Interconnection between Computer Networks in Germany

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Abstract:

The "Deutsche Forschungsnetz - DFN" is an ensemble of interconnected computer systems in the German scientific community. It bases on standardized public services (CCITT) on the lower communication layers. For the higher levels protocols are used which follow as closely as possible the upcoming ISO-standards. Thus, a future-oriented, vendor-independent communication structure is offered to scientific users and to which other communication architectures might be connected according to the principles of the OSI-reference model. In the context of the main task of DFN - serving the scientific community - the influence of existing and the impact on future implementations are studied in this contribution. Structural concepts for interconnection to contemporary architectures and technical guidelines are derived from theoretical aspects and illustrated by examples in the environment of DFN.

1 A Short Introduction into DFN

"DFN - Deutsches Forschungsnetz" litterally means "German research network", a term which is often used in different meanings: It might refer to a large development and implementation project /DF84-1/, to a user community, or to a set of special hard- and software modules running under different operating systems /DF85-3/ which follow the principles of the reference model for Open Systems Interconnection - OSI /IS83-1/ and offer computer-based communication services between different endsystems /Tr85/. If a communication protocol defines, how a communication service is being performed, then DFN - in the meaning this term is used here - is completely described by its protocols which are published in a manual. This protocol handbook /DF85-1/ is a compulsory source for every implementor within DFN.

To access the lower three layers of the OSI-model DFN relies presently on the CCITT-recommendation X.25 /CC80-1/. Layer 4, the transport layer /IS83-2/, is described by the recommendation T.70. Basic services like "File Transfer" and e"Rmote Job Entry" are implemented on top of the transport layer on the base of nation-wide protocols; the international standardisation lacks so far common agreements in these areas. The character-oriented "Dialogue" according to X.3/ X.28 /X.29 /CC80-1/ used in DFN is built up directly above X.25. Other DFN-dialogue services use the facilities of T.70: Pilot-implementations of a "Virtual Terminal" protocol allow format-oriented dialogue in a subset of the DFN-environment /EG84/; a "Graphical Workstation-Interface" enables a "Graphical Dialogue" between different host systems and remote graphical work-stations /Eg85/. For mailing between computer-based message systems the CCITT-recommendations X.400 ff. /CC84/ are implemented.

In DFN the most popular host systems (and their operating systems) are interconnected via public data services (see fig. 1) and communication services, mentioned already, are implemented on top of them.

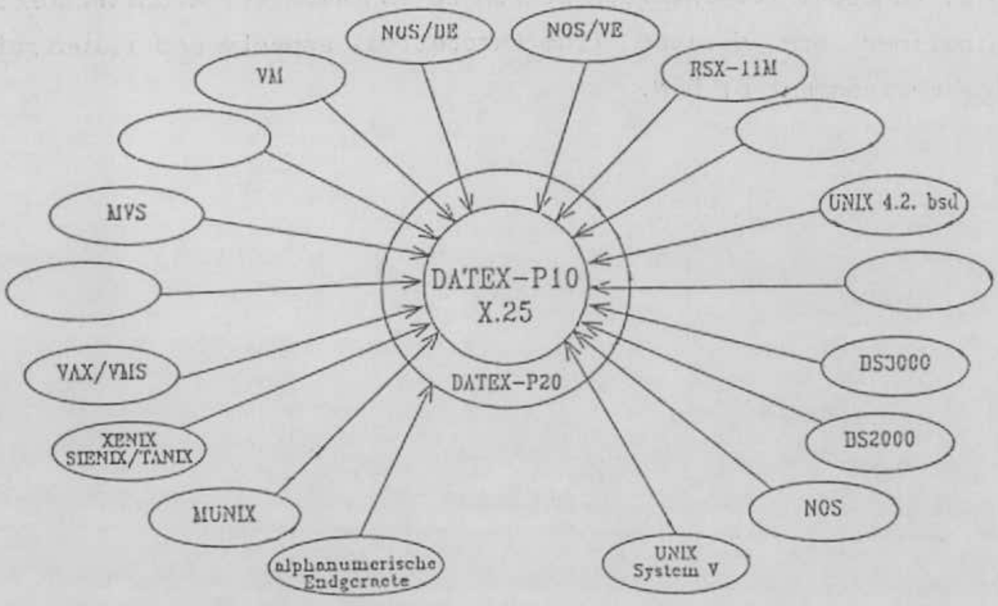

Fig. 1 Interconnectable Host Systems in DFN

The scientific users in Germany belong truely to the early supporters of the idea to built up computer communication services with the clearly outspoken aim towards a support of CCITT- and/or ISO-standards. They form an important nationwide and even internationally organized community, but operate in an extremly heterogeneous world of hard- and software systems. Thus, they have an urgent need to communicate via common application-oriented protocols. Nevertheless, a project like DFN needs more helpful support than only the idea of computer-based communication services on which distributed users "in-spe" have mutually agreed on. Different circumstances forced the BMFT - the German department for research and technology in 1983 - to provide a considerable grant for such a project:

1) Some years ago, the computer industry became aware of the importance of internationally standardized protocols and began, reluctantly at first, to develop and produce corresponding communication products, mainly for character-oriented dialogue services between low-cost terminals and hosts over packet-switched networks.

