1
Early Days

The national research and education networks which are interconnected to provide a seamless service across Europe are taken for granted these days. They have in fact followed different routes to reach this point. Using first-hand experience from some of those involved in their development, this chapter explains the steps that were taken, by whom, and the obstacles which had to be overcome. In addition to these individuals, entire organisations sometimes had to be cajoled to step into line from their differing positions. Different standards and protocols, changing requirements and attitudes, and different national positions all had to be taken into account in achieving the goals. The chapter focuses mainly on the years from the mid-1970s to the mid-1980s.

1.1
The Starting Point

In the early 1980s, almost all the countries in Europe were planning new networks. The technology existed, and the academic and research communities wanted to be able to use it. However, there was no coordination at a European level, just rapid national growth rates.

By the end of 1984, Scandinavia had a coordinated regional network, covering Denmark, Finland, Norway and Sweden. Austria and the United Kingdom each had operational networks, and Germany was in the middle of a major implementation programme leading to the full DFN (Deutsches Forschungsnetz) network. Ireland and Italy were also involved in implementation, and France, the Netherlands, Spain and Switzerland had plans they were about to implement.

Before describing the way all these were brought together on a European scale, we need to review the technologies that were available and the activities that form the backdrop to our story.

1.1.1
The Data Communications Scene

The early 1980s were the height of the age of large-scale multi-user mainframes, and the earliest remote access arrangements were stars of access links converging on

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individual computer centers. These network links had their roots in the use of analogue leased lines connecting first generation modems at speeds starting at 300 bps but rising progressively to a few kbps. From the early 1970s to the early 1980s, most PTTs (post, telephone, and telegraph operating entities) introduced digital leased line services, although still primarily at speeds of 9.6 kbps or less. A few rather expensive 64 kbps services were introduced and the first megabit services were on offer in France and the United Kingdom, but not yet used in the emerging research networks.

The potential for merging the various star networks had already been shown; it had been demonstrated by the first phase of the ARPAnet (Advanced Research Projects Agency network) in the early 1970s and by the first ubiquitous campus network at the National Physical Laboratory in London at the same time. These were the first practical, general-purpose packet networks, separating the switching and routing from the hosts accessed, and setting the direction for the modern generation of data networks.

The first public packet switched network in the world, EPSS (experimental packet switching system), was opened by the United Kingdom Post Office in 1977; the British academic community played a leading part in its user community, particularly in the definition in 1975 of a set of so-called high level protocols to allow applications to communicate over the new network. In 1976, the CCITT (Comité Consultatif International Téléphonique et Télégraphique), the PTT standards body within the ITU (International Telecommunication Union) defined the first version of its X.25 packet switching recommendation, and all the European PTTs rapidly established plans for national packet switched services and for interworking between them. The first technically stable version of the X.25 recommendation was ratified in 1980. In the same year, the United Kingdom EPSS network was replaced by the X.25-based PSS (packet switch stream), and the German PTT introduced its DATEX-P (data exchange -packetized) X.25 network.

The transit arrangements between the national PTTs then gradually became operational, offering communication on a European scale. By the middle of 1985, a United Kingdom PSS customer, for example, could communicate with data customers in any of the COST (European cooperation in the field of scientific and technical research) countries except Turkey and Yugoslavia (although for Portugal, the call had to be initiated from there).

One thing this shows is that the prevailing view of networking at that time was one in which the PTTs played a large part. In their plans reported to the first European Networkshop in 1985, representatives of the research communities in all countries assumed that their infrastructure would be X.25 based, and all but Sweden and the United Kingdom planned either immediate or phased adoption of publicly operated networks as the basis of their networking activities.

1.2 Protocols and Standards

A crucial factor for any network to be successful is the choice of protocols (i.e. the rules that the computers in the network must follow in order to exchange signals and data) that it uses. Standardization is also an important consideration. For two computers to intercommunicate effectively, they must both be following exactly the same rules and procedures.

1.2.1 Interim Standards

The first implementers of networks had to invent their own protocols but only a few of these took root outside the domain for which they had been invented.

One set of protocols which did get more widely used was the set of so-called "Colored Books". This was a family of standards defined in the United Kingdom in the late 1970s and early 1980s, based on the experience gained from EPSS activities. Each book defined a protocol for one function or application, and each had a distinctive colored cover, giving it the obvious popular name. The main ones were:

- The Yellow Book – a network independent transport service
- The Green Book – character terminal protocols on PSS
- The Blue Book – a network independent file transfer protocol
- The Red Book – a network independent job transfer and manipulation protocol
- The Grey Book – the JNT mail protocol
- The Orange Book – Cambridge ring 82 protocol specifications
- The White Book – transition to OSI standards

The White Book was the final book in the series; it mapped out the intended transition from these interim standards. Published in 1987, the White Book was a plan worked out in response to a public declaration by the United Kingdom network funding body in January 1985 that it was committed to adopt the emerging OSI (open systems interconnection) standards; thus this decision had been taken before the main activities described here had even started.

However, the Colored Books were the basis of a thriving networking community over a period of more than ten years, and were the primary infrastructure in the United Kingdom for most of that period. They were also used in a number of other countries around the world but the real competition for acceptance as global standards turned out to be between the OSI and Internet protocol suites.

1.2.2 Open Systems Interconnection

It was widely accepted that ubiquitous networking would only happen if it was supported by a comprehensive set of open standards so that users could communicate no matter what equipment they used. Although the aim was agreed, the standards were not yet available and each pioneering networking group had to create some working set of protocols to get things going. Each equipment vendor also offered its own private solutions.

Some convergence process was urgently needed; to support this, in 1977, the ISO (International Standards Organisation) launched a comprehensive standardization program to provide OSI, a flexible architecture and a complete family of standards for the main functions that users were then demanding. This programme was carried forward by ISO during the next ten years, in close collaboration with, and later by joining forces with, the CCITT (later reorganized as the current ITU-T, the ITU telecommunication standardization sector) who were responsible for the standardization in the telecoms industry.

The technical merits and organization of the OSI standards process is a separate story in its own right, but its influence on the planning of academic networking was profound. Policy makers embraced the concept of open standards as an essential component of open markets; researchers welcomed the promise of vendor independence and open interchange of information; funding bodies welcomed the opportunity for efficient resource sharing. Open systems came to be seen politically as one of the essential elements for providing integration of the European infrastructure.

1.2.3 The Internet Protocols

Since the launch of the ARPAnet, its distinctive family of protocols had been evolving. Their development reached a plateau with the production of a re-worked and consolidated design by Jon Postel, leading to the publication of IPv4 (Internet Protocol version 4) in September 1981. IPv4 was trialled and then the transition away from the older NCP (network control programme) made in a final cutover in January 1983. At the same time the main focus for the network moved from the ARPA (Advanced Research Projects Agency) to the NSF (National Science Foundation), with the introduction of first CSNET (Computer Science NETwork) and then NSFnet (National Science Foundation network), with significant upgrades from 56 kbps to 1.5 Mbps circuits in 1984.

