Gateways - just as important as standards.

How the Internet won the “religious war” about standards in Scandinavia

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Abstract

This article presents the (hi)story about the Nordunet project and its “plug.” This is a (hi)story about how the Internet “won” the “religious war” about computer communication protocol standards in Scandinavia. This history teaches us important lessons about how the Nordic countries (except Denmark) became the leading ones in the adoption and use of the Internet. On a more general level this story also teaches us an important lesson about the importance of gateways in the design and establishment of large scale computer networks and information infrastructures. It is a universal truth the development of such technologies requires standards. And this story teaches us that gateways are equally important. The main conclusion to be drawn is that what really matters in the development of such technologies is to combine and balance the use of gateways and standards in a proper way.

1 Introduction

A dominating view within the communities developing computer communication networks and information infrastructures is that the one and only way to establishing such networks is the definition of standards. Gateways are in practice often found to be important. But such gateways are seen as a consequence of a failed design effort as they are imperfect translators between the networks they are linking. I will in this paper argue for the opposite view: Gateways are key tools for succeeding in building and maintaining the networks we are striving for. They are equally important as standards. The key issue in the making of infrastructures is to find the proper mix of and “collaboration” between both of them.

My main argument will be outlined through the presentation and discussion of one case: the establishment of a computer network between the universities in the Nordic countries, called Nordunet, and in particular the crucial role played by a gateway called the “Nordunet plug.” The focus is on the Norwegian “scene.” This story also illustrates the impossibility of developing large networks from scratch. Such networks are developed by interconnecting smaller, heterogeneous networks through gateways.

A gateway can be defined in general terms as a link between different elements. Within computer or telecommunication it is used to denote an object linking two different networks or different communication protocols or standards. It is often used to denote a converter or translator between different formats. Such translation is one task that gateways between different networks or standards have to do. In some cases the term is used in a broader sense where even a standard or a whole network can be seen as a gateway between different computers or applications. I will in this article use the term in a more restricted sense. I use the term to denote elements linking together different networks which are running different protocols, i.e. a gateway is translating between different standards and accordingly and enabling the interconnection of networks based on different standards. This means that I see gateways as complementary to standards. A network based on standardized protocols should not be seen as a gateway. But there is of course a grey zone here. We can find examples of standards for gateways like, for instance, the Internet standard for conversion between the X.400 body part and the MIME formats.

The empirical material the article is based upon has partly been obtained through two interviews with one of the project leaders and one interview with one project “initiator” and member of the steering group. It also draws upon various documents including reports from the project, in particular the final report from the Nordunet project and one report describing the Nordunet Plug, other papers presenting the history of the Internet in Norway (Spilling 1995, Hannemyr 1999), and to some extent Janet Abbate’s (1999) history of the Internet. In addition, the article is based on participant observation in the sense that I have been a user of (some of) the solutions involved in this story and was also for a shorter period in the early eighties involved in one project within a research program closely related to the Nordunet project.

The outline of the paper is as follows: in section 2 I present theoretical prespectives chosen to interpret the case, in section 3 I present the background for the situation when the project started and the solution one aimed at. In section 4 I present the solution the project arrived at in the end - how and why this happened as well as its future implications. In section 5 I will discussing the lessons to be drawn from this case and the importance of gateways in more general terms, and finally concluding the article in section 6.

2 Theoretical perspectives

Theoretically this article draws on various approaches which see technologcal development as an evolutionary process - both the long term development of technologies or technological paradigms and the short term design of specific solutions or artifacts. The first perspective is found in economic theories of technological development and innovation theories (see, for instence, Dosi, Nelson and Winter), the latter in theories about problem solving and creativity in cognitive psycology and their relations to technological innovation (see, for instence, Kaufmann).

Design is about making something new, something which does not exist. It is an inquiry into the unknown - based on experimentation and learning. A good design can only be developed through the generation of many different alternatives, and through testing and practical use some are dismissed while others are improved (by picking bits and pieces from others) into good ones. The development of useful and well working infrastructures also requires such a process. These principles are well integrated into many design approaches or methodologies for the development of technological solutions - the use of prototyping in information systems development being a paradigm example. But adopting such experimental design approaches is far from trivial in many cases. One problem is related to the costs of developing different alternatives only to select one of them. For this reason there are developed many design strategies based on a specification driven model, for instance by first specifying user requirements, then through a series of steps transforming one specification into another until we in the end have an executable one, i.e. a running information system. The waterfall model of software development is a paradigm example. In general we can say that the closer the system we want to design is to an existing system, the less learning is required - and accordingly experimentation - during the design process (Kaufmann).

This view is also argued forcefully by Karl Popper (1957) from an epistemological perspective, when he compares “utopian” (or “holistic”) and “piecemeal engineering:”

> “The piecemeal engineer knows, like Socrates, how little he knows. He knows that we learn only from our mistakes. Accordingly, he will make his way step by step, carefully comparing the results expected with the results achieved, and always on the look-out for the unavoidable unwanted consequences of any reform; and he will avoid undertaking reforms of a complexity and scope which make it impossible for him to disentangle causes and effects, and to know what he is really doing (ibid., p. 67).”