2) At about the same time the German /BP79/ as well as other PTTs started to offer services on the network layer which eased at least the basic interconnection problems between hosts and terminals.

3) Experience from earlier communication projects in Germany basing on the upcoming X.25 service could form a solid base for an internationally agreed and user-accepted future-oriented communication system.

A project like DFN still incorporated some uncertain sights into the future. A set of communication services like those of DFN, realizes only one specific way among others to implement the OSI-reference model. This model is still incomplete in terms of implementational and operational aspects. Beyond that, other important aspects are additionally essential for the acceptance of DFN and discussed in detail in the following: Interconnection to other communities, techniques and competetive implementations. The users organized in the DFN-association are willing to promote standardized protocols but need access via communication services as soon as possible. Thus, there are other systems - in a broader sense of the word than above - to which interconnection has to take place.

2. Interconnection Needs in DFN

There are large networks in operation, established since many years which provide different, well-accepted services. They are characterized as formed by an organization which in the real sense of the word operates a "network", a set of leased lines connected via switching nodes to the different computers of the community. These networks naturally cannot follow the OSI-architecture and must use other protocols than DFN because they were implemented at a time well ahead of the ideas of an heterogeneous communication world. The operational mode of such "closed" user groups does not allow "any-to-any-communication" and appears to be contradictory to the principles of the Open Systems Interconnection. Nevertheless, there is a remarkable amount of scientific users and potential communication partners hooked up already to those "classical" networks. The network EARN is an actual example; its services base on widely accepted and since a long time established IBM protocols. Thus, it should be a natural effort to interconnect the DFN users to those networks sometimes viewed as "relicts" of the past.

The OSI-architecture is often considered as a perfect remedy which makes heterogenous computer systems communicate easily with each other. This almost seductive appeal drives more and more vendors to announce the embedding of their own communication products in the reference model. Nevertheless, such a company´s policy cannot guarantee benefits for the users residing on systems of different vendors but leads rather at least on application level to a nationwide patchwork of incompatible "communication isles": Interconnection to different realizations of the OSI-architecture forms a second area of problems. At least, those implementations are not completely incompatible with DFN and have a common understanding in terms of layered structure and service requirements.

As a third kind of interconnection demands communication via local area networks (LAN) between rather closely coupled processes meets with the postulate of an open wide area communication. Especially in the scientific community an installation of a LAN and interconnection to a wide area network (WAN) must not be considered as an incisive cut of user habits. In large computational centers with time-sharing facilities the cable consuming coupling of individual terminals might be replaced by a connection over a common medium. It´s high speed data link offers an additional opportunity to replace "simple" terminals by "intelligent" work-stations. These work-stations, process control computers and even complex computerized lab-equipment (like spectrometers) have to considered as equally entitled endsystems of a LAN from which via a WAN the computing power of remote mainframes should be accessable as the resources of other LANs.

There are new communication technologies upcoming for which the interconnection - or better the integration - into DFN is an extremly important indicator for the ongoing success of the DFN-communication world. Key-words like satellite links, ISDN, wide area fiber optics indicate the techical changes and developments. Undoubtless, DFN-protocols and services must be available for users who for instance need to transfer bulk data and like to avoid the tariffs in packet switched networks which might to be unappropriately high for certain applications. Thus, last not least new wide area communication techniques need to be interconnected with the "classic" DFN.