Although there is now a perception that the United States networking scene did not engage with the formal standards process, this was not in fact the case. There were many United States experts working within ISO, and there was a strong commitment to the idea of open standards. The responsibility for standards within the United States Government fell to the National Institute of Science and Technology (NIST), which formulated a Government OSI Profile (US-GOSIP, FIPS 146 - Federal Information Processing Standard 146 – not to be confused with the earlier UK-GOSIP) and eventually published it in 1988. This committed the United States Government to the concept of OSI and established an adoption timescale requiring transition to OSI for procurement purposes by 1990. The DoD (Department of Defense) signed up to this aim in principle. As we know, these plans did not mature, largely because of changes in economic factors such as the effect of bundling the TCP/IP (transmission control protocol/Internet protocol) family as a free component of the UNIX (Originally UNICS, uniplexed information and computing system) operating system. However, the environment in the mid 1980s was one in which a commitment to OSI was being promised by the United States and encouraged by European officials. More will be said later about how things actually evolved.

1.3 European Coordination

All these technologies created the basis for much broader European networking and the user experience from the early national pilots created a small but enthusiastic core of network supporters. People had seen what the networks could do and wanted to exploit them on a much larger scale.

From the earliest days, there was strong interest in following developments in the US but because of the practical difficulties of forming and operating intercontinental collaborations – the Atlantic Ocean was a bigger geographic obstacle than it is nowadays – a European approach to deal with specific European issues was the natural way forward.

1.3.1 Identifying the Need

Because of its commitment to open markets, the EC (European Commission), via the ESPRIT (European strategic programme for research in information technology) program, threw its considerable weight behind open networking developments in Europe. The EC was also the target of significant lobbying from national groups. The greatest impact was achieved between 1982 and 1984 by Professor Zander, who was in many ways the father of DFN, the German research network, and who spent a great deal of time and effort lobbying the EC and encouraging its political commitment to the process. He can justly be credited with stimulating action by the European institutions, particularly in the framework of the ESPRIT research programme. Collaborative academic and industrial research was increasing in importance in many European countries, and EC officials began a process of encouraging the separate networks to join together.

In the United Kingdom, the period from 1981 to 1984 had been one of unification of regional and discipline-specific networks to form the general purpose JANET (joint academic network); this was officially launched to mark the completion of this process in April 1984. This rationalization, under which all the existing regional networks serving universities and the central research support networks were brought into one organization with a single funding source, convinced those concerned of the benefits of harmonization. At the same time, the user groups now benefiting from the more effective communication with colleagues nationally became increasingly vocal about the need for similar connectivity across Europe. This message came particularly strongly from the large international experimental collaborations in astronomy and high energy physics (HEP).

1.3.2 Preliminary Steps

During the autumn of 1984, the JANET network managers and their colleagues from other networking interests, who were then all based at the Rutherford Appleton

Laboratory (RAL), were visited by Dr Nick Newman from the EC, who was contacting national groups and raising awareness of the European situation. He was also promoting the idea of cooperation on a European level.

Following this visit, Paul Bryant of the SERC (Science and Engineering Research Council) engineering support network, James Hutton (HEP), and Peter Linington, Head of the UK's Joint Network Team (JNT) and Network Executive (the JANET operations team), met in the JNT offices on 12 November 1984 to discuss how the kind of integration achieved in the United Kingdom might be encouraged throughout Europe. They decided that some kind of European technical networking summit was needed and, agreeing to pool their resources, set about contacting their colleagues to seek support.

There was an enthusiastic response, and it was clear that many groups were thinking along similar lines. Just before Christmas 1984, the United Kingdom group hosted a face-to-face meeting of the European prime movers at RAL where it was agreed that a larger workshop of all the appropriate representatives should be held. The EC agreed to host the event in Luxembourg and funding for participation was obtained from ECFA, the European Committee for Future Accelerators, ESF, the European Science Foundation, and COST-11. An organizing group was formed that expanded the circle of contacts and gathered background information about the situation in all the participating countries ready for the workshop.

1.3.3
The First European Networkshop

The first European Networkshop was held on May 14th and 15th 1985 in Luxembourg. It took place in meeting rooms made available by Barry Mahon of the EC's DG III (Directorate General III). About 60 people attended, and most of the agenda on the first day was taken up by presentations of the current activities and plans of the participants.

The resulting summary of national activities gives a good idea of both the diversity of practice and maturity, and the significant common themes across all the contributions.

The following thumbnail sketches are derived directly from the presentations used during the Networkshop:

Austria: Networking in Austria had reached the stage of a pilot linking Vienna, Graz and Linz, using the DATEX-P public X.25 service as a base. The pilot, ACOnet (Akademisches Computer Netz), was adopting an architecture in which local subnetworks and hosts were linked to the public network by gateways, operating at either the network or application level. Operations were supported by new gateway management tools, supporting down-line loading of code over X.25 and remote programme development.

Denmark: The core of the Danish activity was a long-established private X.25 network called Centernet, which linked NEUCC (Northern Europe University Computing Centre), RECAU (det Regionale Edb-center ved Århus Universitet), and RECKU (det Regionale Edb-center ved Københavns Universitet). It used the EUROnet (European network) transport protocol and supported a gateway to the public X.25 network. There were detailed plans for migration to the public X.25 service using standard off-the-shelf components. It had been decided that the protocols used in Denmark would be aligned with those used by DFN. Application plans included the early establishment of an electronic mail server.

Finland: FUNET (Finnish university network) had been launched in 1984, initially to provide terminal access to twelve university hosts via the public X.25 network. There were also closed sub-networks carrying manufacturer-specific protocols over X.25. The remaining university hosts were expected to be connected shortly. Early application use had focused on the popular KOM, a bulletin board system, and the PortaCOM conferencing system (originated by Jacob Palme in Stockholm), but electronic mail was seen as an important requirement. There were plans for a file transfer service, probably based on the UNINETT FTP (file transfer protocol). The University of Helsinki was using the GILT (get interconnection between local text system), teletext-based protocols.

France: A project had been launched at the start of 1984 to study the needs of the French research community. It involved all major research organizations and French industry. Its report, issued in February 1985, defined a network project that was under active consideration by the funding bodies. The hope was that implementation would start in late 1985. The plan placed emphasis on international standards, particularly for electronic mail (X.400) and international interworking. One distinctive requirement identified in France was for the support of high-speed file transfer using a broadcast satellite carrier.

