Standards issues in data communications

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The lack of development in standards and compatibility in the field of data communication and processing requires urgent attention. The author discusses the compatibility issues that arise from the introduction of packet-switching networks, which typify the growing interdependence of computer and communication technologies. Focusing on Canada as a case example, he examines issues relating to the compatibility between the communication services offered by different networks and communication functions used for distributed data processing, and also between the procedures employed to provide these services and functions.

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There is a long history of international standards in telecommunications because of the necessity of obtaining compatibility between different national networks. In the data communications and processing areas, however, standards and compatibility are much less developed: data communications have long been a secondary aspect of data processing, and large computer manufacturers tend to try to sell total data processing systems, so that intersystem compatability is not needed. However, with the increasing cost of software development, compared to hardware costs, there is a growing user need to share software modules and thus avoid the duplication of development costs. Compatibility, therefore, is an essential condition for the realization of the large-scale applications of data communications and processing that will soon be technically feasible.[1]

Background

The area of data communications is characterized by a growing symbiosis between communications and computer technology. Data communication was first used in teleprocessing systems, where computers and terminals were connected through leased or switched telephone channels over which data were transmitted. Gradually, the data processing systems incorporated more and more sophisticated communication functions and the carriers relied on digital and computerized techniques for building their communication networks.

A typical example of the interdependence of computer and communications technologies can be found in packet-switched data networks. The first network developed on this principle was the ARPANET.[2] The principle of packet-switching consists of subdividing the data to be transmitted into a number of packets with a maximum length of several hundred characters, and sending these packets independently through the network. Therefore, the physical transmission circuits between the nodes (switches) of the network (built of mini-computers) can be shared between many different users. Based on this principle, a 'datagram' facility was subsequently proposed as a service to be provided by public data networks.

It has been shown in the French experimental network Cyclades[3] that such a datagram service can be used advantageously for establishing reliable communication between application programs in

[1] International implications of computer communications and possible future developments are discussed by I. de Sola Pool, 'International aspects of computer communications', *Telecommunications Policy*, Vol 1, No 1, 1976, pp 33–51.

[2] Funded by the Advanced Research Projects Agency (ARPA) of the US National Defence Department, the ARPANET was the first large-scale experience with packet-switched data transmission. Still operational, it allows resource sharing between a large number of computer centres in universities and research centres. The main objectives and characteristics are described by L.G. Roberts and B.D. Wessler, 'Computer network development to achieve resource sharing', *Proceedings AFIPS*, 1970, pp 543–549.

host computers and terminals connected through a packet-switched data network. However, for the first generation of services to be offered over the new packet-switched public data networks,[4] the carriers chose what are known as 'virtual circuits'. Virtual circuits resemble real switched circuits in many respects, but the service is charged essentially by the number of packets transmitted (not by connect time).

At the same time, several computer manufacturers have developed complex communication hardware and software for building networks of computers and terminals connected through leased or switched circuits. Independently, manufacturers are also developing new kinds of terminals for different applications. It is very common to find strong incompatibilities between the interfaces for terminals and computer systems of different manufacturers and between those interfaces and the new access protocols for public networks. Much effort will be needed to obtain more compatibility and agreed standard interfaces.

Canada will be the first country to have two independent public packet-switched data networks. For several years now, leased digital circuits have been available from two competing common carrier groups, the Trans-Canada-Telephone System (TCTS) and CNCP Telecommunications. Both groups will now provide new data communications services: TCTS has built the Datapac[5] network, to provide packet-switched virtual circuits with a network access protocol compatible with the standard X.25 of the International Telegraph and Telephone Consultative Committee (CCITT). CNCP is building the Infoswitch network which incorporates Infoexchange, a digital circuit switched service; Infocall, a service of packet-switched virtual circuits for transparent packet transmissions; and Infogram, a service of packet-switched virtual circuits similar to those provided with the CCITT standard X.25. In addition, both networks provide for the handling of simple character-oriented terminals, such as teletypes, and other terminal equipment.

The focus of this article is on the compatibility issues that arise from the introduction of packet switching. Other important issues are therefore not considered, such as those related to pulse code modulation (PCM) for telephony, digital switching, integrated services networks (INS), or satellite broadcasting.