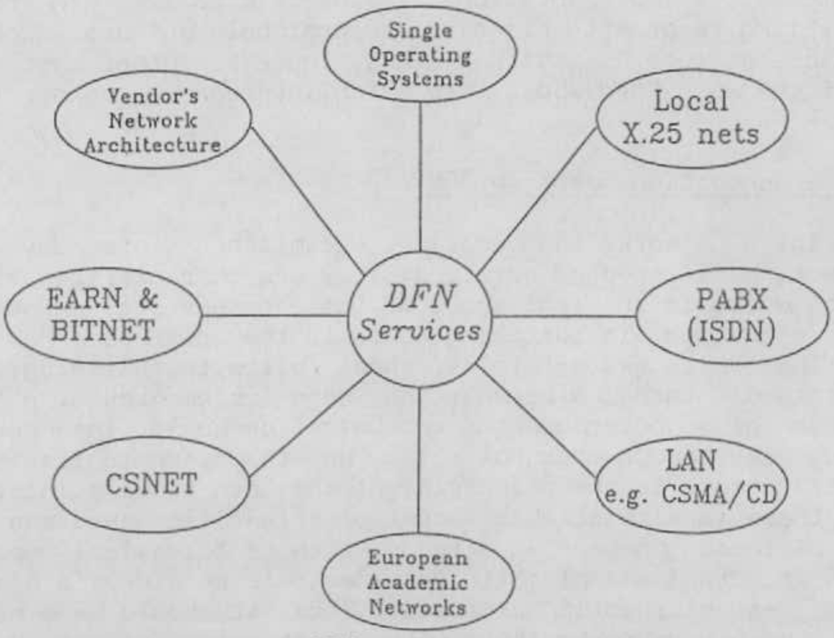

Fig. 2 Interconnection Scenario in DFN

Four different problem areas have been identified as the interconnection issue of the DFN-world: DFN-user services have to be intergated into "classical" networks, other OSI-architectures, LANs and new technologies; an overview is given in figure 2.

3 Interconnection Gateways - An Architectural Reference Model in DFN

3.1 Open Relay Systems (OSI)

In order to find a common base and understanding of these problems a general model for interconnection in accordance with the OSI-model has been developed. Some definitions, described in the ISO-reference model for Open System Interconnection should be recalled to mind:

A "real system" is a set of one or more computers; if it is an "Open System" it must not have any interconnection problems in this context (as this is not the fact for any "non-DFN" set of communicating computers these are addressed as a "foreign system" in the following; consequently a "foreign system" can be realized as well by only one computer or a non-OSI set of computers).

In the OSI-model relays are pròposed: Interconnection via relays covers exclusively subnetwork-connecting, data-link-connections and data-circuits. A relay system resides on layer 3 and is defined as rather interpretating addresses and rerouting network protocol data units.

Two questions arise: Is there a need for handling relay problems in DFN in order to fulfill the demands of the OSI-structure and furthermore, are the interconnection problems solvable by means of OSI-relays? A general answer to those questions would be that hierarchical addressing schemes seem to be either not well understood or not considered at all by the authors of the OSI-model.

According to the OSI-model, any application hosted by some computer is properly identified by the network address (administered in DFN by the PTT) which points out the host and the transport-address which directs to one of several DFN-applications (administered by the operating system of that host). Additionally, any application system - and consequently the DFN-application systems as well - might define its very own naming principle which then covers up the bottom-up ideas of the OSI-hierarchie by the top-down neccessities of application-oriented naming trees.

An example might clarify the situation: the recommendation X.400 for computer based message systems distinguishes between message transfer agents which provide a transfer service on the application layer (!) and user agents which provide the interface to the user. Using the OSI-proposed adressing scheme (the network depicts via relays the endsystem where the user resides) it should exist a direct mapping between a DTE-address (terminal) and the user of such a mailing system. That does not work anymore if the user resides in multi-process /multi-user environment. Neither X.121 /CC80-2/ corresponds to the organisational needs of a then necessary symbolic naming scheme nor a sender of a message must explicitly know where in terms of DTE-address the receiver of message resides. Thus, each message transfer agent in X.400 acts as a relay system but on application (!) level. A similar relay operation is needed if a hierarchical naming principle for files is used and one DFN-hosts is the root, other DFN-hosts are the leaves of that naming tree.

As a result of these observation can be stated, that either relaying is performed by the PTTs and the X.25 branches respectively (layer 3) or it is an inherent part of the application service and has to be specified in that specific communication layer. The definition of Open Relay Systems according to the OSI-model is useless for systems like DFN needs some more work concerning common understanding and does not help to solve the here stated interconnection problems.

3.2 Mapping Systems and Gateways

The general approach to the interconnection problem is more complex. In the first place the existing and probably well accepted (non-OSI) architectures must not be modified from the user's point of view. The available application software and/or lower basic communication modules integrated in the operating systems must remain unchanged unless one is willing to rebuild completely this environment.