Germany: DFN, Germany's flagship networking project, had been initiated in 1982. It was using the new OSI protocols, and was based on the public X.25 network (DATEX-P). The project was in response to a wide range of user requirements. Networking within the universities was well established, and therefore the need for WAN-LAN (wide area network–local area network) interworking was stressed. The user requirements were for interactive terminal access, file transfer, remote job entry and electronic mail. One distinctive requirement was the particular need to support graphics based on GKS (graphics kernel system) – a powerful (for its time) graphics software package – in both interactive and bulk transfer modes. The network would have no central accounting or logging mechanisms.

Ireland: There had been a university network in Ireland since 1979, based on EUROnet activity. This was currently in the form of a private X.25 network. A transition was in progress in which the initial network was being subsumed into a Higher Education Authority network (HEAnet), giving more complete coverage of the country. It would be based on the public X.25 service and was expected to be in operation during 1985–86. At the application level, the network used the United Kingdom Colored Book protocols; it also provided the COM (component object model) conferencing system for ESPRIT at UCD (University College Dublin).

Italy: There were two main networking activities in Italy. The longest-established was the network set up by INFN (Istituto Nazionale di Fisica Nucleare) for use by the HEP community and based on DECnet (network protocol design by DEC – Digital Equipment Corporation), and implemented on the VAX™ family of computers that it manufactured). More recently, a new initiative called OSIRIDE had been set up to create a pilot OSI network. Initially, this was to concentrate on file transfer, but with later targets of supporting electronic mail, conferencing, document transfer and, eventually, video conferencing.

Netherlands: There was no report on the Netherlands in the workshop summary, but the SURFnet proposal published the following autumn showed that detailed planning had been in progress since ministers had approved an initial proposal in December 1984. Requirements had been identified for file, job and image transfer, electronic mail and access to international facilities. There was already significant use of EARN (European academic and research network), and the plan called for connection of all institutions to the Dutch PTT's DATAnet 1 public network by 1987.

The SURFnet plan not only covered the provision of national connectivity, but made it part of a comprehensive strategy: each institution was required to produce a LAN plan by September 1986, together with a commitment for the Netherlands to play an active part in European coordination. The report committed to using OSI standards, while recognising the need for some pragmatic short-term upgrades to improve coverage.

Norway: UNINETT was based on research and development (R&D) starting in 1976 and had been in service since 1983. It supported interactive terminals, file transfer and conferencing. It was based on the use of public X.25 and on the ISO OSI reference model.

Spain: There were existing terminal access services and access networks to the major computing centers. However, strong user requirements based on Microelectronics (CAD, computer-aided design), HEP, AI (artificial intelligence), SoftEng (software engineering), computing center and supercomputer access were being articulated. This had led to Ministry support for a new project called the Interconexión de los Recursos InformáticoS (IRIS). IRIS was to report by June 1985, and a pilot was expected to start by the fall of 1985. The plans placed emphasis on international standards, European harmonization and the relationship to the public X.25 network (IBERPAC, servicio IBERico de conmutacion por PACkets).

Sweden: SUNET (Swedish university network), the existing solution in Sweden, was based on regional private X.25 networks and the use of the public X.25 services to connect them. It had been in operation since 1983. The network supported interactive terminal traffic, file transfer, electronic mail and conferencing.

Switzerland: A detailed study of user requirements and justification for a networking activity had been performed and the study report had proposed further technical work (jointly with the Swiss PTT) to establish a technical and organizational plan. The intended timescale called for a detailed plan to be produced in 1985–87, and for a network to be in service as of 1988.

United Kingdom: JANET in the United Kingdom had been based on a process of rationalization of existing networks, some of which had been in operation since the late 1970s. The unified network had been transferred to a single strategic and management organization early in 1984. At its formal launch, JANET was a private X.25 network with 10 transit switches connecting some 200 terminations, more than 50 of which were local networks. It connected a total of approximately 500 host computers, and 10 000 terminal access (PAD, packet assembler-disassembler) ports. It used the Colored Book protocols for terminal access (X.29), file transfer, job transfer and electronic mail. The JANET community was actively planning a transition to OSI, with the move to X.400 mail as a first step.

It was clear from these reports that there was a lot of activity and that support for X.25 and X.29 was already widespread. They indicated that in this environment, interworking of at least terminal services would be possible within Europe. However, other applications would need harmonization. Of the identified requirements, X.400 electronic mail seemed to be the most pressing. It was also clear that a lot more information needed to be collected and correlated. For example, there was no data about coverage and availability at a local level. There was also little information about how costs would fall on end users.

Informal discussions on the evening of May 14 led to the conclusion that a separate body was needed to act as a European focus and an outline of its mission and initial objectives was put to the final workshop session the following day. What was proposed was a networking association to promote peer-to-peer interworking and harmonization between the national academic and research networks, not the creation of a core international data network, since this was seen as best provided by the PTTs.

The rough outlines of the organization were proposed. The scope was to be Western Europe, which was then taken to mean the EEC (European Economic Community) and COST countries. In addition to the national members, the major European research laboratories such as CERN (Conseil Européen pour la Recherche Nucléaire) would also be eligible to join in their own right. A role was also seen for European industrial research laboratories and for significant user organisations, but not as primary members. ESPRIT was recognized as having a special status, as it represented an important group of infrastructure users within the scope of the association, but the EC would not be a member in its own right.

The stated aims were to provide a high-quality networking infrastructure for the support of research and academic endeavor on a European basis, by taking any necessary actions to ensure that this infrastructure adopted and exploited the most advanced technology available. This was understood to imply the creation of an international OSI network, involving as intermediate steps the short-term interconnection of existing non-OSI networks and the transition of existing networks to open standards.

Once these principles had been debated and agreed, a short summary resolution was put to the workshop and accepted without any objections. The wording proposed on that day is shown in Figure 1.1.

Recommendation A.200

Considering

that national academic networks exist or are planned in a large number of European Countries;

that it is feasible, by coordination and harmonization of these national activities, to provide facilities on a European basis;

that collaborative industrial research requires similar facilities;

the meeting unanimously declares the view that an association should be established to promote the creation of a European research and academic networking infrastructure.

Figure 1.1 The networkshop resolution.

The format and the bogus recommendation number in the text above were an irreverent, high-spirited, parody of the CCITT procedures in use at the time. Once it had decided to go ahead, the workshop did two more things. First, it asked all the representatives if their organizations were likely to participate actively, which they were, and then asked them to take this commitment back to their organizations for more formal ratification. Secondly, it drew up a list of priority items to be carried out in order to set the association up and start its work and attached to each item the name of a member prepared to take the lead in developing it.

The priority items covered both technical and organizational issues. On the technical side, there were:

- Coordination of message handling systems, primarily for X.400, including the EAN (electronic access network) software package (CERN)
- X.25 (84) harmonization of operational requirements (France)
- File transfer protocols and services (CERN)
- Full screen terminal working (United Kingdom)
- Collection (manual) of directory information, covering services, people and help contracts (EC)
- Exchange of operational information (Ireland)

And for the organizational items:

- Organization and support of the association (United Kingdom)
- Scope and mechanisms for liaison with CEPT (Conference of European Postal and Telecommunication Administration).
- Organization of the next European Networkshop, provisionally scheduled for mid-1986 (initially unallocated – Denmark subsequently volunteered).