Need for network interconnection

Interworking of several data networks is essential for international communication through several national data networks. In this case, each of the user's computers or terminals, also called 'data terminal equipment' (DTE), can directly access only the network of the country in which it is situated. Communication between two DTEs in different countries necessarily involves interworking of networks.

The situation is different when several networks cover the same geographical area, as do the two Canadian networks. There is competition between the networks, since the user's DTEs could be connected to either. Two DTEs connected to different networks can communicate only if there is an interconnection between the two networks. On the other hand, two DTEs connected to both networks could communicate through each, possibly using one as a back-up facility.

[3] Building on the experience gained with the ARPANET, the French Cyclades network has contributed much to the development of packet-switched data communications. Its major features are described by L. Pouzin, 'Presentation and major design aspects of Cyclades computer network', paper presented at 3rd Data Communications Symposium, Tampa, Florida, November 1973.

[4] The French and British PTTs, the US Telenet corporation and the Canadian TCTS were the main proponents of the virtual circuit service for public packet-switched data networks. The CCITT has adopted Recommendation X.25 for this service in its plenary session of 1976. Several public networks providing such a service are being planned (eg France, Japan, and the UK) or are already working (Telenet (US), Datapac and Infoswitch (Canada)).

[5] W.W. Clipsham, F.E. Glave and M.L. Narraway, 'Datapac network overview', paper presented at Third International Conference on Computer Communication, Toronto, Ontario, 1976.

Interworking of packet-switched data networks is a field in which considerable research and development are underway. Such work is necessary to determine the appropriate scheme of interworking for the applications described above. Different schemes have been proposed[6] and several have been tried out.[7] All use some kind of 'gateway' that implements the connection between two networks through which user data as well as control and administrative information are exchanged. For distant international communications, the user data may pass through several such gateways involving one or more intermediate data networks. A typical situation, including a country with two national data networks, is shown in Figure 1. The figure also shows an 'international' network providing long-distance interconnection services between different national networks, possibly over satellite links, and a 'multinational' network that extends over several countries.

Another aspect of interworking is the identification of users and their connections to the networks. The CCITT is in the process of elaborating an international numbering plan for use between public data networks. The plan also foresees the possibility of interworking with switched public telephone networks and telex networks. Since the proposed numbering scheme is structured by country, allowing several data networks per country,[8] there remains the question of what kind of numbering plan would be appropriate for multinational networks such as EURONET,[9] or other private networks that extend over several countries.[10]

[6] Telenet corporation proposes the use of a variant of the X.25 protocol for interconnection of packet-switched data networks (L.G. Roberts, 'International interconnection of public packet-networks', paper presented at Third International Conference on Computer Communications, Toronto, Ontario, 1976). This approach, however, has drawbacks and other approaches for interworking of packet networks have been proposed and/or implemented (V. Cerf, A. McKenzie, R. Scantlebury and H. Zimmermann, 'A proposal for inter-network end-to-end protocol', IFIP WG 6.1, General Note 96, September 1975; D. Lloyd, M. Gallard and P. Kirstein, 'Aim and objectives of internetwork experiments', IFIP WG 6.1, Experiment Note 3; D. Lloyd and P.T. Kirstein, 'Alternate approaches to the interconnection of computer networks', paper presented at European Computing Conference on Communication Networks, London, 1976).

[7] Interconnections between the networks Cyclades in France, EIN (the European Informatics Network) and the NPL network in England became operational in 1976.