> “..the holistic method turns out to be impossible; the greater the holistic changes attempted, the greater are their unintended and largely unexpected repercussions, forcing upon the holistic engineer the expedient of piecemeal *improvisation* [italics in original]. .... it continuously leads the Utopian engineer to do things which he did not intend to do; that is to say; it leads to the notorious phenomenon of *unplanned planning*. Thus the difference between Utopian and piecemeal engineering turns out, in practice, to be a difference not so much in scale and scope as in caution and in preparedness for unavoidable surprises” (ibid., p 68-69).

The article also drwas upon theories, in particular Actor-Nnetwork Theory (Latour 1999) from the Science and Technology Studies field, seeing technological development as a negotiation process where technological as well as human and social elements participate and are closely tied together into heterogeneous networks. Lastly, the article drwas upon a couple of theories addressing more specific issues related to the development of the kind of large scale infrastructures and networking technologies which is focused in this article.This includes "network economics" and the field often called "Large Technical Systems."

A key issue in network economics (see, for instence, Shapiro and Varian, 1999) is the fact that the use value of a standard increases with the number of users having adopted the standard. This leads to what is called path-dependent development and diffusion processes and possibly lock-in situations where the change of an infrastructure based on one standard to a new and superior one does not happen because of the fact that the new standard has no value for its potential users as long as nobody is using it. Accordingly, everybody may wait for the others to switch, and nothing happens.

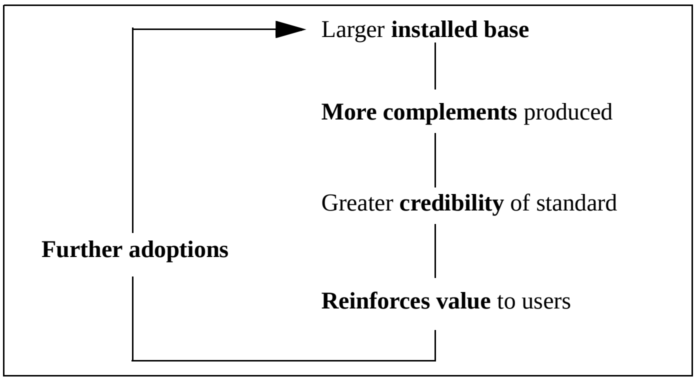

Fig 1. Standards reinforcements mechanism (Grindley 1995).

Among the stuidies of "Large Technical Systems" the most widly cited and influencial one, is Thomas Hughes’ (1983) research on the development of electricity from 1880 to 1930. One event in this evolutionary process which is of particular relevance for this article, is the "battle between systems" that unfolded over a period between the original technology based on direct current (DC) and the more resent - and superior - technologies based on alternating currents (AC). This "battle" endend when the roatry converter was developen which served as a gaeway linking AC and DC networks. The converter enabled a rather smooth transfer from AC to DC which was crusial for a wider adoption of the DC technology. AC did not disappear, however. Its technology continued to improve in niches wher it could be used in compination with AC (Hughes 1987, David and Bunn 1988).

3 Background and status 83 - 85

In the late seventies and early eighties, most Nordic universities started to build computer networks. Different groups at the universities got involved in various international network building efforts. Around 1984 lots of fragmented solutions were in use and the level of use was growing. Obtaining interoperable services between the universities was emerging as desirable - and (technologically) possible.

The networks already in use - including their designers, users, and operating personnel - were influential actors and stakeholders in the design and negotiations of future networks - including Nordunet. We will here briefly describe some.

3.1 Networks

IBM had set up and operated a network, which they called EARN. The network was based on IBM's proprietary technology. (This meant RCSC protocols which later on were redesigned and became widely known as the SNA protocol suite.). It was connected to BITnet in US. Most large European universities were connected. The universities were normally linked to the EARN network through nodes at and operated by their EDP centres. The network was based on a "star" topology. The Nordic countries were linked to the European network through a node at the Royal Technical University in Stockholm. In Norway, the central node was located to Trondheim. The network was based on 2.4 - 4.8 KB/second lines in the Nordic countries. Users were found among many groups within the universities collaborating with colleagues at other universities. The main services were e-mail and file transfer. A chat service was also used to some extent.

Another important network was HEP-net. This was established to support collaboration among physics researchers around the world, in particular among researchers collaborating with the CERN lab outside Geneva in Switzerland. The network was based on DECnet protocols. Its user community represented "big science," they had lots of money and were a strong and influential group in the discussions about future academic networks. The EDP department at CERN was also very active in developing solutions that were established as regular services for this community (just in the same way as they developed the web technology some years later.)

EUnet was a network of Unix computers based on UUCP protocols. EUnet was rather weak in Norway, but it was used to some extent in computer science communities. Its main node was located at Kongsberg until 1986 when it was moved to the IT department at the University of Oslo. EUnet was mostly used by Unix users (doing software development), within academic institutions as well as private IT enterprises.