The workshop ended on a very positive note. The technical and organizational tasks were to be started straight away. The association would be set up with a formal constitution so that it could hold funds and become self-supporting. It would seek financial support to help during the launch period but the members would not wait for these things to happen. Rather, they would move forward immediately in whatever way was open to them. This willingness to take risks and to make things happen without waiting for the formal niceties typified the spirit of optimism that pervaded the workshop, and indeed all the early stages of RARE's (Réseaux Associés pour la Recherche Européenne) history.

1.4 RARE: From Proposal to Reality

Despite the impatience to get things moving on the part of many of the people involved, it was necessary to go through a number of administrative steps to put a robust, stable and adequately funded organizational structure in place.

1.4.1 Laying the Foundations

After the Luxembourg workshop, the delegates went home and consulted their organisations. The Netherlands came back rapidly with an extremely positive response, backed by the charismatic and far-sighted Hans Rosenberg. He obtained support from SURF, the organization responsible for the Netherlands research network, to provide funding for the embryonic organization to pay for an interim secretariat. This secretariat was operated by James Martin Associates (JMA) in Amsterdam who got to work immediately and helped in the drafting of Articles of Association. This involved agreeing procedures and legal responsibilities, which were derived from a Dutch legal template. It was also necessary to agree a business plan, providing analysis of various proposed funding models to ensure that the association would indeed be self-sustaining in the longer term. The main burden of carrying this through fell on Rob Brinkhuijsen and Frank van Iersel of JMA.

One of the tasks that proved unexpectedly difficult was the choice of a name for the new entity. Many immediately intuitive names were already taken by existing organizations or led to acronyms that were already well established in members' home countries. The name "European Networking Association", although initially supported by many, would have been abbreviated to ENA, meaning Ecole Nationale d'Administration to any Frenchman. Other names proposed all seemed to be taken, confusing or even obscene in one country or another. Finally, the French name Réseaux Associés pour la Recherche Européenne, or RARE for short, was accepted despite some misgivings concerning future jokes about RARE implying half-baked ideas and from August 1985 that name was fixed.

Gradually the rest of the constitution came together, with a proposed structure in which a fully-representative Council of Administration delegated short term decisions to a smaller rotating Executive Committee. The Association was to have a President to chair both these bodies, a Vice-President, a Treasurer and eventually a Secretary-General as a full-time officer to oversee day-to-day business and run the permanent administration.

In parallel with the organizational work, this was a time of widespread lobbying for support. Members explained the objectives of the new body to their national organizations, to many European research groups, to international contacts such as the NSF in America, and to many parts of the EC. Finally, in December 1985, the officers of RARE met Michel Carpentier, the Director General of DG XIII (IST, Information Society Technologies) and his officials, and explained RARE's plans and goals to him. This led to a commitment from the EU (European Union) to fund the secretariat until regular support on a subscription basis could be put in place, thus providing bridging from the Dutch support.

Two important relationships with existing organizations were established during this preparatory period. First, the responsibility for liaison with the CEPT that Switzerland had undertaken to organize was progressed by Albert Kündig of ETH (Eidgenössische Technische Hochschule) Zurich. Kündig had moved to academia from the Swiss PTT and had a wide network of contacts. He laid the foundations for RARE's credibility with the PTTs, so that they began to see the organization in a positive light, and not as a potential threat.

The second key liaison was with EARN which, at the time, was also a relatively young organization and which was providing services based on the use of IBM equipment and protocols (see later for details). EARN was in many ways a natural competitor to RARE but there were several people who were involved in both organizations and there were clear advantages to cooperation. A series of meetings was held between Dennis Jennings, the President of EARN and Peter Linington, the President of RARE, in which common objectives were set out. This led later, after EARN had adopted a statement of intent on the transition to open standards, to EARN becoming an international member of RARE.

1.4.2
The First Step for COSINE

Although they were primarily academics, many of the members of the new association had strong links with their national industry or research ministries. These contacts were very supportive, and the discussion with industry ministries, particularly the BMFT (Bundesministerium für Forschung und Technologie) in Germany, the Ministry of Education and Science in the Netherlands and the Department of Industry in the United Kingdom, resulted in these bodies seeing RARE as a flagship for standards policy and, more generally, for open networking.

During the second ministerial conference in Hanover on November 5–6 1985, Andreas Vogel, an official from the BMFT, was lobbying other countries to get support for putting a project called COSINE, cooperation for open systems interconnection networking in Europe, on the first list of EUREKA (European Research Coordination Agency) projects that ministers would announce. A subsequent full meeting of COSINE participants in Bonn on February 19 1986 asked RARE to prepare the technical specification for the project by midsummer. (The required draft was delivered on time although the workshop set up to discuss it was not held until November 1986 because of the need for negotiations between EUREKA officials).

RARE was now in the position of being a contractor to the EUREKA programme before having its own legal existence! This put a very real pressure on the preparations for RARE's formal foundation.

1.4.3
The Second European Networkshop

The Second European Networkshop was held in Copenhagen on 26–28 May 1986. The whole of the July/August edition of the Computer Compacts Journal was dedicated to a report on the event, including an overview of RARE's mission and a feature interview with its President-elect. This edition also carried a full-page advertisement for the post of Secretary General of RARE!

The second Networkshop was a much more orchestrated and better planned event than the first; it was already more of a conference than an informal workshop. There was a series of activity reports covering the priority tasks set out by the conclusions of the first workshop, followed by technical sessions dealing with current technical challenges, new standards and longer-term opportunities such as broadband. There were also sessions looking at a number of EU industrial research projects and at plans from the PTTs for new services.

As well as being a forum for the interchange of information, the workshop also provided a sounding board for testing the level of support in the community and confirming that, after a year of largely organizational activity, the creation of the association was still welcomed at a working level within the research networks.

Associated with the main workshop, most of the technical working groups that RARE was setting up also met; these groups had started as task groups in response to the priority items identified in Luxembourg, but were already running smoothly with stable membership and with enthusiastic chairs able to take responsibility for their organization and for the delivery of results. There had been some changes in responsibilities of the Working Groups (WGs) during the year, and the line-up reporting in Copenhagen was (Figure 1.2):

- WG1: Message handling systems (Alf Hansen)
- WG2: File transfer, access and management (François Fluckiger)
- WG3: Information services exchange of operation information (Barry Mahon)
- WG4: Network operations and X.25 (Piet Bovenga)
- WG5: Full screen services (Brian Gilmore)
- WG6: Medium- and high-speed communications (Jacques Prévost)
- Task 7 – Liaison with CEPT performed *ad hominen* by Albert Kündig in direct collaboration with the secretariat, and so no separate working group was needed.
- WG8: Management of network application services (Mats Brunell).