[8] The CCITT is considering a proposal for a numbering plan which foresees four

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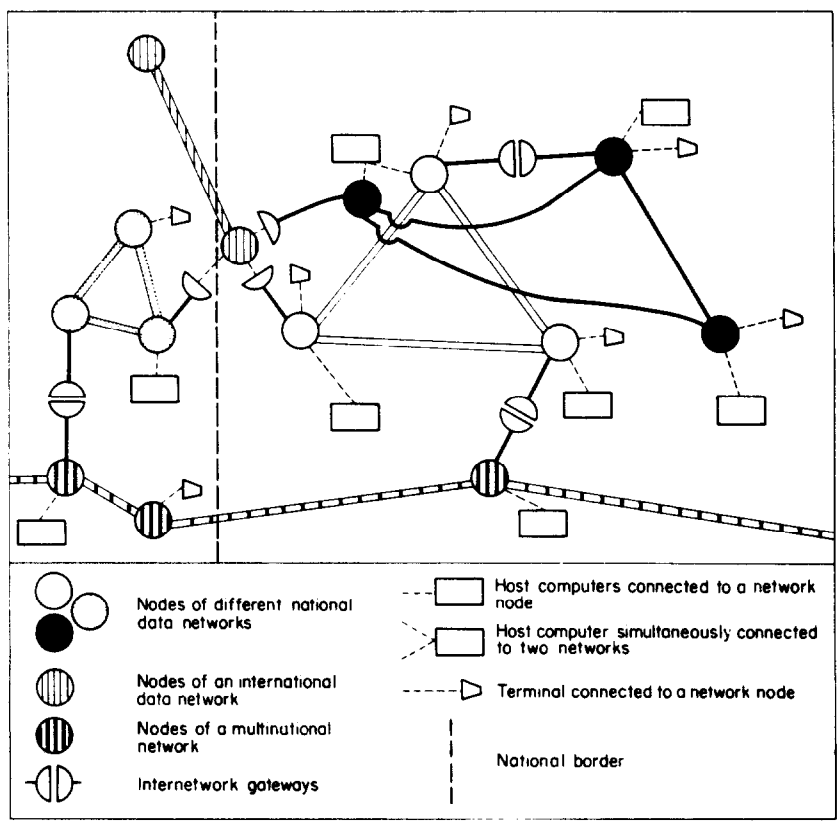

Figure 1. The possibilities for internetwork data communications.

Compatibility issues

It is important to distinguish between two degrees of compatibility: (a) the similarity of the services and functions considered, and (b) the compatibility of the protocols, ie procedures, used for providing a service or function. For example, Datapac and Infogram provide essentially the same service, but the network access protocols used in the two networks are incompatible.[11]

For interworking between different system components, ie network and user subsystems, there is the requirement that the services offered by the networks and the services needed by the user systems are similar. When this similarity exists it is possible to adapt the protocols of the different system components, if they are incompatible, by introducing adaptation modules in the form of additional software and/or hardware. These adaptation modules must be placed between the different system components, for instance in internetwork gateways or user/network interfaces.[12] But when the protocols are compatible no adaptation is needed; the components can be connected directly.

International standards

As the foregoing discussion shows, international standards on data communication protocols are very important. Several organizations work on their elaboration and maintenance. The CCITT has been very active in determining standard access procedures for public packet-switched data networks. The scientific community has contributed to the discussion by providing many interesting proposals for new developments and critical evaluations of existing suggestions. Many of these proposals have been presented through the Technical Committee TC6 of the International Federation of Information Processing (IFIP). The computer and terminal manufacturers work through organizations such as the European Computer Manufacturers Association (ECMA) or directly through the International Organization for Standardization (ISO). The ISO has the difficult task, among others, of bringing together the carriers, computer and terminal manufacturers, and the communications users to agree on data communications standards. To date, communications users seem to be under-represented in such discussions.

So far, the main activity of international standardization in data communications has been the definition of line control and network access procedures. For the physical and electrical interface with digital transmissions circuits, a new family of more efficient procedures, called X.21 by the CCITT, has been developed and is to replace the interfaces currently in use with modems for communication through analogue telephone circuits.[13]

ISO has recently adopted the HDLC classes of procedures for obtaining reliable data transmission over different kinds of circuits. They provide functions such as link and flow control, recovering from transmission errors by retransmission, and servicing possibly several terminals over the same circuit.

During the past few years, the CCITT has worked out procedures for accessing the newly developed public data networks. For packet-switched networks, the X.25 recommendation contains the

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decimal digits for specifying the destination network; three digits identify the country and one digit identifies the data network within that country. Whether a multinational network would have several four digit codes, one for each country served, is an open question.

[9] Euronet is a data network planned by the European Economic Community and will be used mainly for access to shared data bases.

[10] The importance of private networks for international data communication applications is discussed by W.H. Read in 'Network control in global communications', *Telecommunications Policy* Vol 1, No 2, 1977, p 125. We note that many of these applications may use public data networks as soon as international data traffic is supported by the carriers.

[11] The situation is similar with screws made to metric and imperial standards: they provide the same service (as long as they are approximately the same size), but they are not interchangeable.

[12] The adaptation between different protocols may be termed 'protocol translation'. Translation of protocols that provide a similar service is not particularly difficult to implement, but for dissimilar services it is complex and awkward.