Norway was the first country outside US linked to ARPANET (Abbate 1999, Spilling 1995). A node was set up at Norwegian Defence Research Establishment (NDRE) at Kjeller outside Oslo by Pål Spilling when he returned from a research visit in the US. The second node was established by Tor Sverre Lande at the department of informatics at the University of Oslo. This happened when he also returned from a one year research visit at a university in the US. Lande brought with him a copy of the Berkeley Unix operating system which included software implementing all ARPANET protocols. The software was installed on a VAX 11/780 computer and linked to ARPANET through a connection to the node at Kjeller. Later on more ARPANET nodes were set up. NDRE was using the net for research within computer communications in collaboration with ARPA (in particular communication via satellites). Lande was working within hardware design, and wanted to use the net to continue the collaboration with the people he visited in US, all using VLSI design software on Unix machines linked to ARPANET. At that time ARPANET was widely used among computer science researchers in US, and computer science researchers in Norway very much wanted to get access to the same network to strengthen their ties to the US research communities. At that time Unix was also diffusing rapidly. All Unix systems contained the ARPANET protocols, and most Unix computers were in fact communicating using these protocols in the local area networks they were connected to. Accordingly there were lots of isolated IP islands in Norway and the other Nordic countries. By linking these IP islands together a huge Nordic network would be created.

In Norway the development of one network connecting all universities started in the early eighties. The goal was the establishment of one network linking every user and which would provide the same services to all. With this goal at hand, it was felt quite natural to link up with the ongoin effort aiming at developing the so-called Open Systems Interconnection (OSI) protocol standards within the framwork of the International Standardization Organzation (ISO) and then build a network based on what would come out of that. Those involved tried to set up a X.25 network. First, it was tried to build this based on an X.25 product developed by a Spanish company. The quality of this product was low, and it seemed out of reach to get the network up and running.[1] The use of this product was given up, and it was replaced by an English product called Camtech. Based on the English product one managed to keep the network running and an e-mail service was established in 84/85 (based on the Canadian EAN system implementing the OSI X.400 standard).

3.2 Ideologies and universal solutions

As the networks described above were growing, the need for communication between users of different networks appeared. And the same was happening "everywhere," leading to a generally acknowledged need for one universal network providing the same universal services to everybody. Such a universal network required universal standards. So far so good - everybody agreed on this. But what the universal standards should look like was quite a different issue.

This was a time of ideologies. The strongest ideology seems to be that of the ISO/OSI model, protocols, and approach. In general there was a religious atmosphere. Everybody agreed that proprietary protocols were bad, and that "open systems" were mandatory. The Americans pushed IP based technologies. They did so because they already had an extensive IP based network running, and extensive experience from the design, operations, and use of this network. The network worked very well (at least compared to others), and lots of application protocols were already developed and in use (ftp, telnet, e-mail, etc.).

As the IP based network (ARPANET, later Internet) was growing, the protocols were improved and tuned. New ones were developed as it was discovered that they were needed to make the network work smoothly, or new ideas emerged as one used and explored the existing services. An example of the first is the development of the Domain Name Service, DNS, mapping symbolic names to digital IP addresses. This service made the network scalable. Further, the decision to build the network on a connectionless transport service made the network flexible, robust, and simple due to the fact that no management of connections was required during communication sessions.

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1. The product got the nick-name SPANTAX, after the Spanish airline with the same name. At that time "Spantax" became a almost generic term for low quality services in Norway due to lots of tourists having bad experience with that airline when going to Spanish tourist resorts, combined with one specific event where a flight was close to crash when the pilot thought a large area with lots of football fields was the airport.

American research and university communities pushed IP, while both European researchers within the computer communications field and telecom operators pushed OSI. The role of telecom operators had the effect that the whole of OSI protocol suite is based on "telephone thinking." (The assumed importance of a connection oriented transport protocol - opposed to the connection less mode of operation of TCP/IP - which will be mentioned in the next section is one example illustrating this.[2]) The Europeans wanted a non-IP based solution believing that that would close the technological gap between Europe and US.

4 Nordunet

The Nordunet initiative was taken by the top managers of the EDP centres at the universities in the capitals of the Nordic countries. They had met at least once a year for some time to discuss experiences and ideas. Most of them had a strong belief in computer communication. In Norway the director of the EDP department at the University of Oslo, Rolf Nordhagen, was a strong believer in the importance of computer network technology. He had pushed the development of the BRU network at the university, linking all terminals to all computers. He also worked eagerly for establishing new projects with wider scopes, and he was an important actor in the events leading to the conception of the idea of building a network linking together all Nordic universities. When the idea was accepted, funding was the next issue. The Ministry of the Nordic Council was considered a proper funding organization. They had money - an application was written and funding granted.

Arild Jansen, a former employee at the EDP department in Oslo was at this time (1984/85) working at the Ministry for Public affairs in Norway. He played the role as the bridge between the technical community on the one hand and the political and funding communities on the other. He was also the one writing the application for funding. Later on he became a member of the steering group.

4.1 Strategy one: Universal solution, i.e. OSI.

The Nordunet project was established in 1985. Einar Løvdal and Mats Brunell were appointed project coordinators. When the project started, they had hardly the slightest idea about what to do. Just as in the larger computer communications community, those involved in the project easily agreed about the need for a universal solution - agreeing on what this should look like was a different matter.

The people from the EDP centres, having created the idea about the project, all believed in the OSI "religion." Next, they made an alliance with public authorities responsible for the field that computer networks for research and education would fall into and the funding institution (which was also closely linked to the authorities). Obtaining "universal service" was an important objective for them, accordingly they all supported the ideas behind OSI. This alliance easily agreed that an important element in the strategy was to unify all forces, i.e. enrolling the computer communications researchers into the project. And so happened. As most of them already were involved in OSI related activities, they were already committed to the "universal solution" objective and to follow the OSI strategy to reach it.