1.4.4
The Birth of RARE

The formal establishment of RARE was activated by the signing of the constitution by the new officers in Amsterdam on 13 June 1986. Present at the ceremony were the key officers of the new organization, namely Peter Linington as the first President, Klaus Ullmann as Vice-President and Kees Neggers as Treasurer, plus long-term supporter and benefactor Hans Rosenberg and the Notary who witnessed the signatures (Figure 1.3). After some 22 international meetings to agree the details of the

Figure 1.2 RARE working group leaders, 1986: (a) Alf Hansen, (b) François Fluckiger, Barry Mahon (no photo), Piet Bovenga (no photo), (c) Brian Gilmore, Jacques Prévost (no photo), Mats Brunell (no photo).

organization, the final signing was over in an hour, and was followed by a pleasant social lunch. RARE was now in existence; the initial RARE Executive Committee consisted of the three officers present at the signing, plus Birgitta Carlson, who brought a wealth of experience from the running of NORDUnet (Nordic university network). Francisco Ros was later co-opted as organizer of the third networkshop in Valencia.

The constitution allowed only one member per country, and limited eligibility for full membership to: Austria, Belgium, Denmark, Finland, France, Germany (Federal Republic), Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom of Great Britain and Northern Ireland, and Yugoslavia. The document signed that day in Amsterdam was in Dutch and ran to 11 pages. However, the flavor of what was being agreed is given by the key clause shown in Figure 1.4, taken from the certified English translation provided at the time.

1.4.5 The End of the Beginning

Just over 18 months after its first international planning meeting, RARE was now an established organization with a constitution, a permanent secretariat and enough

Figure 1.3 Adoption of the RARE constitution. Left to right: Peter Linington, Klaus Ullmann, Hans Rosenberg, and Kees Neggers.

resources to support its activity. Within this time frame, its influence had grown to the point where it was a recognized player in shaping European policy and it was a credible prime contractor for a major activity like the EUREKA COSINE project. It also had a thriving technical program supported by its working groups and, after two Networkshops, it was well on the way to establishing its long-running and well-respected conference series. RARE had arrived and the beginning was, so to speak, over.

1.5
EARN, the First International Service in Europe

The networks for the research and academic environments appeared as test-beds in different stages of evolution in various countries in the 1970s. Towards the end of the decade, some of these test-beds began to involve foreign partners and began to offer international services. To assert that EARN (European academic and research network) developed the first international network service in Europe is too strong. Yet, one can say that EARN was the first network in Europe offering an international service in a structured way. The diffusion of the research network services in the United States in the early 1980s was based mainly on networks such as ARPAnet, BITNET and CSNET. EARN constituted the European extension of the BITNET network. BITNET was a "store and forward" type network developed at the City University of New York by Ira Fuchs in 1981, initially baptized as "Because It's There Net" and later "Because It's Time Net".

The system was originally based on IBM's VNET (virtual networking) email system and used RSCS (remote spooling communications subsystem) and NJE (network job

RARE Constitution: Objectives - Article 4

1. The objectives of RARE are to promote and participate in the creation of a high-quality European computer-communications infrastructure for the support of research endevour. It will take whatever steps are required to ensure that this infrastructure adopts the most advanced technology available, according to the principles of Open Systems Interconnection as defined by the International Standards Organisation (ISO), in order to ensure open international interconnection. It will wherever possible use the data carrier services of the European Postal, Telephone and Telegraph services.
2. In order to attain the above objectives, RARE shall, inter alia:
   - remove technical and organisational barriers between national networks, by harmonizing their technical facilities;
   - provide for the exchange of operational, directory and technical information;
   - protect and serve the interests of RARE with respect to other organizations, in particular governmental, standardization, PTT and industrial bodies;
   - where appropriate, set up and run common services and technical facilities;
   - establish working groups to perform technical activities in line with the objectives of RARE;
   - assist identified international user groups in the definition and provision of computer communications facilities;
   - support and organize conferences.
3. RARE may negotiate and secure rights in the name of its members but has no authority to undertake obligations or liabilities in their name, unless so instructed by an express authorization from the members concerned.
4. Generating profits for the purpose of distributing the same among the members shall not be permitted.
5. RARE shall take an independent attitude towards political groups, whether national or international.
6. The language of communication within RARE shall be the English language, entirely without prejudice however to Article 22, paragraph 4, last sentence.

Figure 1.4 Extract from the RARE constitution.

entry) application protocols on IBM’s VM (virtual machine) mainframe operating system. Later, RSCS was emulated on other popular operating systems such as DEC VMS (virtual memory system) and UNIX. The network was designed to be inexpensive but efficient, so it was built as a tree structure with only a single path from one computer to another. By the end of 1982 the network included 20 institutions in the United States. At this point IBM extended BITNET into Europe. Basically, BITNET began as a network for IBM computer users but was soon opened up to other manufacturers. This increased its appeal to the research and academic environments.

1.5.1
Preparation and Constitution of EARN

In 1982 the management of IBM research centers across Europe launched the idea of building a network dedicated to the research community. In 1983 the first dedicated lines were installed on a national basis. In the following year a set of international lines was deployed, including an intercontinental connection from Rome to the coordination centre of BITNET in New York.

The international lines were installed via an IBM-funded project to support the network over a four-year period. After the establishment of the first international links and the activation of the software, the European partners started to organize the network. An international network like EARN needed a good management structure to handle this organizational activity, distribute information, and address subsequent international issues.

It was a challenge to merge the operational experience gained in North America by BITNET with the requirements of the European research and academic community. The idea had been to define the role of an EARN coordinator for each country and create a Board of Directors. The first meeting of a group which would eventually become this Board was held in Geneva in February 1983; at another meeting later in the year, the participants agreed that Dennis Jennings would be their Chairman and President of the embryonic organization (Figure 1.5 and 1.6). During 1983 and 1984, there were four Board meetings to reach an agreement for the incorporation of the EARN Association in Paris on February 12.

The Articles of Association of EARN, registered in France, specified that EARN is a computer network open to any non-commercial academic and research institution located in Europe, the Middle East or Africa, aiming at information and data exchange to improve scientific collaboration. Looking through the statutes, the following items are notable:

- The geographical coverage includes the Middle East and Africa. This is connected to the fact that the sponsor of the initiative was IBM EMEA (Europe, Middle East and Africa) and that the international lines provided included these areas.