Thus, interconnection is satisfied only by regarding the differently communicating sets of computers as homogeneous subnets and coupling them through a "mapping system" /EG83/. This mapping might be performed on any, up to highest communication layer. Nevertheless, the sole attentation to this principle will not allow connection of a further system and requires "any-to-any-mapping" which leads to n*(n-1) mapping systems to interconnect n systems. To bringing forth the ideas of open systems the different types of communication architectures are coupled via interconnection gateways which map always into a "neutral" communication architecture with overall understood protocols.

The DFN as a whole is now considered as an OSI-"system" which offers an ideal base for such a "neutral" architecture: DFN is an open reference system with closely connected computers and terminals. The mapping towards DFN allows integration and therefore communication of "non-open" or "foreign" systems with DFN and, additionally, communication between not directly coupled foreign systems by using DFN as an "Open (Interconnection) Gateway System" (fig. 3).

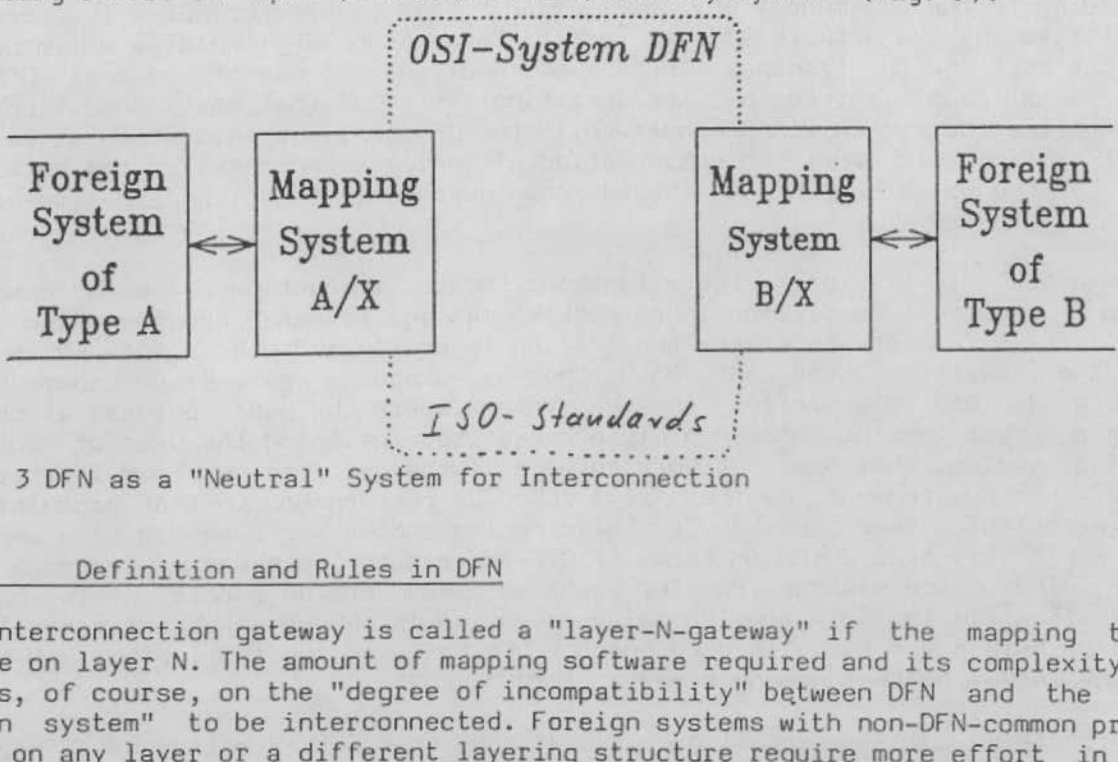

Fig. 3 DFN as a "Neutral" System for Interconnection

3.3 Definition and Rules in DFN

An interconnection gateway is called a "layer-N-gateway" if the mapping takes place on layer N. The amount of mapping software required and its complexity depends, of course, on the "degree of incompatibility" between DFN and the "foreign system" to be interconnected. Foreign systems with non-DFN-common protocols on any layer or a different layering structure require more effort in the gateway than those which share for instance the transport protocol (T.70 /ISO transport class 0). In order to provide a common understanding in the DFN-community for the mapping by means of a gateway the following rules for a reference architecture are defined:

1. Mapping can take place on any OSI-layer except layer 5 or 6.

2. Mapping is provided by one or more (N+1)-entities within the (N+1) layer which use a service provided by the lower layers and might require enhancement of that lower layer. It will not influence the service required by the next higher layer

3. Mapping takes place in general between different protocols <u>within</u> the layer and is not considered as an action using the services offered. Only mapping on layer 7 might be performed on service level as well.