However, products implementing OSI protocols were lacking. So choice of strategy, and in particular short term plans, was not at all obvious. Løvdal was indeed a true believer in the OSI religion. Mats Brunell, on the other hand, believed in EARN. To provide a proper basis for taking

2. For more on this, see (Abbate, 1995).

decisions a number of studies looking at various alternative technologies for building a Nordic network were carried out:

1. IP and other ARPANET protocols like SMTP (e-mail), ftp, and telnet.
2. Calibux protocols used in the JANET in UK.
3. EAN, an X.400 based e-mail system developed in Canada.

All these technologies were considered as possible candidates for intermediate solutions only. The main rationale behind the studies was to find best currently available technology. The most important criterion was the number of platforms (computers and operating systems) the protocols could run on.

Neither IP (and the other ARPANET) nor the Calibux protocols were found acceptable. The arguments against IP and ARPANET were in general that the technology had all too limited functionality. Ftp had limited functionality compared to OSI's FTAM protocol (and also compared to the Calibux file transfer protocol which FTAM's design to a large extent was based on). The Nordunet project group, in line with the rest of the OSI community, found the IP alternative "ridiculous," considering the technology all to simple and not offering the required services. There were in particular hard discussions about whether the transport level services should be based on connectionoriented or connectionless services. The OSI camp argued that connection oriented services were the most important. IP is based on a connection less datagram service, which the IP camp considered one of the strengths of the ARPANET technology.

JANET was at that time a large and heavily used network linking almost all English universities. The network was based on X.25. In addition it provided e-mail, file transfer, and remote job entry services. The protocols were developed and implemented by academic communities in UK. The fact that this large network was built in UK was to a large extent due to the institution that was funding UK universities required that the universities bought computers that could run these protocols. JANET was also linked to ARPANET through gateways. The gateways were implemented between service/application protocols. The people involved in the development of the Calibux protocols were also active in and had significant influence on the definition of the OSI protocols. The main argument against Calibux was that the protocols did not run on all required platforms (computers and operating systems).

One important constrain put on the Nordunet project was that the solutions should be developed in close cooperation with similar European activities. This made it almost impossible to go for ARPANET protocols, and also Calibux although they were closer to the OSI protocols unanimously preferred by those building academic networks and doing computer communications research throughout Europe.

The IP camp believed that IP (and the other ARPANET protocols) was the universal solution needed, and that the success of ARPANET proved this.

The users were not directly involved in the project, but their views were important to make the project legitimate. They were mostly concerned about services. They want better services - now! But in line with this they also argued that more efforts should be put into the extensions and improvements of the networks and services they were using already, and less into the long term objectives. The HEPnet users expressed this most clearly. They were using DECnet protocols and DEC computers (in particular VAX). DEC computers were popular among most Nordic universities, accordingly they argued that a larger DECnet could easily be established and that this would be very useful for large groups. The physicists argued for a DEC solution, so did Norsk Romsenter. Nobody argued, however, for a "clean" DECnet solution as a long term objective.

Both on the Nordic and the global scene (Abbate 1995) the main fight was that between the IP and OSI camps. This fight involved several elements and reached far beyond technical considerations related to computer communications. At all universities there was a fight and deep mistrust between EDP centres and computer science departments. The EDP centres were concerned about delivering ("universal") services to the whole university as efficiently as possible. They thought this best could be done by one coherent set of shared services delivered by a centralized organization. The computer science departments found most of the time the services provided by the EDP centres as lagging behind the technological edge and unsatisfactory in relation to their requirements. They saw themselves as rather different from the other departments as computers were their subject. They had different requirements and competencies, believing that they would be much better off if they were allowed to run their own computers. But the EDP centres were very afraid of losing control if there were any computers outside the domain they ruled.

The computer science departments also disagreed with the EDP centres about what should be in focus when building communication services and networks. The EDP departments focus first on their own territory, then on the neighbouring area. This means, first establishing networks across the university. Second, extending and enhancing this so that it becomes linked to the networks at the other universities in Norway, then the Nordic countries, and so on. The computer science departments, however, were not primarily interested in communicating with other departments at the same university. They wanted first of all to communicate and collaborate with fellow researchers at other computer science departments. And not primarily in Norway or other Nordic countries either, but in the US. They wanted Unix computers to run the same software as their colleagues in US, and they wanted connection to ARPANET to communicate with them.

The EDP centres would not support Unix as long as it was not considered feasible as the single, "universal" operating system for the whole university. And they would not support IP for the same reason. And thirdly, they wanted complete control and would not let the computer science department do it by their own either. To get money to buy their own computers, the computer science department had to hide this in applications for funding of research projects within VLSI and other fields. The fight over OSI (X.25) and IP was deeply embedded into these networks of people, institutions, and technologies.

Tor Sverre Lande and Pål Spilling participated in some meetings in the early phase of the project. They were sceptical about Calibux and wanted an IP based solution. But they did not have much influence on the Nordunet project and decided to go for the establishment of the IP connections they wanted outside the Nordunet project. And most people involved in the Nordunet project were happy when they did not have to deal with the IP camp. At this time there was a war going on between the camps with lots of "bad feelings."