(a) (b)

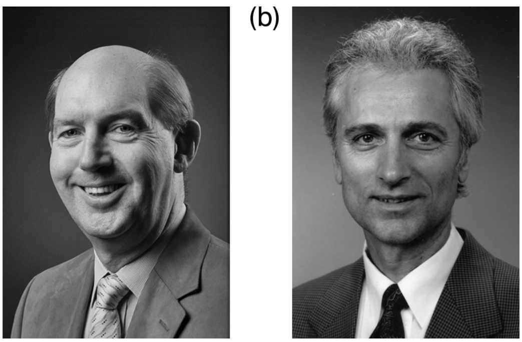

Figure 1.5 EARN Presidents: David Lord (no photo), (a) Dennis Jennings, (b) Frode Greisen.

- The non-commercial nature of the network: this referred not only to the potential partners but also to the utilization of the network.
- The importance and focus on information made available for public consultation.
- The national representation formed by the members of the Board of Directors: Stefano Trumpy was the acting director of EARN, Italy from the preparatory phase until 1990.
- The national contributions to ensure the annual budget for the association.
- The establishment of the following officers: President, Vice-President, Secretary General and Treasurer.

During the meeting of the Board of Directors in December 1984, David Lord was elected President, Dennis Jennings Vice-President, Stefano Trumpy Secretary-General and Jean Claude Ippolito Treasurer. During the October 1986 meeting, Dennis Jennings was elected President, David Lord Vice President and M. Hebgen Secretary-General. The Treasurer remained unchanged. Stefano Trumpy moved to the position of CEPT liaison. At the end of 1987 IBM considered that the network had reached maturity and withdrew its financial support.

In the beginning, IBM's assistance in creating EARN encountered some hostility due to the following doubts:

- Was it IBM's intention to boycott OSI protocols?
- Did IBM want to be the only acceptable manufacturer in universities and research institutions?
- Did IBM intend to dominate the market for networks?
- Telecom operators did not wish to support EARN's ideas.

The problem of the relationship between EARN and the CEPT was first raised during the EARN Board meeting of May 1984. EARN wanted to get support for the network from CEPT but the position of CEPT at that time was as follows:

- EARN, like all data networks, should use OSI protocols as much as possible.
- EARN should use the public X.25 network for its international links.
- Some CEPT members wanted to apply a form of volume charging for their leased lines.

CEPT then specified that these positions had to be considered as recommendations for the national PTTs. At the time, CEPT had a very conservative approach, later contradicted by history. For at least a couple of years, discussions had been very heated. The EARN Board closely monitored the relationships with the local PTTs. The EARN Board position, since the beginning, had been: "to agree to progress towards the adoption of X.25 and OSI but to ask for no volume-dependent component in tariffs for leased lines". In the beginning, British Telecom, the major telecommunications operator in the United Kingdom, wanted to impose one of the highest volume charges. Other PTTs across Europe proposed milder tariffs but the idea of a volume-related charge on top of the leased line cost was retained for some time.

An extract from a communication on the subject from Dennis Jennings to the Board, dated November 1985, reads as follows: "The connection of the United Kingdom on the basis of the imposition of this volume charge (one of the first and the highest), and EARN's implicit acceptance of this volume charge, sets a precedent for the imposition of a similar volume charge by every country PTT in Europe. EARN should never accept the imposition of such a volume charge." It could be said that Dennis Jennings was a good prophet as volume-related tariffs were later abandoned.

The reason for the CEPT position was the fear the PTTs had of losing their very rewarding income from telephone traffic to the networks. The introduction of the volume charges would compensate for this loss of telephone traffic. This situation was severely penalising to researchers in Europe when compared to the cost structure for leased lines in the United States.

The recent evolution of the Internet where VoIP (voice over Internet protocol) has gained momentum shows how conservative that position was. The imposition of using the public X.25 network for international connections was also a conservative position, one that might have been accepted as a compromise.

In 1985 the EARN Board discussed requests to join from institutions in Eastern European countries. At the time, a serious problem was the existence of COCOM (coordinating committee for multilateral export controls) export regulations that prohibited the export of sensitive technology (which covered almost all networking equipment) to communist countries. It was also not clear how the United States Department of Commerce would have reacted to the extension of EARN into Hungary and Poland, the countries which had asked to join EARN. These arguments seem quite amusing today but are linked to the political climate prevalent at the time. The conclusion of the Board was to move carefully and to investigate the position of the United States in this regard. During a Board meeting in October 1986 there was a vote concerning the request from South Africa to join EARN. The request was rejected with ten votes against and only one in favor – at the time, South Africa still implemented an apartheid regime.

There is no doubt that EARN helped spread usage of networks in European academic and research environments. In addition, EARN helped to weaken the domination of the telecommunications monopolies in Europe. EARN can take credit for setting up an international organization capable of designing and managing the network, as well as ensuring the financing of that infrastructure after the financial support of IBM ended in December 1987. At the beginning of 1987, EARN and BITNET were able to connect some 3000 scientific institutions (two thirds of them connected through gateways) with an estimated audience of 150 000 correspondents. Today these numbers do not seem so impressive, but until the early 1990s EARN provided the main instrument for cooperation in Europe amongst research and academic institutions.

The first gateways were activated by BITNET. The most relevant was the gateway to the IBM VM operating system. There was also a gateway to ARPAnet and one to CSNET. Columbia University developed the gateway to DECnet. A gateway was then

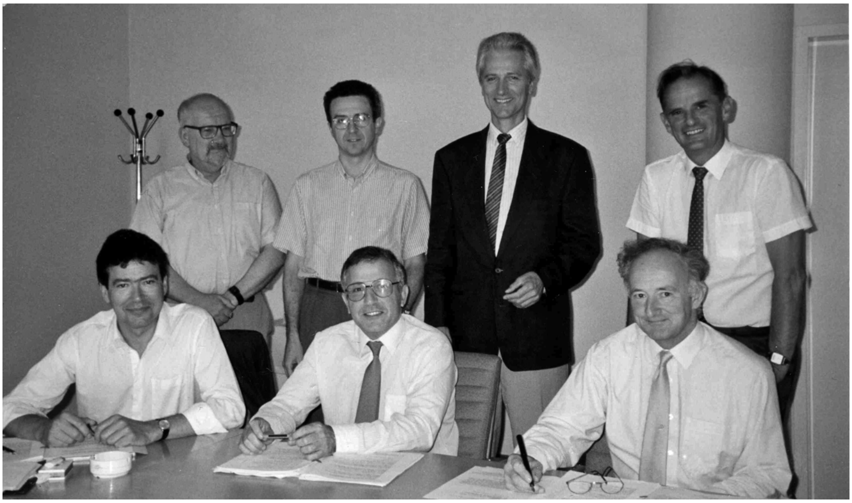

Figure 1.6 The EARN Board of Directors (about 1991). Back row, left to right: Hans Deckers (EARN Manager, not a member of the Board), Marco Sommani (Treasurer), Frode Greisen (President), László Csaba. Front row, left to right: Jean-Loïc Delhaye, Avi Cohen, Paul Bryant (Secretary).

developed for UNIX systems. These gateways were initially developed as test-beds. They were not easy to use and were subject to code errors but gradually became more reliable. Later the number of protocol emulators[1] would reach 32. In this way BITNET and EARN gained the reputation of a heterogeneous network.

