, it was very *natural* in the late 1970s to specify and implement your own network protocols.

CERNET is a typical example of a *design by committee* project. By the time the specifications were finished and the CERN-wide internal network implemented, it became obvious that many features were missing (e.g., Terminal Access hence a Virtual terminal Protocol (VTP) was implemented on top of CERNET); furthermore, the network was, in practice, very little used until some new un-envisaged applications came up, e.g., bridging Ethernet across CERNET (FRIGATE [120]), implementing high speed remote printing through CHIMP [121] (CERN High speed Inter Mainframe Program[44]), that met immediate success despite the fact that the consumption of CPU resources was far too high for the CPU limited mainframes of those times!

The fact that CERN was using INDEX, a popular dumb terminal switching system from Gandalf[45] Technologies (Canada), partly explains the reasons behind the lack of remote login facilities in CERNET; in addition, CERNET was built to interconnect computers not terminals.

Admittedly, gathering the needs of the users, be they physicists, was very difficult, if not impossible, in the early computing and networking ages, where the predominant model was a highly centralized one based on mainframes with home-made RIOS[46] providing job submission and printing facilities site-wide.

Furthermore, in the CERN multi-vendor environment proprietary solutions could not be applied on a wide scale therefore, home-made solutions had to be developed. Likewise, the functionality of commercial software (e.g. network management) and/or operating systems were rather primitive and CERN had to extend/develop several basic components (e.g., new drivers, improved schedulers, new utility programs like FIND [122]).

4 European Committee for Future Accelerators (ECFA): Subgroup 5 (Links and Networks)

ECFA [123] Subgroup 5 assembled an exceptionally bright set of people like, the late Mike Sendall, boss of Tim Berners Lee, the initiator of the Web; Rob Blokzijl, who became the chairman of RIPE; James Hutton, who became the first secretary general of RARE; Paul Bryant,

[43] together with Intel and Xerox, the, so called, DIX standard, i.e. 10Mb/s Ethernet than later became IEEE 802.3

[44] implemented in Pascal by Geerd Hoffman who joined the European Center for Medium-range Weather Forecasts (ECMWF) afterwards

[45] Quoting Paul Bryant again: "*RAL also had a Gandalf exchange: A massive machine and a step in the wrong direction. However, at that time terminals were all the rage. No doubt you can remember the coax cables needed for the IBM 3270? We went in for an asynchronous 3270 emulator that was far cheaper and went over Gandalf. Interestingly, the early Ethernet Ungermann-Bass product [125] was sold as a terminal system by providing terminal concentrators.*"

[46] Remote Input and Output Station

who became chairman of the EARN Technical Committee and was the *father* of the EARN/OSI (i.e. X.25) transition [124]; Brian Gilmore who became Chairman of the TERENA Technical Committee; Enzo Valente (Chairman of GARR); the late Jacques Prevost (RARE WG6 chair); François Flückiger[47] (CERN).

François Fluckiger was then a very strong proponent as well as a very persuasive advocate of an "*all X.25*" strategy and played a decisive role in its introduction at CERN, as well as inside the emerging HEPnet as the "*Universal"* networking solution.

In fact, this position was not particularly *original* <u>because there was not much else available</u>!

Indeed, ECFA WG5 quickly became convinced that public X.25 networks could serve as the basis of the HEPnet backbone; however, public X.25 services were horrendously expensive as there was no flat charging but telephone-like usage-based charging; in addition, CERN's connection to Telepac[48] was only 48 Kb/s. Therefore HEPnet quickly realized the financial drawbacks of public X.25 and moved into private X.25 leased lines. While public X.25 was well suited to the remote login style of operation of HEP but not much else, private X.25 could also be used as DECNET or even TCP/IP transport, however, native operations could also be provided in a more flexible and efficient manner through the use of "*intelligent*" statistical multiplexors such as Stratacom [126], IDNX [127], etc.

The work of ECFA subgroup 5 is another excellent example of where "*top-down design by committee*" can lead to, namely the assembling of a bright set of personalities with strong and innovative, though not necessarily either right or convergent views!

There is only a subset of the ECFA subgroup 5 reports available from the CERN document store [128] but two reports are of particular historical interest: "*Networks for High-Energy Physics*" (August 1982) and "*Progress towards Networking Facilities for High Energy Physics*" (September 1983).

The first report [129] laid the founding principles of HEPNET, namely:

1. *Wide area communication by network or leased lines should use the X25 access protocol.*
2. *Communication should normally be via the Public X25 services, particularly for international traffic. Cost studies have shown[49] that leased lines tend to be more expensive than the public network unless the line capacity is heavily used. For international traffic, PTT regulations appear to prevent general HEP usage of private networks[50].*
3. *All HEP institutes should attach themselves to their national X25 network when available, both for computer-computer traffic and for terminals.*
4. *Interactive terminal access should use the X3, X28, X29 ("Triple X") standards, <u>after study and agreement on the particular dialect[51] of triple X to be used by HEP.</u>*
5. *The main HEP institutes and supporting centers should agree on a short/medium term project for the development and installation of File Transfer Protocol converters between the existing systems.*
6. *Studies should continue on the possibilities of converging towards the general use of international higher level protocols as they become known.*

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[47] A recognized X.25 expert recently recruited by CERN and coming from SESA (France) where he had participated to the design of TRANSPAC, the 1st French public X.25 network.

[48] The Swiss PTT public X.25 network

[49] Typical "*proceed by assertion*" rhetoric, as the studies in question was very biased, to say the least!

[50] Despite the fact that there were very large networks already available (cf. J. Quarterman)

[51] A very diplomatic way of expressing the difficulties of defining a common "*dialect*" out of the proliferation of options available in most International Standards, resulting from their "*political nature*", e.g. X.25 had a *"datagram mode"* that, to the best of my knowledge, was never used!

The above recommendations appear to have been strongly influenced by François Fluckiger as well as by the UK scientific community that was then well ahead of everybody else in Europe, with an already well developed, "*Coloured Book*" [69] protocols based, network funded by SRC[52] and initially dubbed SRCNET[53], then SERCNET[54] and finally JANET[55] [130]. The network was given to the JNT[56] that later became UKERNA, and after that SERC part funded the network together with the universities.

As mentioned earlier, these protocols were only meant to be used as interim "*standards"* and were actually fed into the ISO standards making process through BSI.

Regarding recommendation #2 (use of public X.25 networks), Paul Bryant believes that it was essentially a political posture: "*we all made promises for the future on the use of the public networks in the hope that by the time we had to fulfill the promise things would have moved on - particularly the people making the promises. EARN was just the same. The interesting difference with EARN was that when we decided to fulfill our promise[57] we found that the receivers of the promise suddenly found that they did not want us to fulfill the promise our way but their way, that is, to use the public networks or some yet to emerge academic infrastructure*."

The report goes on with a definition of four classes of services named: N-HEPNET, I-HEPNET, F-HEPNET and M-HEPNET where N, I, F and M stand for Network, Interactive, File transfer and job submission, Mail, and teleconferencing, services respectively. The report built on the fact that existing 9.6 Kb/s analog lines were indeed very expensive and not error free, whereas public X25 networks held the promises of much higher access speeds, i.e. 48 Kb/s, with better performance at a better price; however, the reality turned out to be quite different!

As a matter of fact sections 3.1.1.3 "*Costs and Tariffs*" and 3.1.1.4 "*The Impact of New PTT Services"* are a masterpiece of "*biased"* information aimed to promoting the use of public X.25 networks.

The second report [131] edited by Paul Van Binst is actually much more interesting as it provides an excellent overview of the networking situation within the HEP community and the development of commercial X.25 networks worldwide. There is also detailed information about the projected functionality of F-HEPNET that was later renamed GIFT[58] and implemented on a VAX/VMS system at CERN, but was neither very much used nor fully functional either!

A third ECFA Subgroup 5 report titled "*Report on Results of Questionnaire on Links and Networks*" [132] was published in October 1983 by A.P. White from Imperial College (London) and is a very interesting testimony of the state of use of networks inside the HEP community (154 institutes contacted, 48 replies received) with the following main findings: back in 1982 most HEP users already had access to terminal, file transfer and job submission/retrieval facilities, however their use was rather low, nonetheless use of electronic mail was starting through three main systems: Wylbur, VAX/VMS, UK SERCNET (i.e. Grey Book). One of the most surprising answers is that only 33% of the respondents foresaw a definite need for "*regular transfer of large amounts of data over existing or future network*" whereas 41% saw no need! But, who could have reasonably foreseen that the world of telecommunications would evolve so quickly and that the

[52] Scientific Research Council
[53] Scientific Research Council NETwork
[54] Scientific Research and Engineering Council NETwork
[55] Joint Academic NETwork
[56] Joint Networking Team
[57] Editor's note: however, by that time it was the use of private X.25 networks that was at stake and no longer the use of public X.25 networks.
[58] Generalized Interchange File Transfer

prices would literally *collapse* in those days where the typically cost of a trans-border 9.6 Kb/s line in Europe was of the order of 100KUSD/year

The ECFA networking strategy documents were published just before EARN[59] came about which *messed up* the whole thing, though it accelerated the creation of the RARE association; indeed, an informal workshop on research networking was held in May 1985 in Luxembourg with representatives of 12 countries (CERN included) where it was proposed to form a European association to foster research ISO/OSI networking! Thanks to Paul Bryant, who happened to be the secretary of this very informative, but also historical, meeting the minutes are available at [133].

Quoting Paul Bryant again: "*The meeting was set up by James Hutton (ECFA), Peter Linington (JANET), Nick Newman (EEC[60] [134]), so that we could get funding, and myself as one of the conveners. There is absolutely no doubt that EARN was a major influence bearing in mind the threat of a dreaded IBM world domination.*"

4.1 HEPNET

CERN played a central role in the European networking history being one of the main sources of data worldwide (i.e. multiple Petabytes[61]/year in 2011 [135]); this sheer fact was the justification for a mission oriented High Energy Physics Network (HEPnet) centered around CERN where all related costs were borne by the requesting institutes which suited everybody, as CERN had no say about what amount of bandwidth was needed to connect a particular HEP institute and was in a kind of "*slave*" mode.

There is a very informative 1989 article written by Brian Carpenter and François Fluckiger titled "*European HEPNET - Where we are and where are we going?*" [136], presenting the structure as well as the status of HEPNET with interesting statements about the state of the DECNET Phase V transition seen as a catalyst towards the wide adoption of OSI, as well as the end of the GIFT *gateway* at CERN.

HEPNET was perceived as a *threat* by the emerging NRENs, as well as by DANTE, that were well aware of this situation and firmly believed, as networking was still in a very early phase, that they absolutely needed to incorporate the HEP community into their *nascent* infrastructure, in order to have some significant amount of traffic from the beginning, and thus justify the investment. There was also a *hidden* agenda item which was to bring the HEP community under their control in order to *jugulate* it.

However, having fought hard in order to fund HEPNET the physicists were little inclined to put this funding into a general purpose network, especially as the capacity of these new *emerging* networks was very small. IXI[62], a 64Kb/s X.25 backbone, was preceded by a pilot service whose main characteristic was that it had no or little traffic.

Indeed, real traffic was carried out by EARN and EUnet and it was hard for the few X.400 *aficionados* to make full use of it, fortunately EUnet that was pioneering the use of TCP/IP over

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[59] Towards the end of 1983, IBM took the initiative of establishing and funding EARN. A network conceptually similar to BITNET linking selected computer centers via, mostly 9.6 Kb/s, leased lines.

[60] European Economic Community, the predecessor of the EC (European Community), also named EU (European Union), after the Maastricht treaty (1993)

[61] 2 to the 50th power, or 1,125,899,906,842,624 bytes.

[62] The International X.25 Infrastructure (IXI) pilot service had emerged from the COSINE project. IXI started service between all the COSINE countries in July 1990, i.e. after Killarney meeting. The service was provided by PTT Telecom (Netherlands) under a contract with the European Commission. It provided an X.25 service at 64kbps to 18 access points and also had connections to the public X.25 services in nine countries.

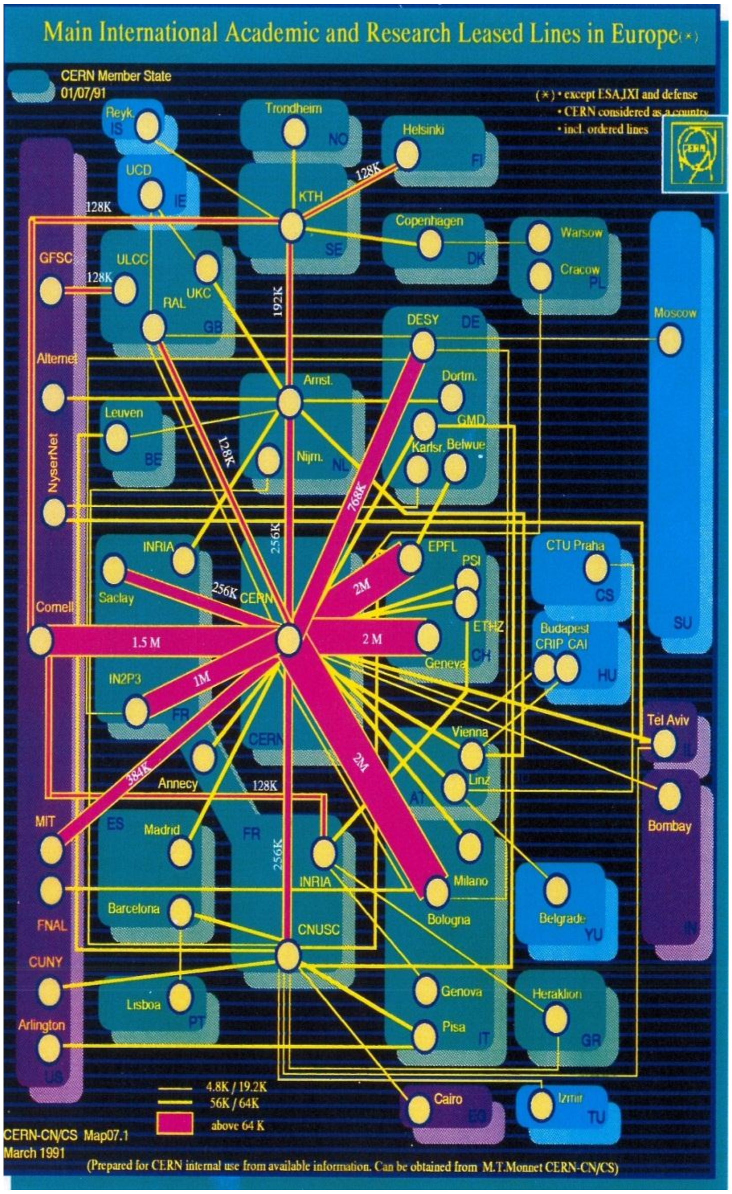

Figure 2 HEPNET at its Zenith in 1991

X.25 in Europe was well positioned to make use of IXI by connecting backbone sites in low volume countries that would not have sufficient traffic to warrant leased lines.

That way there was some constant traffic load at least and the IXI folk could claim usefulness by usage[63]. The sad reality, though, was that, whereas everybody else was already in the 2Mb/s era in the late 1980s, the only thing RARE/IXI could offer in the early 1990s was a pitiful 64 Kb/s backbone that was skillfully presented as a major *political* achievement, that it probably was, but certainly not a significant technical achievement. One result of this conflictive atmosphere as well as the new, very strict, hierarchical networking structure was that the "*poor user*" only had indirect access to other networks. If anything went wrong then he had to go via its NREN that would go to IXI and so on. Thus, the time to get a response and whether the response would be useful tended to create the lack of trust.

Spurred by SURFnet's Ebone initiative, it took another two years to DANTE, i.e. October 1992, to provide a 2Mb/s multiprotocol[64] backbone dubbed EMPB/Europanet. Unfortunately, it is fair to state that neither IXI nor Europanet were really suitable for production, compared to, e.g. HEPNET, because of the *chronic* saturation of these early *under-dimensioned* pan-European backbones and the resulting high packet-loss rates. Another reason for sticking to private networks was also the glaring *lack of trust* in RARE and DANTE, because of their political and technical biases as well as their lack of transparency that is still lasting more than twenty years afterwards!

Indeed, for many years, the problem was that both DANTE and the NRENs were *systematically* losing the race towards higher bandwidth, because of their *inefficient* bureaucratic as well as political approach to building networks (e.g. by *systematically* refusing presence at popular Internet Exchange Points), until GEANT [137] finally came up in 2001 with a 2.5Gb/s

[63] Private conversation with Daniel Karrenberg

[64] EMPB, provided by PTT Telecom/Unisource, offered a 2Mbps multiprotocol (X.25, IP, CLNS) service in all COSINE member states.

first and then, *finally*[65], a 10Gb/s backbone. The amusing "*anecdote*" is that, because of the lack of affordable 40Gb/s circuits that was however compensated by the availability of cheap 10Gb/s *lightpaths* over leased dark fibers [138], GEANT was reluctantly "*forced*" to evolve from a "*single"* Global pan-European backbone into "*multiple"* Mission Oriented Networks, e.g. DEISA, JIVE, LHC, i.e. back where the scientific community was in the 1980s with HEPnet, MFEnet, NSI, which is, in my opinion, an excellent evolution, though not exactly what had been planned by DANTE and Telecom Operators who thought that transmission technology would continue to evolve steadily towards higher speeds, i.e. 40Gb/s (OC-768/STM-256), 160Gb/s and eventually Tb/s, at affordable prices!

Furthermore, they were neither willing to share power nor leave a role to anybody else than themselves; a "*conflict of interest"*, so to speak, but a "*chicken and egg*" situation too, in the sense that the HEPnet community was not willing to merge its well suited and well working networking infrastructure into a shared network which, in the early 1990s, was, almost by definition, highly congested because of the non-availability of high speed circuits at affordable prices (i.e. one had to wait until 1997 to have TEN-34, a 34 Mb/s Pan-European backbone, operational). However, this was not completely the fault of DANTE, as before the Telecom deregulation that took effect on January 1st 1998, the National PTTs were extremely reluctant to sell >2Mb/s circuits; worse again the cost of two 2Mb/s circuits was essentially twice the price of single 2Mb/s circuit, while, when the market was opened to competition and thanks to the economy of scales that could be achieved through the wide use of SDH's G.702 hierarchy [139], it became common to upgrade the bandwidth by a factor four in bandwidth at a factor two or even less in cost. The original PTT price structure was not cost based, hence the numerous abuses observed in most countries. A positive effect of the Telecom deregulation was the emergence of new, so called, "TELCOs[66]" [140], however, a very negative effect was that, in order to gain market shares, they started to dump prices; in addition, too many operators and too many transoceanic cables, especially across the Atlantic, the introduction of DWDM[67] [141] had a "*devastating*" effect that worsened the "*bandwidth glut*" thus greatly accelerating the demise of many new TELCOs, e.g. KPNQWest, TeleGlobe in the 2002-2003 period, also called the "*Dot-com*" bubble [142].

When the question of CERN's connection to DANTE's backbone came about, some HEPnet leaders, e.g. Enzo Valente, were violently against CERN having to pay for its own connection[68], under the argument that the HEP institutes were already being charged by their NREN to connect, via DANTE, to CERN, a case of *double charging* so to speak. The whole argument made little sense actually; nonetheless, it was very difficult to convince the CERN management that they had no other option than to find the necessary budget, which they finally did. The issue was further complicated by the fact that connection to DANTE was a *bundled* offer including access to existing European NRENs, as well as access to the commercial Internet that had become an absolute necessity in order to communicate with scientists worldwide and, in particular, with US scientists in the post-NSFNET period (i.e. April 1995-1997) that, apart from the vBNS [143] (very high speed Backbone Network System) connected sites, were only accessible through the commercial Internet, until Internet2 finally came into being.

Nonetheless, following the end of ECFA SG5, HEPnet started to structure itself, though not without very painful initial disputes, essentially because of leadership questions, in particular the *role or non-role* of CERN; indeed, as CERN did not participate in the funding of the HEPNET

[65] i.e. well after SURFnet and CERN
[66] Telecom Operators
[67] wavelength-division multiplexing
[68] actually shared with SWITCH (the Swiss NREN)

lines but only to their operations, some HEPnet leaders thought that CERN had to keep the lowest possible profile.

There is another interesting article presented at CHEP89 in March 1989 in Oxford by François Fluckiger titled: “*Overview of HEP Wide Area Networking: Producer Perspective*” [144] whose 12 conclusions are extremely informative, but I will only quote three of them: *3) TCP/IP services will be in use everywhere within 18 months 4) OSI is late; it will work for several services. It deserves to remain a strategic direction 6) Protocol flavor disputes (e.g. ISO CONS versus ISO CNLS) are nonsense*!

HEPNET was also one of the pioneers in establishing leased lines to Eastern countries, i.e. two 9.6 Kb/s lines from CERN to the Particle Physics Institute of the Hungarian Academy of Sciences (KFKI) in Budapest (1989) and to the Institute of Physics in Cracow (Poland) (early 1990). However, the CERN administration was almost *paranoiac* about the strict compliance to the CoCom rules (refer to chapter 6.1) that prevented remote login from Eastern European countries, despite their CERN membership, while electronic mail and file transfer were tolerated! So, the above two lines were isolated from CERN’s main internal network by a firewall (sic). This was actually a completely ridiculous situation as, although access to the Cray XMP supercomputer was severely restricted, even to CERN staff members, the same physicists who could not login to CERN from their home institute, could access in all legality most CERN computers when they were visiting CERN! Fortunately, this sad situation did not last long after the fall of the Berlin wall, late 1989.

Although HEPnet had no formal (i.e. legal) existence, it could be considered as acting under the ECFA umbrella, having been created by ECFA SG5, therefore ECFA had *observer status* at the RARE CoA and at the EARN Board although it was rarely physically represented.

Nonetheless, the HEPnet Technical Committee (HTC) and the HEPnet Requirements Committee (HRC) were created during the first half of 1989. The HTC was initially chaired by François Fluckiger and had several sub-committees: DECNET, IP, SNA, Converters (i.e. GIFT, MINT [145] (Mail INTerchange)), X.25.

4.1.1 HTC-SNA

For the sake of completeness, it is worth mentioning that there were a small[69] number of SNA islands in Europe during the 1980s and the early 1990s, much like the European Internet islands before 1989. Hence, the HTC-SNA activity that included links between CERN, CEA, RAL, CASPUR, ETH, in particular.

In Germany, prior to the emergence of WIN, AGFnet, a native SNA network of the German National Research Centers and Universities was initially run by GMD Bonn, linking the main German research centers and universities (e.g., DESY[70] [146], Jülich Research Centre [147], MPI[71] [148]). AGFnet was subsequently merged into DFN’s WIN in the form of an SNA over X.25 sub-network.

As explained in Peter Streibelt’s EASinet article “*Those EASI sites that need connectivity for their mainframes running SNA (IBM's Systems Networking Architecture) are connected via the SNI technique. SNI (SNA Network Interconnection) allows to manage large SNA networks by splitting them into many small networks or to connect other autonomous networks. Within EASInet the 'back-to-back' technique of SNI has been implemented. With 'back-to-back' the participating SNA networks remain nearly autonomous. They only need to agree to a few definitions of a common 'Null-net' to which they are connected via one or more gateways. The gateway function is part of the SNA access methods on the IBM mainframes.*

[69] in terms of number of nodes but actually very large IBM mainframes
[70] Deutsches Elektronen-Synchrotron
[71] Max-Planck-Institut für Physik

The SNI network of EASInet itself has gateways to other SNI networks within Europe e.g. EARN, HEPnet or AGFnet."

4.1.2 European HEPnet Consortium

"*The European HEPnet consortium [149] was formally established in December 1992 as part of the already existing HEP-CCC (HEP Computing Coordinating Committee), so combining within a single body the functions of each. The HEP-CCC will revise its membership and its terms of reference as appropriate to take proper account of its wider role. The Chairman of the HEP-CCC is also the Chairman of the Consortium. In addition, a body known as the HEPnet Consortium Executive Board acts as the executive arm of the Consortium and reports through its Chairman to the HEP-CCC Consortium. The Executive Board [150] has five members, namely, the Chairman, Vice Chairman, and Secretary, who are appointed by the Consortium for a two year period, and the conveners of ECFA's HRC and HTC Committees, who are ex-officio members of the Board.*

There are no doubts that both HEPNET and EASInet played a major role in the creation of the European Internet and it would be a mistake to be silent about it!

The HEP-CCC [151] Technical Advisory Sub-Committee, HTASC [152] [153], a new structure replacing both the HTC and the HRC, was created in 1995; at the same time all the subcommittees of the HTC disappeared, however new ones were created, e.g. security, windows 2000. HEPNET actually "died" in 2001 or so, "*miserere nobis*"!

Strangely enough, one of the main problems with HEPNET was the lack of common interests between the supporters, sometimes the "*missionaries*" even, of IBM, DEC, ISO/OSI, X.25, etc. Also, many of the HEPNET actors wore too many "*hats*" so, despite the fact that the physical network was not only real but also huge compared to the other international networks of those days, HEPNET was a very chaotic, though very necessary, undertaking!

4.2 DECNET

DECNET was then extremely popular within the LEP experiments that were making extensive use of DEC's PDP then VAX computers. This trend was accelerated by the generalized introduction of Ethernet based LANs and the emergence of HEPnet where DECNET could be run either natively or above X.25. However, DECNET phase IV suffered from many addressing limitations due to the limited number of areas and hosts (i.e. 63 and 64,449 respectively), hence the urgent need for DECNET phase V; given the "*hype*" surrounding ISO/OSI, DEC decided to make DENET phase V OSI compliant, maybe for marketing reasons?

The main new feature of DECNET Phase V that resulted from its near-compliance with ISO's CLNP [154] protocol was the extension of the limited phase IV address space available from 16 bits to up to 160 bits (i.e. 20 Octets). An interesting aspect of the new addressing scheme was that addresses were of variable format and length and could also include a 48 bit Ethernet address in the low order portion.

The migration from DECNET phase IV to DECNET Phase V was actually extremely urgent as the limited number of DECNET *areas*[72] was slowing down the deployment of the wide-area DECNET infrastructure which the high energy physics and space community were then heavily dependent upon. A sophisticated, *dual-stack* oriented, migration strategy was developed by DEC that made lot of sense in rather *small* networks with *limited* number of hosts and sites. However,

[72] Support for networks of up to 64,449 nodes (i.e. 63 areas of 1023 nodes)

the DECNET phase V transition was *brutally* stopped by DEC itself for a mixture of technical, marketing but also political reasons.

Native DECNET access to CERN from Italy and UK was stopped in early 1998.

To conclude on DECNET, I cannot resist writing that if there were legitimate concerns about the widespread use of proprietary IBM protocols by some people, it is quite amusing that the same people had no similar bias against the extensive use of DECNET phase IV, a proprietary DEC protocol ☺

5 The Protocol War and the OSI Standards battle

5.1 A Tribute to IBM and DEC

For reasons unknown to me IBM always kept a very low-key profile about its role in the establishment of an operational European networking infrastructure One reason could be that the implemented solutions were not along the main IBM lines of those days, namely MVS, SNA, TSO, CICS/IMS (databases), whereas most EARN central switching nodes (one per country) were VM/CMS[73] [155] based, in fact using the same technology as VNET[74] [156] i.e. RSCS networking and NJE protocols, another reason may be that IBM, being well aware that EARN was perceived by the OSI activists as counter-productive, did not want to appear as exacerbating further the already "*heated*" European networking atmosphere by bringing in unnecessary politics.

Therefore, it is not well known that without IBM's very significant seed funding in the framework of their EARN and EASInet initiatives, Europe would probably have lagged behind the USA for many years whereas it actually caught-up surprisingly rapidly:

1. By funding[75] EARN for 4 years starting at the end of 1983. Besides many 9.6 Kb/s intra-European lines, modems and a few VM/CMS systems to act as country nodes, IBM also contributed two 9.6 Kb/s transatlantic lines in Roma and Bonn (GMD) initially and later one 64 Kb/s line in Montpellier (CNUSC), in order to provide the needed interconnection with BITNET. Last, but not least, IBM also contributed organizational support, both technical (Berthold Pasch) and managerial (Alain Auroux, Peter Streibelt).
2. By providing a T1 link [157] between CERN (Geneva) and Cornell (USA), the newly born NSFNET T1 backbone, in fact, extending NSFNET to Europe while, at the same time, establishing 2Mb/s lines between IBM supercomputer centers (EASInet initiative)
3. By agreeing together with other partners, such as HEPnet, to integrate these into Ebone, thus greatly facilitating the establishment of the Ebone consortium and the creation of an *embryonic* pan-European Internet backbone.

Likewise, the role of IBM in the early NSFNET T1 backbone NSS (Nodal Switching Subsystem), the 2nd generation T3[76], before Cisco took over when NSFNET moved to ATM,

[73] IBM's Virtual Machine Operating System that predated by several decades the widely spread virtualization techniques in use today
[74] IBM's internal mail network
[75] According to Frode Greisen the total IBM funding amounted to 40Million USD, not including IBM manpower
[76] 45Mb/s

155Mb/s 1st then 622 Mb/s in the form of 4*155Mb/s, as there was no 622Mb/s ATM interface available on the market, has been largely ignored!

Herb Budd (IBM), though of American origin, played a decisive role in the History of European Networking, and was definitely playing for Europe. This opinion is also shared by Paul Bryant: *"I think that Herb Budd was senior enough to get money without too many questions being asked and also he was not particularly interested in furthering IBM's interests*." One of Herb Budd's favorite sentences was about *"the vacuum of networking leadership in Europe"* which was not liked, at all, by the RARE Council of Administration (CoA). Actually, the problem was not so much the *lack* of leadership than the abundance of "*would-be*" leaders whose first priority was to take control of European research networks, no matter what! Of course there is no such thing as a "*free lunch*", however, there was a clear "*win-win*" situation; therefore, it is not only strange but also disappointing that the decisive role of IBM in the foundation of European Networking, thanks to their seed-funding of EARN first and EASInet next, is not better recognized! The problem was that for the OSI activists EARN was diversionary and took resources from the final OSI solution. Paul Bryant's view, which is fully in line with mine, is that "*the OSI contingent finally started to realize they could not go on promising forever*".

Last, the role of DEC with their EARN/OSI initiative should not be underestimated as without the DEC funding that brought additional bandwidth, parts of the EARN community would have had some difficulties in the 1989-1990 period. Paul Bryant recalls: "*Certainly the DEC finance was extensive. I well remember when Odd Jorgensen*[77] *marched in and had a brain storming session on how it was to be done, a rather embarrassing event. He decided to rip up my Perugia document and start from scratch. It succeeded because of the large resources put in. Remember the control centre in Amsterdam run by a guy from DEC Jerry Striplin, Nial O'Reilly and a couple of others. In my view the GBOX was the key to the project which not only gave us NJE over X25 but NJE over IP that allowed us to get rid of the short lived NT switches. I sent the RAL switch to Kees Neggers whose network used them."*

5.2 The semantic discussion on "*standards*"

The question of what was a "*standard*" and what was not a "*standard*" was then an extremely "*hot"* issue, National vs. International standards, European standards (e.g. ETSI) vs. International standards organizations like CCITT/ITU, ISO or self-proclaimed bodies such as the IETF. Whereas everybody understood the needs and advantages of standards, few countries were ready to abandon their national standards for international standards, e.g. electric plug formats is still an issue today. In other words, nationalism was still prevailing in the 1970s as exemplified by the PAL [158] SECAM [159] battle on broadcast Television systems standards [160] and the repeated failures to build a coherent European computer industry, as every partner was entangled in his own short-sighted interests.

Without doubts, there is a hidden agenda behind any standard as the proposer(s) clearly intend to derive significant competitive advantage from its wider adoption. The above PAL/SECAM story is a representative example of this; likewise, ISO/OSI standards were pushed by the European Commission under the assumption that the European industry would reap significant benefits from their adoption by the networking community, at large, given their, supposedly, *superior* status of International standards over the ARPA, aka Internet or TCP/IP, protocols that did not qualify as such! However, there was one significant exception the CCITT/ITU standards that were widely used by Telephony and Telecom operators worldwide. Indeed as pointed out by Larry Roberts in chapter 19.2.5 "*Unlike most standards activities, where there is almost no incentive to*

[77] the EARN/OSI project manager in DEC's headquarters in Geneva

compromise and agree, carriers in separate countries can only benefit from the adoption of a standard since it facilitates network interconnection and permits easier user attachment".

Unfortunately, ISO standardization did not follow the CCITT example and was a slow, four-step process that depends on the voted approval of many committees. The IETF, on the other hand, was much more freewheeling. A statement made in 1992 by Dave Clark has been its informal motto: "*We reject kings, presidents and voting; we believe in rough consensus and running code*". Hence, this is no wonder that the IETF during its early years, could make progress much faster than other more "*democratically"* structured standards bodies such as ISO, thanks to the contributions of many worldwide networking experts and, in particular, those of INRIA[78] and UCL[79].

The issue of using International standards rather than proprietary solutions, such as IBM (SNA and RSCS) or DEC (DECNET) but also TCP/IP protocols was the object of "*heated"* discussions. For example, every time someone referred to the TCP/IP standards, James Hutton, then chairman of RARE, would, literally speaking, become "*red*" explaining in his usual "*calm*" manner, often starting with "*For Christ's sake*", that, unlike, CCITT, ETSI, ISO, ITU, etc., the IETF was not an International standards organization; in other words, IETF RFCs, although open, were similar to proprietary standards.

However, this had not prevented the UK academic community from developing its own "*interim*[80]*"* standards the, so called, "*Coloured Book*[81]" which, as explained in the next chapter, were originally designed to run over X.25 networks, thus the cornerstone of the new protocol suite was the NITS[82] transport layer also known as YBTS[83].

The UK "*Coloured Book"* never succeeded in reaching ISO standard status and was thus only used across JANET, the national academic network in the UK. During the course of their existence which was actually rather short[84], the "*Coloured Book*" was a source of problems outside the UK in the area of electronic mail[85] and file transfer[86]. However, the choice of not promoting the "*colored book*" outside the UK was quite deliberate, Paul Bryant recalls: "*We were rather reluctant to export coloured book protocols, <u>as we did not want to undermine OSI</u>. We expected that there would be a lot of gateways between national and ISO networks that would be part of a long transition. Indeed we already had many of them, e.g. "Grey Book*[87]*" to EARN mail gateway at RAL, the EARN/OSI GBOX. I think most university sites had a gateway of some sort. Actually my team had "Blue Book" over X25 working in about mid-1980 and JANET "coloured book" ended around mid-1990 so it gave a service for 10 years – quite a long time."*

As already mentioned in chapter 2.4, although the "*Grey Book*" was compatible with SMTP [161] at the application level, it introduced *unfortunate* changes to the format of ARPA mail

78 Christian Huitema, Christophe Diot, etc.

79 Mark Handley, Steve Kille, etc.

80 An innovative way to self-ascribe the standard status

81 It is not clear to me whether they ever reached the status of a British standard; however, they were submitted as a contribution to BSI's DPS/20 working group, which was concerned with architecture and higher level protocols.

82 Network Independent Transport Service

83 Yellow Book Transport Service

84 1984-1997 where support for X.25 was stopped thus marking the end of the "*Coloured Book*", however, an IP over X.25 service had been introduced in 1991 quickly followed by native IP links. By 1993, IP traffic already exceeded the X.25 traffic.

85 "*Grey Book*"

86 "*Blue Book*" aka NIFTP (Network Independent File Transfer)

87 File transfer aka "*Blue Book*"

addresses, as specified in 1982[88] by RFC 822 [162], by reversing the order of electronic mail addresses, i.e. user@uk.ucl.cs instead of user@cs.ucl.uk according to the reasoning that electronic mail should follow postal code and/or telephone numbers, but also to stay compatible with the naming conventions defined at the transport layer in the new UK protocol suite[89], that was designed around the same time as new ARPA domain-based email addresses. In other words, the construction of UK names followed a "*big-endian*[90]" convention [163] regarding order of components.

As explained in C. Cooper's JANET History *"*Original JANET Protocols[91]*": "Although it was known that ARPANET and UUCP/Usenet were adopting the opposite, 'little-endian' convention, this was not then regarded as sufficiently significant to cause the UK to change, since ARPANET (and UUCP) protocols had no particular standing at the time in a standards context. Moreover, to have mail service names use the opposite convention to transport service names seemed both confusing and inconsistent. As we shall see, the consequences of this apparently innocuous, but ultimately contentious, decision were to haunt JANET for nearly 15 years!"*

Indeed, the different addressing styles caused a number of interesting problems as according to the above example *".cs"* (computer science) also happened to be the country code of Czechoslovakia before the split into the Czech Republic and Slovakia, therefore, it was not always possible to know whether an address was a "*Coloured Book*" one or an ARPA one!

It is also funny to observe that the UK academic community, which was pushing as hard as it could towards the use of ISO standards, refused to use the two characters ISO country code [164] of their own country, namely ".gb[92]", for their email addresses and preferred to continue using ".uk" along the well-known principle "*Do as I say not as I do*" ☺

As pointed out by Dennis Jennings the matter was not as straightforward: *"To be fair, the country is actually called the United Kingdom of Great Britain and Northern Ireland – not Great Britain – and "uk" is correct and the ISO standard "gb" is incorrect for that country. Car registrations however, do use GB*". For more information on this amazing "*controversy*" refer to C. Cooper's JANET History "*Naming, the last word*[93]".