As all intermediate solutions were dismissed, it was decided to go directly for an OSI based solution. The first version of the network should be build based on X.25 and the EAN system providing e-mail services. This solution was very expensive, and the project leaders soon realized that it did not scale. X.25 was full of trouble. The problems were mostly related to the fact that the X.25 protocol specification is quite extensive, and accordingly easily leading to incompatible implementations. Computes from several vendors were used within the Nordunet community, and there were several incompatibilities among the vendors' implementations. And more trouble was caused by the fact that lots of parameters have to be assigned values when installing/configuring an X.25 protocol installation. To make the protocol installations interoperate smoothly, the parameter setting has to be coordinated. In fact, they required coordination beyond the capabilities of the NOIRDUNET project.

4.2 Strategy 2: Intermediate, short-term solutions

The project worked on the implementation of the network as specified for about a year or so without any significant progress. The standardization of OSI protocols was also (continuously) discovered to be more difficult and the progress slower than expected, making the long term objectives continuously more distant. The Nordic Council of Ministers was seriously discussing to stop the project because of lack of progress. New approaches were desperately needed.

4.2.1 Strategy element one: The Nordunet Plug

At the same time other things happened. IBM wanted to transfer the operations of its EARN network to the universities. Together Einar Løvdal and Mads Brunell then over some time developed the idea to use EARN as backbone of a multi protocol network. They started to realize that OSI would take a long time - one *had to* provide services before that. OSI was all the time ideological important, but one had to become more (and more) pragmatic. The idea about "The Nordunet Plug" was developed. This idea mean that there should be one "plug" common for everybody that would hook on the Nordunet network. The plug should have 4 "pins:" one for each of the network protocols to be supported: OSI/X.25, EARN, DECnet, and ARPANET/IP.

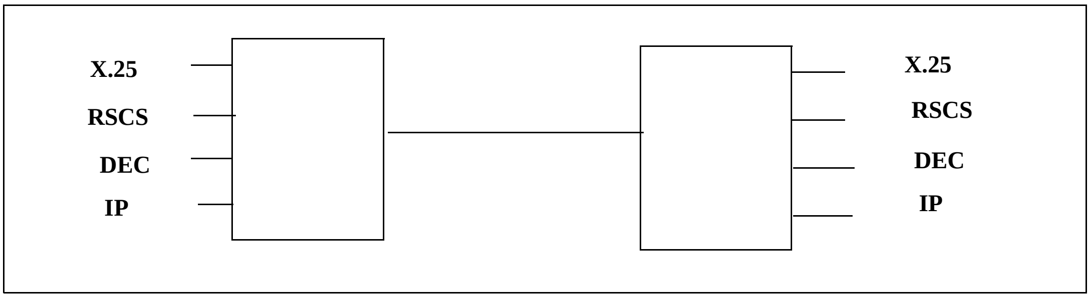

Fig 2. The Nordunet Plug, seen as gateway

The idea was presented as if the plug implemented a gateway between all the networks as illustrated by fig.1. That was, however, not exactly the case. The plug only provided access to a shared backbone network as illustrated by fig 2. An IBM computer running EARN/RSCS protocols could communicate only with another computer also running the same protocols. There was no gateway enabling communications between, say, an RSCS and an IP based network.

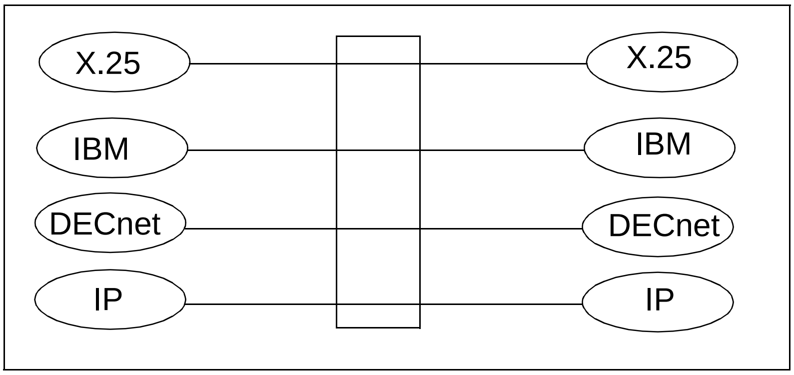

Fig 3. The Nordunet Plug, as shared backbone

The EARN idea received strong support. Løvdal and Brunell got hold of the EARN lines through some very quick decisions, and the implementation of a Nordic network based on the "Nordunet plug" idea started. They succeeded in finding products making its implementation quite straight forward. First, Vitalink Ethernet bridges were connected to the EARN lines. This means that Nordunet was essentially an Ethernet. To these Vitalink boxes the project linked IP routers, X.25 switches and EARN “routers.” For all these protocols there were high quality products available that could be linked to the Vitalink Ethernet bridges.

This solution had implications beyond enabling communication across the backbone. The EARN network was originally designed by a centralized IBM unit and was based on a coherent line structure and network topology. Such coherent topology would be difficult to design by an organization containing so many conflicting interests as the Nordunet project. However, the EARN topology meant that the Nordunet network was designed in a way well prepared for further growth.

Further, the EARN backbone also included a connection to the rest of the global EARN network. A shared Nordic line to ARPANET was established and connected to the central EARN node in Stockholm. 64 KB lines to CERN for HEPnet were also connected.