The main services provided by EARN were:

- e-mail
- file transfer
- instant messaging
- resource sharing between computers in the network
- access to libraries and databases
- LISTSERV (mailing list server), a system based on a distribution list that supports interaction amongst groups of users with common interests.

The naming system adopted in the first years used the form “hosts.txt”, a non-standard convention. ARPAnet adopted the DNS (domain name system) in 1984 and EARN adopted it in the late 1980s. In 1988, DEC began supporting EARN with funds. In 1991, EARN started to use the Internet for data transport and the justification for keeping an independent international structure alive progressively vanished.

By early 1993, RARE – through the COSINE project – had set up the IXI (international X.25 infrastructure) network and its plans for establishing an operational unit were well on the way to fruition. In April 1993, Marco Sommani

1) A protocol emulator is a device inserted on a line connecting two computers which use incompatible protocols. It manipulates signals and data passing between the two computers in such a way that it appears to each of them as though it was a compatible machine.

(Trumpy's successor as EARN's Italian Director) and Stefano Trumpy (who was also a member of the COSINE Policy Group, CPG) reported on the possible future of EARN and provided an evaluation of COSINE as follows:

- The COSINE project pulled together the wish for a pan-European network services organization based on the existence of well-organized national research networks while using a federated approach.
- COSINE helped link the research networks with the relevant financing bodies of the research and academic sector.
- COSINE ensured that RARE was involved with the organizational aspects of a pan-European network. The EARN Board tried to promote a role for EARN as one of the major service providers of the academic and research environment, but this failed due to the misconception that EARN was still linked with IBM.

COSINE failed to create user services for the broader community. But on a positive note COSINE created a managed multi-protocol backbone (EuropaNET, European multi-protocol backbone network) and a central structure OU (operational unit) that offered European-scale network services to the research networks. This OU still lacked structure but RARE had a fundamental role in defining that unit. A merger of EARN with RARE could be an excellent opportunity although it had recently been rejected, not through lack of initiative on EARN's part. If the proposal cannot be reformulated, an alternative partner should be found to make the best use of EARN's networking expertise gained over the last decade.

The relationship between EARN and RARE had been discussed for the first time as long ago as 1986 and there had subsequently been an exchange of representation on the two bodies; the EARN President had been nominated as the EARN representative on the RARE Council of Administration and RARE had become an EARN international member.

Despite these elements of cooperation, a merger with RARE was not generally favored within the EARN community and another year would pass before the topic was taken up again.

1.6 IXI

On completion of the COSINE specification phase as a result of the work undertaken by RARE during 1987/8, it was decided that the first step in the COSINE implementation phase (CIP) would be to establish a pan-European network for the academic and research community, which became known as IXI (International X.25 infrastructure).

The European PTTs were still mostly state monopolies. The concept that they should provide their customers with a "one-stop shop" for an international service was a novel one. They were contemplating setting up a joint MDNS (managed data network service) venture through the CEPT and at first it was thought that this service might be used to meet the research networks' requirement. In practice, the MDNS never materialized but an offer was received in October 1988 from the Netherlands PTT Telecom with several other telecom operators in Europe as sub-contractors.

Preliminary discussion within and between the organizations involved started in autumn 1988. Because of the urgency of setting up a service, it was decided that the technical planning and implementation of IXI would be carried out by staff from the research networks in parallel with continued negotiation of the COSINE implementation phase execution contract (CIPEC) with RARE. Since the CIPEC was not yet ready to be signed, RARE was not in a position to take responsibility for managing the funds required for IXI and the EC took on this role.

RARE established the IXI co-ordinating committee with one representative per participating organization to provide overall direction of the project and the IXI project team to provide day-to-day technical management. A contract between PTT Telecom (now KPN, Koninklijke PTT Nederland) and the EC acting on behalf of the CPG was signed in October 1989 and the pilot service started a few months later. The full IXI service was officially inaugurated on June 8 1990 in The Hague.

For the first few months, service availability and reliability were poor, due to software problems with the X.25 switches. These problems were mainly in the software modules that had been implemented to meet IXI's specific requirements. IXI was meant to be a one-year pilot service, but it continued until October 1992 when it was replaced by the European multi-protocol backbone (EMPB) network. By this time, the 64 kbps bandwidth was a major limitation. In addition, many of the connecting research networks were moving towards the use of IP (Internet protocol) rather than X.25.

The IXI project was started because it was clear that the international interconnections provided by the public X.25 networks were inadequate to support the European research community and match the bandwidth available nationally. Subject-specific networks, such as HEPnet (high-energy physics network), were starting to be established but it was clearly necessary to establish an interconnection for the national research networks for their general traffic. Although the initial target was for access at 64 kbps, it was a stated requirement that access at 2 Mbps should be available in due course because the requirements of this user community would obviously grow. In the research network environment, traffic was typically doubling every year.

There were many issues that had to be addressed in the IXI planning phase, technical, organizational and political. Many research networks had been created to support universities and government research laboratories and because of national connection policies (sometimes determined as a result of in-fighting between different ministries) could not widen their range of client organizations; others were already moving towards support for the whole education sector. "Acceptable use" rules also varied and while it was easy to get agreement that the transport of "commercial" traffic should be forbidden, there was no agreed definition of which traffic was "commercial".

Despite the PTTs' earlier exploration of the MDNS (or perhaps as a result of it) PTT Telecom in its lead role in IXI found itself in conflict with some of the other PTTs, particularly when it had to locate a network switch on another PTT's premises. Sometimes it was even difficult to get good quality service specified in the contract. Perhaps fortunately, the EC agreed to be the contracting party on behalf of the CPG, rather than RARE having to accept the risks involved. PTT Telecom was concerned, however, that the EC would try to use the contract to get the European PTTs to drop their restrictive practices. The EC was concerned that RARE should not be too flexible in the negotiations with PTT Telecom, to ensure that the EC's policy aims were met. It was issues like these that resulted in long drawn-out contract negotiations.

While the CIP execution contract was still being negotiated, RARE did manage to create the necessary working groups and project team by using experts from the national research networks, consultants and its own staff. All those involved found the project interesting, if challenging. The organizations accessing IXI also had to take responsibility for supporting their IXI connections, not only to support their own users but also to ensure that users from other networks could access them. RARE developed software to test both the initial delivery of network connections and the ongoing performance of the network as a whole. The initial acceptance tests ensured that a newly connecting network was able to reach all the other connected networks over IXI. There was concern from PTT Telecom that RARE's ongoing performance-monitoring would itself load the network unduly. Yet this extensive testing helped identify problems before they had an impact visible to the user networks; it also provided early availability and reliability reporting before it was available from PTT Telecom.