Commenting rule 1, it might be surprising that layer 5 and 6 are excempted from hosting a mapping system. Only in layer 7 or on the lower layers 1-4 a gateway can be implemented. Nevertheless, after a thoroughful look into the basic OSI-reference model that is evident. Communication requires always a description of a behaviour in time; in the session (5) and the presentation (6) layer only subsets of functions are defined. These functions are applicapable by layer-7-protocols between partners uniquely addressed on layer 4. Thus, it is unlikely that one application protocol uses two different sets of session services which might have to be "mapped" into each other. A common syntax, defined in the presentation layer helps to convert data from one physical representation into another, but it likewise does not demand a gateway-system because no communication takes place.

Rule 2 is somewhat contradictory to an OSI-statement which says that any relay in communication is not known by the lower layer. Another OSI-statement, nevertheless, allows the usage of sublayers for routing and relaying functions in layer 3 - the network layer and to use the services of the lower layer to perform this task. Still, this proceeding does not satisfy real gateway problems. A lower layer service <u>must</u> know about interconnection taking place on a higher layer because it might be enhanced in order to fulfill the requirements of the service which is expected on the interconnected next higher layer.

From the OSI-reference-model nothing at all can be derived how mapping should take place or has to be implemented. It still remains open if software interconnecting systems on layer N is a "user" of the services offered by the different systems on layer N and therefore resides on layer N+1 or has it to be considered as an integrated part of layer N. In other words, are service specifications sufficcient in order to specify a gateway or should the protocol specifications used as the common sources, what are the elements to be mapped? Rule 3 states that interconnection is understood in DFN as the mapping of one or more protocol-data-units of one protocol to one or more protocol-data-units of the other protocol which naturally takes place <u>within</u> the corresponding layer. Only layer 7 offers the possibility to map either the protocols or the services into each other which leads to different results in the behaviour for the user. In all other cases no common application service can be implemented on top between different systems if mapping takes place between services

4 Interconnection Architectures

4.1 Systems using DFN-Protocols and Services

For any (private) set of computers using already the DFN-technology no problem arises for the basic interconnection to the nationwide DFN-community. Private gateways, here this term is used for automatic branch exchange systems (PABX), must interconnect with the public services of the PTTs. According to the German law, such a subnet is allowed only in a local environment and is operated completely by the owner.

Interconnection to systems in other countries is performed by the German PTT with gateways using the X.75-recommendations /CC80-2/. Nevertheless a layer-N-gateway has to be installed if a higher level protocol at layer N is different. Thus, if in a private or in a X.25/T.70-environment of another country a file transfer (FT) protocol different from DFN is used a layer-7-gateway has to interconnect these two FT-protocols.

4.2 Distributed Endsystems and Subnets

To define the lower layers in different LANs the IEEE started efforts to develop a common understanding of LAN-architectures /IE83/ similar to the Open System Interconnection and to define a framework for the lower layers of LANs documented in the IEEE 802.x standards. For users it might still be of some interest to implement the DFN-application protocols to be used in the local environment and in wide area comunication as well. The mappping has to take place either on network or on transport layer, in order to provide a common view of what is called a "system" in the OSI-environment. A LAN is considered as a "foreign" system which's meaning consequently includes these two options. The specific decision depends on the answers of the the following questions.

1) What kind of network service has to be provided at the endsystem (connection-less vs. connection-oriented)?

2) How should endsystems and processes in the endsystems be addressed?

3) Should public services (e.g. Teletex) or a dialogue following X.28 /X.29 be provided?

These resulting alternatives can also be discussed in regard to the interconnection of "classical" networks or other wide-area "non-DFN"-OSI-systems: Any foreign system (either a single computer or as it is dicussed here a set of computers) might be interconnected to DFN either as as a distributed endsystem of DFN or as a subnetwork.

It serves as one distributed endsystem for DFN if it has no addressable entities on the network layer (fig. 4). The DFN-network layer ends in the gateway system which results in rather simple gateway architecture and in the fact that the foreign system is addressable only by just one DTE-address. Either the T.70-address has to be used to pick out the endsystem or a specific interpretation of names at application layer has to be implemented. Any direct connection of X.28/X.29-hard- or software is impossible because the foreign system does not provide a X.25-service on which these protocols base directly. On transport layer a different protocol (e.g. ISO-class 4) can be used or a connection-less service is still offered internally.