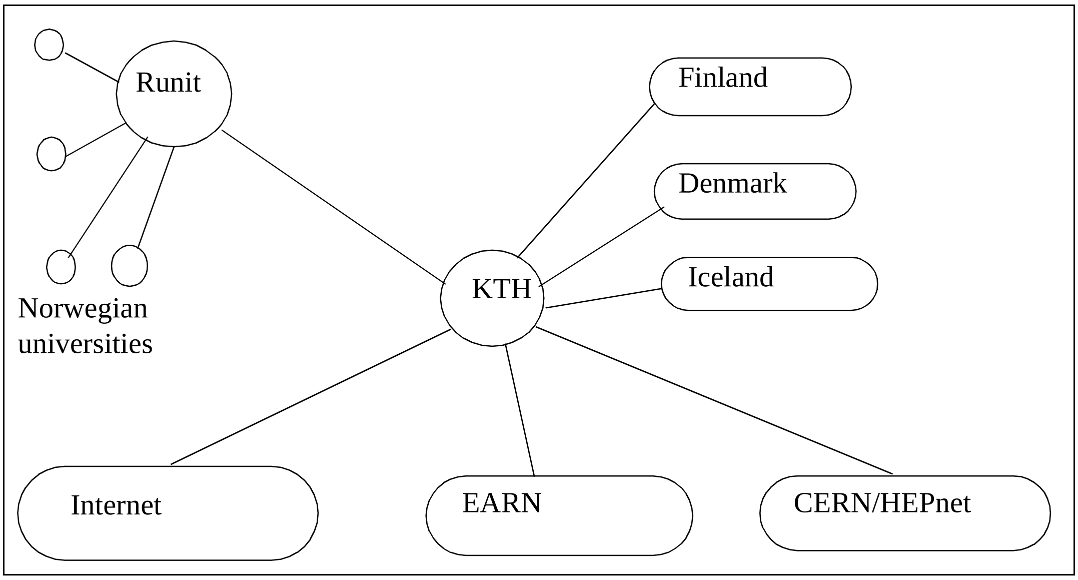

Fig 4. The Nordunet topology

4.2.2 Strategy element 2: Application protocol gateways

Having established a shared backbone, the important next step was of course the establishment of higher level services like e-mail, file transfer, remote job entry (considered very, very important at that time to share computing resources for number crunching), etc. As most of the networks in use had such services based on proprietary protocols, the task for the Nordunet project was to establish gateways between these. A large activity aiming at exactly that was set up. When gateways at the application level were established, full interoperability would be achieved. A gateway at the transport level would do the job if there were products available at the application level (e-mail, file transfer, etc.) on all platforms implementing the same protocols. Such products did not exist.

Before this, users in the Nordic countries used gateways running on computers in the US to transfer e-mail between computers running different e-mail systems. That meant that sending an e-mail between two computers standing next to each other, the e-mail had to be transferred across the Atlantic, converted by the gateway in the US, and finally transferred back again. The Nordunet established a gateway service between the major e-mail systems used. The service was based on software developed at CERN.

File transfer gateways are difficult to develop as it requires conversion on the fly. CERN had a gateway between file transfer protocols, called GIFT (General Interface for FIle Transfer), running on VAX/VMS computers. An operational service was established at CERN. It linked the services developed within the Calibux network (often called "Blue book"), DECnet, the Internet (ftp), and EARN networks. The gateway worked very well at CERN. Within Nordunet the Finnish partners were delegated the task of establishing an operational gateway service based on the same software. This effort was, however, given up as the negotiations about conditions for getting access to the software failed. In spite of this, a close collaboration emerged between the Nordunet project and CERN people. They were “friends in spirit” - having OSI as the primary long term objective, but at the same time concentrating on delivering operational services to the users.

4.3 From intermediate to permanent solution

When the Nordunet Plug was in operation, a new situation was created. Users started to use the network. The network services had to be maintained and operated. And users’ experiences and interests had to be accounted for when making decisions about the future changes to the network. Both the maintenance and operation work as well as the use of the network were influenced by the way the network - and in particular the “plug” as its core - were designed. The “plug” became an actor playing a central role in the future of the network.

Most design activities were directed towards minor, but important and necessary, improvements of the net that its use disclosed. Fewer resources were left for working on long term issues. However, in the Nordunet community, long term issues were still considered important. And the researchers involved continued their work on OSI protocols and their standardization. The war between Internet/IP and OSI/X.25 continued. The OSI supporters believed as strongly as ever that OSI, including X.25, was the ultimate solution. Some, however, turned their focus more towards practical solutions. Among these were Einar Løvdal, fighting for making bridges to the growing IP communities.

In parallel with the implementation and early use phase of the “plug,” other things happened. Unix diffused fast in academic institutions, and the ARPANET was growing fast as its protocols were implemented on more platforms and created more local IP communities (in LANs). On the other hand, there was in practical terms no progress within the OSI project.

The increased availability of IP on more platforms led to an increase in use of “dual stack” solutions, i.e. installing more than one protocol stack on a computer linking it to more than one network. Each protocol stack is then used to communicate with specific communities. This phenomenon was in particular common among users of DEC computers. Initially they were using DECnet protocols to communicate with locals, or, for instance, fellow researchers using HEPnet, and IP to communicate with ARPANET users.