[13] Arrangements for a smooth transition from the old to the new procedures have been provided. See, for example, 'Transition to the new generation of data communication interface standards', US National Communication System, TIB 76-1.

procedures for using a service of virtual circuits, which is functionally similar to real digital circuits with a low error rate.[14] Virtual circuits, however, are usually charged for by the number of data packets transmitted and not by connect time, and several virtual circuits originating from the same subscriber equipment can be multiplexed through one single physical circuit accessing the network.

The technical problems involved in the development of these new standards are very complex and include many aspects of networks and user subsystems. Therefore, it is necessary to concentrate in the future, in addition to the development of particular protocols, on an analysis of the overall structure of communication systems. Work on this topic was started in Subcommittee 6 on Data Communications, and will be continued in the newly created Subcommittee 16 of the ISO Technical Committee TC97 on Computers and Information Processing. As an example, Figure 2 shows an overview of some major functional levels for data communications within the architecture of a system involving user host computers, networks and terminals.

The lower three procedure levels (physical and electrical, link, and packet level) have been extensively studied, as explained above. The packet level procedures for virtual circuits in public data networks have been developed relatively quickly and little experience has been gained to date with the use of such a service. There is still considerable debate over the question of whether public packet-switched networks should provide a datagram or virtual circuit service, or both.[15] In several countries with plans for public data networks, there are no immediate plans for providing packet-switched (virtual circuit or datagram) services; only dedicated or switched circuit services will be available in the near future. The choice between different data transmission services is related to the type of user applications, and also has a strong impact on the design of the other system components, such as host and front-end communications software and terminals and terminal handlers.

The remaining levels of procedure shown in Figure 2 are:

- A transport protocol controlling the exchange of data in the form of messages between the data source and destination. Depending

[14] The CCITT recommendation X.25 specifies three layers of protocols: a physical and electrical level, a link level (link access protocol) providing reliable communications between the DTE and the network, and the packet level which provides the communications service of virtual circuits. It is relatively complex, and proposals for revising X.25 have been made (L. Pouzin, 'The case for a revising of X.25', *Computer Networks*, Vol 1, 1976, p 143). An overview of computer communication protocols and of problems that are not satisfactorily solved by the adoption of X.25 (for instance, provision of a datagram service, network interconnection, broadcast networks) is given by V.G. Cerf in 'Computers and communications', paper presented at the US Federal Communications Commission Planning Conference, November 1976, the proceedings of which are available from AFIPs, Montvale, NJ.

[15] Experience with the Cyclades network led to the proposal of a datagram service ('Proposal for some basic elements of public packet-switched services', submitted by France in April 1974 to the Rapporteur on Packet Node Operation of Study Group VII of CCITT). A more detailed proposal for a datagram protocol has recently been made by the UK Post Office ('Proposal for a datagram service', COM VIII24 (October 1976), CCITT), but the carriers made it clear at the CCITT that there were no plans for providing a datagram service in the immediate future. In a paper favouring datagrams ('Virtual circuits versus datagrams – technical and political problems', *Proceedings AFIPS*, NCC, 1976, p 483), L. Pouzin observes that the datagram notion is fundamental to the internal operation of packet networks. Indeed, a datagram is nothing more than a packet which is accessible to the subscriber. The main point of the discussion is that subscribers should have

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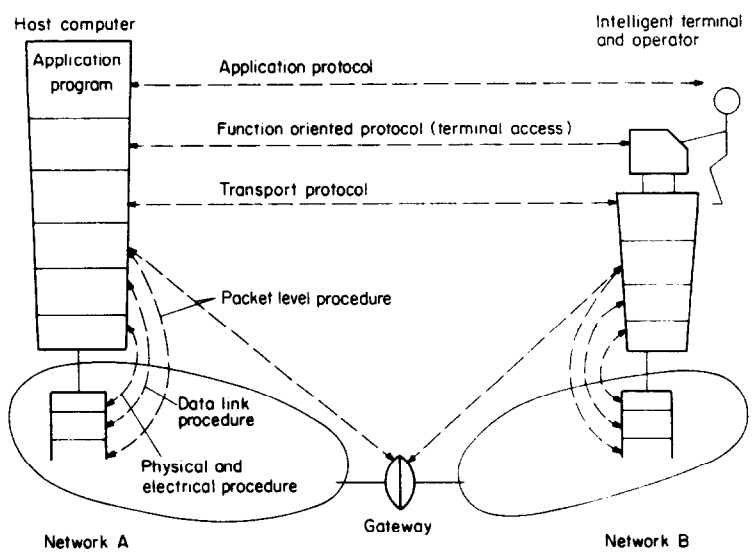

Figure 2. Overview of major functional levels for data communications between a host computer and a terminal through interconnected data networks.

on the system configuration, the transport protocol may make use of different kinds of data transmission services.