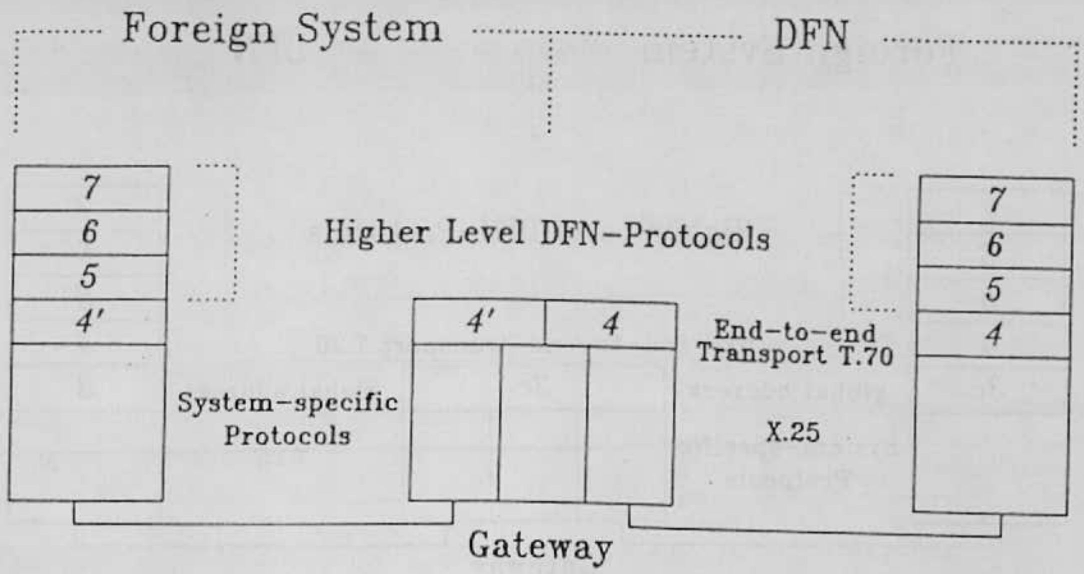

Fig. 4 Interconnection of a Foreign System on Transport Layer

Consequently, advantages of this solution are :

1) the internal structure of the foreign system remains unchanged on network layer

2) there is only one transport protocol in an endsystem of the foreign systems

Both properties are important for contemporary LAN-architectures but inhere the following disadvantages:

1) Routing takes place in transport layer

2) No adressing of endsystem via network-address

3) No portability of layer 7 implementations into different environments

Especially to interconnect large wide-area networks (e.g. SNA, Transdata) to DFN the distributed endsystem approach is obviously not the best choice. Those foreign systems to be interconnected consist from the "naive" user´s point of view of several endsystems which have to be addressable one-by-one. Therefore, a design of a global network layer must be oriented to two goals: the interface of the network layer should be in conformance with the ISO definition of the network service and, in order to interwork properly with public (CCITT-) networks, features available at the DTE/DCE interface should be available as well at the endsystem in the communication architecture to be interconnected.

As a consequence such a set or ensemble of endsystems can be considered as a subnet from DFN by being addressable via different DTE-(sub-)addresses (fig. 5). Nevertheless, such a foreign system has to offer a connection-oriented network layer which, for instance in LANs, is not implemented and might collide with some special application protocols requiring connection-less services. The then commonly usable transport protocol makes implementations of DFN-application protocols (layer 7) portable.