In any case, the Americans did even worse in a similar situation by assuming that, as the whole world was being led by them, there was no need for an ".us" suffix in their electronic mail addresses, but who could have guessed then that ARPA style addresses would become so widely used? This type of common behavior can be qualified as "*the creator syndrome*". Indeed, as noted by Paul Bryant: "*the UK invented postage stamps and so they are unique in not having the name of the country on their stamps.*"

Another interesting discussion was about the use of car plates vs. ISO country codes and I am not aware that other "*champions*" of ISO standards such as Germany, for example, have any plans to change their car plates from "D" to "DE", whereas, strangely enough, the United Kingdom is one of the few countries that follows the ISO country codes with GB on their car plates ☺

[88] There has been numerous RFCs (i.e. 196, 561, 680, 724, 733), dealing with Mail, however, as strange as it may look, the concept of domain named electronic mail addresses was only formally introduced in 1982. Prior to RFC822 the notation was 'name at mailbox'.

[89] i.e. "net.institution.dept.host.servicename"

[90] By analogy with the way in which a sequence of bytes is stored in computer memory, i.e. most significant byte first or last

[91] Sec2:54, page 72

[92] The term Great Britain was first used officially in 1474, although it dates back to 1136 and refers to the island of Great Britain as Britannia major ("Greater Britain"), to distinguish it from Britannia minor ("Lesser Britain"), the continental region which approximates to modern Brittany (France).

[93] Sec2:120, page 138

In terms of layers, X.25 consisted of several, of which the uppermost was the network layer. The CCITT/ITU-T versions of the protocol specifications are for Public Data Networks (PDN). The ISO/IEC versions address additional features for private networks (e.g. Local Area Networks (LAN) use) while maintaining compatibility with the CCITT/ITU-T specifications.

The user facilities and other features supported by each version of X.25 and ISO/IEC 8208 have varied from edition to edition. Surprisingly, there were six major protocol versions of CCITT/ITU-T X.25 recommendation named as follows: 1) Orange Book (1976), 2) Yellow Book (1980), 3) Red Book (1984), 4) Blue Book (1988), 5) White Book (1993), 6) Grey Book (1996)!

Needless to say, the related migration issues were far more difficult to handle than incremental changes like Windows software update for example.

5.3 The UK "*Coloured Book*" epic

Regarding the UK "*Coloured Book*", it is quite humorous to observe that the first thing that the "*promoters of standards*" do is to publish their own, be they *interim*, standards, in order to address the shortage or the shortcomings of existing standards. However, in so doing they could not ignore that it was bound to create additional problems by increasing the "*entropy*" of the already overly complex networking "*standards*" universe.

Nonetheless, the very bold and innovative approach taken by the UK academic community back in 1973 with the first Wells report that proposed to establish a national academic research network using *interim* UK developed standards to be deployed over the, yet to come, pre-X.25 based EPSS[94] network [165] of the GPO[95] [166] deserves to be underlined. Although this first report was not very well received as it had taken for granted the need for a national network and therefore concentrated on how to build it rather than why it was needed, it finally led after a second round to the establishment of the JNT[96] at the end of 1979 and the inauguration of JANET in 1984. Indeed, the original ambitious planning was delayed for many reasons, e.g., EPSS[97] was only started in April 1977 instead of 1975 and after a successful trial was replaced by BT's[98] commercial X.25 PSS[99] service in August 1981[100] [167] whereas JANET was finally launched in 1984, i.e. more than 10 years after the visionary Wells report. However, it interesting to note that BT's international X.25 network service IPSS[101] was launched in 1978 i.e. well before PSS went into operation due to the high demand for affordable access to US based database and other network services. Nonetheless as rightly pointed out by Paul Bryant "*The PTTs were very pedestrian particularly in the pre deregulation days. <u>They believed firmly that voice was and would be the predominant use of their network with data a minor amount riding over it</u>. At the time of EPSS we were told that although an interesting experiment they did not expect it to last. Fast switching (now known as ISDN) would take over and that would be more than sufficient to meet any needs we had with its generous 2x64K. This view continued for a long time and to some extent explains the PTT or <u>at least BT[102] attitude to data and their love of the telephone exchange.</u>*"

[94] Experimental Packet Switched Service
[95] General Post Office
[96] Joint Network Team
[97] EPSS became PSS in January 1980. At that time, the protocols changed from the locally-defined EPSS protocols to the ISO Standard X25 protocols.
[98] British Telecom
[99] PSS (Packet Switch Stream)
[100] After an 18 months pre-operational period testing with mostly academic customers
[101] International Packet Switch Stream
[102] Editor's note : all European PTTs more or less adopted the same attitude

This very intricate but fascinating piece of the European Research Networking history is remarkably described by Christopher S. Cooper in his book "*JANET: The First 25 Years*" [172] prefaced by P. Kirstein. I found the following two excerpts of particular relevance to this article.

1. Basing a UK service network on ARPANET would have left the UK[103] network without control over its own technology – and, indeed, it was already known that there were likely to be changes in the ARPANET protocols. Moreover, expertise in development and operation of its network would be a continuing requirement for the UK community but, with development of ARPANET technology *centered* in the USA – in spite of the contributions of Peter Kirstein's group at UCL – it was very likely there would be continual *leakage* of the best UK expertise to the US. *This was no idle speculation: the scientific 'brain-drain[104]' [173] to the USA was something which the UK had by then been experiencing for two decades owing to post-war lack of finance to match USA facilities.* The Working Party recommended that a priority should be the adoption of community-wide standard protocols: indeed, national *or international standards if possible*.
2. In April 1984, the Joint Academic Network (JANET) came into service. It was indeed the first such network which connected the facilities both of the main academic computers, and those needed for specific research. This network required close collaboration also with BT, so it necessarily used the X.25 protocol at the network level. In fact the British had developed a complete set of protocols covering terminal traffic, transport, LANs, mail, name serving and file transfer. Some, in particular the network level[105], was part of international standards; the rest were specific to the UK. The UK had also started having experience with US network, from the gateway to UCL which had already been providing operational traffic for over 10 years. In addition, JANET provided gateways to the commercial BT packet services and to EUNET.

As reported by Paul Bryant, other important network developments happened in parallel with the Wells reports as, as early as 1974: "*SRC wanted to connect its three sites together to share their resources and they decided to take advantage of EPSS[106]. It was a few people interested in networks such as myself at the Atlas Laboratory, Peter Girard [168] at RAL and Tony Petefield at Daresbury. I think we really did it because it looked interesting and we saw we could do a bit better than directly connected terminals and card reader line printer sets. We used EPSS because it was given to us - for no better reason. We did not know a lot about what was going on in the USA but knew enough to know that ARPANET's IMPs were very expensive and we had little confidence that the technology would survive. Having got it going X25 came along and it was an obvious and easy step to convert to X25 albeit using BSC (remember HDLC chips were rare and built interfaces even rarer). By the time JNT came along we could demonstrate X25 and triple X and a bit more and we firmly believed that BT would provide us with the network infrastructure and we could do away with leased lines and experimental work. If we had gone for ARPA then we would not have expected to be able to use a public service. In retrospect the flaws in that argument are clear but not at the time. Although we were fairly proud of what we are doing I don't think it was national pride or anti USA that drove us, it was a belief that we were doing the right thing. It was later that that translated to religious dogma.*"

There is a very informative article by Paul Bryant titled "*The rise and rise of SRCnet*" [169] that explains its key role played: "*Without SRCnet, I think that the UK would have been in no better position than the other NRENs".*

Although UK is *the* natural partner of the USA in Europe, they cannot stand the de facto master/slave relationship. Vis-à-vis Europe, UK is one among many other countries and their ancestral rivalry with French is still lasting, therefore everything proposed by France is suspect of "*pulling the covers to oneself*", hence their dislike of EIN[107], that was (too) strongly influenced by

[103] Editor's note: UK not Europe
[104] Editor's note: It is exactly for that same reason that CERN was established in 1954
[105] Of course, because of the X.25 predicate
[106] In practice, EPSS having been delayed, SRCNET started with leased 2.4 Kb/s circuits
[107] Despite that fact that it was led by Derek Barber (NPL)

the CYCLADES work, as UK understandably "*does not want to be fooled*"; however, this attitude, that was unfortunately shared by several other large European countries[108], was self-destructive and actually led to the situation Europe is now in, i.e. excessive dependence over US technology. However, Paul Bryant is very right in his observation that "*We must also remember European industry did have the opportunity to build equipment for IP had it wanted to. Why are there no European routers[109]? <u>Perhaps some of that EU money should have gone in that direction rather than on a range of ill-conceived expedition</u>. In the UK we did start a network industry - the CAMTEC PADs and switches [170], Cambridge Ring. But when IP came about we just rolled over and bought Cisco and then Juniper etc.*" The final issue of the Engineering Computing Newsletter dated March 1996 that deals, among other things, with the death of British computing industry is also of very high technical as well as historical relevance [171].

Finally, since there were too many contenders to a single winner, the easiest solution was to have only losers, an organized scuttling in a way!

Here are some relevant comments from Paul Bryant about my comments on the insular behavior of the English people: "*The British do have a significant European problem - very few speak anything but English (that is changing but the new languages emanate from the Indian sub-continent). This makes picking up ideas and technology from Europe as opposed to the USA difficult. We were aware of EIN but not of the detail and it were relegated to a possibly interesting experiment, certainly not anything on which one could build a network. I think the dislike of France was at the political rather than the personal level.*"

As already mentioned NITS was the cornerstone of the "*Coloured Book*" protocols and quoting C. Cooper again: *"although it was designed with X.25 in mind, it also included descriptions of how to realise it over a variety of underlying networks such as leased lines, (PSTN[110]), X.21 circuit switched networks. The other significant extension to the collection of YBTS specifications appeared in 1981/2, as campus networking was being developed; this specification, together with other parts of the Cambridge Ring specifications were reworked into what became known as CR82 (Cambridge Ring 1982), the Orange Book, which was in a form suitable for submission to standards bodies. Subsequently, in 1983 a procedure was published which defined how YBTS could be realised over asynchronous lines, a simpler option than synchronous lines (as used by PTTs), with or without X.25, and suitable for use with microprocessor based systems by then in widespread use."*

Unfortunately, excessive/blind dependence on X.25 had undesirable effects, e.g. moving functions normally held below the network layer up to the transport[111] layer but even worse*: There was one awkward point about this otherwise apparently complete solution to handling interactive terminals: what if the underlying network[112] did not use X.25, and in consequence X.29 [174] was unavailable? And the community had already developed the Yellow Book Transport Service to enable networks of diverse technology to be interconnected so as to allow high-level protocols to operate end-to-end over the concatenated set of networks. The approach taken to this problem was to define a terminal protocol which had all the same features as X.29 but which operated over YBTS: this was known as TS29. By design it could operate over a concatenation of networks supporting YBTS. Since the features and capabilities of TS29 and X.29 were the same, an exact mapping between the two was possible.*

Postulating X.25 at the network layer led to a number of complications that are very well explained by C. Cooper below, showing that the application layer cannot be completely agnostic about the intricacies of the network layer with respect to charging, in particular.

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[108] France in the first place but also Germany

[109] Editor's note: a possible explanation is that in the PTT monopoly regime, connection-oriented services were much more lucrative than flat-charged packet-oriented services like the emerging Internet, furthermore, the PTTs as well as the healthy European X.25 industry wanted to continue to reap the commercial benefits of their technology. Their lack of foresight was largely due to the fact that they lived in a closed world and were blind to the long announced emergence of the Telecom deregulation in 1998.

[110] Public Switched Telephone Network

[111] However, the transport layer is the natural place to interconnect networks with different technologies.

[112] Editor's note: Typically the campus LAN

"The significance of transport service (TS) in the UK protocols was now becoming clearer. It was not just that transport was the layer at which network independence, that is, independence from low-level technology such as LAN or WAN, could be achieved: that same independence also meant that it could be used as the layer at which to interconnect networks. By implementing TS on each network technology, it could be used as the common layer above which any application protocol could operate end-to-end."

C. Cooper then goes on with the following realistic comment on the Cambridge Ring development (Sec2:90 page 108): "*However, experimental development is one thing: a supported service product quite another".* This is confirmed by Paul Bryant*: "The Cambridge ring was a sad story. The first implementations were via a box interfacing to the ring on one side and (I think) a synchronous interface on the other. And there it stuck. There were a number of attempts to build the ring chip but they all failed. I think it was something to do with jitter. Without the chip, ring interfaces were never likely to be very popular. It was also designed at a time when memory/electronics etc., was expensive so you tried to make the protocol simple so making the hardware simple. However, both the ring and Ethernet were wrong in expecting shared media to work well when you have users able to clobber the system at the pull of a plug."*

But continuing on the Cambridge Ring story (Sec2:90 page 108): "*This picture of early LAN technology exploitation is typical of what happens in the early adoption phase of a technology. Most of the basic research for LANs had been accomplished in the mid-1970s; but bringing the technology to market, with the accompanying standardisation, software development and overall product support, together with the eventual market shake-out which has to occur before market and product stability are achieved, <u>took about a decade</u>. In this case there were several other factors. The PC and the single-user workstation both appeared in the same timeframe. <u>The PC was an almost immediate success in the office; however, disk storage and printers were expensive. For sharing information and expensive peripherals in this context, the Ethernet began to proliferate quite rapidly</u>".*

Editor's note: Whereas early adoption of new technologies may turn out to be an advantage, it may also turn out to be an expensive undertaking, examples of this flourish in the fast moving LAN area, e.g. CERN with Apollo domain, Ultranet, FDDI, IBM Token Ring, UK, with the Cambridge Ring. On the contrary lagging behind can turn out to be an advantage as it may avoid adoption of intermediate technologies and therefore save costs. Similar behavior has been observed in the telephony world where investments are huge on a national scale and where countries that were leading in terms of analog telephone coverage (e.g. Germany) started lagging behind countries that were way behind in terms of their analog telephone network coverage and jumped directly to digital telephone networks (e.g. France with ISDN). On the other hand, as evidenced by the sad ISO/OSI story, while you are waiting for the "*right*" technology the user does not have a service!

C. Cooper then points out an artifact of running your own protocols on a commercial network (sec2:44 page 62): *"Like all protocols, issues arose after YBTS had been defined, either as a result of experience or because of later external events, and these led to revisions. We mention just one here, partly because it had financial implications and partly because exactly the same issue reappeared a decade later in the more international context of broadband ISDN. As EPSS evolved into the commercial service PSS, so it was revealed how BT would charge for the service. Communication service charges can typically involve a number of elements: a per-call element, distance, duration, line speed and volume of traffic, for example. The charge for a fixed line telephone call has traditionally depended on the first three. <u>For PSS, BT tariffs, like those for ordinary telephone calls, included a per-call charge</u>. <u>For the common case of a computer with a number of users making use of the same remote service, such as a regional or national service, it would be common for a number of simultaneous calls to be in use between the two. If the transport service had the ability to support (multiplex) a number of transport connections over a single X.25 call then the per call element could be reduced to one for any given destination.</u> This extension was added but, although significant, it is not clear how much it was eventually deployed because, as it would turn out, neither PSS nor any other commercial network would after all form the basis of the academic network."*

The list of UK "*Coloured Book*" is extremely impressive: 1) Blue – NIFTP, 2) Red - JTMP (Job Transfer and Manipulation Protocol), 3) Yellow - NITS/YBTS, 4) Green - XXX/TS29[113] (Character Terminal Protocols over PSS), 5) Grey – Mail, Orange - CR82[114] [175] & TSBSP[115], 6) Pink - CSMA/CD, 7) Peach - OSI CR, 8) Fawn - SSMP[116]/ATS[117], 9) White - OSI (Transition to OSI standards[118]).

Amazing as it may look the "Coloured Book" were behaving very well with respect to both stability and performance, as evidenced by Paul Bryant: *"As one who implemented coloured book protocols then I can say unequivocally they did work and were stable. True they were not commercial products or not wholly. Remember I had a network of an IBM, 20 or so GEC [176] and 20 or so PR1ME [177] computers which all exhibited X25, triple X, Blue Book and Grey book. The only commercial product was the X25 and triple X from PR1ME (one USA manufacturer that had a measure of faith in the ISO world). I am not so conversant with what was happening at other sites. Performance was largely restricted by the pitiful line speeds of 9.6K. I remember talking to Peter Linington on a long train journey about whether X25 would scale with speed. Some performance could be got from link by link rather than end to end acknowledgements. However, Peter's view was that you could get the speed by putting more of the protocol into hardware."*

To be fair the *heroic* work then made by UK scientists, as well as the historical role of the SERC/JNT team, must be applauded, unfortunately, as noted by P. Kirstein in his preface it is clear that these endeavors did not significantly benefit the UK industry: "*Successful commercial companies frequently emerge from academic activities and the networking field is no exception. The US-sponsored Internet IP family eventually won out internationally and this book shows how JANET was able to make the transition to IP without interrupting services to the research and education community. The transition took until 1993 to complete and was no mean task, with the result that there were few UK commercial spin-offs arising out of the JANET development activities*".

Last, the migration to TCP/IP was not easy to swallow, quoting Paul Bryant again: "*What happened was that we planned to use old DEC machines as routers and to do it all for nothing but before that plan came to fruition JNT decided to provide CISCO routers. The Shoestring name was my invention. At that time there was a television program about a fictional detective called Shoestring set in Bristol (near where I come from) and it just seemed to be an appropriate name. Bob Day who eventually moved from RAL to JNT was a prime mover in persuading JNT that it would be better for them to take an active interest in the project and thus get control over it and to fund it. It was a better solution than using DEC machines.*"

5.4 The ISO/OSI protocols

The ISO/OSI vs. Internet protocols controversy, i.e. International Standards against the "*rough consensus*" driven, mostly US led, IETF, showed the dangers of a technocratic and doctrinarian approach to urgent problems requiring, well working, operationally validated, solutions.

Although the ISO/OSI reference model [178] and its associated protocol suite had lot of appeals, they were far too immature at the time where they started to be highly praised and actively promoted. In other words, they were very far from having reached the required level of stability and usability, in addition there was far too much politics behind them to make them credible at all, despite the fact that availability of OSI protocols according to the relevant

[113] A recommendation on the use of X3, X28 and X29
[114] Cambridge Ring 1982
[115] Transport Service over Byte Stream Protocol
[116] Simple Screen Management Protocol
[117] Asynchronous Transport Service
[118] Never actually happened, however, transition to IP happened but there was no need for a new book!

GOSIP[119] profile, was then a mandatory requirements of public procurement procedures in many countries, including the USA, as has also been the case for IPv6 for many years with the *amazing* success that everyone knows!

RFC 1169 [179] "*Explaining the Role of GOSIP*" by V. Cerf (IAB[120]) and K. Mills (NIST[121]) issued in August 1990 is extremely informative and illustrates well the embarrassment of the Internet community, in general, but more specifically the Federal agencies (e.g. DoE, NASA) that would be obliged to comply with FIPS[122] 146, the US GOSIP, issued by NIST [180]. US GOSIP protocols were mandatory for US Federal Government purchases from 1990 until 1995.

Indeed, mandating the availability of particular protocols is not the same as forcing their use, in other words it did not serve any useful purposes in practice. The only non-negligible remains of OSI are actually LDAP[123] [181] developed by the ISODE [182] consortium that met wide acceptance almost immediately and was standardized by the IETF.

A very "*intriguing*" aspect of the OSI protocols, whose number one purpose was to strengthen the European industry, is that their complexity was such that only American companies, such as IBM and DEC, really managed to implement them! However, despite the public procurement rules that mandated their availability, the potential market was essentially non-existent. In addition, not being distributed as an integral part of the operating system they were, in practice, very difficult to install and even more difficult to use.

One reason behind the complexity of many international standards is that they are often the results of compromises[124]; therefore they include many options but, for cost reasons, only few of them are implemented, therefore, in the absence of options negotiation procedures, there is no guarantee of interoperability between two implementations of the same standard, hence the need for "profiles" as already mentioned above regarding the need for a common "*Triple X*" dialect within HEPnet.

Another insider comment from Paul Bryant: "*I got involved with functional standards. In fact I did the triple X pair although I doubt whether anyone had read it since its publication. The work was just as slow as the development of the base standards in the first place. This was an incredible waste of time - even more so as the meetings were in Brussels. I wonder whether anyone has estimated the cost of defining the ISO protocols. Having implemented protocols, the biggest problem is the interface with the rest of the system i.e. the basic underlying mechanism. The options are the easier part and I could never understand why crippled implementations were ever written. In the case of triple X on the PRIME computer they fixed all the parameters making it useless for talking to my GECs. It took only a couple of hours to implement the full parameter negotiation.*"

X.25, which can be considered as a successful ITU/CCITT standard, had, for example, two operating modes: "*virtual circuit*" and "*datagram*". To the best of my knowledge, nobody ever used the "*datagram*" variant. X.25, a reliable packet oriented protocol operating on "*virtual circuits*", was implemented on top of circuit based or packet based networks, and had many similarities with ATM and, to some extent, MPLS even!

X.400 [183] was an electronic mail protocol with a rich set of options, which SMTP [184] the, then ASCII restricted, Internet mail protocol did not possess, as MIME [185] had not yet been specified. However, instead of selecting an ambitious X.400 profile that would have made the use of X.400 potentially much more attractive than that of SMTP, the profile selected by

119 Government OSI Profile, the standards in the GOSIPs were generally ISO OSI ones; however, they also included X.25 and X.400.

120 Internet Architecture Board

121 National Institute of Standards and Technology

122 Federal Information Processing Standard

123 Lightweight X.500 Directory Access Protocol

124 consensus was reached by voting

RARE for their Message Handling System (MHS) project was actually as basic, functionality-wise, as SMTP!

In short, the whole debate was spoiled by too many political considerations but also by some insincerity.

That said, I am as much in favor of international standards as anyone else, as long as they have the following properties: 1) adequate functionality 2) technical readiness 3) wide adoption 4) operational resilience 5) good integration and support by the supplier. Unfortunately, the ISO/OSI protocol suite never met any of these essential pre-conditions, hence their predictable fiasco and the resulting *waste time and money*! In addition, the use of standards, although highly desirable in principle, is by no means a lasting guarantee of success, e.g. X.21[125] [186], IBM's Token Ring[126], FDDI, SMDS[127] and early Ethernet products are all completely obsolete by now.

Therefore, I am pretty worried by the speed at which "*cloud computing*" is "*spreading*" throughout the world, and especially in the U.S., without a satisfactory level of common standards, e.g. "*inter-cloud*" and far too many parallel standardization efforts [187] proving that many people share similar worries about this new technology. According to Michel Riguidel (Telecom Paris) "*Cloud computing is seen by some people as the "Anti-Internet", in other words the return of proprietary applications which is rightly seen as the negation of openness and interoperability!*" [188]

Along the same line of thought, Neil Sutton, vice president of BT Global Services, stated in June 2010 that "*IT decision makers were suffering from cloud fatigue* [189]". Indeed, following the Metacomputing [190], Grid then Cluster computing "*hypes*", the history seems to be repeating itself, what will come next, an implosion of the "*cloud*" bubble is not impossible given the number of new entrants? There is only one certainty, the client server model will continue to prosper with more and more functionality added to the user handset, be it a Smartphone, a Tablet, a Notebook or a even a standard PC through more and more functionality-rich Web browsers.

5.5 The Protocol and other wars

Given the prominent role played by the late Klaus Ullmann [191] in European Research networking it is impossible to ignore his key role in the establishment of RARE, DFN and DANTE and in the promotion of CCITT and ISO/OSI standards based networks. Likewise, given that the supporters of the RARE and EARN camps had fundamental disagreements[128], on the technical and organizational options promoted by Klaus Ullmann as Director General of DFN[129] [192] and Chairman of the Board of DANTE [193], it would be *double-tongued* to hide some facts that are even related by Klaus Ullmann himself in DANTE's "*A History of International Research Networking*" book [194].

[125] Circuit switched digital services
[126] IEEE 802.5
[127] Switched Multimegabit Data Service
[128] Actually, the EARN stance was very straightforward: "*we would migrate when there was something to migrate to.*" (Paul Bryant)
[129] German Research Network

Indeed, despite the respect due to the memory of Klaus Ullmann one remains *flabbergasted* by his definition of "Radicals[130] and Conservatives[131] on pages 133-134 of the above book, namely that the "*radicals believe in opportunism, making use of whatever short term means are available for promoting their cause… For the radicals, personal glory is there to be won, at least among one's peer group*" whereas "*the conservatives are more concerned with long-term stability and making careful preparations to minimize the number of problems. The people concerned may be ambitious but, in most cases, get satisfaction from working as members of a team with defined position in a hierarchy.*"!

The above definition is actually an *amazing* dialectical inversion of the reality as, with respect to European networking, the radicals pushed for *proven* solutions whereas the conservatives pushed for *non-existent* solutions that were only good on paper and, not surprisingly, turned out to be complete disasters. Indeed, implying that the choice of TCP/IP protocols was "*risky*" whereas the choice of OSI protocols was "*riskless*" is a rather surprising assertion to make in 2010[132], as one could not then ignore that the really "*radical*" choice, back in the 1980s, was to push the unproven OSI protocols "*beyond reason"*!

Despite the repeated claims made by the "*conservatives*" [195] that they *"avoided the protocol wars",* in other words that the protocol war was never "*real"* and therefore that "*there was never a cease-fire*", there was a genuine *"protocol war*" in Europe, basically Internet protocols[133] against ISO/OSI protocols, back in the mid-1980s.

Like is often the case in real wars, e.g. the Crusades back in the 11th century, ideology is often used as a pretext to seize power, and it is therefore interesting to note that despite the amazing *lack of vision* shown by the *"conservatives"* in a fast evolving networking technology field that made them lose the technological battle, they undoubtedly won the power battle and that a few of them still hold key roles!

As this article is about history, it may be appropriate to remind the readers that Jerusalem was taken by the Christians in 1099 then taken back by Saladin in 1187, hence the 3rd crusade led by Richard I, King of England, also known as "Richard the Lionheart[134]". "*On May 24, 1192, all the Crusaders regroup in Ascalon and persuade Richard to lead the army of Jerusalem, while the latter is considering returning to Europe. The troupe left Ascalon June 7 and arrives shortly after to Qalandiya near Jerusalem. Richard set up his camp but hesitates to attack Jerusalem, leaving the Ayyubid [196] army time to regroup. Finally, Richard decides to retreat, to the annoyance of the Crusaders who will learn later that disagreement between Kurdish and Turkish troops led the garrison of Jerusalem on the verge of mutiny, and that the capture of the city would have been easy!*"

This story led Paul Bryant to wonder "*what would have happened if the OSI brigade had continued with their battle - could they have made it all work? We will never know but I guess we have a good idea!*" Another way of saying that history does not repeat itself.

[130] "marked by a considerable departure from the usual or traditional; tending or disposed to make extreme changes in existing views, habits, constitutions or institutions" (Webster)

[131] "tending or disposed to maintain existing views, conditions or institutions; marked by moderation and caution; " (Webster)

[132] Date of publication

[133] perceived by some European politicians as a technical "*weapon"* of the US government to "*invade"* Europe at the expense of the European industry

[134] Richard Cœur de Lion in French or « Oc e No », i.e. « Oui et non » for its tendency to quickly change his mood!

5.5.1 What was the protocol war about?

The solution on this side of the Atlantic, but also in Japan, was to use new emerging international ISO and CCITT/ITU standards (i.e. X.25, X.400, X.500, etc.) and to build new emerging NRENs according to the layered ISO/OSI model.

There were many competing organizations and projects, those, e.g. EARN, EUnet, HEP/SPAN that were providing services (email, news, file transfer) to the scientific community, and others e.g. RARE, COSINE that were mostly doing paper work and politics (i.e. blocking in a very effective manner all initiatives and services that were not in line with their *dogmatic* views). The RARE community, being more academic than the "*radicals*", self-declared themselves of higher intellectual level and was running closed Networkshop by invitation only! DANTE was not yet born.

Whereas everyone knows that a number of projects and/or organizations had been in frontal competition during the pre-Internet era, i.e. mid-1980s, fewer people know that these *ideological* controversies made their way into some organizations. For example, David Lord and I were not highly regarded at CERN because of our involvement in EARN, the choice of the IBM token ring and Internet protocols for the LEP accelerator control network thus necessitating the deployment of a gateway with the main, Ethernet based, CERN LAN[135] with all possible kinds of proprietary protocols running across it, e.g., AppleTalk [197], DECnet, IPX. These internal criticisms were not very fair given that CERN greatly benefited from a significant IBM technology transfer, basically the same PC based technology developed by Yakov Rekhter's [198] team at IBM's Research Laboratory in Yorktown Heights for deployment across NSFNET's Nodal Subsystem Nodes (NSS); in practice standard PCs, each driving a T1 line, interconnected by a token ring.

The situation of David Lord and I was by no means not unique, Paul Bryant was in a situation at least as difficult at RAL, framed by his OSI "*friends*" James Hutton and Bob Cooper (JNT).

CERN's policy then was ISO/OSI, X.25, DECNET and Ethernet. While Ethernet has proven to be the right choice[136], DECNET, and all other proprietary protocols, were not. However, DECNET, because of the widespread use of VAXes by HEP physicists worldwide but also the fact that DEC, unlike IBM, was perceived as a "*good*" company, because of their "*long-held*" promise that DECNET phase V, that in practice was never fully deployed, would be fully OSI CLNP compatible, was the "*pet"* manufacturer of CERN.

5.5.2 How was the protocol war settled?

It is only during the course of 1988 that CERN, under the impulsion of François Fluckiger and Brian Carpenter, moved away from the OSI strategy and became very pragmatic. Indeed, it is the establishment of RIPE in mid-1989 that marked without any doubts the start of the European Internet era in which CERN, together with EARN, EASInet, EUnet and HEPnet, played a significant role in contributing to establish the pan-European infrastructure as well as its extension to NSFnet, but also by being at the origin of the Web in 1992.

The *glaring* lack of European leadership, actually the lack of a common and coherent European networking vision, was compensated by EASInet, a very significant computing and networking initiative from IBM that gave Europe additional time to get organized, in effect, extending NSFNET to Europe. Indeed, the T1 connection to NSFNET between CERN and Cornell University that became operational in February 1990 created a kind of *earthquake* within the

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[135] Local Area Network

[136] This was far from being obvious back in 1988 because of the distance limitations of Ethernet and uncertainties regarding the CSMA/CD access protocol with respect to fair access to the shared media

academic and research community as the move towards the wider adoption of Internet in Europe then became irresistible thus forcing the *dissident* NRENs to reluctantly wake-up to reality, which had three main results:

1. The protocol war was officially closed during the 1st joint EARN/RARE conference that took place in Killarney (Ireland) in June 1990 and it was agreed to start coordinating the Internet engineering activities of all the stakeholders on a global scale.
2. The IEPG[137] [199] was thus formed there and the founding meeting was held shortly afterwards, next to the 18th IETF meeting in August 1990 in Vancouver.
3. Following the establishment of RIPE and the emergence of an embryonic IP backbone[138] the fate of RARE was also "*settled*" which led to the merging of EARN and RARE into TERENA and probably also accelerated the creation of DANTE.

The emergence of RIPE was far from getting universal support when first set up. Indeed, until the Web came up in 1992, there were still many who fought on with OSI. Paul Bryant mentions that "*there was quite a rift in UKERNA and he does not recall James Hutton rushing over to RIPE meetings or at least the ones he went to*." Paul does not hesitate to even speak of a "*Takeover of EARN by RIPE!!*" and regarding the Open System vs. Proprietary battle, his view is that "*it will never be won. In fact we need new ideas/products to make progress - some will succeed some will fail but that is better than stagnation. In addition, he also feels most/all technologies eventually become obsolete. Some, like FTAM, become obsolete before ever transferring a file in anger.*"

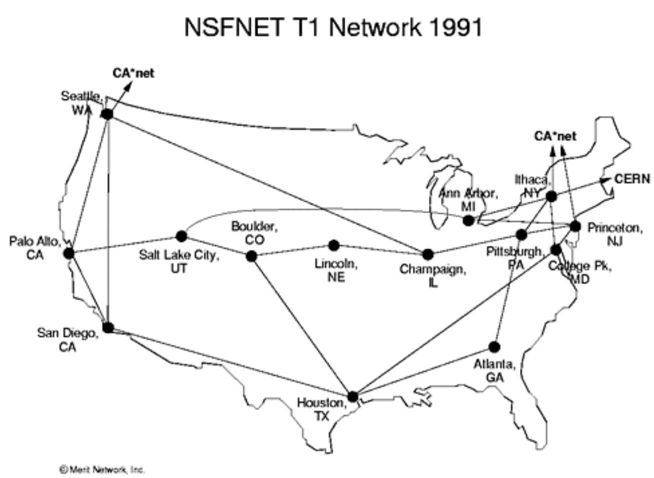

Figure 3 NSFNET Topology

However, the battle for power between the "conservatives" and the "radicals" still goes on, more than 20 years after Killarney! In addition, it is rather *ironic* that these are the same politicians who, along with many others, worked very efficiently towards the deregulation of the European Telecom market[139], who have meticulously built new monopolies in Europe, namely DANTE/GEANT and NRENs, according to the principle that, as far as the academic and research community is concerned, a single pan-European backbone as well as single national networks were better than several competing ones, which is a bit *weird* in my opinion and, at the very least, *questionable*!

As rightly pointed out by Dennis Jennings there were other "wars":

137 Intercontinental Engineering Planning Group

138 The "backbone" was going from Stockholm to Bologna through Amsterdam and Geneva and was connected at T1 speed with NSFnet.

139 The EC directive 98/10/EC also called the "Green Paper" on "Open Network Provision" became effective in 1998 and was initially very beneficial but was then at the origin of the Telecom debacle in 2000 because of the bandwidth "glut" that followed the parallel construction of too many networks.

1. "*The war between those who promoted the PTT public switched low speed volume tariffed network model and those who believed that the private leased line network model was appropriate for the research community,*

2. *The war between those that supported the PTT monopoly and those that supported telecommunication liberalisation.*

Both of which were confused with the protocol "wars". Many people could not separate out these issues, and one of the major culprits here was the EEC who blindly supported the PPTs, public switched X.25 networks[140], volume tariffs and ISO/OSI protocols (and later ATM – a technology fundamentally flawed from conception in that it ignored packet queuing!)".

Part of the problem arose because of fundamentally different conceptions of networking for research:

1. *The PTT model was of "telematics" – basically low speed terminal access to database services, and to centralised PTT provided services (the PTT "intelligent" networks). In this model, PTT provided low speed X.25 packet switched volume charged networks were seen to provide more than adequate performance (as were even lower speed X.75 interchanges for international traffic), while preserving the PTT monopoly.*

2. *For many in the research community the model was of pre-paid networking capacity for the transfer of volume data between computers. Research institutions needed pre-paid capacity because they had no models for dealing with volume based charging, and they had always used leased lines for interconnecting their own campuses. It was a natural step to using leased lines to interconnect universities nationally (as JANET did in the UK), and internationally (as EARN (IBM supported) and the EARN/OSI (DEC supported) projects did).*

3. *And finally, it is sad to note that those who promoted public X.25 / X.75 networks for research networking (and vigorously opposed private leased lines networks, even if using X.25) failed to understand that the double buffering on links between switches and at X.75 gateways imposed inherent limitations on the performance of such networks, and made them unsuitable to meet the higher speed / volume needs of the research community. (…and I won't start on the ATM fiasco, another technology promoted by the EEC and supported by the same type of people!)"*

The comparison with the US is instructive in that telecommunications liberalization had already taken place in the early 1980's, and there was a vigorously competitive telecommunications industry. In addition the use of high speed leased lines (T1 at the time) for voice switch interconnection meant that pricing for bandwidth was cost based not monopoly policy based."

Regarding the intrinsic limitations of X.25, Paul Bryant adds that in a discussion with Peter Linington: "*Peter claimed that all we needed was faster and faster lines and faster and faster electronics to solve any ISO problems. Also in X25 there was the link by link vs. end-to-end acknowledgement arguments".*

While I agree with the above overall negative assessment of X.25 made by Dennis and Paul as it is indeed the case that X.25 was designed for low to medium (i.e. 2Mb/s) speed "*dumb*" terminal access, hence the reliable network layer, and therefore not well suited to intensive data transfers, I think that the negative comments about ATM are far too severe and should therefore be mitigated. I am not as convinced as Dennis about the ATM "*fiasco"*, clearly this technology had its limits, as it could not scale beyond 155Mb/s; however, it was designed to allow graceful coexistence of real-time and non-real time services which is still a "*burning*" issue. ATM was also widely used in ADSL access lines. Because of the need for circuit-oriented technology across the Internet, ATM gave birth to MPLS, a kind of framed-ATM (i.e. packets instead of short 128 bytes cells) that is very popular as an ISP service[141] and is highly[142] priced [200] because of the associated QoS guarantees but does not fit very well the

[140] Paul Bryant blames Nick Newman; "*the self-styled Euro network guru with minimal technical competence.*"

[141] e.g. Data centers interconnections, Cloud computing access, etc.

[142] i.e. from 20 to 200 times the price of a typical "commodity Internet connection

Internet stack and is often referred to as a "*layer 2.5*" technology. In other words, Internet purists still consider it as a "*violation*" of the classic Internet layering introduced under the pressure of former PTT monopolies, like AT&T, Deutsche Telekom, France Telecom. However, the "reliable network layer" debate may resurface despite the "All-IP" credo, as one cannot exclude that for some types of networks, e.g. sensors, actuators, there may be advantages, e.g. lower energy consumption, in relaxing the end-to-end constraints.

6 The Advent of Global Electronic Mail and Web based Collaborations

EARN/BITNET, as well as other operational electronic mail networks, provided a much needed *breath of fresh air*, as they essentially eliminated the *cumbersome* practice of having mailboxes on remote hosts, in order to exchange mail with local users *that*, in addition to being expensive, was very *time-consuming* and did not scale beyond a few remote hosts.