- Function-oriented protocols providing certain functions that are widely used for many applications. Typical examples are procedures for accessing interactive terminals,[16] or file transfer protocols.
- Protocols specific to the application.

These levels of procedures are sometimes called 'higher-level protocols' and are generally implemented in intelligent terminals, terminal handlers and the software of front-end and host computers. To obtain compatibility between different user systems a strong effort for standardization has to be made by computer and terminal manufacturers as well as by (and possibly under the pressure of) users. ISO is beginning to work on these issues, but many compromises will have be to reached if communication between heterogeneous user systems is to be realized.

The Canadian data networks

It is interesting to consider the services offered by the two public Canadian data networks in the light of these international standard developments. The availability of the different services, outlined above, relates to important compatibility issues.

The Infoexchange and Infocall services are very similar, except for the tariff which is determined by connect time and number of packets, respectively. Existing user systems that employ leased circuits or public telephone connections as means for data communications can be adapted to these new data transmission facilities with only minimal changes. However, the full flexibility of packet-switching is not provided by these services.

The Datapac and Infogram services are similar and provide packet-switched virtual circuits, with multiplexing of several virtual circuits through one physical connection. Because the networks' access protocols are relatively complex and must be implemented within the communication software of the user systems, existing user systems cannot use these services without a substantial change of the communication software. It is hoped that in the future the network access protocols will be provided by the computer manufacturers within the operating system software. The fact that two different access protocols are needed for accessing the Datapac and Infogram services discourages the joint use of both networks. However, the use of a unique higher-level transport protocol, based on either service, allows for the constructions of user systems that are compatible with both networks.

Pragmatic considerations

Compatibility issues are an important element of marketing considerations. Large computer manufacturers often do not collaborate in the setting of standards since standards increase the possibilities for competition. Computer and terminal manufacturers with smaller market shares favour standards because they open new markets that would not be economically viable without the resource-sharing advantages that standardization implies. Carriers, on the

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access to the datagram service to have the possibility of building their own end-to-end transport protocols in cases where the virtual circuits of X.25 are not adequate.

[16] For providing access to the new public packet-switched data networks for simple start-stop terminals through telephone connections, an adaptation module is proposed which is to be placed between a public data network and the switched telephone network. The module is called a 'packet assembler and disassembler' or PAD, because its main function is the (dis-) assembly of packets from (into) the individual characters exchanged with the terminal. A proposal has recently been presented to Study Group VII of the CCITT (Com VII 62, January 1977) by those carriers that most urgently need such a standard for their packet-switched networks. Some aspects of the PAD operations involve a particular terminal access protocol and may have to be revised in view of future developments of terminal access standards.

other hand, generally favour standards since (a) network interworking is an important user requirement, and (b) the monopoly situation often eliminates competition for the carriers anyway. From the user's point of view, standards broaden his field of choice by giving him access to a competitive marketplace.

In the absence of standards, competition between different service offerings is limited to the initial period when the user makes the choice of buying one or other of the services offered. Once a service has been adopted, it is very difficult for the user to change to a different service or manufacturer, because the necessary adaptation of this system to the new service would be very complicated. This situation is well known in data processing. It will also arise in data communications, unless appropriate standards are developed and maintained.