The Foreign System – a subnet of DFN

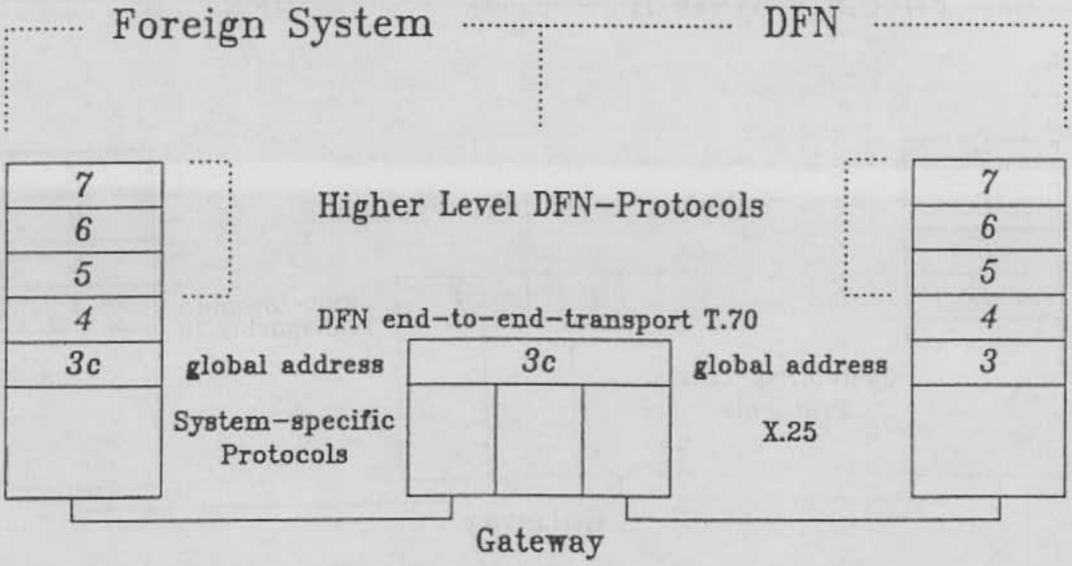

Fig. 5 Interconnection of a Foreign System on Network Layer

At present time standardization has not yet reached a stable stage where interconnection on layer 3 or 4 can be assumed as being completely understood and covering the different needs of LANs or even new upcoming techniques in wide area communication. The DFN-association will stimulate industry to come up with standardized solutions as early as possible and recommends itself as a test-bed for new communication technologies which follow the general rule to be interconnectable in either layer 3 or 4.

4.3 Layer-7-Gateways

Foreign systems which are either completely or from a higher layer upwards incompatible with DFN have to be interconnected via a layer-7-gateway. It either maps the application protocols (fig.6 left) or the application services (fig. 6 right) onto each other.

Synchroneous Operation Mode

Example:
File Transfer from DFN
to Foreign System

1. *Confirm DFN-Connection*
2. *Open Foreign System-Connection*
3. *Perform File Transfer from DFN to Foreign System componentwise*
4. *Disconnect Connection to Foreign System*
5. *Disconnect DFN-Connection*

requires:
- change of communication sofware
- 1:1 mapping of file transfer
- availability of three hosts'

Asynchroneous Operation Mode

Example:
File Transfer from DFN
to Foreign System

1. *Confirm DFN-Connection*
2. *Perform File Transfer from DFN*
3. *Store File internally*
4. *Disconnect DFN-Connection*
5. *Open Connection to Foreign System*
6. *Perform File Transfer to Foreign System*
7. *Disconnect Connection to Foreign System*
8. *Delete File internally*

requires:
- no change of communication sofware
- execution request for file transfer in to foreign system
- resources for file storage

Fig. 6 Synchroneous Protocol- and Asynchroneous Service-Mapping

On the left side file transfer takes place from the DFN-user to the user in the foreign system with an unvisible "on the fly"-mapping of protocol data units in the gateway. On the right side mapping is performed on service level - two complete services are interconnected - which results in a "store-and-forward" operation of files in the gateway. The interconnection between the two services can be performed either automatically by a task, remotely requested from either side, or by manual intervention of the user via dialogue.

Advantages of the (synchroneous) on-the-fly mapping are obvious but this operational principle requires a permanent "receive-ready" state in the hosts of the foreign systems, the unique correlation between endsystems and an "owner", and the possibility of one-to-one-mapping of the different application protocols. Especially the interconnection of personal computers to DFN via some communication architecture might collide with these requirements.

(Asynchroneous) store-and-forward mapping does not require those stringent operational principles; as a matter of fact the foreign systems environment might organize itself completely independent from the "public" DFN services. In general, those gateways are better identified as a "communication server" which serves a specific application like file transfer, print or plot I/O for the community in the foreign system.

5 Gateways and Relays / Examples in DFN

5.1 "Gateways" on the Lower Layers

For mapping in the lower layers of DFN at present time only X.25 private switches can be identified as gateways in the above given sense. They might adjust different external and internal line speeds and map the DTE-subaddresses to the physical lines according to an Open Relay System in the OSI-model. The techniques are well established and no development spawned by the DFN-association is needed.

5.2 Gateways on Layer 3

For the special mapping of the DFN-dialogue service a simple gateway-system available as a product is very often used /Ba85/. With an "inverted" PAD-unit (packet assembly/dissassembly) terminal I/O ports of foreign systems can be connected to the X.25 network layer. This enables for instance the interconnection of sets of personal computers to DFN on dialogue level.

A new operating system (Control Data NOS/VE) using a standardized transport protocol between its distributed resources demands a rather interesting interconnection architecture. The internal transport service in a "LAN-like" system architecture transfers a support layer in order to provide a network layer in the endsystems according to X.25 (fig. 7) on which applications will be build on /DF84-3/.