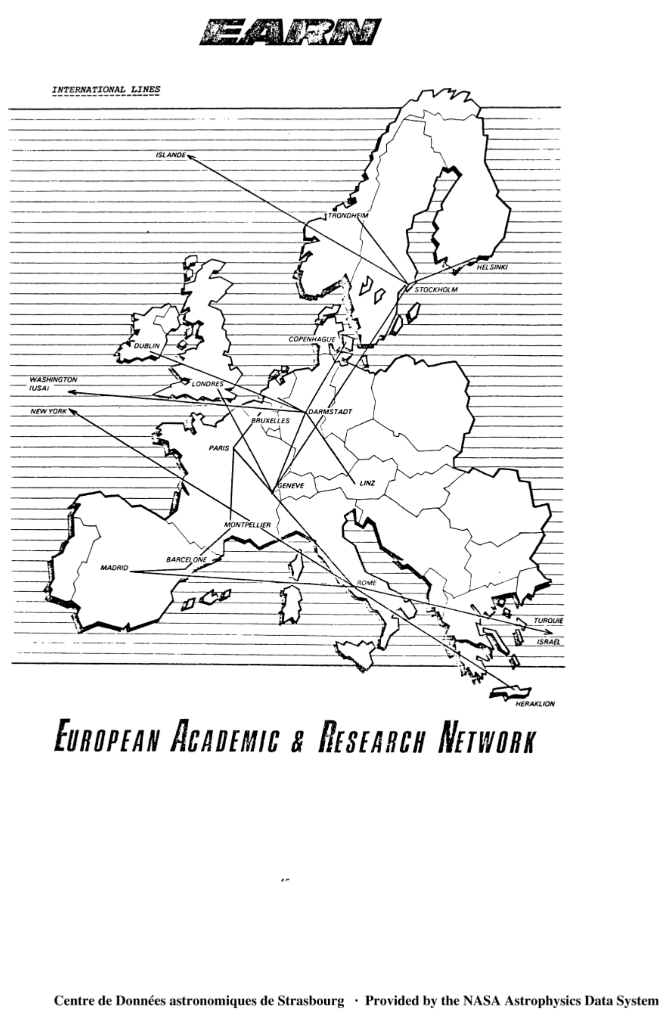

Figure 4 EARN Topology in 1985

Contrary to RARE/COSINE that mostly had a political agenda, EARN [1] and EUnet [201] had a clear service orientation and were very concerned by making optimal use of the scarce network bandwidth available; hence, there was strong cooperation between these two networks; in particular, there were many gateways between EARN and EUnet in order to keep the traffic as local as possible.

Despite the fact that both UUNET [202] and EUnet predated BITNET [203] and EARN, it is not exaggerated to state that, it is EARN/BITNET that popularized the use of electronic-mail-based collaboration between scientists worldwide on a large scale.

However, as rightly pointed out by Daniel Karrenberg the above statement is somewhat *subjective* as, although there was some *overlap* between these two networks, they were also clearly *complementary* depending on the branch of science concerned: *"EARN typically connected the University computing centers and large* *research institutions. EUnet typically connected computer science departments and related research institutions. Furthermore EUnet was open to private industry. In addition EUnet had more sites than EARN*[143] "

One of the most convincing statements about the real impact of EARN/BITNET comes from Mark Humphrys, then a University College Dublin [204] (UCD) student in his "*The Internet in the 1980s.* [205]" article which is extremely well documented:

"*The whole thing (BITNET plus connected networks) was the embryonic Internet. The protocol has simply migrated to IP since, that's all! If BITNET was not the Internet, then neither was ARPANET before it switched to IP in 1983.*"

There are many reasons behind what I believe to be the *historical truth*, however, to be fair, the rapid growth of EARN would not have been possible without IBM's seed-funding, whereas EUnet was self-funded by its users:

1. The respective size EARN/BITNET and EUnet/UUNET in terms of *users* not sites and/or institutions.
2. The form of "*source routing*" initially used[144] by both UUNET and EUnet, i.e. hosta!hostb!host!user was very clumsy to use and prone to errors as routes were likely to evolve, furthermore the return path was unlikely to be symmetric!
3. The somewhat longer delivery delays of UUNET/EUnet, one or more day in some cases, because of the use of low-speed phone lines, compared to the quasi-instantaneous and reliable transmission of small mail messages as well as files offered by EARN/BITNET thanks to the use of leased lines.
4. Access costs (i.e. (mostly[145]) dial-up for access to the EUnet core backbone vs. expensive leased lines for EARN, resulting in essentially orthogonal charging models i.e. variable vs. flat charges, a debate that is still going on today!

6.1 The impact of CoCom rules on the penetration of EARN and EUnet networks in European Eastern Countries and the Soviet Union

CoCom, an acronym for *Coordinating Committee for Multilateral Export Controls*, was established in 1947, during the "*Cold War*" to put an embargo on some Western exports to "*East Bloc*" countries. There is no doubt that the CoCom rules had a stifling effect on the countries concerned and contributed to accelerating the fall of the Berlin wall in November 1989 and the independence of many former communist countries in Eastern Europe. Since 1996, CoCom has been replaced by the Wassenaar Arrangement [206] but network equipments are no longer on the list of forbidden goods, however, export of cryptographic technologies remains strictly controlled [207].

After a careful study of the situation [208], EARN, under the leadership of Frode Greisen, was the first network to establish a *leased line* connection between Copenhagen and Warsaw in mid-1991, however the formal admission to EARN of USSR and several East European countries that was agreed by the EARN Board in April 1990, triggered the CIA to commission networking experts to write a report titled: *"Soviet and East European Computer Networking: Prospects for Global Connectivity"* (CIA report SW 90-10054X, September 1990). This report was

[143] The real question that was the number of users actually served by each network was never clearly answered

[144] The use of *pathalias* on some UUCP hosts alleviated the problem that was eventually solved by using RFC 822 Internet mail addresses.

[145] Possibly Direct (i.e. leased) access to public packet switching networks (PPSN)

declassified, actually *sanitized*, in 1999 but is unfortunately no longer available on line from either [209] or [210] even though it is still listed.

This report says that "*the entry in April 1990*[146] *of the USSR, Bulgaria, Czechoslovakia, Hungary and Poland into EARN is likely to have a profound effect on scientific communities throughout the Soviet Union and Eastern Europe*" and continues by saying that "*the new EARN members will reap significant and immediate benefits by virtue of EARN's links to hundreds of research centers on the US BITNET academic network as well as centers on many other Western networks*". The report goes on by stating that "*While the East's primary incentive to undertake computer networking is to increase the West-to-East flow of information, they believe this can only come to the cost of substantially opening up its own scientific communities*", a *win-win* situation, in the end! This report also acknowledges the fact that networks such as "UUCP[147]" "*already link two institutes in Hungary and Czechoslovakia to the Western world, (but as) this is an extremely inexpensive form of networking based on telephone connections*[148] *with established frequency, typically once per night, (thus) it can take some time for a message to pass to a distant recipient*[149]". The report also mentions "*the increasing use of commercial services as COMPUSERVE that provides access to services such as data bases, news feed and electronic mail and are accessible via the public telephone system, e.g. it is possible to send electronic mail from COMPUSERVE to non-commercial systems such as EARN and/or BITNET*". The interesting conclusion is that "*the EARN decision was not opposed by the US government as, because of the inherent limitations of EARN and internetwork gateways, EARN was not viewed to be a threat as far as direct access to Western supercomputers, or so-called diversion in-place, was concerned*".

The very restrictive CoCom rules explain the early presence of EUnet in Eastern European countries where, unlike EARN, the access technology used was not subject to export restrictions:

1. Early EUnet presence in Eastern countries (i.e. former Czechoslovakia, Hungary, Soviet Union and Yugoslavia) according to the 1990 edition of "The European R&D E-Mail Directory" [211] by A. Goos and D. Karrenberg was made possible through the use of dial-up[150] lines whose use could not be forbidden but whose speed was extremely limited (i.e. typically from 300 to 1200 bit/s). There is an excellent April 1992 report[151] from the RIPE connectivity working group titled "*An overview of East and Central European Networking Activities*" [212] that provides, as detailed as possible, a description of the various network activities in the East and Central European countries.

2. Late EARN presence in Eastern countries as export of network technology was hampered by the CoCom [213] rules until mid-1991, the only exception being Yugoslavia[152] [214]. Indeed a connection[153] between Linz University and the Faculty of Natural Sciences and Mathematics in Belgrade was established in 1989 but had to be cut in 1992 following the UN sanctions that followed the break-up of former

[146] Actually the quoted date is that of the admission by the EARN Board, the physical connections only started to occur from 1991 (e.g. Warsaw-Copenhagen)
[147] EUnet in this case
[148] This statement is actually contradicted by Daniel Karrenberg who claims that as far as he remembers "*at that time EUnet was actually using various forms of X.25 at least to SU, CS and HU.*"
[149] This statement, which is a reflection of the *old* image of EUnet in the mid-1980s, was no longer really appropriate in 1990.
[150] Either public switched telephone lines or (PSTN) or PPSN
[151] written by Milan Sterba (INRIA)
[152] Yugoslavia, not being part of the Warsaw Pact, was covered by lesser restrictions similar to those for Sweden or Austria
[153] initially 4.8 Kb/s then 9.6 Kb/s

Yugoslavia in 1991 and the ethnic wars. Paul Bryant recalls *"traffic building up for Yugoslavia and tapes were sent between countries for a time to get rid of the files."*

6.2 UUNET/EUnet

In addition to being an electronic mail transport network, the main initial advantage of EUnet over EARN was the redistribution of USENET news [215]; however, given the huge success of USENET, the exponential increase of the volume of news was increasingly difficult to handle. Having predated EARN, EUnet had its *aficionados*, of course, and the two networks were somewhat in competition with each other, however, as their goals were very similar, i.e. fostering exchanges between scientists worldwide, this *competition*, actually a cooperation, was not only *friendly but also synergetic*. Whereas EUnet had a BSD[154] [216] orientation, EARN used IBM protocols, thus already raising the issue of *open* versus *proprietary* software; though, in the early 1980s, BSD Unix still shared the initial codebase and design with the original, "*licensed"*, AT&T Unix Operating System. BSD was widely adopted by vendors of workstation-class systems in the form of proprietary UNIX variants such as DEC ULTRIX and Sun Microsystems SunOS.

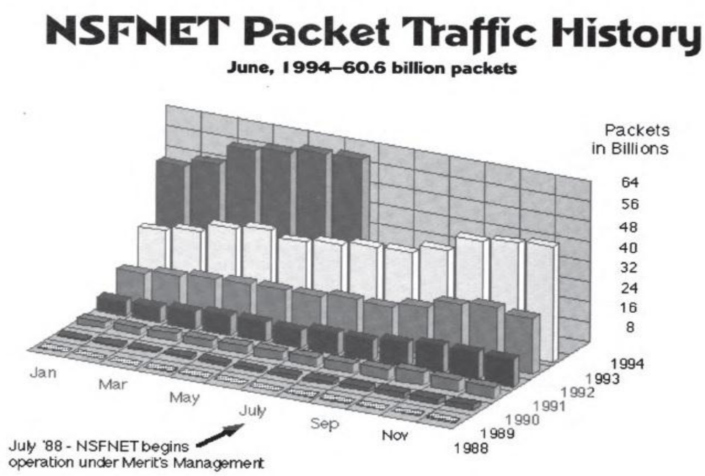

Figure 5 NSFNET Packet Traffic History

Regarding the relative importance of these two networks, the already quoted 1990 edition of "The European R&D E-Mail Directory" [211] only lists institutions/sites and countries "*500 Institutions in 24 countries*" for EARN and "*1600 sites in 22 countries*" for EUnet without any indication regarding the respective number of users and the related traffic; it is actually very surprising to find that, whereas NSFnet traffic statistics have been carefully kept in various forms by MERIT, it turned out to be difficult to find anything equivalent for either EARN or EUnet online[155]! However, thanks to Harri Salminen/FUNET[156] [217], I could retrieve the April 1991 traffic statistics for EARN/BITNET "*International traffic volume by countries*" [218] showing 25 Gigabytes/month between 47 countries (not counting national traffic) with the top country being, surprisingly or not, the most anti-EARN one, namely Germany, followed by France and the USA! If one removes the USA traffic, the International EARN traffic can thus be estimated to 21 Gigabytes/month, i.e. 69Kb/s, that sounds very little nowadays but was not completely insignificant back in 1991. The figure below shows that the NSFNET backbone traffic had a slow start before the emergence of the Web in 1992. The conversion of traffic from packets into bytes can be approximated as follows: half of the packets are 64 bytes (i.e. ACKs) while the other half, especially in the early NSFnet days, were 576 bytes. Hence, the scaling unit of 8 Billion packets roughly corresponds to $4*(64 + 576)*10^9$ = 640

154 Berkeley Unix

155 EARN statistics had to be sent to a central site where they were analysed. Although, there was some reluctance to do this with regularity, enough were received to get a good idea of traffic. These statistics were published in the EARN BOD papers regularly until the removal of the leased lines made them irrelevant. Paul Bryant still has those figures.

156 Finnish University and Research Network

Gigabytes. Thus, in April 1991, the NSFnet backbone traffic can be estimated to be around 200 Gigabytes, i.e. approximately 10 times the EARN/BITNET traffic.

EUNET traffic, which was largely dominated by USENET was certainly much lower than EARN, probably by a factor 5-10; however, the number of USENET[157] sites was undoubtedly much higher, as shown in Hobbes' Internet Timeline [8].

However, other sources use the number of nodes as the metric to compare the respective impacts of EUnet vs. EARN which can be misleading, as what really mattered was the number of users[158], one million or more around 1991 for BITNET/EARN [219]. Indeed, it is well known that EARN nodes were often big IBM mainframes, with many users, sometimes medium to large VAX/VMS, or UNIX systems, whereas single-user PCs with a 300b/s modem could easily take part in UUCP, unlike EARN users who relied on expensive leased lines between nodes.

This analysis is actually confirmed by John Quarterman, in the *"Size & Scope"* section of his "*Notable Computer Networks*" article, where he states that "*while number of hosts makes sense for CSNET like networks which are made of medium-size time-sharing systems and the exact number of users is hard to determine but can be very misleading in case of PC networks (one user/host) or large IBM style mainframes*". Indeed, CERNVM, the central IBM system at CERN, had several thousands of users, therefore "*the right number may be the active number of mailboxes but this is difficult to know*"!

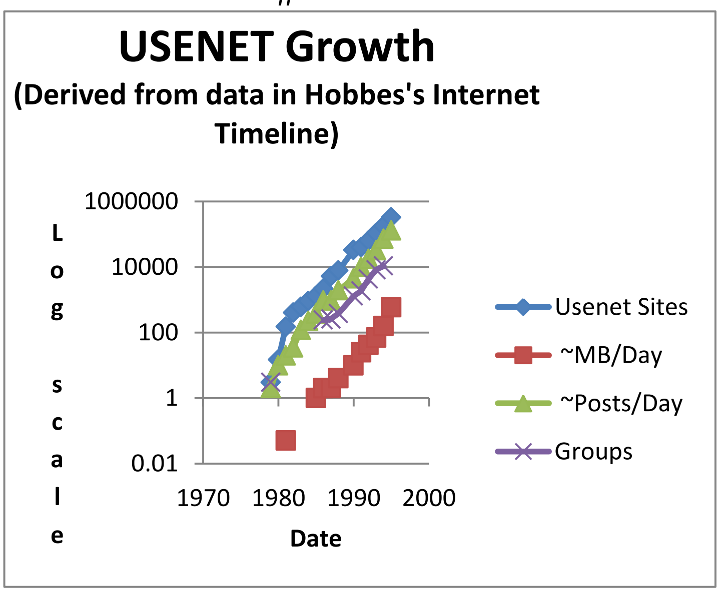

Figure 6 USENET Growth

In any case, there are no doubts whatsoever that driven by Piet Beertema[159] [220], Daniel Karrenberg and Glen Kowack, EUnet was a more dynamic and innovative networking organization than EARN. This may be due to the fact that, unlike EARN, EUnet did not have the Executive and BOD running them that made decision making a lot swifter. By 1982, UUCP links were established between 4 countries (UK, Netherlands, Denmark and Sweden) thus forming the EUnet backbone with a star topology centered on MCVAX [221] in Amsterdam. Later the X.25 link between Amsterdam (CWI) and Sweden (KTH) was upgraded to 64Kb/s and was co-funded by EUnet, NORDUnet [222], HEPnet and EARN. These links were converted to IP over X.25 already in 1988. Likewise, the 64Kb/s X.25 link between Amsterdam

[157] Although today, Usenet has diminished in importance with respect to Internet forums, blogs and mailing lists, the groups in alt.binaries are still widely used for data transfer. Usenet differs from such media in several ways (e.g., Usenet requires no personal registration with the group concerned).

[158] At its zenith around 1991, BITNET extended to almost 500 organizations and 3,000 nodes, i.e. probably 0.5 to 1 million, if not more, users.

[159] Nicknamed the "godfather"

(Nikhef) and Geneva (CERN), co-funded by EUnet[160] and Nikhef [223], established at the end of 1989 played a significant role in the introduction of TCP/IP in Europe.

6.2.1 Excerpts from EUnet history (Wikipedia):

"To completely understand the importance and history of EUnet, it is important to realize that till the early 1990s nearly every European country had a telecommunications monopoly with an incumbent national PTT and that commercial and non-commercial provision of telecommunications services was prohibited or at least took place in a legal "grey zone". During the same period, as part of an industrial political strategy to stop US domination of future network technology, the EC embarked on efforts to promote OSI protocols, founding for example RARE and associated national "research" network operators (DFN, SURFnet, SWITCH to name a few)."

6.3 EARN/BITNET

6.3.1 How it all started

Paul Bryant recalls *"I remember how EARN started. Herb Budd and Alain Auroux did a tour of European sites drumming up support. My management thought they wanted to see what we were up to and so told me to show them round. At that time[161] I was running a network of 20 or 30 multi-user mini computers spread around universities all running the full set of coloured books (UKERNA got jealous and so took it over as JANET). Having heard what they wanted I decided it looked good for our users - a free circuit to CERN so got the support of HEP and my management and didn't tell UKERNA. Since them I have never been all that welcome particularly when I got involved with the SHOESTRING project to run IP over JANET. I named it Shoestring as we were intending to do it for nothing using old DEC machines as routers. In the end they saw the light[162]!"* For more details refer to paragraph 5.3.

Similar visits were made in the future "*core*" EARN countries, including CERN, France, Germany, Italy, The Netherlands, Scandinavia, Spain and Switzerland. At CERN, it coincided with the nomination of David Lord as Head of the new Communications System group, while Paolo Zanella was still heading the Data Handling division. Both were very pragmatic and understood the urgent needs for improved communications within the HEP community and beyond. The connection with BITNET, that was part of the EARN "deal", was particularly attractive given the strong links with the HEP community in the USA. In Switzerland, the leadership was taken by Pr. Kurt Bauknecht (University of Zurich) while Pr. Jürgen Harm (University of Geneva), who was also very active in the setting-up of EARN although his "*heart*" was clearly in the RARE camp took this opportunity to accelerate the creation of the SWITCH foundation.

6.3.2 Management and addressing

Although administered by different entities EARN/BINET were forming a single domain[163] spanning all continents, in which BITNET had an undisputed *leadership*; however, given the European networking orientation of this article, the use of EARN is normally preferred to that of BITNET or EARN/BITNET.

[160] If my memory serves me right, CERN, as a key member of EUnet, also participated to the funding of this link as it actually helped to reduce CERN's EUnet bill
[161] Editor's note: probably end 1982, early1983
[162] i.e. as narrated by Chris Cooper in his book "Janet the 1st 25 years" (sec2:111, page 129) [172]
[163] Together with NetNorth in Canada, Gulfnet in the Persian Gulf, etc.

Contrary to the belief of many people, EARN offered a rich set of services, however there were some "*teething*" problems:

1. Neither EARN nor BITNET could be registered as top level domains in the Internet DNS (Domain Name Service) which then had very restrictive rules. Fortunately, the popularity of BITNET was such that most mail user agents and/or gateways knew how to deal with the *unofficial* .BITNET "*top level*" domain name, however, communications from outside the EARN world was rather clumsy[164], namely: "*user%bitnethost@bitnetgateway.edu*".
2. The native EARN mail notation was the "*user at host*" notation, which was as much as a non-literate network user could understand back in 1984. Fortunately, the generalized use of RICE Mail as a User Agent as well as the Colombia Mailer as the Mail Transfer Agent (MTA) allowed the use of ARPANET addressing over EARN as well as access to Mail gateway to the TCP/IP world)

During its last years, i.e. from 1992, EARN started to publish a very informative newsletter dubbed EARNEST. All 7 issues are still available from the University of Vienna server [224]. Issue number 4, December 1992 [225], provides interesting traffic statistics on EARN servers (Netnews[165], Trickle[166] [226]) and EARN.

In a highly meritorious effort to widen its scope and become more network-user oriented in the emerging Internet world, the EARN Association produced a very successful "*Guide to Network Resource Tools*" [227] in September 1993, which is of high historical importance as it provides an exhaustive description of the networks tools available in these days in a network agnostic manner and, for that reason was even published in 1994 as an Informational RFC 1580 [228].

6.3.3 EARN protocols

The terms NJE and RSCS networks are often *improperly* used as synonyms because of the popularity of EARN/BITNET whose IBM nodes[167] were mostly using the VM operating system instead of MVS[168]. In practice, RSCS is the VM networking component enabling VM/CMS users to send messages, files, commands, and jobs to other users across the network using the NJE protocols. More generally, RSCS allows to interconnect nodes (systems, devices, and workstations) using links. These links allowed data, consisting mainly of CP spool files, to be transferred between the nodes using the NJE protocols; in other words, the right way to describe the early EARN protocols is NJE/RSCS. According to Paul Bryant: *"most early file transfer like systems were for connecting a remote work station (card reader/line printer station) to a central machine and therefore lacked any addressing. I think NJE was the only such protocol that allowed files to be staged through a concatenated set of hosts."*

To be more accurate, here is how IBM describes the respective roles of RSCS, NJE, BSC, SNA and TCP/IP [229] [230]: "*Each link in an RSCS network is associated with a programming routine, called a driver, that manages the transmission and reception of files, messages, and commands over the link. The way that a driver manages the data is called a protocol. All file transmission between networking nodes uses NJE protocol, 3270 printers use 3270 data streams, workstations use RJE protocol, and ASCII printers use data streams appropriate to that printer. Systems Network Architecture (SNA) provides one set*

[164] Arpanet style addresses looked like « Chinese » to the uneducated users of the 1980s

[165] A more general term than Usenet that incorporates the entire medium, including private organizational news systems.

[166] A file-forwarding service allowing EARN users to request a file from an FTP server on the Internet via a gateway server which was connected to both networks.

[167] Less than 50% of the nodes

[168] IBM's mainline Operating System

of protocols that governs communications on links. The method that RSCS uses for sending data to a node varies, depending on the type of connection used to establish the link. RSCS can support non-SNA (such as BSC[169] [231] *or channel-to-channel)* or SDLC[170] [232]*), SNA, and TCP/IP connections."*

The *layered* NJE protocol [233] was specified by IBM as an extension of the RJE[171] [234] protocol to build networks with a focus on, but not limited to[172], Network Job Entry and Output retrieval; the protocol supported multi-leaving[173], compression (removing blanks and duplicate characters), connection procedures, etc.

As correctly stated by Peter Sylvester (GMD) in his "NJE/OSI Service and Protocol Definition" document [235] "*there were many hidden assumptions about the correct implementation of a partner; the major reason being that the NJE protocol was first implemented and then "formally" defined.*"

BSC, a very basic byte oriented link layer protocol, and SDLC were *de facto* link layer protocol standards; SDLC served as input to ISO's HDLC[174] [236] in 1979. IBM's RJE and NJE being also *de facto* industry standards many Operating Systems, including DEC's VAX/VMS with JNET[175] and UNIX with UREP[176], had NJE emulators; actually, most of the BITNET/EARN nodes were DEC computers but there were also some UNIX nodes, significantly including the EUnet node MCVAX at CWI.

Whereas NJE/RSCS emulation software was commonly available, DECNET emulation was also available on IBM systems, e.g. Interlink [237].

For the ISO purists, running BSC or DDCMP [238] in the 1980s was a sheer "*heresy*". However, for the pragmatists like Paul Bryant there were good reasons to use BSC: "*In the UK we ran X25 over BSC for the pragmatic reason that HDLC equipment was unavailable[177]. It was very successful."*

Interestingly enough, there was a very similar situation between the Ethernet II frame format specified by DEC, INTEL and Xerox[178] [239] that was widely deployed in LANs and the ones standardized by the IEEE as 802.2 [240] where, following the OSI model, a 3 bytes LLC[179] header was introduced, with two bytes for the source and destination SAPs and one control byte, at the expense of the Ethernet II frame *type;* this unfortunate decision created a lot of problems as IEEE could not allocate SAP[180] values for "*non-standard*" protocols such as IP because of the one byte limitation, hence two versions of 802.2 called 802.2/LLC and 802.2/SNAP in which a 5 bytes SNAP[181] header is added through a special value of the LLC header in order to cater for proprietary protocols! As a result 802.2 framing was little used in practice on Ethernet but rather on new media like FDDI and Token Ring, however, that was not a problem for the standards supporters as, unlike IBM that was a *bad* company, DEC, Intel and Xerox were *good* companies.

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[169] Binary Synchronous Communication
[170] Synchronous Data Link Control
[171] Remote Job Entry
[172] also included provision to send files as well as Network Management Records (NMR), i.e. real-time commands and/or messages
[173] ability to transfer multiple streams concurrently over the same connection.
[174] High-Level Data Link Control
[175] software originally sold by Joiner Associates enabling a VAX/VMS system to participate in BITNET networks
[176] Unix RSCS Emulation Program
[177] Editor's note: as well as expensive when the first commercial chips became available.
[178] so called, DIX standard
[179] Logical Link Control
[180] Service Access Point
[181] Sub-Network Access Protocol

Both NJE and RSCS shared interesting properties:

1. NJE was not restricted to submitting jobs across the network or sending mail, it also included a file transfer protocol that allowed to send files to anybody across the network as files, not as mail enclosures, as well as an interactive message facility, similar to SMS messages, called TELL, two features still missing in native Internet protocols! Indeed, *Jabber* [241] was only invented in 1999.
2. *Sendfile*, the unsolicited send file utility program was actually very interesting as the main characteristics of the file were automatically preserved (e.g., Binary vs. ASCII, variable length vs. fixed length records, creation/modification dates, etc.) via metadata headers appended to the file itself, *Netdata* format [242].
3. Hierarchical[182] transport ensuring that the minimum number of copies would travel through the network.
4. One serious problem with EARN/BINET was the transmission of large files that, given the limited bandwidth available between nodes (i.e. typically 9.6 Kb/s) was very problematic:
    a. Because they were given low priority and could therefore take weeks to travel from, for example, CERN to SLAC
    b. The maximum file size was limited to 1 Mbytes for operational reasons; furthermore any line *hiccup* would cause the entire file to be retransmitted.
    c. Les Cottrell [243] from SLAC developed BITSEND that would automatically break up a file and transmit the pieces along with control information for putting them back together through BITRCV. A mechanism bearing some similarities with popular file distribution techniques such as BitTorrent and Akamai Download manager that are in wide use over today's Internet, though on a completely different scale.
5. RSCS can be seen as a way of implementing "Delay Tolerant Networking" [244], also referred to as "Disruption tolerant networking" [245], and "*in-network storage*[183], two very fashionable subjects these days!
6. Last, *routing* was done by node *name*, which was operationally complex and required the monthly installation of new routing tables within the EARN/BITNET core in a quasi-synchronized manner, but has also become *fashionable* again. Moreover, this allowed the underlying details to be hidden from the end-user, thus simplifying the "network experience", much as domain names do today.
7. Not directly connected to EARN but worth noting however: the VM "Pass-Through Facility (PVM)" [246] [247], a communications program used by VM users to access other systems independently of SNA that was far too complex and required lot of in-house expertise.

Excerpts from Wikipedia's RSCS article [51]: "*From a technical point of view, RSCS differed from ARPANET in that it was a point-to-point "store and forward" network. Unlike ARPANET, it did not require dedicated interface message processor or continuous network connections. Messages and files were transmitted in their entirety from one server to the next until reaching their destination.*

<u>*Key differences*</u>*: 1) VNET was the first large-scale connectionless network, making it possible for a computer to join the network using dial-up lines, making connection inexpensive while ARPANET required dedicated 50kb lines at first (later raised to 230KB. Most leased lines at the time typically*

[182] Assume a user on a node connected via a single link to EARN sending a file to several users located on different nodes, a single copy of the file will be sent over that link until it becomes necessary to fork the file along the tree rooted at the sending node.

[183] IETF's DECADE (DECoupled Application Data Enroute) Working Group

operated at a maximum rate of 9600 baud. 2) VNET employed a vastly simplified routing and path finding approach, later adopted for the Internet. 3) VNET was a true "distributed control" while ARPANET required a "control" center."

6.3.4 RARE-EARN fights and the CEPT

Needless to say the RARE and EARN organizations were engaged in a frontal confrontation and one cannot exclude the fact that the very restrictive CEPT [248] PGT/10 directive regarding the use of leased circuits, was used as a "*pretext*" among many others to prevent the emergence of EARN and/or to force EARN to develop an, X.25 based, OSI migration plan.

Indeed, well before EARN started, leased circuits such as those of SPAN, the DECNET based NASA network that was extending to Europe, but also those between CERN and CEA as well as RAL were already well established. In addition to being outrageously expensive, because of the "*half-circuit*" concept that was, in effect, (at least) doubling the price, leased circuits were also strongly regulated in Europe by the above CEPT recommendation, i.e. special forms had to be filled in order to support the request, e.g. multi-national companies, e.g. IBM, banks (SWIFT), airline companies (SABRE [249], SITA[184] [250]) were allowed to establish private networks. However, the hidden purpose was clearly to perpetuate the very lucrative PTT monopolies and to force users to either transfer data on switched telephone circuits or to make use of the new public X25 based packet networks, e.g. Transpac in France from 1979, both of them being either time or volume charged.

Fortunately, in March 1990, following the intervention of the Commission, the CEPT decided to revise the "*dreaded*" PGT/10 recommendation "*on the general principles for the lease of international telecommunications circuits and the establishment of private international networks*"; in effect, removing most constraints on the use of leased lines as most European PTTs had always done.

Excerpts from *"Guidelines on the application of EEC competition rules in the telecommunication sector [251] (1991/C233/02)": This recommendation recommended, inter alia, the imposition of a <u>30 % surcharge</u> or an access charge where <u>third-party traffic</u> was carried on an international telecommunications leased circuit, or if such a circuit was interconnected to the public telecommunications network." In effect, these restrictions were mainly:*

1. *making the use of leased circuits between the customer and third parties subject to the condition that the communication concern exclusively the activity for which the circuit has been granted,*
2. *a ban on subleasing,*
3. *authorization of private networks only for customers tied to each other by economic links and which carry out the same activity,*
4. *Prior consultation between the Telecom Operators for any approval of a private network and of any modification of the use of the network, and for any interconnection of private networks.*

For the purpose of an exemption under Article 85 (3), the granting of special conditions for a particular facility in order to promote its development could be taken into account among other elements. This could foster technologies which reduce the costs of services and contribute to increasing competitiveness of European industry structures.

Third party traffic was clearly the "*stumbling block*" for EARN as the potential user community was far bigger than those of HEPNET or SPAN, therefore, it is probably thanks to Article 85(3) that EARN was granted an exception and was allowed to start; however, some

[184] International Company of Aeronautical Telecommunications (Société Internationale de Télécommunications Aéronautiques)

PTTs, like British Telecom, tried their best to force a "*volume based*" charges but had to abandon the idea because of practical difficulties as conformed by Paul Bryant: "*I remember having to send BT our traffic figures so that they could charge us. Eventually they let me know that we would never be sent a bill. In fact I think that BT had no idea how to raise a bill based on figures supplied by the customer - indeed they had no suitable tariff to base the bill on.*"

Nonetheless, EARN had to comply with the above rules and IBM reached an agreement with CEPT under which EARN was temporarily allowed to start a leased lines network using IBM protocols, under the express condition that EARN would develop an OSI transition plan. This is confirmed by Paul Bryant, however, the real agenda was to use this pretext to get rid of EARN altogether: *"Although EARN had to promise to move to OSI protocols and the public network <u>I think that the last think anyone wanted was for EARN to actually convert. The whole idea was to stop EARN as soon as possible and lack of OSI and conversion would be a good leaver to stop the network. They thought conversion would be beyond our capabilities.</u>"*

Indeed, the worse snubs EARN could inflict to RARE was to deploy an X.25 network just before them or nearly at the same time, admittedly with fewer access points than IXI ☺

This CEPT decision, that was maybe the result of a political "*lobby*" was, in any case, a clear abuse of power and a technical nonsense. Indeed, whereas Telecom Operators could, of course, refuse to lease lines according to CEPT PGT/10, because of "*third party*" traffic, they had no rights to impose additional restrictions, such as the exclusive use of OSI protocols, on those lines as, even in these PTT monopolies times, users were allowed to speak the language of their choice over public phone lines!

Thus, the difference of treatment between *public* and *private* networks was not only plain wrong but also very *unfair*. Indeed, for the Telecom Operators "*public*" then meant use of switched 64Kb/s, X.25 or ISDN services, that, being either *time or volume charged*, were not cost effective solutions for establishing private networks[185], also called CUGs [252], especially in the academic and research community.

However, in the 1980s the PTTs had to make huge investment to digitize their phone and data networks. Because of the "*universal services*" principle, i.e. the selling of, for example, phone services (including installation fees) to the same price independently of geographical location (i.e. rural vs. densely populated areas), prices of voice traffic, for example, had little relation to costs. Furthermore, it was tempting for monopolies to "*cross-subsidize*" some services by others. In addition, the costs of the new optical networks were huge, e.g. the typical cost of a transatlantic cable, with 2-4 fiber pairs, was approximately 1 Billion US Dollar in the year 1990s; hence they were typical built by PTT consortiums in order to alleviate the financial risks, nonetheless the RoI[186] was extremely unsure.

Thanks to the help of DEC, the European core backbone of EARN succeeded in running the NJE protocols on top of a minimal OSI TP0 transport-layer shim [253] and X.25 over 64 Kb/s leased lines, a great achievement indeed, but what did this really change?

Later, these same NJE protocols were run on top of TCP/IP which was a far more effective solution.

6.3.5 EARN/OSI

When IBM stopped its financial support to EARN towards the end of 1987, the community was extremely annoyed as they had not fully integrated the idea that IBM's funding would really

[185] Closed User Group
[186] Return on Investment

be limited to four years and isolated parts of the community, e.g., CERN, were not yet ready to self-fund themselves[187]. Furthermore, though the pressure from CEPT/Telecoms/EU to migrate EARN to OSI/X.25 was still very strong, the EARN community neither had the willingness nor the ability to fund such a network as such a transition required the use of SNA in order to make use of X.25. The only country strongly advocating for that solution was Germany through its representative to the EARN Board, admittedly in the *crosshairs* of DFN. This push was obviously related to the existence of the already mentioned AGFnet, a solid "*interim*" SNA/X.25 network in Germany. In the absence of any other solution and X.25 migration being considered as a priority, the proposal was nonetheless endorsed by the EARN Executive during the Nice meeting. Quoting Paul Bryant again "*However, the EARN Executive's main concern was that it would be seen outside as supporting the view that IBM was taking over the networking world. In practice I don't think it caused any problems. This was at the same meeting that we looked at the IBM X.25 switch. Adopting that would have been a radical step. I never heard of anyone who had used such a switch and do wonder if it ever worked as opposed to being an X25 port into an IBM computer.*"

In any case, the EARN management had addressed the OSI migration issue very seriously from the beginning and an OSI transition team headed by Paul Bryant (RAL) had been formed but progress were slow given the complexity of the task due, among other things, to the scarcity of mature and well integrated OSI products. After numerous discussions and meetings, in particular a meeting in Heidelberg sponsored by IBM, the outcome, an extensive draft EARN/OSI proposal known as the "*green book*" [254], was presented by Paul Bryant in Perugia (Italy) in September 1987 under the close scrutiny of RARE impersonated by James Hutton, then secretary general of RARE. The unsatisfactory consensus reached, that was difficult to achieve, cost-wise, was to convert EARN into a private X.25 network[188], which, as already mentioned above, implied the use of SNA therefore significant additional expenses.

Paul Bryant was actually amazed by the mild recption of his OSI migration plan by the RARE *activists*: "*I well recall the Perugia meeting where I presented the EARN plans with James Hutton and Nick Newman trying to do a hatchet job but failing as both lacked the technical background to understand the document. The plans that had already been presented at the RARE Networkshop in Valencia[189] in May 1987 had a very mixed reception. As I have already mentioned, <u>the non-EARN community wanted to get rid of EARN not to see it actually migrate to anything</u>. They wanted to run the networks and not have some organisation like EARN to run one. In other words, OSI as long as it is run by the national networking organisations, <u>in other words national monopolies.</u>*"

Apart from the very informative report produced by Harri Salminen titled "*NORDUnet and EARN*" [255] that provides a wealth of information about the sequence of events that led to the EARN/OSI project jointly sponsored by DEC and Northern Telecom and whose large excerpts are available in chapter 18.1, very few of the documents written during this period are available on line and, in particular, the "*green book*"!