It was not straightforward to get digital connections (64 kbps) for all the COSINE countries for IXI and this issue was one that had to be pressed on PTT Telecom. The Nordic countries shared a single 64 kbps connection and JANET, the United Kingdom national research network, upgraded its connection to 128 kbps in July 1991. The other network connections remained at 64 kbps as the upgraded service, EuropaNET, was being tendered. In the case of Greece, 64 kbps was not provided until EuropaNET was rolled out. Slovenia connected in June 1991, as it happens at the same time as it separated from the Federation of Yugoslavia. Other countries in Central and Eastern Europe had connections to IXI, and later to EuropaNET, funded by the EU under the PHARE (Poland and Hungary: Assistance for restructuring their economies) program.

It was intended that IXI should provide connections for the national research networks, a limited number of international research centers and the public X.25 networks. The public X.25 connections enabled industrial and other researchers to use the IXI service without having to connect to their national research network. In Table 1.1 of IXI connections, the connections are categorized as NREN (National

Table 1.1 Numbers of IXI connections.

IXI connections	NREN	PSPDN	Sites	Total
April 1990	10	3	3	16
At end of 1990	12	4	7	23
April 1992	13	10	6	29

research and education network) including NORDUnet and PSPDN (packet-switched public data network), public X.25 networks sites) international research centers, such as CERN as well as the EC in Brussels.

IXI was the first pan-European network serving the whole research community. The experience gained from this was fed into the successor networks managed by DANTE (delivery of advanced network technology to Europe).

Leased Circuits

At the time when this story starts, telecommunication services almost everywhere in Europe were provided by the same government body that was responsible for the postal and telegraph services, commonly known as the PTT. The main exception was the United Kingdom where competition was first introduced by the grant of a licence to Mercury Communications in 1982, following the establishment of British Telecom as a state-owned company the previous year. When a PTT was split up, the branch which then offered telephone services joined the set of Public Telecoms Operators (PTO), later known as Public Network Operator (PNO). The national PNOs continued to hold a monopoly on the provision of telephone and data transmission services within their country. In some countries, the PNO was owned by the government; in the others, the PNO was controlled by the government.

Digital circuits had only recently been brought into use with 64 kbps adopted as the basic transmission speed, sufficient to handle a single phone call including the signaling needed for call set-up and other management functions. Digital technology was intended by the PNOs to improve the way in which voice telephone services were provided. However, the PNOs did not recognize the scale of the revolution that computers and digital technology would eventually provoke and they appeared to be primarily concerned with making improvements to their telephone services. Circuits could be leased from the PNOs but their use was subject to restrictions. In particular, the re-sale of the circuit capacity was forbidden and switching traffic between third parties was also not allowed.

International leased circuits were normally provided in the form of two "half circuits" one half circuit being provided by the PNO at each end. The tariff for each half circuit was specified in the standard price list of each PNO. If the circuit had to pass through a third country or countries, the additional cost would be reflected in the half circuit tariffs at each end; payment to the PNOs of the intermediate countries for the transit service they provided was handled by the PNOs at each end. The price of circuits bore very little relation to the cost to the PNOs of providing them and was universally high. In some countries, the PNO was effectively used as a hidden tax collector, with the government taking advantage of its PNO's surpluses to reduce the amount they would otherwise have to collect through some more overt form of taxation.

Dealing with user requirements was not high on the PNOs' priority list. Although an indication of delivery delay might be given, one PNO could not be expected to take responsibility for failure by one of its partner PNOs to deliver by a fixed date. When customers, including those in the research community, demanded higher circuit capacity or other services which a PNO was not providing, the standard response was along the lines of "We don't believe that you need this, therefore we will not provide it; and since it is not available, you cannot prove your need". The PNOs were primarily concerned with protecting their lucrative monopoly of voice traffic and were reluctant to make available what they considered to be the basic elements of their infrastructure to organizations which might find a way of exploiting these elements in competition with them.

The liberalization of European telecommunications took effect on 1 January 1999 following several years planning and legislation managed by the EC and it had a dramatic effect. Restrictions on the provision and use of leased circuits were abolished, existing PNOs were free to provide services outside their former national territory and new PNOs (in many cases, companies which had already exploited the possibilities opened up by earlier liberalization within individual countries) were able to expand and extend their coverage internationally.

Under the new regime, customers can acquire a set of leased circuits between several countries from a single supplier and all the major European PNOs can now cover all the countries of the EU with equipment and circuit capacity that they control. In practice, the redundancy and duplication of resources which this implies is not as great as might be expected. Although the newcomers and the established national PNOs had taken steps in the years immediately preceding liberalization to extend their networks, no single organization owns infrastructure that covers the whole of Europe and there is a considerable amount of trading at different levels.

Installing a vandal-proof cable between two cities which are several hundred kilometers apart is a major exercise. There may be civil engineering problems in finding a suitable route, burying the duct which carries the cable, and crossing rivers and other obstacles; there are legal and administrative issues, particularly concerning rights-of-way and access to the repeater stations that are needed along the route.

A PNO which has already dug trenches across one country, installed ducts in the trenches and laid a group of optical fibers in the ducts is in a position to trade on several levels. Such a PNO can make a swap arrangement with a PNO in another country ("you can put your fibers in my ducts if you let me put my fibers in yours"). More commonly, there will be an exchange of fibers, leaving each PNO free to decide what use to make of the fiber's capacity and which type of equipment to control and manage the services for which it is used. In some cases, one PNO might simply lease a fully equipped fiber from another PNO. Through some combination of these arrangements, an organization can claim to have Europe-wide coverage.

Since liberalization, a new facilities management industry has been created. Specialist property development companies (often formed by a consortium of PNOs) have constructed buildings which are designed to meet the needs of operators who wish to interconnect their services. The buildings are equipped with highly reliable power supplies (including back-up in case of failure of the mains supply), tight access control systems and security procedures, and ducts which allow cables to be installed easily between any two points in the building. PNOs can rent space, install their own equipment and use the location as an interconnection point for both their own circuits and for exchanging traffic with other PNOs (such a location is commonly referred to as a “point of presence” or PoP).

The effect of the competition between PNOs which was introduced by liberalization has been to reduce prices (in terms of cost per unit of transmission capacity) by several orders of magnitude, to provide a better match between price and cost of provision, and to allow PNOs and their customers to introduce new services which go far beyond the voice telephony which was traditionally supplied.

It may be noted that although DANTE provides services to only a relatively small but distinct community and does not act as a PNO, it operates by leasing circuits or fibers from a number of PNOs and, since the installation of the GÉANT (gigabit European academic network technology) service, has a network which is more extensive and which has a higher aggregate capacity than any of the commercial network operators in Europe.