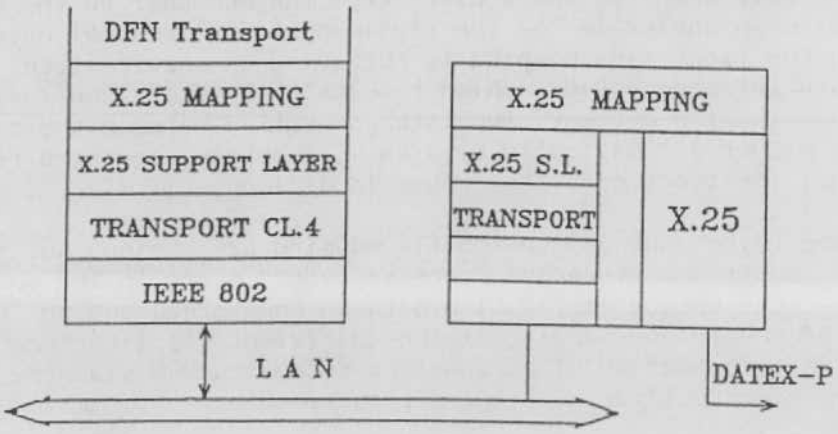

Fig. 7 Interconnection Architecture within NOS/VE

This architecture complies with the ideas of a layer-3-gateway (extended X.121 addressing into the foreign system) and makes the usage of a transport service (T.70) and additionally of all higer level protocols possible in common with DFN. Nevertheless, it violates the layering structure of the OSI-model: the ISO-transport protocol class 4 (layer 4) remains to offer the quality of service which is not available in layer 3 of a LAN due to its technology but transports "only" a layer-3-service in order to make it available in the endsystem.

Concerning new techniques like ISDN there is evidence that the German PTT will use T.70 as well for its public services. With a gateway between DATEX-P (X.25) and ISDN which has to be provided by the PTT no major problems are to be seen for the DFN-service in general.

5.3 Layer-4-Gateways

Some established vendor´s products are already installed with the DFN-community (e.g. Inter-Lan, Net/One); planning starts for products using the standardized ISO class 4 transport protocol (e.g. OpenNet). A DFN-gateway has to connect these products with T.70 and to comply with the different adressing schemes which might be a cumbersome problem. Due to urgent user´s needs expressed so far only one project covers at present time this area by interconnection a vendor´s architecture (XNS) with DFN /He84/. Here on the "Internet Transport Protocol" special real-time-applications will be implemented. In order to avoid changes in the XNS software modules a mapping to the DFN transport protocol requires a "Transport-Enhancement" layer which is performed in a layer-4-gateway. Nevertheless, the DFN-dialogue implemented according to the recommendations directly above X.25 needs special treatment. The operation of the corresponding, standardized hard- or software (e.g. PADs) would require some sort of "Network-Enhancement" in layer 3 of the LAN. Thus, a layer-4-gateway might require a LAN-specific dialogue service on application layer which is then to be mapped in a layer-7-gateway to DFN.

The DFN-association is well aware of other interconnection problems on that layer and expects higher demands with the upcoming usage of personal computers in the community and the increasing installations of LAN architectures /DF85-2/.

5.4 Gateways on Application Layer and for Special Services

5.4.1 Interconnections to a Vendor´s Architecture

For interconnection of different host systems and the communication systems in DECnet-10 a layer-7-gateway maps the DFN-protocols File Transfer and Remote Job Entry into the corresponding DEC-protocols. The DFN-dialogue service must be made available by a second interconnection facility due to its arrangement parallel to the DFN-wide transport service. The DFN-protocol Virtual Terminal, moreover, can be interconnected with installations using SNA or Transdata; a corresponding layer-7-gateway system will soon be available. These gateways allow "on the fly" access to resources and applications in the foreign system environment.

5.4.2 Gateways for Mailing

The project "Mailing in DFN" follows the X.400 recommendations and includes new implementations of message systems as well as the interconnection of existing message systems (KOMEX) or layer-7-gateways to other message networks /HK85/. Additionally EAN, a message system from the University of British Columbia will be installed and becomes an integrated part of the DFN-software. To ease the operational problems, exactly one of these installations will act as the international DFN-gateway to interconnect foreign EAN-systems in order to perform the mapping to non-X.400-systems like CSNET and UUCP.

5.4.3 Interconnection for File Transfer

DFN participates in the project GIFT which connects different File Transfer Protocols via a layer-7-gateway. This gateway system is located at CERN in Geneva and has to perform a layer-7 mapping even if most of the underlying networks operate on X.25. This gateway opens DFN to existing or planned academic networks because international standardisation still lacks a stable file transfer protocol.

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