Thus, Dennis Jennings, who had just been elected president of EARN for the 2nd time and was very pragmatic, was the ideal man to convince DEC to play a key role in the EARN / OSI transition. Indeed, as reported by Harri Salminen, new support came into the picture between the September 1987 Perugia meeting and the May 1988 EARN board meeting in Çeşme (Turkey):

[187] According to Frode Greisen, there was no general EARN funding problem except for CERN but that particular problem was resolved by declaring CERN as the center of the network ☺

[188] In other words run RSCS over X.25

[189] Where Nick Newman tripped over and broke his arm, perhaps because of the "*irritation*" caused by the presentation of the EARN/OSI migration plans!

"*First, DEC promised to support EARN's OSI migration by providing hardware, software, technical expertise and a small grant for upgrading four lines to 64Kbit/s that would form a square EARN X.25 backbone. Then Northern Telecom donated four large PTT-style DPN-100 X.25 switches, one DPN-50 management switch, spare parts and training. Lastly IBM made new offers to support the availability of OSI/SNA software and hardware. In addition IBM offered co-operation with their new emerging EASINET initiative. During the May 1988 BOD meeting in Cesme (Turkey), EARN officially accepted all three offers, subject to further negotiations. During spring 1988 a new group called OSI-TEAM was formed to design a new OSI Migration plan which held several meetings that were sponsored by DEC that finally came to a conclusion that we needed some kind of gateways between NJE and OSI which we called G-BOXes"*

The joint offer of DEC and Northern Telecom[190] [256], a leading Telecom provider of X.25 switches, was difficult to refuse given that it offered significant added value to the existing EARN backbone, in particular much needed credibility with respect to the EARN/OSI transition, but also higher bandwidth (i.e. 64 Kb/s instead of a 9.6 Kb/s) inside the *new* EARN core.

Back in 1988, the credibility of the newly announced IBM's EASInet initiative was not very high and its success was still uncertain; furthermore, few people really believed that, thanks to its multi-protocol design, EASInet would actually provide a key part of the, not yet emerging, European Internet through the extension of NSFnet to Europe at CERN, whereas many others thought that EASInet was just a disguised way of promoting the use of SNA in Europe. In practice, EASInet facilitated the deployment of the European Internet and was instrumental in the establishment of Ebone.

There is an excellent presentation by Niall O'Reilly [119] (UCD) about the EARN/OSI history that lasted about 2 years after a slow start around mid-1989 due to the rather *odd manner* in which DEC was handling the project, as a whole, and its logistical aspects, in particular.

Like Niall O'Reilly, Paul Bryant disliked the way in which DEC managed the EARN/OSI project: *"I was intensely irritated by, Odd Jorgensen, he threw away the work already done and started off with a rather juvenile brainstorming session to determine what to do. I rather stepped back at that point since DEC was intent on doing it their way and with staff paid by DEC - no advice needed."* In addition, "*The NT switches were well over configured for the job. I was in favor of one of the cheap X25 switches that were becoming available, say, from CAMTEC. The NT switches took up an immense amount of floor space with dual power supplies and a lot of other unnecessary bells and whistles*."

Although EARN/OSI was reasonably successful, technically speaking, it failed to become an appealing technical as well as political solution, therefore it did not last beyond its originally planned duration (i.e. 2 years or so) for several unrelated reasons:

1. To a limited extent[191], the emergence of IXI at more or less the same time in 1989-1990; in reality, the predictable failure of X.25 as a scalable technology.
2. The high prices claimed by DEC to continue providing the EARN/OSI service after the end of their sponsoring in 1991 also played a role; actually they shot themselves a

[190] On the occasion of its 100th anniversary in 1995 Northern Telecom, whose origin was Bell Telephone Company of Canada changed its name to NORTEL that filed for bankruptcy in 2009 and has been dismantled since then

[191] As a software solution EARN/OSI was only depending on the availability of a private or public X.25; actually, several countries rejected from the very beginning the use of dedicated EARN/OSI lines (e.g. Ireland, Nordic countries). Tunisia was connected through a public switched data network and Germany was connected through IXI, of course!

ball in their feet, but were they really willing to continue along, what proved to be, a dead end?

3. The advent of EASInet, that brought a lot of additional bandwidth, as well as the wide adoption of Internet protocols in Europe, more or less at the same time as the ability to run RSCS over TCP/IP [257], also referred to as BITNET II.
4. Last but not least, the revision of CEPT's PGT/10 recommendation that removed restrictions on the use of leased lines and, in particular, the *obligation* to run X.25 protocols.

According to Paul Bryant: "*The GBOX was the best outcome of EARN/OSI as it was a solid, VAX/VMS based multi-protocol gear with (DECNET, CLNP, X.25 and TCP/IP), however, the EARN/OSI failure was inevitable in the light of the move to IP. When conceived there was still a strong belief that OSI would succeed in Europe (if not the world). Had that come to fruition, I suspect that the EARN/OSI project would have had a longer life although in the light of the opposition from the NRENs it would no doubt have been an exciting ride!*"

Another interesting aspect of DEC's EARN/OSI funding is that DEC wanted to demonstrate the advantages of managed networks in a "*TELCO like"* manner, whereas, ironically, IBM who was rightly seen as the "*champion*" of mainframes and SNA based solutions, i.e. centralized solutions, was in practice supporting "*community managed*" networks i.e. decentralized though not quite "*self-organized*" networks a concept that is gaining popularity with networks growth and the expected increase of new networked devices (RFID, sensors, actuators, etc.).

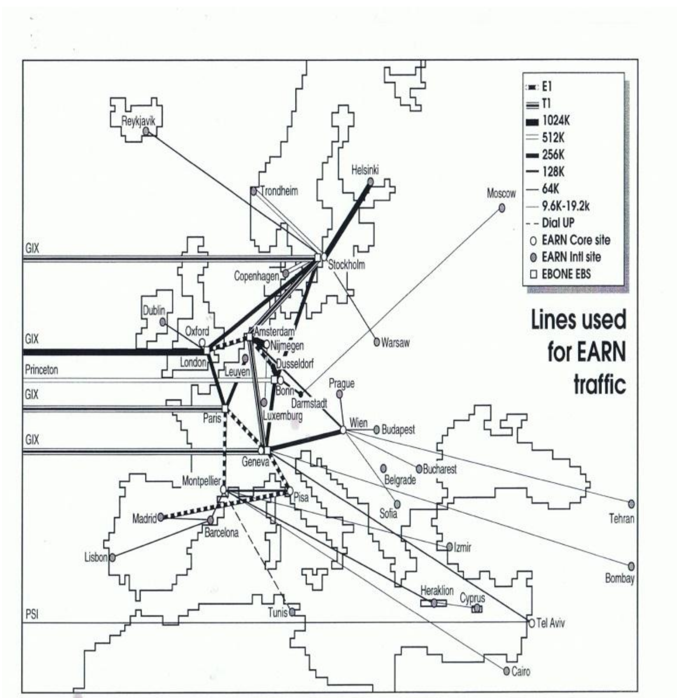

Figure 7 EARN Map 1994 (D. Bovio)

Actually, the proof was made that "*best effort*" decentralized network management could work well, despite some unavoidable outages. This model should be compared with strictly managed networks with very constraining change management procedures, e.g. ITIL [258] that are both time-consuming and possibly de-motivating for the, not yet *robotized*, people, while also slowing down considerably the evolution of the IT infrastructure without even guaranteeing faultless operations.

Niall O'Reilly, who was the Chief Technical Officer of EARN/OSI holds similar views about the interplay of organizational cultures during the time of the EARN/OSI project, not only between IBM and DEC, but between each of them and EARN, and also involving Northern Telecom, kindly provided many interesting and *crisp* details about this period in chapter 18.1 "*EARN/OSI seen by its CTO*": "*IBM's approach was both pragmatic and sophisticated. It was perhaps an exemplary application of the "Subsidiarity principle": they contributed key resources which enabled the community to* *do something useful, and avoided the kind of interference which would have increased their costs and simultaneously antagonized the beneficiaries. They were clever enough not only to find the "sweet spot" on the cost/benefit curve, but also to take a relatively long-term perspective and not look for early and tangible pay-back… When implementation of the new deal with DEC and Northern Telecom (NT) began, NT took an even more "hands-off" position than IBM. They contributed inventory, training and some support, during quite a short time window, and then more or less walked away, apparently content with whatever publicity or collateral benefit[192] they could extract from the exercise[193]. Both of these approaches suited a community of beneficiaries who simply needed resources to run their services, and were both aware of the requirements and competent to address them. DEC, however, took an approach which was less efficient, both for them and for the project for which they were the major sponsor….DEC seems not only to have been unable to comprehend and accommodate the culture within EARN of a network run by the participants for their own or their local customers' diverse needs, but also to have convinced itself that the EARN/OSI project was a campaign in a "turf war" with IBM, from whom DEC was going to seize operational control of the network and deliver the "benefits" of a "managed network" to the "customers"!*

6.3.6 The emergence of RSCS over TCP/IP and the end of EARN/BITNET

During the early days of BITNET, IBM didn't offer a TCP suite. Around 1985, Matt Korn from Wisconsin University wrote a full TCP/IP package known as WISCNET, which IBM later sold as a supported product for both the VM and MVS environments. However, VMNET, i.e. RSCS over TCP/IP was developed by Princeton University[194]. Michael Gettes recalls that when Matt Korn moved to IBM; "*he met Barry Appelman and Jay Elinsky and others who all ended up at AOL along with David Lippke [259] from University of Texas. If you will recall Lippke was instrumental in BITNET - he and I always talked of creating "FredNet" which would entail the best of NJE features like Instant Messaging on a massive scale. Well, it was Lippke, Elinsky, Korn and crew who brought AOL Instant Messaging to the world and forever changing the IM landscape!*"

In 1986 the NSFnet Program provided funding to BITNET to support the TCP/IP protocol suite and to integrate it into the NSFnet as a mid-level community network.

Following the availability of VMNET, i.e. the possibility to run RSCS over the Internet instead of requiring dedicated lines, the BITNET II proposal made by Michael Gettes[195] in February 1990 was widely adopted throughout the EARN/BITNET world during the 1990-1992 period and, as explained above, was one among several other reasons that led to the demise of NJE/OSI. Indeed, the new possibility, that basically eliminated the need for dedicated EARN lines, met some resistance from the EARN Executive.

Whereas the 1st VMNET link was established between CERN and Princeton during the 1st quarter of 1990, due to exceptional circumstances[196], it took almost another year to the EARN Executive and finally the EARN Board to agree on the EARN Regionalization plan proposed by Daniele Bovio[197] in collaboration with the EARN routing group and Michael Gettes (BITNET) [260].

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[192] I seem to recall that NT's selection as supplier and sponsor of X.25 equipment for EARN was significant in enabling them to win other business in the academic community, and that either DFN and/or SURFnet was mentioned, but I am sure that NT didn't waste resources in useless follow-up to their well-defined contribution to the project.

[193] Maybe they were already well aware of the imminent death of X.25 and were concentrating their efforts in other, more promising, technological directions like ATM (comment from O. Martin)

[194] Source: Michael Gettes

[195] BITNET Master Coordinator (Princeton University)

[196] Chronic overload of the EARN-BITNET transatlantic connections

[197] Manager and Chief Technical Officer of EARN

According to Paul Bryant the issue was a timing one: "*I don't think the Executive or BOD were against NJE/IP or the regionalisation project. I think that things were moving very fast and the Executive and BOD did not meet often enough to keep up with the changes",* however, Daniele Bovio remembers the embarrassment of the EARN Executive *"that was still very scared of all the X.25 OSI bullshit. I remember them all wondering if they could afford to have EARN so blatantly embrace the TCP/IP technology while the OSI debate was barely over."*

The service-oriented EARN organization having recognized that it had more or less lost its "*raison d'être*" when Internet protocols and backbone lines started to flourish throughout the world, is one of the very few organizations that decided its own obsolescence. BITNET did the same around the same time in 1996, although some kind of minimum EARN over TCP/IP service was maintained on a voluntary basis by Hans-Ulrich Giese[198] and Michael Gettes which was mainly useful for IBM users.

6.3.7 EARN presidents:

Dennis Jennings [261] was the first EARN president during its early 1983-1984 period, before EARN was incorporated in 1985 and before he moved to the USA (on leave from UCD) to lead the implementation of the NSFNET Programme (1985-86), the inter-network that is really at the origin of the Internet as already explained in chapter 2.4.

David Lord (CERN) was the 2nd. EARN president (1984-1987) and when Dennis Jennings came back to Europe he was re-elected as the 3rd EARN president (1987-1988) at a difficult time where IBM seed-funding was about to stop. Unlike David Lord who was very close to IBM, Dennis Jennings was not particularly "*pro-IBM*" which actually paved the way to DEC's EARN/OSI initiative and despite some fears, because of his prior involvement in NSFnet, did not try to push TCP/IP. Paul Bryant recalls: "*When Dennis returned from NSFnet many members of the Executive and BOD were worried that he would try and turn EARN into some form of IP network. We thought that such a direction would set us against the NRENs in a big way and we would probably lose any battle, maybe a mistake!*"

Frode Greisen (4th and last president 1989-1995) organized the transition of EARN from leased lines to TCP/IP and later became the 1st president of TERENA, but not for very long (i.e. seven months), he also become the General Manager of Ebone from 1992 to 1999.

6.4 The sad X.400 and EAN saga

EAN (Electronic Mail Agent) was developed by and for CDNnet [262] the original registry for .ca. The EAN designers at the University of British Columbia took a very pragmatic approach with respect to X.400 addressing namely that of being compatible with RFC 822, i.e. Internet mail addresses. However, those addresses were internally converted to X.400 format, which meant that between two EAN systems addressing was the same as Internet style addresses, however, they were mapped to X.400 internally before being converted back to RFC 822. This *pragmatic* approach, i.e. taking into account the *fact* that interoperability with the Internet world was already of *prime importance* was very much disliked by the X400 *purists* such as Pr. Bernhard Plattner (ETH Zürich) and Pr. Jüergen Harms (SWITCH), but also Peter Kaufmann (DFN), who very much preferred the "*beauty"* of X400 addressing namely: /C=GB /ADMD=BT /PRMD=DES /O=UCS /OU=CS /S=KILLE instead of steve@cs.ucl.ac.uk (ARPANET style) or steve@uk.ac.ucl.cs (UK "*Coloured Book*")!

[198] EARN Master Coordinator (University of Nijmegen)

Not the least of all X400 challenges was competition between Universities, *shaky* User Agents written by students that were not ripe for production use, as well as loss of attributes given that some X.400 protocol implementations were *richer* than others.

Steve Kille authored native X.400 and X.500 user agents, called "PP" and "QUIPU", was also at the origin of the ISODE consortium which met a number of successes by proposing pragmatic solutions, e.g. standardizing access over TCP/IP to X.500 directories via LDAP.

There are three excellent articles by Denise Heagerty (CERN): "*Practical Experience with High Level Gateways for Mail Transfer*[199]" [263], "*Experience with Mail gateways and Transition to X.400*[200]*"* [264], and Maria Dimou (CERN): "*The Email Gateway Manager Reminiscent of Sisyphus*[201]" [265].

The merging of EARN and RARE into TERENA happened in October 1994 and use of X.400 by some *activists* continued for some time. Paul Bryant is actually questioning this merger and wonders "*what if EARN had merged with RIPE? We were both interested in operating networks rather than politics."* However, this was not an option as the trend was clearly towards "*burying the hatchet*", furthermore, as explained in the minutes of the 24th RARE CoA meeting (October 1992) under the heading "RELATION RARE/RIPE REDEFINED" [266]: "*RARE and RIPE will remain independent bodies. The CoA agreed that RARE will continue to rely on RIPE for the coordination of IP activities - and not establish its own IP coordination group - , while RIPE will rely on the RARE Technical Committee and IETF for the setting up of a technical development plan. To enable close cooperation between RIPE and the RTC, RARE has invited RIPE to appoint a representative on the RTC. With regard to the RIPE NCC, the CoA agreed that it should remain under the umbrella of RARE until at least the end of 1993, even if the funds for operation of the RIPE NCC were to be channeled via the Operational Unit.*"

Regarding the IETF, twenty six RFCs related to interworking/mapping between X.400 and RFC 822/MIME were issued during the period 1986-1998, followed by RFC 3854 and 3855 about the use of S/MIME for securing X.400 content and transporting secured content over X.400 transport networks, in contrast, nearly 100 RFCs are related to LDAP during the period 1993-2011!

According to me, X.400 was far from being a bad standard. It was a very complete, though complex, standard that had much better functionality than its Internet Mail counterparts (i.e. RFC 822 and SMTP), a potential advantage that was not exploited at all. Indeed, instead of selecting an ambitious X.400 profile that could have made X.400 more attractive than SMTP, a very conservative profile was adopted by the RARE MHS working group; while the IETF was fast developing and also implementing MIME!

However, Paul Bryant strongly disagrees with this rather positive opinion of X.400 and is adamant in stating that "*it was a bad standard as it suffered the problem of most OSI protocols in that there were options and it was all too easy to develop products that were correct implementation but would not interwork."* And is adding that: "*he once gave a talk to a UK Networkshop entitled "Minimal Irreducible protocols" that made the case for protocols to have no options at all – it did not get taken seriously.*"

The electronic mail MINT gateway, that was actually the result of the COMICS study led by Ulf Beyschlag, turned out to be a very popular and useful service, provided by CERN for the

[199] RARE Networkshop (Valencia, May 1987)
[200] DECUS Symposium (Roma, September 1987)
[201] IFIP TC6 6.5, International Symposium on MHS (Zurich, October 1990)

benefits of the European academic and research community, thanks to the extraordinary competence and dedication of Dietrich Wiegandt. MINT was impersonated by a number of CERN systems, including CERNVAX (DEC) and CEARN (IBM).

6.5 The Birth of the Commercial Internet and the World Wide Web

There were actually two very unique features in the early Internet, dynamic, Interior as well as Exterior, Routing protocols [267] (i.e. IGP and EGP), and the Internet Domain Name System (DNS) [268]. Indeed, back in 1985, Paul Mockapetris [269] (ISI) and Jon Postel identified the early Internet problem of holding name to address translations in a single table on a single host, and instead proposed a distributed and dynamic DNS database, a *great leap forward* that was probably one of the main reasons to the success of the Internet despite the fact that in the pre-World Wide Web period, i.e. 1992, its functionality was actually rather poor, i.e., the file transfer facilities were very awkward, SMTP Mail servers were very primitive, but there were a few emerging *indexing* and *archiving* tools such as Archie [270], Gopher [271], WAIS[202].

Likewise, the early implementations of the Web browsers were primitive at their inception back in 1990-1991, i.e. a dumb-terminal oriented Web with HTTP and HTML already well-developed, with *Hypertext* [272] links highlighted and followed by pressing the "*Enter*" key or scrolled over. But, it was an already very integrated and nicely built environment with interfaces to the most popular Internet tools and services such as Email (SMTP, UUCP/Unix), ftp, telnet, News, Archie, Gopher, etc.

The Web was demonstrated in many conferences and, in particular, at the EARN Network Services Conference in London in November 1994 where Paul Bryant "*organised an IP link to the hotel. In fact it was an ISDN connection (128K) with the connection ending at a PC running freeware programs PCROUTE and "packet driver" in order to run TCP/IP [273]. SUN lent us a dozen machines for the event."*

In 1993, Mosaic [274], a graphics enabled browser, the precursor of Netscape [275], received almost immediate acceptance from the Internet community at large, and especially the emerging commercial Internet. Since then, Web protocols and technologies have been under *constant* evolution, however, it is customary to distinguish the following phases, Web 1.0, the *static* Web, from 1992, Web 1.5, the *dynamic* Web around year 2000, then Web 2.0 [276], since approximately 2004. Social networks started to emerge with Web 2.0 in the form of services such as Facebook, MySpace and Twitter, Blogs, Wikis, photos and videos sharing sites, etc. One likely reason for the *meteoric* success of the Web, that shares many similarities with that of the Internet, was its initial simplicity; indeed HTTP 1.0 was rather primitive and was actually a simple extended version of SGML[203] [277] that was actively supported by Chris Jones (CERN). SGML, a derivative of IBM's GML, was standardized by ISO in 1986 under the impulse of Charles F. Goldfarb (IBM) with contributions from Anders Berglund (CERN) who later joined ISO.

There is another interesting paper by Maria Dimou (CERN) prepared for the South African Conference on Web applications in 1999 that shows the, then emerging, trend towards using commercial rather than home-made products [279].

The 20th anniversary of the birth of the inception of World Wide Web was celebrated at CERN in March 2009 [280]

[202] Wide Area Information Server
[203] ISO8879

6.6 Tentative conclusions

Although the use of proprietary protocols was the rule rather than the exception nobody seriously wished that situation to continue for too long!

What would have happened if neither IBM nor DEC had helped the European Academic and Research community at times where creating new networking budgets was very difficult? Indeed, apart from the large worldwide scientific communities (e.g. Space, HEP, Magnetic Fusion) where the case for *mission-oriented* networks was well understood, the *sheer* notion of communicating with the scientific community, at large, was less well understood!

Well, it is likely that the use of USENET, remote login, BBS[204] [281] and Computer Conferencing Systems, such as KOM [282] and EuroKOM, would have continued to increase in parallel with the development of *mission-oriented* networks.

IBM was clearly the first to inject very significant amount of seed-funding, thus greatly contributing to the success of EARN but also BITNET by giving a worldwide scope to these compatible, interoperable, but independently managed networks. Later, IBM made another, even more decisive, step with their EASInet initiative that led to the birth of the European Internet with, in particular, a T1 (1.5Mb/s) connection to NSFNET between CERN and Cornell University.

However, the role of DEC should certainly not be underestimated as, without the DEC funding, the EARN community could have met serious problems.

Of course, both IBM and DEC, especially DEC, had a *hidden* agenda, publicity was one, competition between these two leading computer manufacturers was another, OSI was also at stake, DEC was eager to show that it was heading in the right direction with Ethernet, that became standardized by IEEE, and the DECNET/OSI migration that never happened, although it almost succeeded, then its IETF activity for IPng with the TUBA proposal, very similar in essence to the approach taken by the ISODE consortium that later became ISODE Limited [283].

7 Global Networking Organizations and Initiatives

7.1 Coordinating Committee for Intercontinental Research Networking (CCIRN)

The first CCIRN [284] meeting was co-hosted by CERN and the University of Geneva in May 1988 and represented the first attempt to harmonize the inter-regional operation of the emerging worldwide research networks. There is a most interesting article published in the CERN Computer Newsletter article [285] [286] by François Fluckiger that throws some light on the first CCIRN meeting that also had some influence on the establishment of RIPE and the subsequent deployment of the European Internet.

However, there were many other such meetings between the US and Europeans prior to 1988, according to Peter Kirstein: "*the first meeting between NSF people and Europeans in October 1984 should be classed as a milestone. This meeting was on a Friday/Saturday, preceding an ARPA SATNET project meeting on the Monday/Tuesday. At that time NSF had asked me to arrange a meeting with various*

[204] Bulletin Boards Systems

Europeans, but refused to have a meeting joint with ARPA. It was only on the Sunday that both groups agreed to meet socially."

The main purpose of CCIRN was global cooperation between national *peers*, in other words, EARN was not welcome, and one of the "*hot subjects"* was coordination of transoceanic links, making sure, in particular, that they would be consolidated into as few "*big pipes*" as possible, a good idea in principle, but also that they would be landing at the *right* places. Amsterdam, Geneva (CERN), Paris and Stockholm, for example, were among the places to avoid because of their early support of both EARN and Internet; another reason was the cooperation of KTH (Stockholm) and RENATER (Paris) in the GIX[205] [287] [288].

To be fair, it was the CCIRN European delegation, i.e. RARE and later DANTE, who were attempting to twist this "*thorny*" issue in their favor.

Fortunately, CCIRN miserably failed to prevent the *unavoidable* from happening; indeed, DANTE's "*topologists"* were, in the end, forced to build networks around the *main data sources*!

Another very *hot* issue was cost sharing; indeed, for various historical reasons and, apart from the five, DARPA[206] funded, satellite lines [289] to Germany, Italy, Norway[207] (NORSAR[208]) [290] and UK (UCL and RSRE[209]), and the US DoE[210] funded links to CERN, Europe was paying the full cost of the transatlantic circuits which was viewed as "*unfair*".

However, there were also good reasons why some organizations preferred to connect directly to the US like: 1) Higher standing 2) Lower prices of transatlantic circuits compared to intra-European ones, hence lower costs at the expense of longer transit times to connect, for example, Stockholm to Madrid via the USA, back in the early 1990s 3) Better connectivity to the Internet, hence better QoS.

Indeed, as correctly analyzed by André Choo (Teleglobe), the Internet was then largely "*US centric*" due to the fact that *most* Internet content was located in the US; hence, as shown in "*IP traffic measurements at CERN*" [291], a joint article by J.M. Jouanigot, Jessica Yu and myself presented at INET'93, the traffic was completely *unbalanced* in the West to East direction (i.e. most of the traffic traveled Eastwards).

So, a *fair* solution to the transoceanic links cost sharing problem could have been to contribute proportionally to the ratio of inbound vs. outbound traffic. In the mean time the problem has been solved as the traffic is, I believe, balanced, the landing points in the USA are on the East coast and NSF is sharing the costs with the EC through DANTE.

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[205] Global Internet eXchange usually means the MAE-East Internet exchange point in Washington DC, USA, which could also be referred to as a de-facto "NAP". There have been plans to physically distribute the GIX and thereby create a "D-GIX".

[206] Defense Advanced Research Projects Agency

[207] As the first ARPANET connection outside the United States, NORSAR's TIP was installed in June 1973 and became operational in July 1973 a few minutes before the TIP in London, a matter of national pride in Norway as in Scandinavia. A communication link between Kjeller (NORSTAR) and London (UCL) was also established. Sheer objectivity obliges to say that these two historical links became operational at the same time and that the UCL one had a much larger impact as it was used as a gateway to the UK research community and thus served a much wider user community.

[208] NORwegian Seismic Array Research

[209] Royal Signals and Radar Establishment

[210] Department of Energy

7.2 Intercontinental Engineering Planning Group (IEPG)

In the USA several Internet Engineering Planning Groups (EPG) in the USA had already been established. The two Federal Internet exchange Points (FIX) [292], established under the auspices of the FEPG[211] in June 1989, were policy based network peering points where U.S. federal agency networks, such as the National Science Foundation Network (NSFNET), NASA Science Network (NSN), Energy Sciences Network (ESnet), and MILNET were interconnected:

1. FIX-East, at the University of Maryland in College Park
2. FIX-West, at the NASA Ames Research Center in Mountain View, California.

FIX-East and FIX-West were eventually expanded to become MAE-East [293] and MAE-West [294] two of the five NSF supported NAP[212] [295]. MAE-East was a fiber ring around Washington DC, based on MFS[213] technology, and for historical reasons "*was the nearest thing we had to a* "<u>center</u>" *of the Net*[214]".

The GIX proposal was made by Guy Almes, Peter Ford, and Peter Löthberg during the June 1992 IEPG meeting in Washington DC in order to facilitate the interconnection of academic and commercial networks in one place. The proposal was further evolved into the D-GIX[215] [296] at MAE-East[216], KTH (Stockholm) and RENATER (Paris). The D-GIX was based on a route server and routing registry prototypes developed by the RIPE-NCC and deployed at the above three places. Most Internet Exchange Points in the world do include nowadays some kind of "*route server*" service.

There is no doubt that MAE-EAST had had a real impact; however, I am unable to judge the real impact of the GIX, in general, and the D-GIX, in particular, and whether it has ever been used operationally.

NSFnet also had its own Engineering Planning Group (EPG) and, in order to coordinate the activities on a more global scale, the creation of the IEPG was decided during the 1990 Killarney meeting in order to include engineers from Europe and Asia-Pacific regions.

The founding meeting was held in Vancouver (Canada) in July 1990 before the 18th IETF meeting, there were very few participants, including Vint Cerf, Elise Gerich (MERIT), Bill Bostwick (DoE) and three Europeans, Erik Huizer (SURFnet), Fernando Liello (RARE) and myself. Unfortunately the minutes of this meeting are not available from the official IEPG sites. However, the minutes of this 18th IETF meeting [297] are still available where it is stated on page 8 that: "*We were especially pleased to have a delegation from the European networking association RARE at the IETF. Erik Huizer (SURFnet, Netherlands), Rüdiger Volk (RIPE, Dortmund Univ), Fernando Liello (INFN, Italy), and Olivier Martin (CERN, Switzerland). Erik and Rüdiger gave a presentation on networking activities in Europe.*"

211 Federal Engineering Planning Group
212 Network Access Points
213 Metropolitan Fiber System
214 NETTRAIN Archives May 1996, week 3
215 Distributed GIX
216 Basically a MAN based 10Mb/s bridged Ethernet managed by Metropolitan Fiber Systems (MFS), a Washington DC based company in order to provide cheap, cost-effective, 10 Mb/s attachments to customers like Alternet, Sprint, SURAnet, PSI, etc,. relevant to the RIPE NCC Route Server project allowing Europe to present a "*fairly*" consistent routing picture to large portions of the service providers across the Atlantic.

The IEPG mandate evolved over time from an initially very restricted set of Internet engineers, gathered under the auspices of the CCIRN, to "*an informal gathering that meets on the Sunday prior to IETF meetings. The intended theme of these meetings is essentially one of operational relevance in some form or fashion - although the chair will readily admit that he will run with an agenda of whatever is on offer at the time!*"

The first IEPG official meeting was held a few months afterwards in Santa-Fe in October 1990, one of the main agenda item was about the "*rationalization*" of transoceanic circuits. Bernhard Stockman was tasked with maintaining a database of all such links and I was tasked with explaining the pros and cons of merging the multitude of small, typically 64 Kb/s circuits into bigger "*pipes*" typically T1, possibly T3 later.

7.3 Global Interoperability of Broadband Networks (GIBN)

Like many high-level political initiatives that are launched "*in the air*" without any funding behind, GIBN raised lot of hopes but led essentially nowhere, despite some donations such as the 155 Mb/s transatlantic Teleglobe circuit. There are two main reasons behind the failure of GIBN: 1) lack of public funding 2) prohibitive costs of the tail circuits that were grossly underestimated.

The information below is extracted from presentations made by Yves Poppe (TATA, formerly Teleglobe):

"In October 1994 Teleglobe and its partners inaugurated CANTAT-3 [298] with two fiber pairs, capacity of 5 Gigabit (2x2.5 Gb/s) linking Canada to the UK, Germany, Denmark, Iceland and the Faroe Islands. Doubled the capacity under the Atlantic 155 Mb/s was earmarked for data. Engineering estimated 17 years to fill the cable!

1. Towards GIBN:

    1.1. During the meeting in Naples in July 1994, President Clinton urges the G7 nations to develop an international information infrastructure. The G7 agreed to hold an ministerial conference on Information Society in Brussels Feb 1995 meeting hosted by the European Union combined with a major industry leaders meeting and technology showcase

    1.2. During the Brussels conference in February 1995, Teleglobe agreed to <u>provide</u> a transatlantic STM-1 (155 Mb/s) on the new CANTAT-3 cable for the showcase and Deutsche Telekom agreed to connect the European continental part through JAMES[217] [299]. In addition, 11 pilot projects were identified including the "*Global Interoperability of Broadband Networks*" (GIBN) but also "*Environment and Natural resources Management*", "*Electronic Museums and Galleries*", "*Global Marketplace for SMEs*"

    1.3. The fist GIBN meeting took place in Paris in January 1996. The United States, represented by Steve Goldstein (NSF) [300], proposed a number of high performance computing and communications candidate applications that would utilize intercontinental high performance communications links. As part of the Canadian contribution, Teleglobe *donated* the Cantat-3 STM-1 to CANARIE[218] [301], the Canadian NREN, for a "*two year"* period. In turn, Japan got connected with a 45Mb/s satellite link.

[217] Joint ATM Experiment on European Services
[218] Canadian's R&E network

After a successful set of transatlantic demos in Brussels, the transatlantic portion of the link connecting CANARIE to BERKOM [302], the then Deutsche Telekom R&D arm in Berlin, was maintained. A number of projects between the CRC[219] [303] and Europe were completed using this link. This included the first transatlantic native IPv6 transmission, participation in the first multisite conferences under the ABC series. BERKOM also concluded a number of demos and tests with their subsidiary at the University of Berkeley using a connection between Teleglobe and Sprint at the time. In the meantime the Teleglobe and KDD provided 45mb satellite between Canada and Japan allowed for the first transcontinental very high definition videoconferences.

The multisite ABC[220] conferences [304], where CRC collaborated with Pr. Juan Quemada (UPM[221]) [305] had multiple sites in Europe connected through JAMES and using the Isabel software [306], are worth mentioning as these were really world premieres and were without any doubts well ahead of their time; however, despite the fact that Isabel is still alive and "*well*", it failed to have the lasting impact it would have deserved, why? Here are some possible reasons, first of all, back in the early 1990s, high definition video conferencing implied the use of expensive Parallax graphics cards only available on SUN SPARC workstations, second, although (perhaps) because the Isabel application was both extremely innovative and features rich, its stability left much to be desired, last, the design team opted for open source software far too late. Nonetheless, the third TERENA European Network Performing Arts Production workshop [307] was hosted by the "Gran Teatre del Liceu" in Barcelona in June 2011. A virtualized Isabel service in the cloud is offered by the social Website Global Plaza [308] which supports collaborative spaces where Isabel sessions can be organized with automatic MCU, streaming and recording set-up for the virtual meeting.

2. The end of GIBN:

   2.1. From 1995 onwards, the Internet *tsunami* took everybody by surprise; CANTAT-3 was full in less than 3 years and, thanks to the introduction of DWDM cables of 1000 times the capacity of CANTAT-3 were installed during the following five years, i.e. by year 2000.
   2.2. Deregulation, easy access to capital, advances in laser and fiber technology and spectacular Internet growth created a new generation of Global cable builders: Global Crossing [309] , Level3 [310], FLAG [311], 360networks [312] and resulted in a plethora of transmission capacity under the commonly held *belief* that traffic would continue to double every 90 days.
   2.3. The predictable result was that capacity prices *plummeted* that, at last, allowed the Research and Education community to build properly dimensioned networks at affordable prices. Unfortunately, as the underlying economic model was not viable this led to the bankruptcy of many Telecom Operators, including TeleGlobe.

7.4 IETF

7.4.1 IPng and IPv6

Back in 1992, i.e. only a few years after the end of the "*protocol war*", the IPv4 Internet became a *victim* of its own success and was then facing *severe* architectural problems with the

[219] Communication Research Center
[220] Advanced Broadband Conference organized by EU's RACE and ACTS research programs
[221] Universidad Politécnica de Madrid (Spain)

rapid exhaustion of the "*class based*", i.e. A/B/C, address space that was threatening its very future in the fairly near term, hence an urgent need for a new version of IP provisionally *dubbed* IPng[222].

This was perceived as an opportunity by the OSI supporters but also by many others and lot of efforts was therefore invested in the IPng activity resulting into many proposals [313] submitted to the IETF: TUBA, IPAE, SIP and PIP that later merged as SIPP, CATNIP, CNAT, and Nimrod.

The IETF ROAD[223] working group quickly specified the "*Technical criteria for bigger addresses*" in RFC 1380 [314] by P. Gross.

A variant of DECNET Phase V, an ISO/OSI conformant network protocol, was proposed as a contender for IPng to the IETF under the name TUBA[224], RFC 1347 [315], and was rejected for a number of *good* technical reasons, e.g. slight semantic differences between CLNP using ISO NSAP [316] addresses (up to 160 bits) but *bad* technical reasons too, e.g. *"not invented here"* syndrome, general mistrust of the IETF community towards ISO/OSI based protocols[225], too visible political support of OSI protocols by the European Union[226] but also, strangely enough, by the US National Bureau of Standards (NBS), aka NIST. This dispute was also fueled by the CONS[227] [317], pushed by the European PTTs, against CLNS[228] [154] controversy.

Regarding the IPv4 to IPng migration, the *dual-stack* strategy that was adopted has, without doubts, been strongly influenced by the one proposed by DEC for the graceful migration to DECNET phase V, that made lot of sense in small networks with a rather limited number of hosts and sites. However, it is interesting to note that DECNET phase V transition was actually stopped by DEC itself, given unforeseen technical difficulties (e.g. the use of "*hidden areas*" as a way to extend the network) but also organizational, economic, and marketplace reasons. Nonetheless, if the IPv6 transition had been started then, it might well have worked out all right, although this was unlikely given the immaturity of IPv6 in those days, a situation that *persists* today (almost 20 years later), but to a much lesser extent, *strange* as it may seem! Accordingly, the dual-stack IPv6 migration is *half dead* because, in order to work, each new Internet host must have an IPv4 address in addition to its IPv6 addresses which is no longer possible except for the early Internet users such as CERN who have been allocated more than enough IPv4 address space.

Hence, NAT64 [318] or like proposals allowing IPv6 only users to access the IPv4 Internet.