In this context, it is interesting to compare the marketing approaches used for the two Canadian packet-switched data networks. TCTS stresses the compatibility of the Datapac access protocol with international standards, and the ease of connection with foreign data networks, in particular with Telenet and Tymnet in the USA. CNCP stresses the flexibility of its network (three different services, of which Infocall is a packet-switched service particularly adapted to existing data processing systems) and the possibility of providing customized network access protocols for large users.[17]

The importance of network interconnections is outlined above. The degree of interworking available between different networks is determined largely by government regulations and carrier policies. As far as Canada is concerned, Datapac and Infogram offer a similar data communication facility for host computers. If the host system contains the necessary software to interface with the two different network access protocols, it can use both networks. However, the carriers seem to want to prevent this simultaneous access. Since gateways between the networks are not foreseen, it may be concluded that interworking between them is not possible. This clearly restricts the available choices to the user, and limits the competition between the carriers.[18]

A related issue is the use of the telephone network as a means of accessing data networks. While the CCITT is developing a standard for interworking between conventional start-stop terminals connected to the public telephone network and a packet-switched data network, CP Telecommunications has filed an application with the Canadian Radio and Telecommunications Commission (the Canadian regulatory body) for the use of the public telephone network, a monopoly service provided by the competitor, as a means of accessing Infoswitch.

Conclusions

The worldwide growth of private, public, and military computer networks has led to the development of a variety of communication procedures with many incompatibilities. Computer manufacturers, in the apparent absence of any accepted network protocol standards, have developed their own collection of network protocol conventions. Without such conventions, computers and terminals could not communicate with one another. The conventions required range from physical and electrical interface standards, data link procedures and

[17] Interworking with users on other networks is in this case more difficult. It would, therefore, be relatively difficult for a user to change over from the use of one network to the other, or to use the second as a back-up facility.

[18] For example, certain users with applications that cover all parts of Canada may wish to take advantage of the fact that certain geographical areas are best serviced by one network, whereas other areas are best serviced by the other. At present, they cannot really take advantage of this fact because no user system can simultaneously communicate with termals on both networks.

network access protocols, to end-to-end transport protocols, terminal access and specific application procedures.

Generally, these conventions are described in a layered structure, reflecting the underlying system's architecture. The different layers of protocols are relatively independent of one another, and can be defined separately. This simplifies the overall system design,[19] and has the advantage that each protocol layer can be improved or replaced independently of the other layers. Correspondingly, protocol standards can be designed separately for each layer.

For the lower layers of protocols (ie physical and electrical interfaces, and link and network access protocols) some progress towards standards has been made, as exemplified by the circuit interface procedure X.21, the data link procedures HDLC, and the network access procedure X.25. Important issues remaining are the definition of a datagram transmission service and procedures for general data network interconnections.

However, it is crucial to recognize that useful communication between several computers and terminals can be effected only when the higher layers of protocols, as shown in Figure 2, are also compatible. Assuring the consumer a wide range of services accessible from a common terminal, or effecting data communications between computers of different systems will require that computer and terminal manufacturers adhere to standards not only for the lower layers of protocols mentioned above, but also for layers of protocols for end-to-end data transport, terminal access, etc.

Much progress must be made before compatible communication procedures are available between different systems of computers and terminals. This progress will be made only if the users exert sufficient pressure on computer manufacturers to develop and adhere to higher-level protocol standards.[20] Users should also become more involved in the development of such standards. The effort could be focused in national and international standard organizations and in data processing and communications users' associations.

Government policies and regulations could assist in the development of telecommunications standards by promoting interworking between different data networks and data processing systems. The question of accessibility of data processing services and data banks is clearly related.

Another issue is that of competition. This is a sensitive topic because of the monopoly structure of telecommunications in most countries. Competition can, however, be beneficial in the area of data communications.[21]

The layered structure of systems architecture, discussed above, does not show any natural boundary between data communication and data processing. Although such a boundary is often invoked for determining the applicability of regulatory considerations concerning data communications and/or processing, the current trend towards the merging of these two areas will make the distinction increasingly obscure. A new approach is needed for regulating data communication and processing service offerings. In this respect, it may well be worth studying developments in Canada and the USA.

[19] The hierarchical layered structure, used here for the description of communication systems, has already some history in the area of computer software engineering. It is also an essential issue in 'structured programming'. That this structuring principle does not only apply in information systems, but also in many social, biological and other systems, has been shown by H.A. Simon in 'The architecture of complexity', *Proceedings of the American Philosophical Society*, Vol 106, No 6, 1962, p 267.

[20] A similar point has been made recently by R.W. Sanders and V. Cerf concerning the standards for data network access in 'Compatibility or chaos in communications', *Datamation*, March 1976.

[21] As a particular point of interest, it is worth mentioning the area of terminal handling and support, and terminal access to data networks. Conscious regulatory policy action may be needed in this area for preserving a competitive environment, as pointed out by V. Cerf, *op cit*, Ref 14.