The shared backbone, the e-mail gateway, and “dual stack” solutions created a high of interoperability among Nordunet users. And individual users could, for most purposes, choose which protocols they preferred - they could switch from one to another based on personal preferences. And as IP and ARPANET were diffusing fast, more and more users found it most convenient to use IP. This led to a smooth, unplanned, and uncoordinated transition of the Nordunet into an IP based network.

One important element behind the rapid growth of the use of IP inside Nordunet was the fact that ARPANET’s DNS service made it easy to scale up an IP network. In fact, this can be done by just giving a new computer and address and hook it on and enter its address and connection point into DNS. No change is required in the rest of the network. All the network needs to know about the existence of the new node is taken care of by DNS. For this reason, the IP network could grow without requiring any work by the network operators. And the OSI enthusiasts could not do anything to stop it either.

One important task in this period was the definition and implementation of a unified address structure for the whole Nordunet. This task was carried out successfully. The coherent network topology and the unified addressing structure implemented were also important contributions to make the network scalable.

4.4 Nordunet and Europe

From the very beginning, participating in European activities was important for the Nordunet project. The project also meant that the Nordic countries operated as one actor on the European level. This helped them coming into an influential position. They were considered a "great power" in line with UK, France and (at that time - West-) Germany. However, the relationships changed when Nordunet decided to implement the "plug." This meant that the project no longer was going for a pure OSI strategy. For this reason the Nordic countries were seen as traitors.

This made the collaboration difficult for some time. But as OSI continued not to deliver and the pragmatic Nordunet strategy proved to be very successful, more people got interested in similar pragmatic approaches. The collaboration with the CERN community is already mentioned. Further, the academic network communities in the Netherlands and Switzerland moved towards the same approach.

Because of its pragmatic strategy and practical success, the Nordunet had significant influence on what happened in Europe in total. This means that the project contributed in important ways to the diffusion of IP and ARPANET/Internet in Europe - and reduced the possibilities for OSI to succeed.

5 Lessons to be learned

The Nordic countries have been among those where computer networks in general and the Internet in particular have been most widely diffused and most heavily used. (In some periods there have been relatively more Internet user in Norway and Sweden than even the US.) I see the Nordunet project and the "plug" in particular as a most important explanation of this. I will in this section discuss in general terms the important role the "plug" played as a gateway. But I will also discuss gateways beyond what is illustrated by the "plug" and the Nordunet project.

The most important role the "Nordunet Plug" was playing as a gateway in this case was the way it enabled and supported a "rational" process for designing this kind of large scale infrastructures.

5.1 Allowing experimentation and learning

Experimental design of large scale networks and infrastructures is indeed problematic, but nevertheless the most important success criterum. It is absolutely impossible to develop several different alternatives and test them. To find out what works well in the real world, the solutions have to be used in real work by maybe thousands of users. The development of the kind of technological solutions the Nordunet aimed at was about designing something with a significant degree of novelty. Accordingly, a working solution could not be developed without acquiring the knowledge that was lacking. What is a good and well working solution is an empirical question - it cannot be derived from theory. Accordingly, some kind of experimentation is the only way to produce this knowledge. This dilemma has to be solved. On a general level this can be done by adopting some kind of evolutionary approach. This means that we develop one piece at the time, and that this piece is at the level of complexity where experimentation may take place. The problem with this approach is that it may lead us into path-dependent processes and lock-ins. Each piece developed has to be integrated with the existing ones, and accordingly design assumptions made when developing the early pieces may turn out to be inappropriate for the later ones. But at that time the investments made are too big to change this.

The Nordunet project team adopted a mere specification driven approach - first agreeing on needs, then specify the solutions, and implement and use them. Other actors involved advocated more evolutionary design models, arguing that the overall solution should be based on the one they were already using. But this strategy did not work because those already using a network could not accept any of the others - the costs they had to pay to switch were too high. Accordingly another kind of evolutionary process had to be adopted. And the fact that the Nordunet Plug enabled this is the main rationale behind its success. First, the Plug gave all users access to a shared backbone. This was an important achievement from the perspective of all actors being involved because:

- The solution could easily be implemented - the knowledge and technology needed were there.
- It offered the users improved services. All of them could through the Plug and the backbone reach new communicating partners.
- It was a step forward towards the “final” solution independent of how this would look. From the solution established one could - in principle - equally easy move towards any of the alternatives advocated. For this reason the solution was a compromise that all actors involved easily could accept.
- It allowed extended use of all existing alternatives, accordingly it enabled extended experimentation and generation of new knowledge about how the “final” solutions should look - or at least what the most appropriate next steps could be.

I mentioned above that evolutionary development processes may lead to a state of lock-in. Gateways are also important tools in this respect because they help transforming one network form running one protocol standard into another network running another standard.

5.2 User involvement and democratic design processes

Large scale information infrastructures have many users. User influence and involvement in technological design is a topic involving many issues. One aspect is the fact that it is only the users who can decide whether a specific technology is appropriate for their work tasks (or other kinds of use processes) or not. Accordingly they must be involved in the design process in one way or another to inform the designers about their needs and to judge whether a specific technology is acceptable or not. In addition, how and to what extent users have been involved in the design of a solution has significant implications on how the organizational implementation process unfolds, how the solution is used, and what benefits that are gained. The general trend is that the more the users have been involved the more positive they are towards the use of the technology, the smoother the implementation process is running, and the more active the users are in learning how to use the solution in most beneficial ways. User participation in and influence over the design process may also be argued from a political perspective. Such participation is simply a democratic right.