RFC 1454 [319] "*Comparison of Proposals for Next Version of IP*" was written by Tim Dixon (RARE) in May 1993, explaining the numerous weaknesses of IPv4 (e.g. QoS, Multicast) and also comparing the pros and cons of the three main IPng proposals submitted to the IETF, namely: PIP, SIP and TUBA, with a slight bias for TUBA. Tim Dixon also made the following interesting observation "*There is an inbuilt assumption in the proposals that IPng is intended to be a*

222 IP next generation, that became IPv6
223 ROuting and ADdressing Working Group
224 TCP/UDP over Bigger Addresses
225 A strong reason for this mistrust was that the ISO and ITU (then CCITT) standards were developed in a hierarchical manner at "*glacial*" speed and often including too many options for political reasons, another issue is that these standards were not freely distributed as were the Internet RFCs. Actually, the free distribution of RFCs was a kind of *revolution* in the days of proprietary protocols and architectures and was a very significant factor in the success of the Internet protocols. The same comment also applies to open protocols such as the Web and open software.
226 It is rather clear today that OSI standards were seen as a *weapon* against TCP/IP protocols which, in addition to being mostly of US origin, could not, by definition, be considered as standards given that the IETF definitely did not have the status of a standards-making organization such as ISO or ITU. It is less clear who was at the origin of this *war*, namely European governments, Telecom Operators, emerging National Research and Education Networks, such as DFN in Germany, influencing the EU or a few "*visionaries*" inside the EU, who knows!
227 Connection-Oriented Network Service
228 Connectionless Network Service

universal protocol: that is, that the same network layer protocol will be used between hosts on the same LAN, between hosts and routers, between routers in the same domain, and between routers in different domains. There are some advantages in defining separate "access" and "long-haul" protocols, and this is not precluded by the requirements. However, despite the few opportunities for major change of this sort within the Internet, the need for speed of development and low risk *has led to the proposals being incremental, rather than radical, changes to well-proven existing technology*". This remark gives me the opportunity to say that the standard Ethernet frame size of 1500 bytes [320] has become the *plague* of the Internet because it greatly reduces the technical possibilities, such as *recursive* encapsulations, and also end-to-end performances over long paths.

An excellent paper titled "*IP next generation overview*" [321] [322] was written by Bob Hinden, a well known Internet pioneer who started his career at BBN[229] [323], and in which it is clear that the smooth migration and graceful coexistence between IPv4 and IPng was a constant preoccupation of all proposals; unfortunately, this has not quite succeeded because the two protocols cannot easily coexist thus greatly complicating the migration process.

Finally, "*The Recommendation for the IP Next Generation Protocol*" RFC 1752 [324] by S. Bradner came out in January 1995: "*This proposal represents a synthesis of multiple IETF efforts with much of the basic protocol coming from the SIPP effort, the auto configuration and transition portions influenced by TUBA, the addressing structure is based on the CIDR work and the routing header evolving out of the SDRP deliberations.*" In addition, RFC 1752 provides additional information about the reasons for not having selected TUBA: *"There seems to be a profound disagreement within the TUBA community over the question of the ability of the IETF to modify the CLNP standards. In our presentation in Houston we said that we felt that "clone and run" was a legitimate process. This is also what the IAB proposed in IP version 7 [325]". The TUBA community has not reached consensus that this view is reasonable. While many, including a number of the CLNP document authors, are adamant that this is not an issue and the IETF can make modifications to the base standards, many others are just as adamant that the standards can only be changed through the ISO standards process. Since the overwhelming feeling within the IETF is that the IETF must own the standards on which it is basing its future, this disagreement within the TUBA community was disquieting.*

So, the question of the *ownership* of the ISO CLNS protocols appears to have been one of strongest arguments against TUBA.

Fortunately or unfortunately[230], CIDR[231] [326], RFC 1517 [327], was approved in September 1993 and was swiftly fitted into BGP thus postponing the IPv4 transition for at least two decades, *but hopefully not forever*! In addition, *ad-hoc* solutions have been deployed to connect residential customers e.g., NAT[232] [328] and ALG[233] [329]. Firewalls [330] were also deployed to protect against attacks of various sorts, i.e. DOS [331], DDOS[234]. The IETF superbly ignored these developments sticking to its "*end-to-end* and *address transparency*" paradigm according to which security must be dealt with in the end hosts through IPSEC [332].

TUBA that was authored by DEC[235] had many supporters, in particular in Europe, and was actually one of the best proposals, basically replacing IP by CLNP and thus solving the potential shortage of IP4 addresses; unfortunately, it was rejected.

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229 Bolt, Beranek and Newman

230 given that it would have been much easier to transition the Internet to the new addressing scheme back in 1992

231 Classless Internet Domain Routing

232 Network Address Translation

233 Application Level Gateways

234 Distributed Denial of Service

235 R. Callon

While IPv4 was definitely saved by CIDR and NATs and is still alive in 2012, despite the fact that *all the remaining available address space* has now been distributed by IANA[236] [333] to the RIRs[237] [334], is the IPv4 based Internet in a lasting and *healthy* shape?

I agree with Brian Carpenter that the *definite* answer is *not quite!* Indeed, some of the major ISPs[238] have already started to deploy "*carrier grade*" NATs, in effect NATs over residential customers NATs, which are bound to cause some additional disruptions, as various major applications simply fail across double NATs. "*So we get the phenomenon of everything, including real-time streaming, running over HTTP*".

Whereas CIDR has definitely been a very good thing, NATs have also been very useful but have added a lot of complexity and have now clearly reached their limits in the sense that they cannot be used as a *substitute* for large scale deployment of IPv6, however, will this really happen anytime soon if an IPv4 address *trading* market starts to develop?

Both CIDR and NATs definitely delayed the *much needed transition to IPv6* which has now become a potential operational *nightmare* whereas, back in 1993 this transition would have been undoubtedly far much easier as this was only the start of the commercial Internet.

As pointed out by Paul Bryant: "*The key issue is that a transition from IP4 must be more or less invisible to the user. With some millions of IP4 users you cannot expect non-technical users to need to have to do anything. Currently the UK*[239] *is phasing out the analogue TV service. This has involved ensuring that all new TV sets could use analogue and digital for 3 or so years, production of digital boxes to convert existing TV and a large publicity campaign. This has gone well and shows that a transition of the underlying protocols is possible but needs a lot of planning.*"

8 European Networking Organisations

8.1 The establishment of RIPE and the RIPE NCC

CERN, under the impulsion of François Fluckiger, played a major role in the formation of RIPE and it is little known that the founding meeting actually took place at CERN in December 1988 with only six participants: Rob Blokzijl from Nikhef (NL), Mats Brunell from SICS[240] [335], Daniel Karrenberg from EUnet (NL), Enzo Valente from INFN (IT), François Fluckiger and myself from CERN. The first RIPE meeting took place in June 1989 in Amsterdam shortly before the installation of the first international 2Mb/s circuit in Europe between CERN and Bologna in July 1989, funded by INFN, just in time for the startup of LEP [336], thus closing the first European Internet backbone, from Stockholm (KTH) to Bologna (CNAF) through Amsterdam (CWI) and Geneva (CERN). The minutes of the first RIPE meetings can be retrieved from the RIPE archives, e.g. those of RIPE-1 [337] and RIPE-2 [338]. Although SURFnet [339] was more pro-X.25 than pro-IP initially pragmatism prevailed and an agreement was soon found with both EUnet (CWI) and RIPE. In particular, the Ebone study, that had a major impact on the emergence of the European Internet, was funded by SURFnet.

236 Internet Assigned Number Authority
237 Regional Internet Registries
238 Internet Service Providers
239 Editor's note: the same is happening mostly everywhere else, in order to free up scarce spectrum space; despite some minor hiccups and/or complaints, this incredibly difficult migration has been successfully achieved.
240 Swedish Institute of Computer Science

Figure 8 The firewalls between the Internet and the OSI worlds or the "Yalta

The name Ebone was coined by Bernard Stockman (KTH) as a joke alluding to the different circuit speeds in the USA and Europe, i.e. T1 versus E1 with Ebone really meaning "E1 European backbone" in analogy with T-bone[241] steaks [340], not T1 networks, though the NSFnet backbone was initially a T1 based. The 20th anniversary of RIPE [341] was celebrated in May 2009 during the RIPE 58 meeting with many of the "*pioneers*" present. There were two reference presentations on the history of RIPE, "*RIPE 20 years young*" [342] by Rob Blokzijl and "*How the name RIPE came about"* [343] by Daniel Karrenberg.

There were two presentations on the history of RIPE, "*RIPE 20 years young*" [342] by Rob Blokzijl and "*How the name RIPE came about"* [343] by Daniel Karrenberg.

The year 1989 was definitely a very important date marking the real start of the European Internet; it has been a very enjoyable experience for many people, engineers and managers, as it was truly impossible, at that time, to predict that after more than 4 years of fierce struggles between the OSI and the Internet supporters, the wide adoption as well as the impressive growth of the Internet would follow so quickly afterwards.

But was it so quick after all? Indeed, the RARE *citadel* only formally collapsed in October 1994, i.e. four and a half years after the Killarney meeting, through the merger with EARN and the establishment of TERENA[242], a new, far more neutral, association representing ALL European NRENs.

[241] tenderloin steak in the USA

[242] Trans-European Research and Education Networking Association

As already explained in the "*Tribute to IBM and DEC*" chapter above, it is not widely known that things would not have happened the same way without the significant seed funding brought by IBM in the framework of EASInet:

1) By providing a T1 link between CERN (Geneva) and Cornell (USA), thus basically extending the newly born NSFNET T1 backbone to Europe
2) By funding a 2Mb/s multiprotocol infrastructure between IBM supercomputer centers based on intelligent IDNX multiplexors, thus allowing the graceful coexistence of X25, DECNET, SNA and TCP/IP and providing a solid basis for building a genuine pan-European TCP/IP backbone in collaboration with other organizations such as HEPNET and EUnet and, in the end, having an instrumental role allowing in the creation of Ebone.

As already mentioned above, François Fluckiger clarified the role of CERN in the establishment of RIPE and the subsequent deployment of the European Internet in a CERN Computer Newsletter article [285].

8.2 RARE

As pointed out repeatedly by Paolo Zanella, former head of DD Division at CERN, in the USA "*rare*" means not "*well-done*"!

Was it just a "*joke"* or his assessment of the rather poor achievements of the RARE association?

Excerpts from the TERENA's 20 years birthday [345]: *« The association started its life as RARE (Réseaux Associés pour la Recherche Européenne) [346]. RARE was established under Dutch law on 13 June 1986 by Hans Rosenberg on behalf of the University of Utrecht and Klaus Ullmann on behalf of the DFN Association and Peter Linington was the first RARE Chairman. RARE changed its name to TERENA in 1994 when it merged with another organization, EARN, the European Academic and Research Network association."*

RARE had a very ambitious work program supported by the EC with 8 working groups:

1. WG1: Message Handling System (MHS) was led by Alf Hansen (Trondheim University)
2. WG2: File transfer, access, and Management,
3. WG3: Information service exchange of operation information
4. WG4: Network operation and X.25
5. WG5: Full screen services
6. WG6: medium and high-speed communications
7. WG7: Liaison with CEPT [347]
8. WG8: Management of network application services

Despite the outstanding work made by Alf Hansen, WG1 turned out to be a failure in the sense that X.400 was too immature and the X.400 UA[243] were also too primitive, therefore it turned out to be *impractical* to turn the pilot MHS project into production.

WG2 (File transfer, aka GIFT) proved that gateway-based solutions were inherently unstable and not scalable, although this is somewhat contradicted by the following statement:

[243] User Agents

"*Multiprotocol converter allowing file access, transfer and management and remote job entry across different network protocols is presented. The gateway architecture and the protocol conversion model, mediated by a file system, are described. It is shown that this approach greatly reduces the complexity of the multiprotocol conversion problem. Some examples of the gateway implementation are given. The gateway, entirely designed and developed by an international collaboration, has been in production since 1985*". In practice, whereas the original idea was indeed excellent, the implementation proved to be very difficult, furthermore by the time it was *nearly* working it was *no longer needed* and therefore very little used. Also, new commercial solutions became available (e.g. DEC-IBM file transfers) but it is really the emergence of the new Internet world that basically eliminated the need for such a gateway,

Figure 9 The torture of an OSI agnostic

For reasons unknown to me, the WG6 group had a *bad* reputation within RARE; however, in the end, it was the only Working Group that proposed a *multi-protocol* backbone, a vision later adopted by IBM, in the framework of their EASInet initiative, but also by NORDUnet and DANTE.

With the support of the EC, RARE WG6 organized three very successful symposiums in Brussels on "*High-speed Networking for Research in Europe*" in 1989, 1991, 1994.

Back in 1988 I wrote a short report to RARE WG6 about the possible impact of NSFNET over European networking, in which I basically stated that "*without any doubts NSFNET will have a profound impact on European Research and Education networking, however, as Unix was still little used in Europe and, as the main protocols used were those of DEC and IBM (i.e. DECNET, RSCS and SNA), a <u>prerequisite</u> was the availability of products allowing transparent encapsulation of these protocols over TCP/IP).*"

As proved later, the NJE protocols, much like the DECNET ones, could run over any network stack as they were application level protocols, e.g. Multinet [348], later fully integrated into the VAX/VMS operating system, allowed to running DECNET over TCP/IP and was one of the first products of this kind but many others quickly followed, e.g. VMNET (i.e. RSCS over TCP/IP).

A rather *disturbing* aspect of RARE is that most of the information available, e.g. RARE Networkshop, needs to be bought from Elsevier's International Journal of Computer and Telecommunications Networking: "*Computer Networks and ISDN Systems*" [349]; thus, following this tradition, the proceedings of the WG6 symposiums are only available from the above journal. The very informative presentation [350] made by Howard Davies (DANTE) during the 3rd symposium, back in 1994, is actually one of the very few exceptions I am aware of!

Nonetheless, a definite strength of RARE was to gather a set of *high-level* people, University professors and the like, but this was also one of their main *weaknesses,* as most of these "*eminent*" personalities had a "*glaring"* lack of experience with operational networks. The RARE WGs were more open[244], nonetheless, as pointed out by Paul Bryant: *"the experts were filtered through their NRENs, or at least in the UK, so only friends (friends of OSI) tended to be appointed to the RARE WGs. So that is why I never attended a RARE WG."*

In order to preserve both proper *intellectual level* but, more importantly, right *networking protocols culture*, attendance at the RARE Networkshop was "*controlled*", an effective way to exclude the EARN supporters and to keep RARE as a "*closed club"* of people sharing the same OSI "*ideology"*. However, some RARE members started to realize that OSI was late, e.g. Brian Carpenter gave a presentation at the Networkshop in Trieste (Italy) in May 1989 titled "*Is OSI too late*" [351] that received a standing ovation as well as that of Løvdal (University of Oslo and NORDUnet Technical coordinator) "*Initial NORDUnet – the first multiprotocol network*" [352].

As related in the "*Reactions to the NORDUnet plug*" chapter of the "History of NORDUnet" [353] Einar Løvdal pointed out in his speech that there were already a great number of unconnected IP networks in Europe and there was a need for European IP coordination. He also pointed out the scalability of the IP networks, as opposed to the OSI technology. "*I still remember the tense and silent atmosphere during my talk, presenting these ideas to the several hundred European networkers plus guests from overseas; the enthusiastic applause from one half of the audience, the silence from the other half; and the intense discussions afterwards.*"

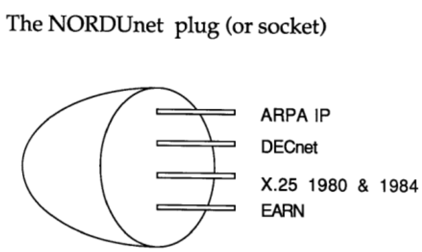

Figure 10 Nordunet plug

Indeed, a growing number of RARE members had *finally* understood that the ISO/OSI *battle* had been lost; however, it was impossible for the RARE leaders to admit this fact without *undermining* their own personal positions. In other words, the problem was between the RARE management, a *not so small* set of *activists* or *evangelists* and their *supporters*, or rather *followers,* who were somehow *cheated* in the end, but definitely not with the RARE community, at large, that had a very wide overlap with the EARN community. Nonetheless, the proposed NORDUnet Multiprotocol *plug* that was meant to be *consensual* turned out to be very *controversial*, if not provocative, as the Trieste Networkshop was meant to mark the start of the COSINE implementation phase, leading to European OSI transition and that *much of* the RARE *funding* was coming from the EC through the COSINE project.

244 Having been both a member of RARE WG6 and a strong proponent of EARN it is difficult to pretend the contrary! However, my presence was due to the fact that, CERN presence was needed given our role as one of the main scientific data sources in the world, and Francois Fluckiger was too busy writing the FTAM COSINE specifications. Furthermore, I had good knowledge of ISDN having been tasked with writing a technology impact report

RARE quickly grasped the fact that the wide adoption, by the academic community at large, of operational services such as EARN/BITNET and EUnet was a real *threat* to their OSI strategy, therefore they tried their best to counter it using all their political links.

Indeed, the political approach of RARE proved to be very effective because they had closed links with relevant ministries, European Commission officials, etc., therefore, as they had all the required budgets nothing could make them change their minds, hence they pushed the CCITT/ITU protocols, such as X.400, beyond reason, i.e. quoting Paul Bryant: "*unfortunately for them, the funds did not go into the implementation of working protocols but only into talking about them.*"

In summary, many years were actually wasted in *futile* protocol battles, *personal rivalries* and *power struggles*! Nonetheless, RARE then DANTE very skillfully turned a technical *failure* into a political *success.* As stated by Paul Bryant "*Many of the people ponding about in the politics of networking had never written a line of code in their lives. The EARN problem was that we had a lot of experts in IBM/NJE/SNA and not a lot on the other network technologies but we were light on the politics.*"

To close this chapter on a more positive note, most of the RARE *activists*, e.g., Alf Hansen, Jüergen Harms, James Hutton, Peter Kaufmann, Christian Michau, Bernhard Plattner, Jacques Prevost, Enzo Valente, Paul Van Binst, were actually nice individuals; however, the problem started when their strategy and associated implementation plans, which were often unrealistic being primarily motivated by ideological considerations, were questioned!

8.3 Ebone

Most of the information below has been kindly provided by Frode Greisen (ex-GTS/Ebone) and Kess Neggers (Surfnet):

In 1991 Bernhard Stockman from KTH in Stockholm produced a table of all the International telecommunication links used by universities and research institutions in Europe. It was a long list with lots of duplicates between countries so people realized that there must be scope for rationalization. SURFnet then commissioned a report [354] and a proposed MoU[245] [355] for organizations to cooperate in building and sharing a European Internet backbone. Several NRENs signed the MoU as well as some PNOs, EARN and IBM. The proposal was sent by Kees Neggers to the RARE CoA and RIPE on 19 September 1991 [356] and, unsurprisingly was not well received by RARE, despite the fact that the proposed "*Ebone plug*" had OSI-CLNS and Internet/IP interfaces as it was seen as a devious way to undermine Europanet, despite the fact that it had always been made very clear that Ebone 92 was only an interim solution and that the NRENs supporting it would move to the equivalent *canonical* EC funded multiprotocol backbone.

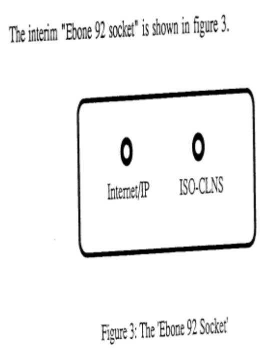

Figure 11 The Ebone Socket

The 1st Ebone consortium meeting took place at CERN on the occasion of the 10th RIPE meeting in September 1991 [357] [358]. A key statement of this meeting was the agreement that "*By linking the IXI and Ebone 92 backbones (via an EBS router) the connectivity for IP can be readily extended to the IXI connected networks. Thus all IXI users can join Ebone 92 and benefit from the managed IP service.*" The signatories of the Ebone MoU agreed to pool

245 Memorandum of Understanding

existing international links for joint use, and it elected a management group with Kees Neggers as chairman and with technical groups for operations and development. The 2nd Ebone consortium meeting took place in Amsterdam in October 1991 [359] and dealt mainly with organizational matters: "*1) The RARE offer to undertake the clearing house function previously offered by SURFnet was accepted. 2) The Ebone Action Team (EAT) will prepare and implement the initial resilient kernel network. The initial EAT members were confirmed*[246]*. A draft paper "Technical Aspects of an EBS system" has been prepared by Bernhard Stockman, Peter Lothberg and Juha Heinänen in preparation for the EAT activities.3) A Management Committee (EMC) is to be formed to coordinate the activities for the execution of the MoU and external liaison. The following persons*[247] *indicated their willingness to assist in these tasks: This interim team will establish the EMC and coordinate further the Ebone 92 formation activities; the actual membership of the EMC will be determined at the end of November to conform to the management principles as laid down in the MoU.*"

Last but not least, the formal agreement of IBM that welcomed the Ebone 92 initiative and the use of the EASInet lines was sent by Harry Casper to Kees Neggers in December 1991 [360]. As reported in the minutes of 25th RARE CoA meeting in February 1993 under the heading "<u>EBONE IN 1993</u>" [361]: "*The Ebone 92 backbone continues in 1993. At the Ebone consortium meeting on Feb. 3 in Luxembourg the partners finalized the budget, decided on an upgrade of the backbone and set up the organization to operate Ebone in 1993. Ebone's long term strategy was confirmed to concentrate in the future on providing a neutral interconnect for all networks, while it is assumed that provision of backbone services will be offered by one or more (competing) providers in the longer run. Until such offers are forthcoming, Ebone will take care of its partners' needs in this area too. <u>The RARE Secretariat will continue to provide administrative services and act as a clearing house</u>.*"

In September 1992 the initial IP backbone with 256 kbps links was completed and in operation. Frode Greisen was appointed general manager and Peter Löthberg was the de facto architect of Ebone during its lifetime. A cost-sharing mechanism was set up where all members paid proportionally for access to the network according to their access bandwidth, and members were refunded for the cost of the links and other resources that they provided to the network

The network was upgraded to 512 Kb/s in 1993, to 2 Mb/s in 1994, to 34 Mb/s in 1996, to 155 Mb/s in 1998 and to 2.5 Gb/s in 1999. Getting international leased lines was extremely difficult, expensive and slow at the time. For instance, when Ebone ordered a 34 Mbps line to Paris in 1995 they were told by France Telecom that such a product would not be provided at the time, and indeed that it was unlikely ever to be offered. Only a competitive line supplier eventually installed high speed links to Paris. The total access volume offered to members increased from 4 Mb/s in 1992 to 235 Mb/s in 1999, and since the network was basically full, except in short periods after upgrades, one can infer that traffic increased by a factor of 60 over seven years, i.e. a doubling every fourteen months. This is closer to Moore's law than to the doubling of traffic every three months reported in the US by Mike O'Dell of UUnet, but then most of the time Ebone growth was capacity constrained, not demand constrained.

Initial Ebone members were NRENs including NORDUnet, SURFnet, RENATER and ACOnet, a few research institutions as well commercial ISPs and PNOs, around fifteen in total. Over the years this increased to around 100 customers in 1999 and over this period nearly all European incumbent PTTs were Ebone customers for some period as they joined the rush to build Internet offerings to their customers.

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[246] Wilfried Woeber, Peter Streibelt, Bernhard Stockman (chairman), Niall O'Reilly, Michael Norris, Peter Lothberg, John Hopkins, Juha Heinänen, and Eric-Jan Bos

[247] Kees Neggers, Dennis Jennings, Peter Villemoes, Harry Clasper, Phil Jones, Glenn Kowack, Ron Catterall, Brian Carpenter, Klaus Birkenbihl, and a possible EARN representative.

In 1996 the Ebone consortium transformed itself into the Ebone Association which again set up a wholly owned company Ebone Inc. A/S in Denmark. Consortium members became members of the association as well as customers of the company.

In 1999 the Ebone Association sold Ebone Inc. to GTS, and Ebone members shared the proceeds and subsequently dissolved the Association.

The Ebone network and brand continued for some years, until GTS was sold to KPNQWEST early in 2002. However, in summer 2002 KPNQWEST went bankrupt following a glut of international fiber transmission capacity and fierce price competition in both data and telephony services.

As Ebone was in direct competition with Europanet and as its operating mode did not exactly follow DANTE's train of thoughts, DANTE was doing its best to promote their network management concepts. In that respect the following table extracted from "DANTE in Print" (DIP #6, 1993)" [362] is rather *illuminating of the propaganda style of DANTE*. So, one learns that, unlike Ebone, Europanet had predictable behavior, and defined QoS!

EuropaNET	Ebone
Managed service, specified in detail and contracted to professional operational suppliers (including the national research networks).	Co-ordinated service, taking advantage of latest developments; development and operations closely linked.
Quality of Service (availability, performance) defined in specifications and operational contract.	Best efforts - usually very committed - maximum use of capacity given priority over performance for individual user.
Imposition of Management Discipline (labelled bureaucracy by technicians).	Try it and see if it works; if so OK, if not then deal with problem.
More orderly (but slower) progress.	Rapid adoption of new techniques.
Predictable behaviour, performance dependable (even if not high).	Actual performance unpredictable, depends on load imposed by others; priorities determined by technicians rather than users.

Table 1. EuropaNET vs. Ebone - organisation and service characteristics

The "DANTE in Print" series [363] was followed from 2004 till 2006 by "The Works of DANTE" [364].

Next to come is the "*beatification"* of the DANTE "Davies" twins for their outstanding contributions to the benefit of the networked mankind!

8.4 TERENA, the Merging of EARN and RARE

8.4.1 "*Data Networking for the European Academic and Research Community: Is it important?*"

It is actually Paul Bryant who reminded me about the existence of this very informative and very relevant report [365] that was published in "*Electronic Networking Research Application and Policy*" in June 1992 but was derived from an internal CN division report in October 1991, i.e. right after the Killarney meeting and only a few months after the EASInet connection between CERN and NSFnet was established.

This report undoubtedly had some impact on European Networking policy, which is why large excerpts are reproduced here, although not exactly what its author[248], the late David Williams (CERN), had hoped for, namely the creation of a focused European Network Agency in charge of European Academic and Research Networks!

The original report was written in the utmost secrecy behind the back of two deeply involved persons in the subject matter, namely Francois Fluckiger, deputy CS group leader, and myself in charge of External networking and CERN's representative to the EARN Board, which was a bit weird ☺

Neither BETEL (1993), nor DANTE (1993) and TERENA (October 1994) had been launched

The report makes strong criticisms of the RACE program which, in my view, are due to sheer ignorance[249] of the authors, however, the intent is clear namely make "*better*" use of the 250 MUSD yearly funding (i.e. future DANTE's "*EU funding cannibalization*" syndrome) and is basically a plea to bring the European Scientific community at the same level as the US, also taking into account the lack of involvement the European industry and therefore its consequences.

There is a good survey of the US and Pacific, that was even well behind Europe with respect to US connectivity 64 Kb/s, situations, also mentioning the 45Mb/s NSFnet backbone plans and a reasonably objective survey of the European situation with mentions of EARN, EUnet, NORDUnet, RARE, COSINE (IXI) and last the emerging[250] European Internet, coordinated by RIPE, under the RARE umbrella as a new WG[251]. Although, there is a mention of IBM's EASInet initiative, as well as its substantial influence on the emerging, though "*anarchical*[252]", European Internet, with the positive comment that "*It is encouraging that the supplier of many of Europe's biggest scientific computers has agreed to sponsor a European network based on open protocols (TCP/IP) rather than on the vendor's proprietary protocols*[253].", there is no explicit mention of the EASInet 1.5 Mb/s (T1) link between CERN and NSFnet which is somewhat strange to say the least as this was really the "*coup de grace*" to RARE's OSI strategy, however, CERN was indeed rather reluctant to "*bring the cat among the pigeons*"! Actually, this is not really strange given that the CERN management, including some influential individuals like David Foster, had a very negative reaction to IBM's proposal to terminate the T1 link at CERN despite the repeated attempts of

[248] Although listed as a co-author Brian Carpenter, told me in a private message that he was asked to review this paper but did not actively participate in its writing

[249] Refer to chapter 11.1 for more information about the RACE/ACTS EU programme

[250] was actually started in 1989

[251] Editor's note: This is factually wrong as RIPE was fully independent from RARE, however, the RIPE-NCC was not. For further details please refer to paragraph 6.4.

[252] i.e. not officially planned and relying on very informal management techniques, so what was the problem as it worked very well in practice thanks to a 1st class engineering team?

[253] When IBM announced its EASInet initiative there was deep suspicion in some circles that it would use it to promote SNA, which was completely preposterous given the EARN/BITNET history, furthermore the T1 link to NSFnet was, by definition, a pure Internet circuit!

Herb Budd who rightly saw CERN as the natural European end-point of this “*historical”* connection. Indeed, CERN being afraid to be perceived as the “*traitor*” to the sacred cause of OSI, proposed to IBM to terminate this link to IN2P3 in Lyon which IBM reluctantly had to agree to.

Both Francois Fluckiger and I were devastated, how anyone could pass up such an opportunity!

I had no leverage; finally, Francois found the right words paraphrasing Marx “*the history never returns the same dishes twice*[254]”, *therefore it is totally unrealistic to imagine that this circuit will be moved back to CERN when political circumstances are more favorable*” and so the CERN management finally, though reluctantly, agreed at the very last minute to accept what they initially saw as a “*poisoned”* gift that could only weaken their position in the European networking arena by helping the penetration of Internet in Europe at the expense of OSI!

Back to the “*Is it important?*” report, the summary of chapter 4 “The situation in Europe” is quite good “*A pale copy of US, data networking seems to be planned in Europe on a country-by-country basis, and the pan-European strategy and infrastructure is missing. The authors are convinced that Europe is in the process of abandoning, almost by default, a vital segment of tomorrow’s commercial and industrial base to our competitors.*”

Chapter 4 goes on with section 4.2 “Plans” (points 1-2) and 4.3 “Barriers to Progress” (points 3-2)

1. The plans for the 2Mb/s EMPP[255], the 64 Kb/s IXI successor, are well advanced[256] and that there is also a consortium known as Ebone 92 that has been created to consolidate the existing European Internet, but none of its international lines[257] are as fast as 2Mb/s.
2. The RARE Operational Unit (proposed in 1991, is expected to become operational in 1992, but plans unclear (as proved since it was decided to create DANTE Ltd instead)).
3. “*As a community, European researchers and academics have failed to convince Europe’s politicians, civil servants, industrialists, and carriers, that data networking is important and that everyone should collaborate to improve the European infrastructure.*”
4. ONP[258] as well as plans of existing PTTs, Cable and Wireless and various US companies to cover the whole European market are mentioned.
5. Regarding leased lines tariffs, the comparison between US and Europe shows a factor from 3 to 10.
6. Long paragraph on Europe’s conservative approach to telecommunications that is dominated by Alcatel, Ericsson, and Siemens that are more focused on voice than data as also observed by Paul Bryant.
7. Criticism of RACE program 250MUSD (200M ECU[259]) that is too much focused towards the industry and not enough (i.e. not at all until BETEL) on the academic and research community.

[254] “L’histoire ne repasse jamais deux fois les mêmes plats”
[255] European Multi-Protocol Pilot
[256] Actually materialized in October 1992
[257] This is “kind of true”, however, T1 is not far from E1, and most Ebone 92 lines were already much faster than IXI’s 64 Kb/s lines.
[258] Open Network Provision
[259] European Currency Unit, the predecessor of the EURO

8. On Protocol issues: "*Unfortunately, OSI products have taken much longer to arrive than expected, and they still offer limited functionality and performance. Furthermore, products based on another set of Open Networking protocols, the Internet TCP/IP suite, have become widely available on computers and workstations from all vendors. So while OSI undoubtedly will still have an important role to play, it is no longer realistic*[260] *to use it as the sole basis*[261] *for Europe's data networking strategy*". Users need to confirm their commitment to non-proprietary Open Networking and to plan the phase-out, as quickly as possible, of proprietary protocols.

9. Under the heading "*No fully European scientific computing companies*", there is a mention of Carlo Rubbia's[262] HPCC[263] [366] report [368] commissioned by the EEC that suggested to "*developing HPCC in the emerging socio-economic and industrial context and proposed an investment program of ECU 5 billion over a period of ten years.*" Strangely enough, this report that is widely referenced by a related 1994 OECD report [369] titled "National R&D Programs for new Computer-Communications Networks and Applications" as "*The most prominent effort towards a comprehensive European program for HPCC*" cannot be found online. Not even at CERN!

10. Lack of collaboration as well as lack of focus are rightly emphasized

Section 4.4 "*What happens if we do nothing?*" concludes chapter 4

"*The authors are convinced that European data networking will remain underdeveloped in the short term and will then be quickly colonized by companies based in the USA who have understood the development needed in this market. Put bluntly, we will have abandoned European data networking to a combination of American computing and networking companies.*"

Chapter 5 "Recommendations and conclusions" is very interesting;

1. ECFRN[264] proposal for Senior Officials Group

2. The necessity to give a <u>stronger emphasis to the service needs of academic and research users, rather than to the choice of particular protocols</u>. These services should be based on non-proprietary Open Networking protocols including TCP/IP and OSI (interesting to note that TCP/IP comes out first, however, the statement also implies that OSI is not dead, probably because of DECNET phase V and CLNP?

3. Build same kind of collaboration in the field of data networking as in the USA involving government, industry, the common carriers, and the academic and research community.

4. Hope to see more liberal regulations and competitive international carriers as soon as possible.

5. <u>The multi-service operational unit originally proposed by RARE should be set up with the goals of satisfying all users and supporting all open protocols</u>.

6. Merging of EARN and RARE in order to radically improve the European focus on research networking.

7. RARE, <u>or the merged EARN/RARE</u> should concentrate on long-term planning and policy issues and leave day-to-day matters to the operating agency.

[260] Editor's note: what a foresight!
[261] "Ménager la chèvre et le choux" in French "to meet halfway" in English
[262] Then Director General of CERN
[263] High-Performance Computing Cluster
[264] European Consultative Forum for Research Networking

8. In the medium term (2-3 years) we would like to see the creation of a European Treaty Organisation, or a legally simpler NGO[265], as an agency to plan and oversee the operation of Europe's data networking infrastructure[266]…. <u>It should keep its own staff members at a low level and aim to use commercial services as soon as the requirements for these services are clearly understood, but not before</u>.

8.4.2 TERENA

According to DANTE [370] "*DANTE's sister organization is TERENA [371]. TERENA is the Trans-European Research and Education Networking Association, and is based in Amsterdam in "The Netherlands". TERENA carries out technical activities and provides a platform for discussion to encourage the development of a high-quality computer networking infrastructure for the European research community. The activities of DANTE and TERENA are separate but complementary, and our two organizations cooperate together in many activities. TERENA is the successor organization to RARE, which founded DANTE.*"

I am quoting the above example as it is the "*typical*" DANTE way of "*misinforming"* people by deliberately omitting the names of people and/or organizations for which they have a profound dislike, in this case EARN.

For example, "*consensus*", as exemplified in the excellent TERENA booklet [372] "*20 years of collaboration in research networking 1986-2006*" is a very nice thing: *"There has definitely not always been total agreement on the exact path to take at any point in time, but these differences of opinion have proved fruitful, ensuring in-depth deliberations and discussions"*.

Of course, TERENA, as a very successful *consensus-building* association of NRENs could not write anything else and the above phrasing is a very nice *euphemism* hiding as much as possible the *ferocity* as well as the *intensity* of the underground battle between the supporters of conflicting networking models and protocols. A battle which is actually not completely over still! Nonetheless, it is interesting to note that this truly "*historical"* event in 2006 that is described as the 20th anniversary of RARE, which is factually *incorrect* as both the EARN and RARE associations disappeared in October 1994, as a result of their merger, to become TERENA. So, it should have been the 12th anniversary of TERENA or the combined anniversaries of EARN (22 years) and RARE (20 years) but not just the anniversary of RARE alone, especially given the *counter-productive* role of the RARE association during its first 10 years of existence.

Indeed, one of the main *rationale* of RARE was to fight the EARN association by all possible means so, taking the RARE viewpoint for once, EARN had at least one *virtue*, that of having accelerated the creation of RARE ☺

One of the major difference between RARE and other networking associations like, e.g., EARN, BITNET, EUnet and UUNET, was the clear orientation of the latter towards providing operational services to their users using *proven* technologies.

In contrast, RARE had a very strong *political* agenda and was using all possible ways to force what they believed to be the *right technical* solution for Europe in the interest of both the European industry and the technical independence of Europe against the *dreaded* US Internet protocols (i.e. TCP/IP).

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[265] Non-Governmental Organisation

[266] Reminiscent of the European Grid Initiative (EGI), where the hidden agenda was to base it at CERN and be driven by CERN. For the same reasons that CERN has too many enemies in the closed world of national networks but also that CERN must concentrate on its primary mission, both proposals were rejected although implemented in different manners, namely; DANTE a limited company based in Cambridge (UK) and EGI based in Amsterdam.

Unfortunately, the main RARE technical *weapons,* namely X.400, X.500 and the OSI protocol suite were kind of "*work in progress*" as implementations were lacking, scalability and resiliency were yet to be proven. In other words, the solutions proposed by RARE were *political rather than technical* solutions, whereas the European academic and research community absolutely needed *operational networks,* in order to facilitate worldwide collaborations and exchange of ideas.

It is rather sad to observe, that the European networking history bears many similarities with the way in which Europe reacted to recent crisis[267] namely, national interests prevailing over general interest, lack of institutional EU leadership, etc.

In that respect, the story of the TERENA voting rights is rather *instructive*! Indeed, even though the RARE politicians had very carefully devised the new TERENA bylaws such that the "*big countries*", also dubbed "*the gang of four*" could have the majority of the new TERENA organization *voting rights* without contributing the matching part of the budget[268], things happened differently during the TERENA founding meeting because one of the pro-RARE delegates who held several votes left the meeting just before the election of the new TERENA board, thus allowing Frode Greisen to be elected with a majority of only one vote!

So, was the *small* amount of money saved in *twisting* the voting rights *really* worth losing the election and thus creating additional chaos and mistrust?

Needless to say, Frode Greisen as well as the newly elected TERENA Executive Committee had a very difficult year as their investiture was considered by the former RARE people as an *imposture*. After one chaotic year, Frode Greisen was forced to resign and was succeeded by Stefano Trumpy (CNR) and then David Williams (CERN).

It is actually thanks to David Williams during his four year presidency that the *antagonism* between DANTE and TERENA slowly evolved into a *fruitful and mutually beneficial relationship*, leading to the joint SERENATE [373] [374] study but also to the TERENA compendium of European NRENs [375].

Thanks to its secretary general, Karel Vietsch, TERENA has now become a unanimously respected networking association that is the organizer of a very high quality annual networking conference[269], as well as many ad-hoc working groups, workshops and training courses.

Therefore, <u>*all is well that ends well.*</u>

8.5 DANTE

I am well aware that some of my comments on RARE and DANTE are pretty harsh and may therefore be seen as unnecessarily aggressive, however, since the purposes of this article are mainly historical, I think these comments reflect quite well the atmosphere and the conflicts that have occurred within the European NREN community during the last 25, or so, years; however, I have to agree that things have improved slowly but slowly since then, although they are still far from being perfect as both the Board of DANTE and the GEANT [376] consortium are still largely driven by politics.

Although RARE considered creating an *Operational Unit*, they finally opted for the creation of DANTE, a commercial company based in Cambridge (UK), in 1993.

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[267] Subprime, sovereign debts, etc.

[268] Germany together with a few other large countries having claimed that it was absolutely impossible to fund additional contributions of the order of 50KEuro per annum to either EARN or TERENA

[269] Terena Networking Conference (TNC)

8.5.1 The DANTE and NREN monopoly question

European NRENs and DANTE share the same *vision,* actually a *dogma,* about *single* national as well as *single* pan-European *backbone,* providing both accesses to other R&E institutes as well as to the commercial Internet. In practice, the creation of monopolies, with initially worthwhile objectives but bearing the risks inherent to any monopolistic organization, namely: lack of interest for *captive* users, obsession of its own survival, possibly "*hidden agenda*" e.g. bias towards specific protocols through *differentiated* charging, etc.

NLR [377] who was the precursor of a US-wide dark fiber based networking infrastructure failed several times to merge with Internet2 [378] and, as far as I am aware of, this did not lead to a *catastrophic* situation, on the contrary it even had the positive effect of *spurring* Internet2 as NLR was from the very beginning more innovative, technically speaking.

To my knowledge, this is the first time that the near-universal *dogma* that an NREN is a *natural monopoly* is seriously questioned; and it is also interesting to note that it has rather been beneficial to the US academic and research user community, as far as I can judge.

The comments above are not intended to be negative as I have been very impressed by the spectacular progress achieved by both DANTE and the European NRENs in building the successive generations of pan-European and National networking infrastructures, thanks to the continued support of both the EC and the National governments. However, I believe that a more *network research* oriented approach might have been more appropriate than just *mimicking* the Telecom Operators, using "*off the shelf*" equipment; indeed, while I fully appreciate the *political challenges* in carrying out such an ambitious undertaking, I am rather disappointed by the more *technical aspects*. Therefore, I am very *concerned* that these *monopolies,* especially that of DANTE, could last much longer than necessary as very few people seem to *question* their very existence!

In this sense, I found the following excerpts from a recent report on e-infrastructures [379] commissioned by the EC and titled e-Research 2020: "*The Role of e-Infrastructures in the Creation of Global Virtual Research Communities*" very *illuminating*:

"*This last point also highlights two interconnected and overlooked feature of infrastructures. Firstly, they need to be standardized, and secondly, they need to be monopolies. Traditional infrastructures are monopolies, and attempts to break up monopolies have shown that this is a nearly impossible task. It is also worth noting that there is a tension in this monopolistic nature: innovation is thought to rely on competition, which monopolies eliminate or quash. On the other hand, standards that monopolies provide are in some cases an essential precondition for advancing knowledge. This means that oftentimes, it may be useful if there is only a single infrastructure without rivals or parallel efforts.*"

Whereas I fully agree that monopolies are not necessarily bad, e.g. the French TGV [380] or the EDF [381] are very interesting success stories in that respect, going as far as stating that standards that monopolies provide "*are in some cases a pre-condition for advancing knowledge and that oftentimes, it may be useful if there is only a single infrastructure without rivals or parallel efforts*" is rather surprising, especially considering the rather *average* technical achievements of most European NRENs, in general, and DANTE, in particular!

What is even more *amazing* is that DANTE apparently managed to convince the EC that their *anti-competitive* approach was the only *practical* way to proceed, which was definitely "*true"* before the Telecom deregulation of 1998 but is highly *questionable*, to say the least, more than 10 years afterwards!

However, this is not to say that *seed-funding* is not the right way to proceed when *local* funding sources are either very *limited* or even *non-existent*, in order to allow sufficient time for the beneficiaries to organize themselves; for example, the connections to non-EC countries should definitely be applauded, e.g. ALICE [382], CAREN [383], EUMEDCONNECT [384], TEIN [385] [386] and more recently Africa-Connect[270] [387]. More precisely, it is the EC and *not* DANTE that must be *commended* for these excellent, much needed, initiatives.

Whereas, the *systematic* involvement of DANTE is highly *debatable*, the connection of these new countries/regions to GEANT directly or indirectly is excellent. What about separate call for proposals for external connections to GEANT PoPs[271] or even better to the main European IXPs[272] [388], open to DANTE, NRENs, Telecom Operators and other interested parties, instead?

Another *important* issue related to the DANTE monopoly over the pan-European backbone is whether DANTE would be *economically viable*, compared to commercial Internet providers, without the EC subsidies.

Unfortunately, given the fierce competition between Telecom operators on many routes, e.g. most of Western Europe and Transatlantic, the answer is most likely to be *negative*[273] for a number of reasons:

1. DANTE's costs are essentially fixed during the duration of the EC project, usually 3 years, whereas the Telecom market is highly dynamic and competitive,
2. Massive use of *sub-contracting,*
3. High overhead costs inherent to EC projects.

While sub-contracting is a very effective way to leave operational responsibilities to others and, if/when things go wrong, put the blame on them, this *zero-risk* approach is not only *expensive* but also very *inefficient* and it is definitely not the right way to *leapfrog* US networking initiatives such as GENI. The FEDERICA [389] project (a 2.5 year project with a 3.7 M€ EC contribution, 5.2 M€ budget, 20 partners, 461 Person Months) is very instructive in that respect, as hardly anybody used that infrastructure to the extent that the project was not even *renewed* by the EC, which is rather *rare*!

DANTE's strategy always was to grasp *all* available EC funding, under the premise that they were the *only* organization capable of satisfying the user needs at the smallest possible costs, whereas the only thing that really mattered to them, as well as to their NREN *masters*, was to *fully control and manage pan-European networks,* be they *"research networks"* or "*networks for research*[274]*".*This *greedy* strategy proved to be a very effective way to prevent potential "*competitor projects"* to break into their "*walled"* garden, despite the fact that they could not prevent some EC projects like, e.g., BETEL and/or DataTAG from being funded!

Of course, I am fully aware that there is no *single* answer and that, in some parts of Europe, competition is much less developed than in others; however, perpetuating a model that is *unlikely*

[270] EUR 14.75 million contract for support to a sub-Saharan African intra-regional research networking infrastructure which is already interconnected to the pan-European research network, GÉANT. Eighty percent of the project's funding will come from the European Commission's EuropeAid Cooperation Office, and the remainder will be contributed by the African partners in the project.

[271] Point of Presence

[272] Internet eXchange Points

[273] This remark is based on confidential information resulting from recent call for tenders

[274] For example testbeds

to be self-sustained in the long term is, I believe, a fundamental *mistake*, in addition to being a potential *waste* of public money.

8.5.2 Political and technical assessment

Both RARE and DANTE share an *amazing* series of political successes and *mixed* technical achievements that are very likely due to their *ideological* biases as well as their *thirst for power*.

Regarding their *political* achievements they undoubtedly deserve the *top* marks, regarding their *technical* achievements they deserve *average* marks and regarding the price/performance ratio they probably deserve *poor* marks as, without the EC subsidies DANTE's prices would probably be well above the commercial market prices; in addition their cost sharing model is highly questionable!

The *sad* reality is that the *average* technical results of DANTE are not due to the lack of competence of their technical staff but to the fact that *each and every* technical decision is taken, independently of its *soundness*, according the *political* agenda of DANTE.

For example, during many years and for purely political reasons, DANTE carefully avoided borrowing some of the successful building principles of Ebone, e.g., having PoPs at the major IXPs, in order to facilitate peering with commercial ISPs, which was something rather obvious to do, at least for the technical experts! Interestingly enough, DFN was also not present at the DE-CIX [390] for many years; could there be a *correlation* between these very similar behaviors?

This sheer fact, together with many others, explain why I have little consideration for DANTE's management and why I am also *appalled* by the very high costs resulting from the "*pyramidal*" structure of contractors, sub-contractors as well as the lack of proper consultation with their end users[275].

Although this assessment may look too *harsh*, I believe that almost anybody else, without such a loaded, often hidden, *political* agenda, would have done a much better job!

However, DANTE is *slowly*[276] learning from its own technical mistakes, for example having PoPs in *Telecom supplier* premises, PoPs in *independent* locations, e.g., the Telehouse PoP in New-York city, but also the LDCOM [391] PoP at the Geneva airport[277], as they finally, although very reluctantly, agreed to the obvious, i.e. having PoPs in University premises and/or near the main data sources, e.g. CERN. Nonetheless, as strange as it may look, the GEANT PoP at CERN does not participate in the CIXP [392], the local Internet Exchange Point in Geneva for *weird* reasons that the average GEANT user cannot easily grasp but which can be easily understood[278]! As this *abnormal* situation could not continue forever, a *revolution* happened in September 2010 when "*DANTE Ltd / GEANT became operational at the DE-CIX.*", i.e. 15 years or so after the start of TEN-34, a *most* impressive *achievement* indeed!

[275] The problem with DANTE, but also some NRENs like RENATER, is that they have few users in the conventional sense but National or Regional network organizations; nonetheless they could try to organize Internet2 like meetings.

[276] 10 years or so only!

[277] The LDCOM PoP at Geneva airport was specially created for DANTE, in order to avoid being located at CERN, and so was very expensive to the extent that nobody else ever used it, especially as the value of an exchange point is proportional to the number of ISPs present, but this is not a valid argument for DANTE as the last thing they want is to *peer* with commercial ISPs in order to make access to GEANT difficult unless you are directly connected!

[278] In fact DANTE's reasoning is that if they open GEANT to commercial ISPs by peering with them at the major IXPs there is a risk that good connectivity with GEANT will no longer require direct connection to GEANT, in other words the end of the DANTE world ☺

The question about the (lack of) presence of GEANT at major IXPs is not insignificant as, if DANTE was playing by the "*rules of the game*", i.e. peering with major ISPS, a *significant* part of the commercial Internet traffic would be *free* and also *high quality* being, by definition, not *transit* traffic. Of course, this would not eliminate the need to purchase Internet transit through at least two major ISPs but could be a significant cost reduction factor to the DANTE community, at large, including the NRENs that take care of their own commercial Internet connectivity.

To conclude, DANTE must be seen as an *indisputable* success in terms of bringing NRENs together while also gaining the trust of the EC, therefore substantial amount of funding, and, last but not least, building a European-wide *monopoly* backbone interconnecting most European National Research and Education Networks with an *impressive* number of connections to other NRENs worldwide; however, as correctly stated by Peter Villemoes, one must not forget that the first *usable* DANTE backbone was TEN-34 in 1997, i.e. 7 years after IXI, which is not really very impressive!

8.6 ERCIM

ERCIM [393], the European Research Consortium for Informatics and Mathematics remains a "mystery" to me as its visible achievements have been largely invisible outside its own community, apart from being the European host of the W3C consortium [394]; however, it appears to be a much respected organization.

9 The pre-1998 European PTT monopoly regime and the emergence of new monopolies in the academic and research community

Besides the historical aspects that make up the bulk of this article and were initially the main motivation for writing it, a secondary goal is to take a critical eye at the *new* monopolies that have solidly established themselves in the European academic and research community as the sole Internet connectivity suppliers. Indeed, it is rather strange to observe that the *old* PTT monopoly has been replaced in the academic and research world by *new* monopolies dubbed NREN, at the national level, and DANTE/GEANT, at the pan-European level. While there was unanimity that the *old* PTT monopoly was a bad thing, hence the 98/10/EC directive in 1998 about "*Open Network Provision*" (ONP) [395], that is usually referred to as "*Telecom deregulation*" instead of "*Telecom liberalization*", nobody seems to be seriously worried by the new *monopoly* situation in, admittedly, a small market segment, i.e. that of research and education networks.

While it is *undisputable* that, in the early days of the Internet, it was the academic and research community that led the development of new Internet protocols and services (e.g., the World Wide Web that was started at CERN in 1992) and that the NRENs, being well ahead of commercial ISPs, also played a major role in the creation of the modern Internet. Therefore, the emergence of NRENs and DANTE have not only been *natural* but also *essential* steps to providing *state of the art* Internet infrastructures to the academic and research community, that the emerging commercial Internet Operators were then *unable* to provide.

However, it is also a *fact* that things have changed considerably since the mid-1990s, indeed, thanks to healthy competition between ISPs, high bandwidth as well as good quality of service are now available at very aggressive prices; hence it is amazing that the NREN/DANTE monopoly model is not subject to closer *scrutiny* and it is quite *legitimate* to wonder whether this, over 20 years old, model is still the best suited one, what are its mid-to-long term prospects and whether it should not start to *evolve*, both architecturally and organizationally? In particular, is there still a need for continued public subsidies[279] beyond 2013 at the level of those of the 2009-2013 periods, i.e. €93 million for GEANT3 [396] for what has mostly become commodity services and where fierce *competition* between Telecom operators *continues to drive the prices down*?

Indeed, an *inversion* of DANTE's "*economy of scale*" model[280] may well happen given the steady *decrease* of the commercial Internet prices that DANTE is unable to reflect, having mostly become its own supplier through its long-term lease of dark fibers. Hence, unlike conventional TELCOs that have to deal with double-digits growing demand, DANTE's *captive* market does not exhibit the same growth profile, in other words it is more or less *stagnating*; therefore, I fail to see how DANTE could *maximize* the *smart* investment they made by leasing dark fibers, unless they *expand* their business role beyond the academic and research community thus become a *genuine* TELCO, which they have already been for many years for the benefits of the European NRENs? This was indeed what Ebone did in the 1990 years, allowing it to become the fastest International network in Europe in terms of offered bandwidth.

DANTE's expertise in the area of procurement having been proven, one possible *new* role could be that of a *procurement* agency for leased lines[281], dark fibers, optical transmission and Internet related equipment, thus allowing additional services to be provided by other parties, including themselves !

According to the 4WARD [397] terminology, this means that DANTE could *resell* capacity to VNOs[282], instead of being themselves the only VNO using their own infrastructure. As a matter of fact several FP7[283] [398] EC projects like 4WARD, already mentioned, but also GEYSERS [399] have proposed new roles for Telecom operators taking advantage, in particular, of virtualization techniques, that open a bunch of new promising perspectives: *"The Physical Infrastructure Provider (PIP) owns and manages the physical infrastructure (the substrate), and provides wholesale of raw bit and processing services (also known as slices), which support network virtualisation. The Virtual Network Provider (VNP) is responsible for assembling virtual resources from one or multiple PIPs into a virtual topology. The Virtual Network Operator (VNO) is responsible for the installation and operation of a VNet over the virtual topology provided by the VNP according to the needs of the Service Provider (SP), and thus realizes a tailored connectivity service."*

Regarding joint procurement, Mary Lennighan wrote an article in Total Telecom's Easter review in April 2011) titled: "Eggcellent news" [400]: "*European Telco adopt chocolate egg procurement model, This is effectively what France Telecom and Deutsche Telekom plan to do. The European incumbents on Monday revealed that they will combine their procurement activities into a joint venture that will eventually enable them to save €1.3 billion a year. They referred to the deal as the start of "a new era of smart industry cooperation". The bulk of the savings will come from the joint purchase of network equipment, the operators said, which comes as no surprise given the growing pressure Telco are under to boost network capacity to support traffic growth, particular the data volumes being generated by increasing Smartphone use. And given that demand for network capacity is only going to go up, the days of network operators going Easter egg shopping alone is coming to an end.*

Another issue is that the main purpose of both NRENs and DANTE is to provide high QoS levels to *research traffic*, i.e. traffic between researchers, however, the *common practice* of sharing a single NREN access line for research as well as commercial Internet traffic may *defeat* this *sound* principle, if the capacity of the access line is not *properly* dimensioned and/or

[279] Not including the NRENs share of roughly the same amount!
[280] joint procurement of high speed (e.g. 10Gb/s) circuits
[281] Including connectivity outside the GEANT community which is one of the most valuable aspect of GEANT
[282] Virtual Network Operators
[283] Seventh Framework Program of the European Commission

managed, with the result that QoS cannot be guaranteed; therefore, I believe that the *canonical* NREN configuration should be *two* access lines, either *physical* or *logical*, in order to ensure high QoS to the research traffic.

In addition, there is a *schism* between commercial and academic and research networks as exemplified by GÉANT3, a state of the art R&E backbone running all the services and features that almost no commercial ISP is offering, e.g. Multicast, IPv6, QoS, BoD[284]. Even worse, these promising *new* services are, to the best of my knowledge, *little used* by the very community who claimed they needed it, thus there is a definite *risk* that the available effort and expertise is misused and that, instead of pioneering new technologies and services together with Telecom Operators and ICT[285] suppliers, off-the-shelves networks and/or new special purposes services (e.g., *lambdas* on demand) with *questionable* commercial viability, i.e. *high* costs, hence *no or little* demand, are built!

Furthermore, the proportion of commercial vs. research traffic (i.e. *intra and inter* NRENs) traffic is difficult to know, however, it is one of the most critical metrics to measure in order to design new NREN networks; in other words, is the traffic composition roughly balanced or grossly imbalanced in favor of commercial traffic? Unfortunately, DANTE's definition of *commercial* traffic, namely that *all traffic originating from or destined to universities* can be classified as *research* traffic, does not *help* especially as the *public* visibility over the GEANT traffic is utterly unsatisfactory, e.g., why are the traffic statistics of GEANT [401] not publicly available, unlike those of Internet2 [402]?

Admittedly some progress have been made in the right direction recently as a "*weather map*" [403] visualizing the instantaneous traffic between NREN and GEANT in both directions is now publicly available, actually showing that the customers of DANTE's World Services[286] appear to have a much higher use of their access line to GEANT than the NRENs that take care of their own Internet connectivity, e.g., France, Germany, Switzerland.

9.1 The Birth of European National Research and Education Networks

Major differences of attitudes can be observed between European countries and network research centers, namely: a few were constructive and creative, e.g. UCL [404] (UK) and INRIA [21] (France) with their significant contributions to the MBONE tools and the related protocols, e.g., SIP [405]; JANET (UK) with the "*Coloured Book*"; unfortunately, several countries followed *counter-productive* academic and research networking policies for purely political motivations, i.e. that of taking power, e.g. Belgium, Germany, Spain. Fortunately, many countries were more pragmatic e.g., the Nordic countries through NORDUnet actually led the way to wider adoption of TCP/IP in Europe as well as the Netherlands and Switzerland through SURFnet and SWITCH, and, of course, CERN which in many respects can be seen in the networking *arena* as a *country* in its own right, because of its *leading* role due to its dependence on first class networking infrastructure to fulfill its mission.

Another major issue very well explained by P. Kirstein was the dilemma between "*networking for research*" versus "*networking research*". The Research and Education community clearly needed the two, given the lack of suitable standards in these very early days of the networking history, hence the big confusion that arose. In practice, most NRENs and, in particular, DANTE bear troubling similarities with commercial ISPs and "*networking research*" is clearly outside their remit; therefore, it should be left to more qualified partners such as, Universities, Private

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[284] Bandwidth on Demand
[285] Information and Communication Technologies
[286] Commercial Internet as well as NREN traffic

and/or Public Research Laboratories in collaboration with the Internet industry (i.e. equipment suppliers, ISPs) and when additional funding is needed, the European Commission, which is rather more healthy.

There are good and bad NRENs as well as small, medium and large NRENs; the larger NRENs, e.g., RENATER (France), DFN (Germany), JANET (UK) being more difficult to manage than the smaller ones like ARNES [406] (Slovenia), RHNET [407] (Iceland) or SWITCH [408].

There is no *generic* NREN model; their only *common* characteristic is to provide a *single* access to the Internet, at large, i.e. the commercial Internet as well as other NRENs worldwide, including, of course, the European NRENs.

Indeed, few NRENs share the same organizational and architectural structure. For example, RENATER has a structure similar to GEANT in the sense that it mainly offers a backbone interconnecting the, so called, "*plaques régionales*[287]" which is actually very similar to the original NSFnet structure with Regional Networks and/or Internet2/Abilene with GigaPops. NORDUnet bears some similarities with RENATER, if one considers the Nordic countries as "*Scandinavian*" regions; otherwise, it could be considered as a *mini* or rather a *regional* clone of GEANT.

The cost model is also very different going from central funding, i.e. *captive* users, cost shared using all possible combinations of "*more or less fair*" key distribution. The services *portfolio* also varies considerably, e.g. RENATER provides an anti-spam service. In the early days of RENATER, most "*regional networks*" were commercial networks serving a region or parts of it, whose infrastructure was usually not dedicated to research customers, thus providing extremely variable quality of service, though at fairly high prices to RENATER customers.

To the best of my knowledge, Chile is one of the very first countries that tried to build its NREN in a more open way, i.e. by accepting commercial customers in addition to research and education members in order to be self-sufficient. Indeed, according to article by Larry Press[288] "*Will Commercial Networks Prevail in Emerging Nations?*" [409] back in spring 1997 "*The Internet is clearly in commercial hands in Chile, and the university and research community has not suffered. Will this happen in other emerging nations with market economies? If so, will it be good for the university community?"*

The above article is well worth reading although its title is misleading, indeed what it describes is that, back in 1997, there were two National Research and Education Networks in Chile, REUNA (National University Network) [410], the oldest and RdC (Networks of Computers) and that "*From their inception, (both) RdC and REUNA planned to become self-sufficient by providing commercial service as well as by serving universities. Today RdC is roughly 60 percent commercial, and a visit to the REUNA offices has the feel of REUNA's being a completely commercial enterprise with an aggressive marketing department*". The presentation made by Florencio Utreras, REUNA Executive Director, in Hawaii at about the same time "*How an Academic Network can be Self-Funded*" is also very interesting [411] as well as the history of REUNA [412].

Since then, the Latin America National Research and Education Networks have federated themselves under the CLARA consortium [413].

I must admit that I do not know whether REUNA continued along the same line, however, in the early days of the European Internet, similar evolutions/temptations could be observed, e.g. CESNET (Czech Republic), NASK (Poland), RENATER (France), SWITCH (Switzerland) and

[287] Regional Networks
[288] lpress@isi.edu

probably many others had non-academic and research customers for good or bad reasons, e.g. historical, special commercial links, local administrations etc. Although there is nothing wrong with that on a national scale, problems may rise if/when public funded infrastructures, such as GEANT, carry traffic between non R&E members, even if this phenomenon is probably very marginal.

The situation in the USA is also very instructive as, following the demise of NSFnet and the failure by the emerging commercial ISPs to satisfy the needs of the R&E community, Internet2 was very successfully built on the ashes of NSFnet without public funding. What is, however, intriguing is the emergence of NLR as an Internet2 competitor, a *first* case in the NREN history as the battle for power usually happens *before* the establishment of an NREN and not *after*!

During the last 10 years there has been an *irresistible* trend towards the use of dark fiber based network infrastructure, either long term lease, also called IRU[289] [414], or purpose-built and it is not clear to me whether this is a positive evolution in the long term despite the fact that the cost benefits are undisputable in the short-to-medium term?

9.1.1 Tentative conclusions

Whereas most NRENs were initially established with public funding, I believe that most of them have become financially independent; however, this is far from being the case of GEANT!

There are no doubts that NRENs are monopolies but, as already stated, this was definitely a necessary step as there were many benefits resulting from *joint procurements*, e.g., economy of scale, ease of operations, added value services, etc. However, given the falling prices of the commodity Internet, the efficiency of the NREN model in terms of price/performance may be questioned?

Should they all be *privatized*, or *split* or just kept "*as is"* is not an easy question as there is no single answer? But, at the very least, a cost/benefit analysis <u>must</u> be conducted, in my humble opinion.

The NREN model having been almost *universally* adopted there can be no doubts whatsoever about its attractiveness. However, the NREN model is a *closed* one and this is questionable, e.g., TERENA, apart from a few special cases such as CERN and ESA, only accepts National Networks as members which has two implications:

1. The nation in question must be recognized by the International community at large, whatever this means, e.g. UN membership. There have been several problematic cases in the past with Northern Cyprus [415] and Macedonia [416]; without any doubts, there will be many other cases…
2. There must be <u>one and only one</u> NREN per country, hence a lasting problem with Russia which had three research networks competing for the NREN *title*, namely: RASNet[290], RUNNet[291] and RBNet[292]. The problem is not only with TERENA, where Russia is not represented, but with DANTE and therefore GEANT. It is only very recently[293] that a hopefully lasting agreement was reached [417] thanks to "*the joint efforts of DANTE and the e-ARENA Association [418], Russia's National Research and Education Network (NREN) jointly with JSCC of RAS*".

289 Indefeasible rights of use
290 Russian Academy of Science Network
291 Russian Federal University Network
292 Russian Backbone Network
293 May 17th 2011

Nonetheless "*the dice are loaded*", in other words there are clearly *dogmatic* issues, e.g., NORDUnet is breaking the TERENA as well as the DANTE/GEANT model; therefore, within TERENA the Nordic countries are members and NORDUnet is an associate member, whereas within the GEANT consortium NORDUnet is the formal partner; indeed, there is a single connection between GEANT and NORDUnet, an exception that the DANTE management would not like to see *repeated* as, according to a private conversation I had with a DANTE director long time ago, this would *break* the DANTE/GEANT *model* which is a rather surprising statement!

Of course, it would diminish the power of DANTE, if various parts of Europe were to follow the NORDUnet model; however, there would still be a need to connect these regional networks together. So, what is the real problem apart from the relative loss of influence of DANTE which would be a rather positive than a negative evolution, I think!

DANTE's logic regarding Russia and NORDUnet was utterly disconcerting, given the respective size of the Russian federation compared to the Scandinavian countries, as they could have had three connections to Russia instead of a single one while, more or less at the same time, they insisted on having 5 connections to the Nordic countries instead of one connection to the NORDUnet PoP in Stockholm!

The other *significant* remark is that the Internet traffic shifted from being mostly *academic* to being mostly *commercial*; in addition, commercial ISPs performance improved very significantly, e.g., most Tier1 ISPs can sign contracts with SLAS guaranteeing near-zero packet losses within their backbone. Admittedly, NRENs improved too but if the traffic composition shifted from R&E to commercial, i.e., 50% or more, what is the real meaning of NRENs beyond 2011, especially as the bandwidth-demanding user communities have rebuilt their own mission-oriented backbones?

The question of whether NRENS should be involved in networking research activities should also be asked.

In my opinion, this is the role of their members be they Universities or research organizations like INRIA, KTH, University of Amsterdam, consequently, NRENs, as such, should not be involved in EC projects, apart from infrastructure building projects, i.e., GEANT or like projects. Obviously, it is also clearly the role of NRENs to introduce new services ahead of commercial ISPs, e.g. IPv6.

The good news, though, is that I am not the only one to question the need for updating the roles of the NRENs and GEANT; indeed as part of the GN3 project [419], ASPIRE[294] [420], an 18 months long study led by John Dyer (TERENA) [421], has been launched on 1 April 2011. However, the not so good news is that the EC released a report titled "Knowledge without Borders: GEANT 2020 as the European Communications Commons" in October 2011 [422]. This report was produced by the GEANT Expert Group that mainly gathered the main actors, i.e. DANTE, NRENs, and TERENA. Getting together *the judge and the parties* is a well proven way to plead for its own cause without seriously looking at the deficiencies[295] of the system. Not surprisingly, the report is proceeding by assertions, only vaguely alluding to tough yet unresolved issues, and is essentially self-congratulations for the outstanding research and innovative results achieved by GEANT and the NRENs, while carefully avoiding being too specific [423]!

To conclude on a slightly provocative remark, most early networks, including EARN/BITNET, disappeared why would not some NRENs, including GEANT, follow this trend or, at the very least, change their business model radically?

[294] A Study on the Prospects of the Internet for Research and Education

[295] Reading between lines allows identifying some possible divergences of opinions between the partners and/or topics for further discussions!

9.1.2 Some Specific National Research and Education Networks (NREN)

It would not make much sense to comment on each NREN given that this article is already too long; therefore, I tried to "*pick-up*" the most representative ones in more or less random order.

9.1.2.1 JANET [130]

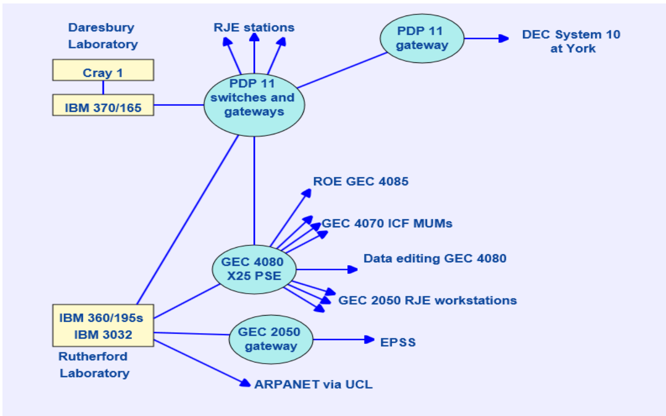

Figure 12 SERCNET Topology (1977)

The unique aspects of JANET have already been widely covered in several chapters of this article, in particular the use of the UK "*Coloured Book*"; however, it is worth stating again that the UK was well ahead[296] of any other European countries; indeed, SERCNET[297] [169], the first European NREN, although a rather embryonic one, was started in 1974[298], together with EPSS[299]. Its successor, JANET, a full scale NREN, came into service in April 1984 which is truly exceptional.

9.1.2.2 DFN [425]

As rightly pointed out by Peter Kirstein in [13] "*The question of whether everything should be connected together was still a problem, partly because Germany having a federal structure, much of the educational funding is by "Lander[300]" rather than national. This is reflected in DFN, "German Research Network" rather than German National Research Network*". Although all European countries had networking activities, few, except the UK had a real NREN even in planning. "*Germany was an exception; they started planning DFN in the early '80s, and the official organization was founded in April 1984".*

DFN's first network WIN only went live in 1989 and was a 64 Kb/s X.25 network, as useless as IXI, where, if my memory serves me well, additional charges were even requested for non-ISO/OSI users, i.e. Internet users! However, DFN had to face some hard opposition, for example University of Dortmund (Rüdiger Volk) was very active in EUnet, Karlsruhe University had the project to build a CSNET node and BelWue, the Academic Network of the Federal State of Baden-Wuerttemberg was openly challenging the DFN organization for many years and, although it has a direct connection with DFN, it also has direct connections to SWITCH through a cross-border fiber and to the DE-CIX [426] in Frankfurt, one of the three largest IXPs in Europe and also has its own commercial Internet connection through TELIA [427].

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[296] 10 years or so; in addition UK was the 1st European country to liberalize the telephony and data communications market as early as 1990.

[297] Originally known as SRCNET (Science Research Council NETwork)

[298] "The real start of networking can be accurately dated to 22 March 1974" P. Bryant [169]

[299] As shown in the enclosed network topology diagram, SERCNET was a leased lines network with gateways to EPSS and ARPANET, in particular.

[300] German regions, sixteen in total, also called "Bundesland" for "federated state"

9.1.2.3 BELNET [428]

Belgium was, by far, one of the *least advanced* countries, networking wise, under the influence of a (now retired) University professor who had a marked dislike of American-invented protocols, especially TCP/IP and whose dream was an "*all OSI*" world. Because of his close connections with the EC, he may have played, together with many others, a questionable misinformation role! When BELNET was finally created in 1993, its representative at the EARN Board of Directors told me that his main achievement had probably been to delay the creation of BELNET by several years, which was surely a bad "*joke*" ☺

9.1.2.4 NORDUnet [222]

Not surprisingly, given the consensus building culture of Nordic[301] countries, NORDUnet was built in a very pragmatic and effective manner avoiding, in particular, the *trap* of being divided into too many small networks with no political weight. NORDUnet played a major role in the adoption of EARN, EUnet and Internet in Europe and, for that reason, was very much disliked by the RARE *activists*. However, NORDUnet was very innovative in many ways with, for example, the sharing of networking roles between Denmark (education), Finland (services), Norway (research) and Sweden (infrastructure as well as services).

9.1.2.5 SURFnet [429]

It is not very clear whether the much heralded results of SURFnet's are really up to the expectations. However, it is an undisputable fact that NETHERLIGHT has become the highest concentration point of high speed, academic use, circuits[302] in Europe and probably in the world, thus surpassing StarLight in Chicago and CERN, and that SURFnet is the NREN that is most engaged in Networking Research.

But, whereas CERN together with the LHC community worldwide have a clear mission and will no doubt make heavy use of their networking infrastructure, it is far less obvious to predict what NETHERLIGHT will really achieve apart from being an extremely convenient transit point in Amsterdam that is also known as *Europe's Internet capital*, actually a well-deserved *title*.

As noted in my article "*State of the Internet and Challenges ahead*" [430], the emphasis on all-optical networks, bandwidth on demand, etc., is puzzling as I am extremely doubtful about the viability of commercial on-demand lambdas, especially inter-provider ones, as most, if not all, major Telecom Operators are able to provide a more or less equivalent service with MPLS layer 2. The confusion between "*fast provisioning*" and "*switched*" lambdas (i.e. sub-second set-up time) appears to be purposely maintained; in any case, the related work does not appear to be progressing very fast, to say the least!

In any case, the repeated failures of commercial switched data services, e.g. 64Kb/s, SMDS [431] do not appear to have been taken into account!

9.1.2.6 RENATER [432]

The fights between IN2P3 and CNRS, on the one hand, but also between the Ministry of Research and the Ministry of Education in France, considerably delayed the creation of RENATER that only took place in 1993. Although France was a very active RARE member and was not short of RARE *activists*, the relationship deteriorated after the Killarney meeting in 1990 and the creation of Ebone. One reason why France was unhappy with both RARE and DANTE, though I am not completely sure, may be related to the results of several RARE and DANTE

[301] Denmark, Finland, Iceland. Norway, Sweden

[302] 2.5Gb/s, 10 Gb/s, 40 Gb/s "optical" circuits dubbed "lambdas"

tenders (e.g., IXI, EMPB) where France Telecom, probably for very valid reasons, had not been selected. Therefore, RENATER became a strong supporter of Ebone and as it was also participating in the D-GIX and one of the recipients of the NSF ICM award, there were three "*good"* reasons for not being *appreciated* by RARE and DANTE. In the end, RENATER under the leadership of Danny Vandromme [433] became a shareholder of DANTE in 2000; Danny Vandromme then served as member of the DANTE Board[303] from January 2001 before becoming the Chairman of the DANTE Board for 2 years from January 2003.

9.1.2.7 GARR [434]

There was a very similar situation to that of France, in Italy between INFN and CNR and, to some extent in the USA between DoE and NSF; however, Italy being one of the founding member of DANTE was therefore a shareholder.

9.1.2.8 SWITCH [408]

SWITCH was the very first NREN to be 100% IP, a very *brave* undertaking that deserves to be underlined. SWITCH was also the first NREN to deploy a dark fiber infrastructure. Unfortunately there were a number of unconditional X.400 adepts in Switzerland; for example, a now retired Geneva University professor was not only the very first but also the very last X400 users in Switzerland; as gateways between the fading X400 world and Internet were very fragile, the assistance of an almost full time student was necessary in order to keep the illusion that Switzerland was on the right side of the, long time lost, standards battle ☺

9.2 Tentative conclusions

Would not both NRENs and DANTE/GEANT have been much more successful if less time had been spent in building new monopolies and is it not time to take a fresh look?

In this regard, a very interesting set of comments was provided by Paul van Binst (ULB) in the last-but-one slide of his excellent presentation at TNC2008 [435] "*Is the non-NREN world overtaking us"?*

1. "*We have far exceeded our wildest expectations/dreams in terms of Quantity*
2. *We are (happily?) often forgetting about Quality*
3. *The non NREN world is overtaking us with Functionality*
4. *Food for thought: does the NREN world need a (new) business model?*"

Very similar views have actually also been expressed in my article "*State of the Internet and Challenges ahead*" [430].

To conclude I cannot refrain from quoting the humorous and sarcastic remarks of Paul Bryant: "*Talking about competition and monopolies, I wonder what would happen if DFN, for example, were to offer to connect up a UK university in competition with JANET? Interestingly, schools in the UK can be connected via JANET, or their Local Authority or via a commercial ISP and examples of all these exist. Also, interestingly, JANET now runs a backbone with regions running regional networks. I suspect that in the long run the NRENs will have difficulty competing with other network providers. Maybe in the spirit of the EU the NRENs should amalgamate[304] and then they may have the same outstanding success[305] as the EU* ☺"

[303] Board of Directors
[304] Editor's note: thus probably *fulfilling the dream* of DANTE of forming a single super-NREN!

10 The roles of DARPA and NSF

The lack of wider Internet acceptance in Europe, in particular, was largely due to the involvement of DARPA [436], the Defense Advanced Research Projects Agency of the US DoD[306] nourishing suspicions about the real agenda of the "*big brother*"!