User influence is, as argued in the previous section, an illusion unless it is based on practical use of one or more alternative solutions in a realistic setting. Users can only give designers trustworthy advice if they have practical experience with the technology.

All these principles apply to the design of infrastructures just as much as any other technology. Compared to information systems it might be seen as even more important. Within an organization, management may decide that a specific solution should be developed and/or implemented and instruct the departments to use it. Concerning the design and implementations of an infrastructure, those involved in projects like Nordunet, or the OSI standardization, have very weak influence over potential users. If the users do not like the technology, they will just not use it.

For all these reasons an evolutionary process which gateways are enabling is crucial.

5.3 Adaptation to changing environments

All technologies are designed to satisfy needs derived from specific ways of living or working. Over time these conditions change and technologies need to adapt to them to remain useful and appropriate. So also with infrastructures. This implies that also standardized network protocols need to be changed. The ongoing transformation of the Internet from running IP version 4 to the new IP version 6 is a paradigm example of this (Hanseth et al. 1996, Monteiro 1998). The new IP protocol is required first of all because the growth of the Internet requires an extended address space. But support beyond what the old version of IP is offering is required by several emerging services and ways of using the Internet. This includes (enhanced) support for security, accounting, boradband networks, real time multi media, etc. (Not all of these are supported satisfactorily by the new version either.)

The IP example also illustrates the fact that an infrastructure generates new requirements as its range and use grow.

As one network or infrastructure and its use grow, the infrastructure will also "meet" other networks that were initially assumed to be independent and generate needs for integrating these. This may be seen as the history of the different networks which were in use before the Nordunet project started and which one wanted to integrate (i.e. HEPnet, EARN, etc.).

Gateways are key tools to enable the change of an infrastructure and (some of) its standards from one version to another and accordingly avoid being trapped in a lock-in situation.

5.4 Living with heterogeneity: Gateways as final solutions

Gateways are important beyond representing compromises and being tools enabling transitions towards "final" solutions. They are often also important components of such "final" solutions. Gateways are interfaces between different but related services. The world is heterogeneous. There is a high number of computer networks and information infrastructures around - and the number is currently rapidly increasing. Many of the networks are and will be related but still different. This means that they should be connected to enable some kind of interoperation at the same time as they should be kept as separate as possible to make their co-evolution with their changing environment easier and simpler. This is what happened with the developemnt of AC and DC together with the rotary converter. Another example can be EDI networks in health care. Most information in such networks is exchanged between institutions within the same country. However, some information is also exchanged across national borders. So in principle one might argue that there should be only one set of coherent and consistent set of global standards. Such a set of standards has indeed been tried defined at the European level - with modest success to say the least (Hanseth and Monteiro 1997). The problem is that the variation among national health care systems requires very complex standards if the standards are to satisfy all needs. Experience so far indicates that the standards become all too complex to be implemented at all (ibid.). An alternative approach would be to develop national standards and then gateways to enable the (limited - but slowly increasing) transnational information exchange.

When larger networks are already built, linking them through gateways may be easier and cheaper than moving to one shared protocol although the functionality will be well covered by one such universal standard. This seems to be the case in the world of e-mail. Several protocols and networks exist: The Internet based on SMTP, X.400 based networks, and networks based on proprietary protocols and systems like cc:mail Notes, Microsoft Exchange, etc. Gateways are established between these networks and protocols. Although they are not translating perfectly, in practice most users experience their e-mail system as providing access to a service through which any e-mail user can be reached.

Another example may be the “global” web. This network gives us access to any information - in any data base - through a web browser. A key tool enabling this are various gateways between web servers and the data bases where the information is actually stored. Gateway technologies here include in particular cgi scripts. These gateways link together networks internally in an organization an external ones. One might imagine that there could be one universal solution used to access a database both from outside and inside an organization. However, this is not a good solution for at least two reasons:

1. The Web technology is developing rapidly. How to integrate corporate networks and the global Internet is yet an unsettled issue. How to do this is a matter of experiment for a long time. Such experiments require modular and flexible solutions - one must be able to change the modules independently. This requires interfaces between the modules, and what is going on inside the interface is irrelevant for outsiders. Gateways are exactly the interfaces needed to make larger networks flexible.
2. There is no reason to believe that the requirements from and service provided to insiders and outsiders will be basically the same. Accordingly, insiders and outsiders will see a system as completely different, and need accordingly to get access to it through different technologies.

6 Conclusion

I have in this article presented the (hi)story about the Nordunet project and its “plug.” This is a (hi)story about how the Internet “won” the “religious war” about computer communication protocol standards in Scandinavia. This history teaches us important lessons about how the Nordic countries (except Denmark) became the leading ones in the adoption and use of the Internet. On a more general level this story also teaches us an important lesson about the importance of gateways in the design and establishment of large scale computer networks and information infrastructures. It is a universal truth the development of such technologies requires standards. And this story teaches us that gateways are equally important. The main conclusion to be drawn is that what really matters in the development of such technologies is to combine and balance the use of gateways and standards in a proper way.

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