NSF played a major role being the initiator of CSNET and NSFNET while also funding transatlantic links.

"In 1984-1985, the NSF began construction of several regional supercomputing centers to provide very high-speed computing resources for the US research community. In 1985, four new supercomputer centers were established with NSF support—the John von Neumann Center at Princeton University, the San Diego Supercomputer Center (SDSC), the National Center for Supercomputing Applications at the University of Illinois (NCSA), and the Cornell Theory Center, a production and experimental supercomputer center. NSF later established in 1986 the Pittsburgh Supercomputing Center (PSC). The Interim NSFnet Backbone went online in 1986, as a backbone to which NSFnet regional and academic networks would connect. The six backbone sites were interconnected with leased 56 Kb/s and routers were PDP-11 minicomputers, called "Fuzzballs". As NSFnet's regional networks began to grow the NSFNET backbone traffic experienced exponential growth, therefore very high packet loss rates and became essentially unusable. The Interim NSFNET backbone also proved the fragility of the External Gateway Protocol (EGP) and the need for a better structured network. As a result of a November 1987 NSF award to a consortium of universities in Michigan, the original 56 Kb/s links were upgraded to 1.5 Mb/s by July 1988 and again to 45 Mb/s in 1991. More important, the network was managed in such a way that the routing announcements of the external networks, i.e. US regional networks, but also international networks, were filtered in order to avoid routing loops and sub-optimal routing because of routing announcement mistakes by external peers but also back doors, i.e. connections between regional networks, for example."The main victims of the dismantlement of NSFNET were the US Universities, as the mission oriented communities such as the space, magnetic fusion and high energy physics communities were already self-organized. However, the original purpose of NSFNET was to interconnect supercomputer centers which were continued after the demise of NSFNET as a specialized network dubbed vBNS (very Broadband Network Service).

The Interim NSFnet backbone proved the need for an NSFnet backbone network – as originally envisioned – and was replaced by the T1 backbone (and later T3, etc) at the earliest opportunity. The success of the NSFnet Programme was in building a three tier national research inter-network (or Internet) comprised of campus networks (of which there were very few when NSFnet was started), a large number of Regional networks (all stimulated by the NSFnet Programme, including a T1 network, BARRnet), Supercomputer Centre Networks (SDSCnet centered on SDSC in San Diego and the T1 JvNCnet centered on CSC/JvNC in Princeton), the expanded ARPANET, CSNET, BITNET (with TCP/IP), and the NSFnet Backbone.

In order to implement NSFNET's Acceptable Use Policy (AUP), NACR[307] and PRDB[308] were used to filter incoming routing announcements, with two distinct purposes: 1) avoid routing loops to EGP 2) authorize networks one by one thus preventing access to NSFNET by some networks.

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[305] Editor's note: as already exemplified by DANTE. Regarding the EU, while I agree that it could work better I do not consider its construction as a failure, on the contrary.
[306] Department of Defense

In order to counter the result of NSF's AUP that were *de facto* preventing former Eastern-bloc countries to participate in the "*nascent*" Internet, political routing was made by Peter Löthberg, the Ebone "*skipper*", in order to ensure Internet connectivity to these countries. Ebone itself was AUP free, a major step forward in the early 1990s.

One reason behind the dismantling of NSFNET was the increasing pressure from the commercial ISPs who saw public NSF subsidies as unfair competition and it is actually surprising that, to my knowledge, nobody has challenged the procedures through which the EC allocates huge amount of money to DANTE, as the sole bidder, in response to Call for proposal to interconnect NRENs, being understood, however, that, because of the "*Subsidiarity*" principle, NRENs fall out of the EC remit.

10.1 DARPA funded links to Europe

As already explained in chapter 2.4, DARPA played a fundamental role in the creation of the Internet by funding the research as well as the deployment of ARPANET. DARPA also funded five satellite links to Europe (chapter 7.1 CCIRN).

More information about the early Internet history and the role of DARPA as well as the pre-ICANN Internet organization can be found in [437] and [438]

10.2 The first general purpose link between Europe and NSFnet

As already indicated, NORDUnet pioneered the coordinated use of TCP/IP between the Nordic countries therefore, not surprisingly, they established the first general-purpose link[309] between Europe (KTH in Stockholm) and NSFnet (JvNC in Princeton) as early as August 1988. This very important historical feat is reported in detail in the "US Connection" chapter of "The History of NORDUnet" [353]. The main drivers on the NORDUnet side were Mats Brunel (SICS) and Juha Heinänen (FUNET) [439], whereas on the US side Lawrence Landweber (Wisconsin University) and Steven Wolff (NSF) had the key roles.

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10.3 NSF ICM award and STAR TAP

The NSF ICM award that was followed by the Euro-Link [440] award (1999-2004), greatly helped selected European networks, initially, IUCC/ILAN (Israel), NORDUnet, RENATER and SURFnet, later CERN, to connect to the STAR TAP exchange point in Chicago.

STAR TAP and ICM made many people unhappy; first of all, unsurprisingly, those who did not receive the award, but also the choice of the location that was seen as "*non-neutral*" i.e. not enough East coast for Europe and not enough West coast for the Asia-Pacific countries, only adequate actually for CANARIE.

One objective reason for the choice of Chicago was undoubtedly the richness of the scientific community in the Chicago area (ANL, FNAL, University of Chicago, UIC, NCSA, Northwestern University, University of Michigan, MERIT, etc.) and the existence of the MREN[310], a multi-state

[307] Network Announcement Change Request
[308] Policy Routing Data Base
[309] At first the satellite link was set up with 56 Kb/s capacity, according to the US standard, but it was later upgraded to a 64 Kb/s terrestrial (submarine) link.
[310] Metropolitan Research and Education Network

advanced network devoted to data intensive science which connected all of these institutions and others. STAR TAP leveraged the existing MREN infrastructure...

Whereas, the additional costs of reaching STAR TAP were initially relatively marginal compared to the prohibitive costs of transatlantic circuits back in 2005, they became rather significant afterwards following the sharp decrease of these due to the fierce competition between Telecom Operators and the transatlantic bandwidth "*glut*"

One of Steve Goldstein's favorite jokes when talking to the RARE people about sharing the costs of the transatlantic lines was: "*I am the hub you are the spoke*" needless to say this kind of joke was not very well taken by people like James Hutton, Klaus Ullmann, Enzo Valente and, more generally the non-ICM awardees!

Another recurring difficulty was about who should pay the cost of transatlantic lines, i.e. Europe only, shared costs, etc., a "*thorny"* subject that was only settled rather recently between NSF and DANTE.

11 The Role of the European Commission (EC)

During RARE WG6 meetings, EEC's DG XIII representative used to say that he was acting according to the orientations provided by the member states, while those, when questioned about the *wisdom* of the EEC orientations, would tell you exactly the opposite, a kind of "*cat and mouse"* game! Being better informed than I was at the time about the EC way of working, it is very likely that it was the *conservatives* who were able to influence the EC and not the reverse; there is also nothing wrong with that except for the lack of "*intellectual honesty*".

On the contrary, Paul Bryant believes *"that the EEC was influenced by a set of ISO fanatics who suggested that adoption of ISO would be good for European industry and good for European political cohesion."* And has some rather hard words against Nick Newman: *"I suspect that he played no small part in that process. I first met Nick when he was doing a tour of European networking sites possibly in 1983 when he was attempting to get some idea of what part the EEC could play in networking or maybe finding a use for DG XIII and himself."*

I personally think that Nick Newman was a kind of "*free electron*" that contributed to exacerbate the ISO/OSI debate, which is kind of normal and also frequent in High Energy Physics Laboratories such as CERN but was definitely utterly inappropriate for an EEC civil servant.

11.1 Advanced Communication and Telecommunication Services (ACTS)

The ACTS [441] "*program was established under the 4th Framework Program of European activities in the field of research and technological development and demonstration (1994-1998) with a budget of 671 million ECU, i.e. about 5% of the total budget available for European research under the 4th Framework Program. Given the global nature of the communications business, ACTS encourages participation from non-EU countries. Indeed organizations from anywhere in the world can participate in the Program on a project-by-project basis without Community funding once their participation is shown to be of mutual benefit to the parties involved.*".

ACTS was an excellent, high impact [442], program; one of its most visible achievements was in the area of mobile networks with the work on GSM[311] and UMTS [443]. However, GSM came

[311] Global Service Mobile

through ETSI [445] and ETSI was setup by the EU. The GSM history [444] is very informative about the "*hard*" technological battles preceding the adoption of a common industrial standard between the major players, in this case the "*big four*", namely UK, Germany, Italy and France. There are actually troubling similarities with the RARE-EARN battle except that the GSM standards battle was industry-led, therefore more efficient because of the expected short-term commercial impact.

The BETEL project (1993) was followed by the European ATM pilot [299], during 1994-1995, whose main objective was to confirm inter-operability of ATM "*cross connects*" in a *multi-vendor* and *multi-operator* environment. The pilot was organized with the collaboration of 17 European PNOs with one National Host [446] per country and was succeeded by JAMES[312] during 1996-1998 with twenty PNOs. "*A second objective was to test the support of services and, in particular, the interworking between ATM and existing network infrastructures. User approval conditions, technical aspects and four benchmark services supported over the Pilot network are discussed.*"

The Role of BETEL [447] should not be underestimated given that, technically speaking, it was a very advanced project, well ahead of RARE's *pathetic* attempts to establish a useful pan-European networking infrastructure. BETEL, in very much the same way as DataTAG [448] and other targeted testbeds proved that well focused, user driven, projects could yield useful results far quicker that bureaucratic-led projects involving too many partners.

BETEL was actually a *meta-computing* project a then fashionable concept, that Ben Segal (CERN) [449] rightly qualified as "A (*very) distributed mainframe*"[313] [450]; in fact, a pre-GRID project on CERN's emerging SHIFT infrastructure. BETEL would not have been possible without the active support of Frederic Hemmer and Bernd Panzer-Streidel who extended the CERN authentication mechanisms to IN2P3 and used the infrastructure to run real physics analysis jobs.

11.2 COSINE

For those interested in the COSINE study commissioned by the EC, there is an exhaustive description of it in DANTE's book "*A History of International Research Networking*".

To be fair, the COSINE study "*probably*" made sense when it was started in January 1987 as a EUREKA [451] [452] project, but why did it take 18 months after the 1st Networkshop held in Luxembourg mid-1985?

In addition, it quickly became apparent that the COSINE project did not lead anywhere in the short term, which the OSI supporters refused to admit, hence the interesting statement of Horst Huenke (Vice Chairman of the Cosine Policy Group) when he realized he had been somewhat *fooled* by the OSI activists: "*A constant property of OSI is that it is always around the corner*" (RARE WP6 Symposium Brussels, 28 February 1989). He also had a solid sense of humor and several of his statements will remain in the OSI history, for example:

1. *"[Acronyms] is an area where we in Europe have profound experience. Our acronym technology is leading the world*".

[312] The ACTS project JAMES (Joint ATM Experiment on European Services) aimed at testing and evaluating, in collaboration with R&D user projects and national research networks, new ATM-based, broadband services and applications throughout Europe.
[313] CHEP'94 conference (San Francisco)

2. "*If we ignore RIPE – we ignore the 'real' requirements; if we accept RIPE we sin against the holy principles of standardization.*" (RARE Networkshop Blois, 14-15 May 1991)

There were three outcomes of COSINE [453] after a couple of years:

1. "*Set of 10 very thick, very blue volumes of COSINE specifications was issued. These 10 blue books were summarized in a red book, which in turn was summarized in an orange executive overview.*"
2. It clearly helped to establish RARE as well as DANTE, i.e. provide an EC supported framework for European Research Networking.
3. IXI[314], a *pitiful*, more or less off-the-shelf, pan-European 64 Kb/s X.25 network that lasted until the end of 1992, that was basically unusable but which was nonetheless considered by its supporters, most notably James Hutton, then secretary general of RARE, as a "*great*" political achievement. IXI was later replaced by EMPP[315] then EMPB[316] (ended in Sept. 1995) that paved the way to Europanet from Oct. 1995 onwards. In the meantime, i.e. since 1991 the really useful, i.e. used, backbone was Ebone, itself largely derived from EASInet but also HEPNET and EUnet.

The presentation given by Tomaz Kalin, then secretary general of RARE, at INET92 is a masterpiece of *misinformation*[317] [454] as it purposely overemphasizes the role of COSINE, IXI and RARE while minimizing the role of Internet, whereas the battle had already long been lost!

The remark made by Rainer Zimmermann (EC) during the FIA [26] meeting in Budapest in May 2011, speaking about the bureaucratic approach of the EC makes complete sense when applied to COSINE, in particular: "*we are doing things right, process like, but are we doing the right thing?*"

Indeed, according to me, the COSINE study gave birth to a mouse i.e. a waste of money, time and efforts; however, according to DANTE's History of International Research Networking (page 68) it was "*both a political and an organizational success, both of them having contributed substantially to the progress of European research networking*". In practice, there is little doubt that COSINE essentially contributed to slowing down rather considerably technical networking progress in Europe by actively promoting already obsolete solutions such as X.25, X.400, X.500 and the ISO/OSI protocols and thus delaying the introduction of Internet protocols, while also making EARN's life as difficult as possible.

In the end, it, however, *failed* to have a truly lasting *negative* impact which is, by itself, a great success☺.

The "*Subsidiarity*" [455] principle was often used by the EC to oppose the RARE WG6 group led by the late J. Prevost from CEA who was, to my knowledge, the first person to propose a pan-European multiprotocol 2Mb/s backbone which was exactly the right vision at that time. Like many pragmatic persons, Jacques Prevost was not well considered by the RARE CoA (Council of Administration).

The same multiprotocol concept was reused by NORDUnet and EASInet in order to satisfy the needs of the divided networking community (X25, NJE, DECNET, SNA, TCP/IP) but came too early, in particular NOT an X.25 only backbone. The 64 Kb/s IXI (X25) *fiasco* was apparently a

[314] International X.25 Infrastructure
[315] European Multi-Protocol Pilot (2 Mb/s)
[316] European Multi-Protocol Backbone (2 Mb/s)
[317] *Falsification* may even be a better word

necessary stage to pass before envisaging working solutions for the vast majority of users and not only the handful of X400 and FTAM addicts. The successor of IXI was EMPB which, although much more restricted than EASInet, represented a significant progress.

There were actually several ways to provide a multiprotocol backbone:

1. Everything on top of X.25
2. Everything on top of ATM
3. Everything on top of TCP/IP
4. Use of hardware multiplexers, either static or statistical, i.e. with dynamic reconfiguration. (similar to the NORDUnet "*plug*")

With the advent of Multi-Protocol Label switching (MPLS), it has now become even easier to provide multiprotocol functionality over the Internet, at large, using layer 2 VPNs.

In practice, COSINE turned out to be a very expensive undertaking, producing a more or less "*useless*" study that led essentially nowhere from a practical perspective, i.e. IXI, Europanet and EMPB, that is three *almost unusable*[318] Pan-European backbones! However, from a management perspective it led to the establishment of the DANTE company that, following the failures already mentioned, finally managed to deliver increasingly useable, therefore *useful*, though very high cost, networks to the Research and Education community, namely: TEN-34, TEN-155, then GEANT[319]. Unfortunately, GEANT3 is unlikely to mark the end of this undesirable and expensive monopoly as GEANT4 and its successors are more or less on their way already!

To terminate on a more positive note and despite the fact that IXI *brought too little too late*, it cannot be denied that it had some positive effects. First of all it was a *proof by demonstration* that *federated* X.25 networks were not at all easy to operate, second it actually *helped* the introduction of TCP/IP in Europe! More precisely, IXI could not prevent the Internet wave from reaching Europe as X.25 had, at least, one nice property that of being *protocol agnostic*.

Niall O'Reilly has a more balanced view of the impact of IXI:

1. *Politically, it paved the way for DANTE*
2. *It undermined the (already shaky) motivation for an EARN X.25 backbone*
3. *Operationally, it Balkanized the X.25 efforts of the subscribing NRENs, as interoperability among this "federation" was not made a priority. Running an application (in my case, EARN's NJE/OSI) in a cloud of IXI-connected nodes required pairwise manual tuning of the application parameters in order to accommodate differences among the countries' profiles. Essentially, this was a PMTU*[320] *problem! In contrast, on the EARN/EUnet/Nordunet X.25 backbone which IXI displaced, a quick phone call to the right person was all that was needed to ensure that any problem was resolved at the network level, once and for all, instead of escalating the problem through the complex and slow IXI operational procedures.*
4. *Finally, IXI facilitated the expansion of IP networking in Europe, especially in peripheral countries like Ireland. This was due to Rob Blokzijl's opportunistic and subversive initiative in offering IP/X.25 tunnel endpoints to interested partners on a router adjacent to the IXI AP at NIKHEF. I seem to recall that the NIKHEF AP was regularly reported at AP Managers' meetings as carrying the greatest traffic*[321] *load.*

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318 Because of the heavy packet losses due to the fact that they were grossly under-dimensioned
319 Release 1, 2 and 3
320 Path Maximum Transfer Unit
321 As mentioned earlier, this was due, in particular, to EUNET

12 New Pan-European Backbone (PEB) Architecture Proposal

Along the same line of thought that, relying on IBM proprietary protocols was indeed not a long term solution, relying on a single pan-European provider is also not a long term solution. Indeed, already 5 years ago or so the EC should have made a call allowing multiple providers to compete in order to spur *innovation* rather than "*conservatism*".

My rather poor opinion of DANTE is actually substantiated by their overly expensive *achievements* but also by their rather disappointing results from an advanced technical perspective. I also have the same opinion of some major NRENs, therefore my one and only recommendation is not "*to dismantle DANTE*" but to make an open call for tenders allowing a few (i.e. more than 1 and up to 4) complementary but innovative and interoperable backbone network providers to emerge.

Organizationally, the actual setup of DANTE, a company whose shareholders are the NRENs and whose members of the Board are the same NRENs, is not very "*appropriate*", to say the least, as a clear separation of roles is clearly needed in order to avoid conflict of interests. In the new proposed set-up, DANTE could still bid for one or more of the PEBs but NOT for ALL of them in order to preserve diversity and encourage innovation.

This could actually be rather straightforward to implement if one were to adopt the following simple principles for future, i.e. post GEANT, Pan-European Backbones (PEB):

1. Allow multiplicity; say up to four overlapping PEBs, with the overlapping zones well defined in the call for proposal, e.g. North, West, South, Central, and East. A regionalization of GEANT, so to speak, i.e. a replication of the Nordunet model with the various regions interconnected by a much reduced "GEANT" core.
2. Impose presence in a minimum number of countries; say 5-10, at the major Internet Exchange Point in those countries. In most countries, there is only one sensible choice, e.g. AMS-IX in the Netherlands, the CIXP at CERN in Switzerland, the LINX in London, etc.
3. Encourage innovation not conservatism and status-quo, by making it an explicit part of the project proposal.
4. Be cost effective, i.e. a PEB should be as cost effective as its commercial counterparts, if not cheaper because of joint procurement, economy of scales and not for profit.
5. Separate data transmission from the services provided on the transport infrastructure in the same manner as it is done in the field of railways, electricity and airports, indeed, the separation of "*containers*" from their "*contents*" should there not be one of the guiding principles?

A model similar to that used in the USA to create the RBOCs[322] [456] off AT&T could be used. I would even propose to take one further step and apply the same design principles to some large European countries, e.g. France, Germany, in order to break the monopoly of the existing NRENs for the benefit of the users.

It is interesting to note, that although Telecom deregulation was done in the USA much earlier than in Europe, it was poorly done as access lines were not deregulated which created lot of problems. Whereas, in Europe, the regulators introduced the concept of "unbundling" the local loop (i.e. not only the phone line, but also the access line, also called "*backhaul*") which was far

[322] Regional Bell Operating Companies

better. To take a practical example the cost of pulling a pair of fibers between two racks, even belonging to the same Telecom Operator inside what the Americans called a "*Carrier Hotel*" could be absolutely prohibitive.

For example, reaching STAR TAP that was part of the Chicago NAP operated by Ameritech proved to be a nightmare, hence its later replacement by StarLight a new IXP with the choice of multiple carriers. Same problem in, so called, Carrier Hotels, i.e. "*horrendous prices*" to interconnect two floors and even to pull cables between two cabinets, e.g. in the Quest PoP I Chicago!

13 "Future Internet"

There is a lot of activity on both sides of the Atlantic, but also in Japan with the Akari project [457] about the "*Future Internet*" and its relation to today's Internet, namely "*evolutionary*" or "*revolutionary*" (i.e. *clean-slate*). NSF, NICT and the EC are all very active. Although these projects produced few tangible results, so far, things may well be changing with the recent creation of the "*Open Network Foundation*" [458] in March 2011, whose first task will be to adopt and then lead the ongoing development of the *OpenFlow* standard [459]. Internet2's recent announcement [460] about NDDI and OS^{3}E is extremely informative in this regard, as is Chris Robb's (Ciena) Internet2 blog entry [461]: "*Now that the Bandwidth Challenge is solved, what we are going to do with it*?"

But there are other proposals floating such as the *"Beyond TCP/IP"* [462] proposal made by Fred Goldstein and John Day for the Pouzin Society [463] in April 2010. The TSSG[323] [464] and i2CAT[324] [465] will be joining forces with the Pouzin Society to contribute to the development of a RINA[325] prototype based on the TINOS platform. A RINA tutorial as well as a short presentation are available from [466] and [467].

Virtualization technology is clearly opening new design opportunities, however the single vs. multiple Internet argument is slightly *biased* given that, with the advent of the new multilingual Internet, there is a *de facto* partition of the Internet as, because of the language barrier, large parts can no longer talk together! Therefore it is not as clear as before that the Internet *dogma* of a single network still is still so *essential* given that it has lost much of its original *universality*, nonetheless, the Internet is still clearly *ubiquitous* and the roles of the "*social networks*", such as Facebook, Twitter, are growing at impressive speed!

14 Conclusions

The history of "*European Networking"* like, to a large extent, all history is one of power struggle; the protocol war was only used as a pretext in order to give some ideological foundation to the establishment of RARE, DANTE and, to some extent, a limited number of NRENs, in order to make it easier for the non-initiated to "*separate the wheat from the chaff*" (i.e. the good from the bad.)

This article is about the worse aspects of the mankind i.e. self-interests, however, being also a networking article it is interesting to note that many of the network protocols and network names mentioned throughout this very long, though far from being exhaustive, article have already been forgotten long time ago. Of course the Internet will remain but who really cares about the

[323] Telecommunication Software and Systems Group
[324] Internet2 in Catalonia project
[325] Recursive Inter-Network Architecture

underlying protocol as long as it preserves the fundamental property of the existing Internet, namely striving to stay a "*single network*".

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16 Am I qualified to write about the pre-history of the European Research Networks?

As pointed out in the preface of the DANTE's "History of International Research Networking" "*a large number of people counted in hundreds if not thousands, have played some part*". However, what is not said in this preface is that an even larger number of people tried their best to fight, by all possible means, the penetration of the Internet in Europe. Unfortunately, many of these people are still in a dominant position which explains the repeated mistakes of DANTE and GEANT.

While it is indeed true to state that the number of actors was more than just a handful of people; it is also a fact, even at the risk of looking pretentious, that I happened to be one out of very few European people that were uniquely placed to follow the development of the European Internet as well as its interconnection with the US Academic and Research Internet (i.e. NSFNET, Internet2) at Cornell University first, then STAR TAP and StarLight [468] in Chicago.

Indeed, I was one of the three people at CERN who were very active during the whole pre-Internet and proto-Internet periods, together with Brian Carpenter, Head of the Communication Systems (CS) group and François Flückiger, Head of the External Networking section until I took over his function mid-1989 when he was promoted CS group deputy leader. Hierarchically speaking my influence was very limited; nonetheless, I had some impact because I happened to be on the right technical side, either out of pure luck or maybe because I had sound technical judgment!

In any case, I participated in the establishment of RIPE and in the development of EARN, EASInet and Ebone. I also served on the EARN Board of Directors and then on the TERENA board as the CERN representative and I was one of the three Europeans that participated in the founding meeting of the IEPG, that was held in Vancouver in August 1990 following the end of the protocol war. In other words I have been the witness of many important meetings.

However, I was clearly "*the last wheel of the carriage*", in other words I was mostly active operationally while the policy and decision makers at CERN were Paolo Zanella, David

[326] Actually the "living memory" of EARN as he is the only one to the best of my knowledge that was both on the EARN Executive and on the EARN BoD from the beginning to the end. He also kept paper copies of most official EARN documents.

Williams, David Lord, Brian Carpenter and François Flückiger. Therefore, I hope that this article will not give the false impression that I had "*the*" major role in the whole "*pre and proto*" Internet period that was definitely a collective undertaking.

16.1 Am I neutral?

I have no shame in admitting that, back in the late 1970s early 1980s I was very appreciative of IBM, in general, and of its truly remarkable Research Laboratories, in particular.

I also have to admit a strong *bias* against DANTE, first of all because, having rubbed shoulders with them for many years, I am well aware of their practices, in particular, the monopolistic style of the company but also their *questionable* attitude regarding information transparency (e.g. traffic statistics) and their rather *mixed* results in terms of both technical innovation and price/performance.

Like many technically-oriented people, I had preferences for technically efficient, as well as proven, solutions offering good functionality and ease of use; hence my dislike for the overly complex as well as "*ill-cooked*" OSI technical standards developed under the ISO [469] umbrella.

16.2 Is this article still relevant?

Anything that contributes to establishing the "*truth"* is, in my opinion, useful even if it is not exactly the same "*truth*" as that of the other actors. In any case, as there have been far too many deliberate cover-ups and hypocrisy by some of the key actors, I find it worthwhile to reflect about it, in order to try to understand how intelligent people can have been "*blinded*" to the extent of proposing "*still-born*" solutions that could have been detrimental to many people and, first of all, the academic community, but also the world, at large, given the importance of the Internet as a counter-power and a symbol of freedom of expression.

Indeed, would there be a single worldwide Internet today if Europe, followed by other countries, had persisted in its "*all-OSI*" approach?

There is no lack of historical examples of "*collective blindness*", e.g., the sad communist experience and the numerous 20th century genocides. Unfortunately, the scientific community that was expected to be above politics and politicians has shown in the Internet case as well as in some others that, being subject to various political pressures, they could easily lose their objectivity; indeed, as the history is repeating itself, one can see similar biased discussions around nuclear energy, global warming, use of GMO [470], etc.

Therefore despite its limited scope and ambitions I hope that this article may be useful!

17 The actors

As stated earlier, the people mentioned in this article were for the most part very nice individuals; however they could be collectively "*very dangerous*". As I like parodies and caricatures, the portraits below of some of the most emblematic European networking figures are probably excessive. In any case, I deliberately omitted the names of the people whom I consider to have had a bad influence; therefore they should easily recognize themselves ☺

17.1 CERN

In addition to Brian Carpenter, François Flückiger, David Lord and myself, many other people at CERN played a decisive role because of their hierarchical position, most notably, P. Zanella, Data handling Division (DD) leader, his successor David Williams, Computing and Networks (CN) Division leader, Jacques Altaber, LEP accelerator control network group leader, as well as successive CERN research directors, J. Thresher, W. Hoogland, H. Wenninger who brought their political support to the networking strategies developed and implemented within the DD then CN divisions.

However, the CERN person who was definitely the most influential and visionary one during the pre-Internet era was David Lord thanks to whom:

1. The key role of CERN in EARN was agreed by the CERN hierarchy which greatly contributed to the quick adoption and penetration of EARN in Europe.
2. TCP/IP was selected together with the IBM Token Ring as the technology for the LEP accelerator control network.

Unfortunately, David Lord who was the 2nd president of EARN (Dec. 1984-1987) retired from CERN fairly shortly afterwards and was therefore neither involved in the setting-up of RIPE nor in the subsequent development of the European Internet.

Many other people played very important roles during this period, e.g. Maria Dimou, Denise Heagerty, Jean-Michel Jouanigot, Christian Isnard, Paolo Moroni, Ben Segal, Dietrich Wiegandt and, of course, Tim Berners Lee [471] and Robert Cailliau [472] with respect to the Web; however, neither Tim, Robert nor Ben were directly involved in the establishment of CERN's external networking infrastructure.

Dietrich Wiegandt designed and operated the MINT Gateway whose purpose, as excellently described by Denise Heagerty [473], was to interconnect recommended mail systems at CERN, i.e. EAN/X.400, Wylbur, Columbia Mailer and RICE Mail (i.e. ARPANET addressing over EARN plus gateway to the TCP/IP world) but also had connections to other systems thus indirectly providing an unequaled number of indirect mail gateways to every possible mail system, including DECNET, Grey Book, UUCP, native X.400 (which EAN was not), etc.

Mervyn Hine [474], one of CERN's founder members, was also very instrumental in the CERNET and STELLA [475] projects as well as in the RARE WG6 group *"Medium and High-Speed communications*".

17.2 Peter Villemoes

Peter Villemoes (NORDUnet) almost became an *outlaw* after the *historic* RARE Networkshop that took place in Trieste (Italy) in May 1989, i.e. only one month before the first RIPE meeting and where some "*eminent*" members of the RARE CoA (Council of Administration) stated that, as long as they would be in charge of their emerging national networks, these would "*under no circumstances whatsoever*" run the "*infamous*" Internet protocols, thus showing "*a truly remarkable lack of vision"* by even refusing to talk about IP and shutting down any mention of it!

For those who have had the privilege to know Peter Villemoes, it was extremely difficult to attack him as he was the very example of an intellectually honest and collaborative man whose only motivation was to maximize the satisfaction of the NORDUnet user community in terms of quality of the infrastructure, innovation, quality of service, etc. Not surprisingly, one of the NSFNET funded lines to Europe ended in Stockholm (ICM award), KTH was the host of the first non-US DNS root server, Finland was extremely active in providing multimedia file repository, good FTP servers, remote conferencing, multimedia repository of academic courses and seminars, etc.

17.3 Jan Gruntorad

Thanks to his remarkable vision, Jan Gruntorad played a key role in the establishment of both CESnet [476], the Czech National network, and also CEEnet [477]; in my opinion, the palm of innovation should go to CESNET which has been deeply involved in developing cheap "*PC based*" routers as well as cheap "*optical transmission equipment*" which could greatly benefit former Eastern countries but also many others in Caucasia, Central Asia as well as Africa, Middle-East, etc.).

17.4 James Hutton (RAL/RARE)

Despite the fact that James Hutton was responsible for a leased 9.6 Kb/s line between Rutherford Lab (Oxford) and CERN using IBM's RJE[327] protocols, he was, at the same time, a very strong proponent of the UK "*Coloured Book*".

A contrasted personality, who became the 1st secretary general of RARE and, as such, was at the heart of the IXI project, James Hutton was an unconditional supporter of X.25 to the point of becoming almost "*addicted*"!

How intelligent persons such as James Hutton, as well as several others, e.g. Peter Linington[328], could push X.25 protocols beyond reason remains a mystery to me. Indeed, whereas X.25 protocols were well suited for Videotex [478] like applications like the French Minitel [479], i.e. low to medium speed interactive access to online databases and other interactive services (e.g. telephone directory access, e-services), they were ill-suited to high-speed networking[329], in general, and to academic networking, in particular, as explained by Dennis Jennings in chapter 5.5.2.

17.5 Kees Neggers (SURFnet)

A controversial, though most successful, individual, Kees Neggers was, to my knowledge the only person representing his own NREN, SURFnet, at both the EARN Board of Directors and the RARE Council of Administration (CoA). As a result, very few people really trusted him which may be one of the reasons why he missed, by only one vote, the presidency of TERENA against Frode Greisen, the former president of EARN, at the time of the RARE/TERENA merger back in 1994.

Thanks to his outstanding political skills and his international experience, Kees Neggers quickly learned from the Americans the virtue of marketing *advanced* technical plans as well as their expected results, well ahead of time!

17.6 Enzo Valente (INFN)

Enzo Valente was a very interesting personality as, unlike some others, he could be both very creative but also very destructive, maybe an interesting case of networking "*schizophrenia*" ☺

[327] Remote Job Entry stations were rightly considered like natural extensions of the prevailing mainframe environment of the 1970-1980 period and had therefore little to do with the emerging networking world.
[328] The first president of RARE (1986-1988)
[329] Above 2Mb/s

Indeed, his complex personality was difficult to grasp, he definitely had a very strong dislike of American people, in general, but also David Williams, Kees Neggers and Peter Villemoes, and was the faithful ally of José Barbera (Spain), Jüergen Harms (Switzerland), James Hutton (United Kingdom) and Klaus Ullman (Germany). Although he had very original and subtle ideas, his poor command of English and his somewhat *abrupt* manners were a major handicap to get his ideas properly understood and therefore widely accepted.

Whereas INFN was one of the main driving forces behind DECNET, they were also the first to understand that DECNET Phase V was *still-born* and that TCP/IP would then be ineluctable. Being very innovative, Enzo could not ignore historic collaborations between INFN and US Physics Lab (e.g. Fermi, SLAC); for example, INFN was the first European organization to try out Condor [480] (Wisconsin University project), that became one of the essential ingredient of the HEP Grid, and was also a very early adopter of Grids

Enzo Valente, like many other networking leaders of those times, wore far too many *hats*: INFN Computing Committee, GARR, HEPnet, RARE, etc. In addition, INFN was in fierce competition with other Italian organizations, e.g. CNR [481], in particular, but also CINECA [482]. There was a very similar situation in France between IN2P3 [103] and CNRS [483].

17.7 Eric Thomas

Eric Thomas [484] is the perfect illustration of next-generation Information and Computing Technology experts; born in 1966, he was already a self-educated programmer at the age of 15, a rather exceptional precocity! A very young 20-years-old student in the early EARN days he immediately established himself as the EARN *guru* and could already speak as an *equal* with almost any computer specialist in the world. Eric Thomas was the author of the Chat/Relay service based on IBM's NJE TELL command as well as the, so called, Revised LISTSERV [485], now L-Soft, file distribution system, which can be seen, in some way, as a *precursor* of Content Distribution Systems (CDN) such as Akamai, Google, Yahoo and various network appliances.

17.8 Peter Löthberg

Peter Löthberg, a leading Internet personality but also its "enfant terrible", undoubtedly played a major role in the engineering of Ebone. While an extremely bright person, patience and tolerance were notoriously not his forte. Indeed, he had quite a few biases against the non-commercial world, e.g., CERN, NSF, RARE, most NRENs, but also former Telecom monopolies, e.g., Telia, as well as IBM. In contrast, Cisco, Tele2 and Sprint were then his pet companies. Needless to say, all the ingredients for personal clashes were there, as he could not stand being contradicted by anyone. In addition, his high speed of speech made him difficult to understand - nonetheless, one must admit that he was right most of the time. Peter always carried tongs and screwdrivers in his pockets and enjoyed messing with routers and telecom hardware, but he was equally keen to give presentations to high level management. During this key phase of European Internet development, Peter was assisted by Björn Carlsson (KTH), a top level IP engineer, and Frode Greisen, the General Manager of Ebone. Together, they achieved the goal of making Ebone one of the best engineered and managed IP network worldwide – for as long as it lasted.

18 EARN/OSI

18.1 EARN/OSI seen by its CTO Niall O'Reilly (UCD)

"*As I recall, IBM's 4 years sponsoring of EARN began back in 1983 or so. Besides lines, modems and a few VM systems, IBM contributed organizational support, both technical (Berthold Pasch) and managerial (Peter Streibelt, Alain Auroux). An important cultural characteristic was the idea that IBM would not "run the show", but rather was expecting the responsibility for this to be taken on by the community.*

I see IBM's approach as both pragmatic and sophisticated. It was perhaps an exemplary application of the "Subsidiarity principle": they contributed key resources which enabled the community to do something useful, and avoided the kind of interference which would have increased their costs and simultaneously antagonized the beneficiaries. They were clever enough not only to find the "sweet spot" on the cost/benefit curve, but also to take a relatively long-term perspective and not look for early and tangible pay-back. I seems to recall also that, when the initial sponsorship ran to term, and EARN was not yet ready either with a replacement sponsor or with a means to draw adequate funding from its membership, IBM extended the sponsorship so that EARN would not collapse. When implementation of the new deal with DEC and Northern Telecom (NT) began, NT took an even more "hands-off" position than IBM. They contributed inventory, training and some support, during quite a short time window, and then more or less walked away, apparently content with whatever publicity or collateral benefit[330] *they could extract from the exercise*[331]*. Both of these approaches suited a community of beneficiaries who simply needed resources to run their services, and were both aware of the requirements and competent to address them. DEC, however, took an approach which was less efficient, both for them and for the project for which they were the major sponsor. Just as IBM was contributing resources both from European HQ (Paris) and Networking Centre (Heidelberg), DEC could have chosen to use Geneva and Valbonne to ensure that the project's Operations Center in Amsterdam was always in a position to do what was needed and useful, rather than merely following a plan which was too rigid. DEC seems not only to have been unable to comprehend and accommodate the culture within EARN of a network run by the participants for their own or their local customers' diverse needs, but also to have convinced itself that the EARN/OSI project was a campaign in a "turf war" with IBM, from whom DEC was going to seize operational control of the network and deliver the "benefits" of a "managed network" to the "customers". This Quixotic view of the situation led DEC to be frustrated on a number of counts: that EARN was so slow to migrate its traffic to the new backbone, that the EARN President was seemingly unable to command the organization to make this migration, and that DEC was contributing so much for such a slow return. In addition, there was a deep suspicion towards the EARN Office, where IBM's own Alain Auroux was "clearly" obstructing the migration ☺ My own impression is rather that Alain was doing all he could to support the OSI project while maintaining IBM's avoidance of operational interference, as also was Peter Streibelt on the EBOX front. The actual obstacle to migration was the lack of bandwidth between each GBOX and its local connection point to the EARN backbone. It seems not to have occurred to DEC that IBM had taken its turn as main sponsor of EARN, and was not only quite happy to see someone else taking on the burden, but ready to co-operate as far as possible in enabling the community to continue running a service.*

DEC also seemed to suffer from a rather rigidly Balkanized corporate structure. Although Geneva kept more than just "a finger on the pulse", the Earn/OSI Operation Center (EOC) manager apparently reported into DEC NL in Utrecht. Delivery of the GBOXes was by DEC's profit centers in the target countries on the order of the EOC (as budget-holding cost center). An amusing consequence of this was that, each time I had to make a site visit to a GBOX, I was faced with a different keyboard layout. A less amusing effect was that support for each GBOX was available only from the local DEC operation in the target country, which was in some cases not capable of delivering that support in English, as the following example may illustrate: Late in course of the project, it was finally understood that more bandwidth was needed between key GBOXes and their local national EARN nodes. A key site was of course the CNUSC at Montpellier, where an SNA connection between FRGBOX and FRMOP22 was recognized as necessary. After DEC had, apparently reluctantly, agreed to fund the SNA module of the jNET product for installation on that GBOX, and the connection had been made, some debugging was necessary. Support from DEC was available, but only from DEC FR in Paris, and only in French! I expect that IBM, in similar circumstances, would have provided support at European level and certainly in English."

330 I seem to recall that NT's selection as supplier and sponsor of X.25 equipment for EARN was significant in enabling them to win other business in the academic community, and that either DFN and/or SURFnet was mentioned, but I am sure that NT didn't waste resources in useless follow-up to their well-defined contribution to the project.

331 Maybe they were already well aware of the imminent death of X.25 and were concentrating their efforts in other, more promising, technological directions like ATM (comment from O. Martin)

18.2 NORDUnet and EARN (Harri Salminen/FUNET)

"The "green book" was used as the base document at the EARN to ISO Migration workshop in Perugia, there it became clear to us that a private fixed cost X.25 network would be economically more suitable for academic networking and that we needed continuity of NJE service over X.25 for an interim period to support our users before we had good OSI based alternatives for all the NJE services. The heaviest arguments were, as usual, in the X.25 infrastructure group on the use of public vs. private X.25, policies, topology and traffic statistics. The NJE over X.25 group concluded that the only available solutions for carrying NJE over X.25 were SNA which was recommended and JNET/DECNET which was seen as a possibility for some non-transit countries like Finland….Around that time, a NORDUnet project named X.EARN was started to design a multiprotocol Nordic academic and research network which would share same lines with the existing EARN traffic. Although the project's name came from X.25 and EARN the successful result from its work was the NORDUnet network based on multinational bridged Ethernet for TCP/IP, DECNET, X.25 CONS and CLNS instead of a X.25 based OSI only backbone as most other Europeans were planning at that time. During the course of the X.EARN project I wrote a paper on different ways for sharing lines with NJE, which is included as appendix G[332]. The paper was subsequently used in a part of the X.EARN project's report. Most ideas I presented then are still valid except for the NJE/OSI that was realized afterwards with the backing of new sponsors. After the Perugia meeting new support came in to the picture: First, DEC promised to support EARN's OSI migration by providing hardware, software, technical expertise and a small grant for upgrading four lines to 64Kbit/s that would form a square EARN X.25 backbone. Then Northern Telecom donated four large PTT-style DPN-100 X.25 switches, one DPN-50 management switch, spare parts and training. Lastly IBM made new offers to support the availability of OSI/SNA software and hardware. In addition IBM offered co-operation with their new emerging EASINET initiative. During the May 1988 BOD meeting in Cesme (Turkey), EARN officially accepted all three offers, subject to further negotiations. During spring 1988 a new group called OSI-TEAM was formed to design a new OSI Migration plan which held several meetings that were sponsored by DEC that finally came to a conclusion that we needed some kind of gateways between NJE and OSI which we called G-BOXes. At the end it became clear, of course, that such boxes could be made from VMS VAXes with DEC OSI/X.25 support and JNET. It (also) became clear that we need to support full NJE protocol on the future X.25 network for an interim period and many proposals for that were made. SNA/X.25 and NJE/DECNET were discarded since they were proprietary and were not available both for IBM and DEC operating systems which were seen as the major operating systems in EARN. The BITNET II efforts for developing NJE over TCP/IP were known and were discussed, but since DEC and many others insisted that we must use OSI and X.25 and that a EARN wide IP network was politically impossible anyway, it wasn't accepted. Finally, developing a new protocol to carry NJE over OSI session layer was seen as the most Open solution for providing NJE connectivity, since it could be implemented on both IBM and DEC systems using many real OSI layers and we did have financial and technical support to do it. Steve Arnold from Joiner Associates, who had very actively participated in the OSI-TEAM, promised to produce a working prototype of NJE/OSI driver in the summer 1988. Implementation for the IBM systems, which were called E-BOXes, were also expected to appear soon and maybe even supported by IBM. In the meetings other gateway functions were also discussed and the most important ones were mail, file and job transfer gateways from NJE to X.400, FTAM and JTM. But since no quick ways to implement this were found and the first priority was NJE over X.25 the OSI-TEAM left them for further study."

19 Miscellaneous information about the inception of the Internet and related Networking Technologies and Infrastructures

In general, it is much easier to identify the originator(s) of particular networking initiatives than the person who is really at the origin of key networking developments such as the Internet or the World Wide Web for example, as these is usually the result of distributed team work.

[332] Two innovative proposals were made regarding NJE: 1) BSC over X.25, 2) TCP/IP

As written by Robert Cailliau (CERN) in his "*A short history of the Web*" speech delivered at the launching of the European branch of the W3 Consortium in Paris (Nov. 1995) [486]:

"*The history of every great invention is based on a lot of pre-history. In the case of the World-Wide Web, there are two lines to be traced: the development of hypertext, or the computer-aided reading of electronic documents, and the development of the Internet protocols which made the global network possible….We need to make a Web browser for the X system, but have no in-house expertise. However, Viola [487] (UCB & O'Reilly Assoc.) and Midas (SLAC) [488] are WYSIWYG [489] implementations that create great interest….The world has 50 Web servers! In 1993, Viola and Midas are shown at the Software Development Group of NCSA*[333]*. Marc Andreessen [490] and Eric Bina [491] write Mosaic [274] from NCSA. This is easy to install, robust, and allows in-line colour images. This causes an explosion in the USA.*"

19.1 Who are the funding "*fathers*"?

19.1.1 INTERNET

As already explained, DARPA was first involved in the research whereas NSF (Stephen Wolff [492] and Steve Goldstein [300]) funded the NSFnet infrastructure.

19.1.2 BITNET

BITNET was a cooperative USA university network founded in 1981 by Ira Fuchs [493] (CUNY[334]) and Greydon Freeman (Yale University). The first network link was between CUNY and Yale. BITNET was essentially a clone of IBM's corporate network VNET [156]. Contrary to a common belief, and unlike its European counterpart EARN that was funded by IBM, BITNET was essentially self-funded apart from BITNIC[335] that received IBM funding.

19.1.3 EARN

Given the confused situation in Europe, it is definitely hard to imagine how EARN could have been started without the significant seed-funding from IBM for a period of years, estimated by Frode Greisen to be about 40Million USD. It is equally hard to imagine what would have happened in Europe without EARN, most likely an *indescribable chaos* but who knows!

19.1.4 EASINET

Another major initiative of IBM in Europe that had a lasting impact, as explained in chapter 5.1, and greatly helped the creation of the European Internet. The amount of the 3 years funding (1988-1990) regarding the links between the sites participating to the program as well as the T1 link to NSFnet between CERN and Cornell University is unknown to me.

19.2 Who are the "*founding fathers*"?

As very well explained by Ronda Hauben in [494] "*Finding the Founding Fathers of the Internet"* and Ian Peter in [495] "*So, who really did invent the Internet?*" is not a trivial matter

This question is more difficult to answer as "*Who invited the World Wide Web*"?

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[333] National Center for Supercomputing Applications (Illinois)

[334] City University of New York

[335] BITnet Network Information Center

However, in both cases there were many external influences (e.g. packet switching in the Internet vase, hypertext in the Web case) and more importantly team work.

Therefore, it is interesting to try to clarify the following two points:

1. Who was at the origin of the concept(s)?
2. Who are the person(s) who led the implementation and further development of those original concept(s)?

19.2.1 Packet Switching

According to the "*History of Computers and Computing*" [496] three people can be credited as inventors of packet-switched networks, thus laying foundations for Internet: Leonard Kleinrock [497], Donald Davies [498] and Paul Baran [499]. However, as already mentioned in chapter 2.1, the role of Louis Pouzin [22] appears to have been either forgotten or underestimated.

One of the reasons why packet switching was not welcomed with great enthusiasm was the novelty of the concept, but also the fact that this new approach required more compute power than circuit switching. His only potential benefit was to optimize the utilization of the transmission lines; but, as the computational costs were the dominant factor in the early 1960s, it decreased significantly the value of this new technology.

However, as explained by Larry Roberts [500] in his May 1995 article, "*The ARPANET & Computer Networks*" [501] things changed in the late 1960s thus explaining the growing interest for packet switching and X.25 in the 1970-1980s: *"from 1969 the cost curves crossed and afterward the cost of communications dominated. The composite cost of packet switching thus fell below the cost of circuit switching also about 1969 and since then the margin of advantage has quickly widened."*

Excerpts from [499]: *"Baran's work was accepted by the US Air Force for implementation and testing, but was neglected. His series of papers and book however then influenced Larry Roberts and Leonard Kleinrock to adopt the technology for development of the ARPANET network a few years later. Actually the ARPANET was never intended to be a survivable communications network, but some people still maintain the myth that it was….So Davies initiated the terms packet and packet switching into the network terminology (which is much catchier than Baran's distributed adaptive message block switching). Davies had considered many possibilities, block, unit, segment, etc., before deciding on packet as a sort of small package. And as he later told Baran: "Well, you may have got there first, but I got the name."*

In the UK it was started at the National Physical Laboratory (NPL) under its then Laboratory Superintendent Donald Davies and called the NPL Network[336].

In France, CYCLADES, a pure datagram network that was deployed from 1971 and remained operational till 1979, has already been described in chapter 2.1. As noted by Larry Roberts in [501] "*The ARPANET also operates using datagrams but perhaps the most avid supporter of the concept was the designer of CYCLADES, Louis Pouzin.*". This opinion is also expressed by Vint Cerf in chapter 19.2.3.1.

In Europe, agreement was reached in 1971 to mount an inter-government packet switching network trial based on CYCLADES, originally known as the COST11 project and later renamed EIN [23], but due to the difficulties of multi-national funding it did not become operational until 1976. The project was directed by Derek Barber, one of Donald Davies' colleagues at NPL.

[336] A small scale experimental packet switched network with only a few nodes inside NPL, but with a speed of 768 Kbps.

19.2.2 ARPANET

According to an article [502] published by Louis Pouzin in the French journal "La Recherche" [503] titled "*Cyclades or how to lose a market*": "*The Arpanet is generally considered as the first implementation of the packet switching concept, but it is inaccurate: the Tymnet*[337] *network [17] [504]and that of SITA [250] have been developed simultaneously and on similar concepts.*"

Irrespective of the above statement that actually concerns packet switching, it seems indisputable that: Larry Roberts is the "*father of the ARPANET*" as [505] *"He earned this nickname by directing the team of engineers that created the ARPANET. Roberts was also the principal architect of the ARPANET.*"

Adapted excerpts from the "History of Computers and Computing, Internet Birth, Larry Roberts" [500] and "*The ARPANET & Computer Networks*" [501]:

1. *During the 2nd congress on Information on the Information System Science in Nov. 1964, Roberts met with J.C.R. Licklider*[338] *[506], nicknamed "Lick", Head of ARPA's Intergalactic Computer Network Group*[339]*; according to Larry Roberts' own words he got "infected" by Lick's enthusiasm about computer networks and thus decided to change his carrier. In 1965, he attended a seminar at MIT where Donald Davies (NPL) presented a paper*[340] *about packet switching*[341] *as well as PAD*[342] *to interface character mode terminals directly to packet networks and they exchanged ideas. In return, Donald Davies received a copy of Paul Baran's 1964 internal Rand Corporation report titled "On Distributed Communications" that described similar ideas. "Lick" left ARPA in 1966 and in only a few years his ideas were implemented with the creation of the ARPANET. He was succeeded by Robert Taylor who assumed the directorship of ARPA's Information Processing Techniques Office (IPTO).*

2. *In the 1960s, computing costs were very high and demand for additional computing facilities was also growing fast. Building on the theoretical legacy of "Lick", Taylor decided that ARPA should link the existing computers at ARPA-funded research institutions together. This would allow everybody on the network to share computing resources and results. Having obtained the go-ahead to build a network, Taylor began looking for someone to manage the ARPANET project and his first choice was a young computer scientist named Larry Roberts that was currently working on graphics at MIT's Lincoln Laboratory but also had experience with network computing: Larry reluctantly agreed to move to the West coast in 1967 after one year of discussions with Taylor!*

3. *So, at age 29, Roberts accepted the position of manager and principal architect of the precursor to the Internet. In 1967, he laid out his networking project plans in a meeting with ARPA's PI*[343]*. He wanted to connect all ARPA-sponsored computers directly over dial-up telephone lines. Networking functions would be handled by "host" computers at each site. All in all the reception to Roberts' plans was a cold one as many foresaw problems trying to facilitate communication between machine with many different incompatible operating systems and languages. Instead, a man named Wes Clark [507] handed Roberts a note that read: "You've got the network inside out". Clark suggested instead using small computers at each site to handle networking functions. All of the small computers could thus speak the same language and each host computer would only need to adapt its language once in communicating with its small computer counterpart, which would act as a sort of gateway. The small computers could*

[337] Editor's note: Actually, is it not rather its predecessor TYMSHARE?
[338] BBN (1957-1962), DARPA (1962-1966)
[339] actually a set of research contracts with a dozen or so leading US Universities
[340] « Proposal for Development of a National Communication Service for On-Line Data Processing »
[341] Actually small 128 bytes packets
[342] Packet Assembler and Disassembler
[343] Principal Investigators, i.e. the scientists heading ARPA-funded research projects

also remain under more direct ARPA control than were the large host computers. Roberts adopted Clark's idea and called the small computers IMPs[344]*. By the middle of 1968, Roberts sent out a request for bids to build the IMPs to 140 companies. In late December, the bidding was awarded to BBN. In August 1969, they delivered the first IMP to UCLA. A month later, the second was delivered to SRI. The two were connected and the ARAPNET was born.*

4. *As soon as the first four nodes were brought up and tested in December 1969 the network grew very rapidly*[345]*. By 1971, it was clear that connecting terminals directly to the network through a PAD-type device was important. Such a device was designed and built in 1970/1971, and the first TIP*[346] *was added to the network in Aug 1971. This permitted users with no computer to select a computer from all those around the country. In many cases having the user attach his terminal to a TIP and access even his own host(s) through the network was found to be more reliable. This was the start of a trend which today is almost the rule: workstations should attach to a network, not a computer.*

5. *The technical and operational success of the ARPANET quickly demonstrated to a generally skeptical world that packet switching could be organized to provide an efficient and highly responsive interactive data communications facility. Fears that packets would loop forever and that very large buffer pools would be required were quickly allayed. The work of Leonard Kleinrock and his associates at UCLA on the theory and measurement of the ARPANET has been of particular importance in providing a firm theoretical and practical understanding about the performance of packet networks.*

6. *Roberts left ARPA in 1972 to found Telenet*[347] *on behalf of BBN and was replaced by Robert Kahn (BBN) [508].*

ARPANET's transport protocol was named NCP[348] [509]. In 1983, the TCP/IP protocols replaced NCP as the ARPANET's principal protocol, and the ARPANET then became one subnet of the early Internet. The separation of the network (IP) and the transport (TCP) layers, namely the replacement of NCP by TCP/IP, is one of the main differences between ARPANET and INTERNET.

Although, it may seem heretical, I find that ARPANET bears some similarities with X.25 and ATM, in terms of PADs and message fragmentation into small packets, whereas, in today's Internet, packet fragmentation is the exception rather than the rule thanks to dynamic MTU[349] discovery [510]. Another distinguishing feature was flow control which, in the case of X.25 is done at layer 2 (i.e. by the network operator), whereas in datagram networks it is left to the end hosts to manage end-to-end flows. Of course, unlike ARPANET that was a pure datagram network, X.25 was connection-oriented with virtual circuit set-up; however, most X.25 networks were layered over a packet switched network. This may also explain why Telenet [511], the commercial avatar of Arpanet, offered from the start a virtual circuit interface and why Larry Roberts was active in the development of the X.25 standard.

19.2.2.1 Telenet

Adapted excerpts from L. Roberts' "*The ARPANET & Computer Networks*" article [501]:

[344] Interface Message Processors
[345] December 1970 (10 nodes, 19 computers), April 1971 (15 nodes, 23 computers)
[346] Terminal Interface Processor (actually a functional extension of the IMP)
[347] The first packet-switched network service that was available to the general public, so what about Louis Pouzin's assertion regarding Tymnet?
[348] Network Control Program
[349] Maximum Transfer Unit

"By April 1978 Telenet's network had grown to 187 nodes providing service to 180 host computers and supporting direct terminal access service in 1.56 cities and interconnections to 14 other countries. Telenet was designed from the start to appear to the user as a virtual circuit service with the host interface being implemented over a communications line rather than with a box on site. However, for the first several years Telenet operated a core network based on datagrams copied from the ARPANET but implemented virtual circuits at all interfaces. It wasn't until the complete shift was made to Telenet's TP-4000 packet switch around 1980 that the savings of virtual circuits in the core net could be realized (about 30% for Telenet with a 32 byte average packet size)."

19.2.3 INTERNET

For the general public, it is Vint Cerf [28] [512] who is widely recognized as the inventor of the Internet[350] whereas the role of his colleagues [513] [514] and, in particular his boss, Bob Kahn, is much less known.

There are many reasons to this, first of all Vint Cerf never stopped his total commitment to Internet after he left ARPA in 1976 becoming the 2nd IAB chair [515] from 1989 to 1991 taking over from Dave Clark (1981-1989), playing a key role in the formation of ISOC, as explained in a joint 1992 article with Bob Kahn and Lyman Chapin "*Announcing the Internet Society*" [516], and ICANN[351] [517], also leading the Interplanetary Internet effort[352] [518], being a tireless advocate of IPv6, liaising with numerous committees worldwide to promote and/or defend the Internet (US congress, FCC, IGF, etc.), in other words being the undisputed "*Internet Evangelist*" as he likes to call himself.

Vint Cerf is the author of a considerable number of articles and has been the subject of numerous interviews, e.g.:

1. "*A Protocol for Packet Network Intercommunication*" (V. CERF, R. KAHN) 1974 MEMBER, IEEE [519]
2. "Issues in packet network communications" IEEE Communications 1978 (Cerf, Kirstein) [520]
3. "*The day the Internet age began 2009 (40 years ago)*" (V. Cerf (2009) [521]

According to Vint Cerf himself, in an interview [522] with "*Government Computer News*" in January 2006 when he was Chief Internet Evangelist at Google Inc., "*One thing in particular: I can't really be the Father of the Internet because so many people have had key roles to play. Bob Kahn actually started the "Internetting" project at DARPA in late 1972 or early 1973 and then invited me to work with him on it just after I joined the Stanford faculty. <u>So at most I am 'one of the fathers' of the Internet.</u>*"

19.2.3.1 On the design of TCP/IP

From the very beginning, in accordance with the well-established tradition in the scientific world of working in an open and collaborative manner, the scientists involved in the design, testing and implementation of new techniques allowing to exchange information between networked computers made the results of their work publicly available in the form of IEN[353] then RFC[354]

[350] TCP/IP design
[351] Internet Corporation for Assigned Names and Numbers
[352] This was actually of significance to the real Internet because of the Delay Tolerant Networking aspects and the related IRTF working group.
[353] Internet Engineering Notes
[354] Request For Comments

documents in order to stimulate discussion that proved to be a very effective means of developing working Internet protocols far quicker than Standards organizations.

The emerging networking community was well aware of the need to interconnect dissimilar networks, i.e. the "Catenet Model for Internetworking" (IEN 48 - 1978) [523]. The term "*Catenet*" [524] was actually introduced by L. Pouzin in 1974 in his early paper on packet network interconnection "*A Proposal for Interconnecting Packet Switching Networks*" presented at EUROCOMP, Bronel University in May 1974.

This story about the design of TCP/IP would not be complete without mentioning the role of the INWG[355] that was formed in 1972 and chaired by Vint Cerf (Stanford University) until 1976 at the time he joined ARPA. The INWG was subsequently affiliated with IFIP where it became IFIP 6.1.

There is a truly fascinating article titled "*INWG and the Conception of the Internet: An Eyewitness Account*" by Alexander McKenzie (BBN) [525] that terminates by the following sentence: "*Perhaps the only historical difference that would have occurred if DARPA had switched to the INWG 96 protocol is that rather than Cerf and Kahn being routinely cited as "fathers of the Internet," maybe Cerf, Scantlebury (NPL & EIN), Zimmermann (INRIA & CYCLADES), and I would have been.*"

There is also a most interesting interview [526] with Vinton G. Cerf conducted by Judy O'Neill from University of Minnesota's Digital Conservancy (Charles Babbage Institute) in April 1990, where Vint Cerf credits Hubert Zimmerman, Gerard LeLann and Louis Pouzin (designer of the CYCLADES network) with important work on the design of TCP/IP and also tells the XNS vs. TCP/IP story.

<u>Excerpts</u>: "O'NEILL: *Was the INWG group responsible for your ideas on the INTERNET?*
CERF: *Some of it. In fact several people had a lot of influence on how the design went. Bob Kahn and I spent a lot of time working through various concepts and we wrote that paper in 1974. But I had also a lot of exposure to Hubert Zimmerman and to Louis Pouzin, both of whom had been doing experiments at INRIA on packet switching. They had developed a system they called CYCLADES, and CIGALE, the underlying network, was a pure datagram network Anyway, Pouzin's ideas on windowing techniques were very appealing to me, and I incorporated them into the initial TCP design. A guy named Gerard Lelann was at IRIA working with Pouzin and came to my lab at Stanford for a year and had a lot to do with the early discussions of what the TCP would look like. So did Bob Metcalfe (Xerox PARC) [527]. In June of 1973 we began working together, Lelann, Metcalfe, and I, on the design of the host-to-host protocol for INTERNET. Eventually Metcalfe got impatient with the rate at which things were going. I was trying to get a large number of people to agree on a set of protocols, and every time you brought in a new player we had to go through the argument again. Meanwhile, Metcalfe had five or six guys over at Xerox trying to get the local area nets running. Finally they said they didn't want to wait until this process of agreement and consensus finally concluded, so they went off on a slightly different tack and invented XNS that took some different choices than the TCP did. And they got it up and running before ours, in fact. They kept it secret, and that was a mistake, I guess, now looking back. If they hadn't kept it secret, we might all be using XNS instead of TCP. But as it stood, TCP turned out to be the open protocol that everybody had a finger in at one time or another. That is just how it all worked out.*"

Excerpts from nethistory.info [528] (Archives, tcpiptalk) [29]: *« Following from feedback from Internet pioneer Bob Frankston about the nethistory.info site, the following email exchange with Vint Cerf, Bob Frankston and David Reed took place, on the subject of early TCP and IP separation.*

I'm reproducing it here with the permission of the participants……

[355] International Networking Working Group

Vint Cerf:

David, I think there is something incorrect about your rendition regarding Louis Pouzin.

Louis was the datagram guru. The other French guy was Rémi Després [529] and he was the one who did RCP[356] [530] , a predecessor to X.25. The latter was developed jointly by Rémi, Larry Roberts and Barry Wessler (Telenet), Dave Horton (Bell/CCG) and John Wedlake (British Telecom). When Larry Roberts was building Telenet he asked what protocols to use and I suggested TCP/IP but he rejected that claiming he could not sell datagrams and that people would only buy "virtual circuits" (sigh).

Virtual Circuits were never in Louis' network world - he was all datagrams until you got to the end/end transport layer and there he introduced virtual circuits, not unlike TCP over IP. When another of Louis' team, Hubert Zimmerman, wrote the first OSI architecture spec, I think he had X.25 in mind as the network layer with virtual circuits built in. When I "called him" on it, he said he could not sell datagrams to the rest of the OSI community - but thought AFTER he got the X.25-based OSI specs agreed he might be able to get people to accept a connectionless addition. Eventually there was a CLNP (connectionless Network Protocol) but it was never widely implemented - nor was most of OSI except for X.400 I suppose."

19.2.4 World Wide Web (WEB)

Abstract of "*How the Web was Born: The Story of the World Wide Web*" by James Gillies and Robert Cailliau (CERN) [531]

"In 1994, a computer program called the Mosaic browser transformed the Internet from an academic tool into a telecommunications revolution. Now a household name, the World Wide Web is a prominent fixture in the modern communications landscape, with tens of thousands of servers providing information to millions of users. Few people, however, realize that the Web was born at CERN, the European Laboratory for Particle Physics in Geneva, and that it was invented by an Englishman, Tim Berners-Lee."

The story of the Web is actually much simpler than that of the Internet as the leading role of Tim Berners-Lee in developing the HTTP [532] and HTML [533] protocols is unanimously recognized, however, there were obviously other pioneers, Robert Cailliau (CERN) and Marc Andreessen (NCSA). The original versions of HTTP and HTML were not particularly complex, what precisely mattered was their simplicity as well as their extensibility.

Once more the axiom "*The simplest ideas are often the best*" proved to be right!

19.2.5 X.25

X.25 was developed jointly by Rémi Despres, Larry Roberts, Barry Wessler, Dave Horton/and John Wedlake under the auspices of the INWG and was first ratified by CCITT in 1976.

Quoting L. Roberts' "*The ARPANET & Computer Networks*" article [501] again: "*With five, independent, public packet networks under construction in the 1974-1975 period (USA[357], Canada[358], U.K.[359], France[360], Japan[361]), there was strong incentive for the nations to agree on a standard user interface to the networks so that host computers would not have unique interfacing jobs in each country. Unlike most standards activities, where there is almost no incentive to compromise and agree, carriers in separate countries can only benefit from the adoption of a standard since it facilitates network*

[356] Réseau de Commutation de Paquets (Packet Switching Networks)
[357] Telenet
[358] Datapac
[359] PSS
[360] Transpac
[361] DDX-P

interconnection and permits easier user attachment. To this end the parties concerned undertook a major effort, to agree on the host-network interface during 1975. The result was an agreed protocol, CCITT Recommendation X.25, adopted in March 1976." *The X.25 protocol provides for the interleaving of data blocks for up to 4095 virtual circuits on a single full-duplex leased line interface to the network, including all procedures for call setup and disconnection. A significant feature of this interface, from the carriers' point of view, is the inclusion of independent flow control on each virtual circuit (VC); the flow control enables the network (and the user) to protect itself from congestion and overflow under all circumstances without having to slow down or stop more than one call at a time. In networks like the ARPANET and CYCLADES, which do not have this capability, the network must depend on the host (or other networks in interconnect cases) to insure that no user submits more data to the network than the network can handle or deliver. The only defense the network has without individual VC flow control is to shut off the entire host (or Internet) interface. This, of course, can be disastrous to the other users communicating with the offending host or network….The March 1976 agreement on X.25 as the technique for public packet networks marked the beginning of the second phase of packet switching: large interconnected public service networks. In the years since X.25 was adopted, many additional packet standards have been agreed on as well. X.28 was added as the standard asynchronous terminal interface and X.29, a protocol used with X.25 to specify the packetizing rules for the terminal handler, was adopted as the host control protocol. Also, a standard protocol for interconnecting international networks, X.75 has been adopted."*

20 Network history material

20.1 Internet and NREN history material

There is no lack of material on this fundamental technological revolution that brought so many changes to the world's way of living. However, some of the existing material looks too much like a hymn to the "*heroes/visionaries*" that made it happen, which can be slightly disturbing at times.

1. The History of the Internet:
    a. Part 1 [534] (1957-1976)
    b. Part 2 [535] (1976-1987)
    c. Part 3 [536] (1988-1994)
    d. Part 4 [537] (1995-2005)
1. Connected: An Internet encyclopedia (third edition) [538]
2. Hobbes' Internet Timeline [8]
3. ISOC[362] [539] Internet history portal [540]
    a. Internet history and growth (William F. Slater, Sept. 2002) [541]
4. The Birth of the Internet [542]
5. Commercial Internet exchange Point (CIX) [543]
6. The World's first Web published book:
    a. "Internet history" [544]
    b. "NSFnet history" [545]
7. A critical history of the Internet (Brian Martin Murphy) [546]
8. pre-ICANN Internet organization [438]
9. History of the Internet starting with BBN [547]
10. Internet history – online ! [548]
11. Nerds 2.0.1 "A Brief History of the Internet" by Stephan Segaller [549]
12. The Internet in the 1980s [205] (Mark Humphrys/UCD)
13. History of the Internet [550] (Harri Salminen/FUNET)
14. The Launch of NSFnet [551]

[362] Internet Society

15. NSFnet project history (MERIT) [552]
16. NSFnet project history (Wikipedia) [553]
17. The NSFNET Backbone Service (MERIT) [554]
18. NSF's STAR TAP and ICM awards [555]
19. BITNET History [556]
20. A reflection on UUNET, DNS and the Internet Systems Consortium by Tom O'Reilly [557] [558]
21. Australia's ACSNET [559]
22. Canada's CANARIE [560]
23. Japanese WIDE project (Jun Murai/Keio University) [561]
24. Korea [562]
25. "Will Commercial Networks Prevail in Emerging Nations?" the REUNA (Chile) case [409]

20.2 European NREN history material

The best single source of information about European NRENs is the TERENA Compendium; at the time of writing this article, the latest available version is the 2011 edition.

1. "A History of International Research Networking" [194] (Howard Davies/DANTE)
    a. "The early days" [563], actually the 1st chapter of the above book, is freely available from Wiley, apparently not the only one, is it deliberate or accidental?)
2. EARN, RARE, TERENA (20th anniversary) [372]
3. Ebone [564]
4. ACOnet History (Austria) [565] [566]
5. The History of HEAnet [567]
6. JANET: The First 25 Years [172]
7. The History of NORDUnet [353]
8. "The birth of the Polish Internet" [568]
9. "Les 10 ans de RENATER" [569]
10. Internet History in Serbia [570]
11. Internet History in Slovenia [571]
12. SURFnet "20 years of networking" [572]
13. The History of SWITCH [573]
14. A Brief History of Networking in Turkey [574]
15. History of the Web Beginning at CERN (Cheryl Gribble) [575]
16. "A Short History of Internet Protocols at CERN[363] (Ben Segal) [576]
17. The CERN Courier article: *"Gigabits, the Grid and the Guinness Book of Records*" [577] also provides some insight about CERN's networking history.
18. The European Computer Network Project (EIN), D. Barber (NPL)

20.3 Other computing and networking technologies related material

1. The COOK Report on Internet Protocol: Technology, Economic, Policy [578], "A guide to the Internet "*forest*" which describes the players and the terms and technology they use".

[363] Although slightly *biased* in my opinion, this document counterbalances some of the views and opinions expressed herein and is very worth reading

2. The Network guide [579] by M.A.H. MacCallum (Queen Mary and Westfield College) is another excellent article with lot of very objective information on national and international networks, interworking between various technologies, etc.
3. Hypertext Glossary of Computer Science related Acronyms and selected Terms [580] [581]
4. Computing History [582]
5. IBM's VM Operating System history and the VM community by Melinda Varian (Princeton University) [583]
6. Columbia University Computing History [584]

21 Major European Research Internet milestones

1) June 1989: RIPE (Réseaux IP Européens)
2) February 1990: IBM's EASInet initiative links between IBM supercomputer sites ; T1 connection to NSFNET (CERN-Cornell University)
3) June 1990: Official end of the protocol war (OSI vs. TCP/IP) on the occasion of the Joint European Networking conference in Killarney.
4) Creation of the IEPG (Intercontinental Engineering Planning Group) under the auspices of CCIRN (Coordination Committee for Intercontinental Research Networks).
5) 1991, Creation of the ad-hoc Ebone (European Backbone) consortium and deployment of a 2Mbps infrastructure.
6) 1993-1994, Creation of DANTE [346]
7) <u>Deployment of various backbones co-funded by the European Union and National Research Networks</u> [585]:
    a. Mid-1989 through June 1990, 64 Kb/s IXI[364] pilot
    b. July 1990- September 1992, 64 Kb/s IXI backbone (COSINE project outcome)
    c. EMPP (exemplifies DANTE's way of working, i.e. pilot, production production cycle)
    d. October 1992-1997, EMPB (European Multi-Protocol Backbone), a 2Mbps backbone, in parallel with Ebone
    e. Europanet (same as EMPB) [586][365], marked the end of Ebone for most NRENs but the start of Ebone as a commercial ISP (1993-1997)
    f. 1997-1998, TEN-34, a 34 Mbps backbone
    g. 1998-2001, TEN-155, a 155Mbps backbone
    h. 2001-2004, GEANT[366], a 10Gbps backbone
    i. 2005-2009 GEANT2 (large scale acquisition of dark fibers (12,000 km) and introduction of, so called, *lambda* services)
    j. 1/4/2009-31/3/2013 GEANT3 (93M€ EC, same amount by European NRENs, i.e. an "astronomic cost of nearly 50M€/year)
    k. Will 2013 mark the end of GEANT or the advent of GEANT4?

22 Reference books and articles.

In my opinion, the best sources, unfortunately not always freely available, are "*Notable Computer Networks*" [1] and "*The Matrix*" [2] by John S. Quarterman but also "*European International Academic Networking: a 20 Year Perspective*" [3] by Peter Kirstein (UCL) and "*Exploring the Internet: A Technical Travelogue*" [4] by Carl Malamud. For the DANTE

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364 International X25 Infrastructure

365 Very informative ISOC bulletin containing, among many other things, information about Europanet but also Ebone

366 Europe which was way behind America in terms of available as well as affordable bandwidth finally closed the gap, thanks to the deregulation of the European Union's Telecom Market in 1998.

"*aficionados*" the "*History of International Research Networking*" [5] by Howard Davies is an absolute "*must*", however, it is a rather *amazing* set of "*counter truths*" and *understatements*, in particular the decisive role of IBM's EASInet initiative [6] in the creation of the European Research Internet would have deserved to be better recognized as well as the role of the main actors, namely, Alain Auroux, Herb Budd, Stefan Fassbender, Berthold Pasch and Peter Streibelt (IBM), Klaus Birkenbihl, Willi Porten and Detlef Straeten (GMD). I must admit that I only glanced very briefly through this book as I have no particular interest about the COSINE and RARE disaster stories and I also did not want to be influenced by its content knowing, in advance, that it was bound to be sheer *propaganda* to the "*glory*" of DANTE and to its "*great*" leaders that have been the sole "*instigators*" of European Research Networking and I must say that I was not disappointed at all, in that respect!

[1] "*Notable Computer Networks*" (John S. Quarterman and Josiah C. Hoskins), "*Communications of the ACM, October 1986, Volume 29, Number 10*" [11]
[2] "*The Matrix*: *Computer Networks and Conferencing Systems Worldwide*" [587]
[3] "*European International Academic Networking: A 20 Year Perspective*" [13] (P. Kirstein/UCL)
[4] Exploring the Internet: "*A Technical Travelogue"* [14] by Carl Malamud
[5] Inventing the Internet by Janet Abbate (MIT Press) [165]
[6] JANET: The First 25 Years [172]
[7] "A History of International Research Networking" [194] by Howard Davies (DANTE)
[8] EASInet: IBM's Contribution to Scientific Networking in Europe [2] by P. Streibelt (IBM)
[9] EARN/OSI transition: "Tempora Muratur" by Niall O'Reilly (UCD) [119]
[10] RIPE 20 years old by Rob Blokzijl [342]
[11] The origins of RIPE by Daniel Karrenberg [343]
[12] "The European Researcher's Network[367]" (François Fluckiger) [344]
[13] Internet: Getting Started (SRI Internet information series) Prentice Hall

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[16] http://en.wikipedia.org/wiki/CompuServe
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[367] This most informative article that was only translated very recently into English provides a wealth of information about CSNET, CCIRN, COSINE, EARN, EUNET, EBONE and RARE.

[18] http://en.wikipedia.org/wiki/Telenet
[19] http://www.euroview2010.com/data/slides/0_Landweber_Keynote.pdf
[20] http://en.wikipedia.org/wiki/CYCLADES
[21] http://en.wikipedia.org/wiki/Institut_national_de_recherche_en_informatique_et_en_automatique
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24 Biography

Olivier Martin was the Project Leader of the DataTAG project [448]. He received a M.Sc. degree in EE from École Supérieure d'Électricité (Supélec[368]), Paris, France in 1964. He joined CERN in 1971, held various positions in the Software Group of the Data Handling Division, and then moved to the Communications Group of the Computing and Networks Division in 1984, where he has been Head of the External Networking Section from 1989 until 2004. Prior to the DataTAG project, he was involved in several European projects (including BETEL, BETEUS and STEN) in the framework of the RACE, ACTS and TEN programs. His research interests include next generation Internet, high-speed networking, transport protocols

[368] One of the best ranked « Grandes Ecoles » in France

and Grids. Since August 2006, he is an independent ICT consultant working, in particular, as an expert for European Commission’s FP7 ICT Projects and Calls (i.e. project reviews and evaluation of project proposals).

