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COMPATIBILITY STUDY OF PACKET-SWITCHED DATA NETWORKS.

by: Gregor V. Bochmann

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DATA NETWORKS*

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1. INTRODUCTION

New data communication facilities are being developed based on the principle of packet switching. Compared to the conventional facilities based on real telephone and high-speed circuits, this new technology is characterized by a higher degree of resource sharing, implying lower cost, and a better transmission quality. However, this new technology also brings new problems for the users. More complex communication protocols have to be implemented in order to make use of the new communication facilities. Different protocols have been developed by different computer manufacturers and carriers, with the result that compatibility between the different systems is a problem.

The users are interested in the compatibility of the different computer and communication systems. Higher compatibility would promote the possibility of choosing the different components of a data processing network independently from different manufacturers and/or carriers. A larger choice for the user often means a better service and lower cost.

In this report we are not so much concerned with the compatibility problem between the data processing equipment on the one side, and data networks on the other. Instead we deal with the compatibility issues raised by the provision of two independent packet-switched data networks in Canada. TCTS' network Datapac and CNCP's network Infoswitch are both scheduled to start operation in 1976.

Section 2 gives a general introduction to access protocols for packet-switched data networks and points out some issues of compatibility and standards. The main part of this report are sections 3 and 4. Section 3 contains a detailed comparison of the access protocols for the Datapac and Infoswitch data networks. We consider the packet mode access protocols, SNAP and Infogram respectively, and the interface for asyncronous interactive terminals. We also discuss CNCP's syncronous Infocall service. In section 4, we discuss the compatibility issues related to these protocols, and show in particular what the protocol differences mean to the user.

Conclusions are given in section 5. First the data communication facilities offered by the two networks are characterized. Then alternative network (inter-) connections are considered for applications involving both networks: We consider alternate and simultaneous connections of a host computer to both networks, and the use of inter-network traffic in the case that the networks are connected by gateways. The protocol compatibility problems are discussed in view of a user that wants to develop an application system compatible with both data networks. Several approaches for obtaining compatiblity are suggested. The section closes with some general comments on the conflicting relation between the computer manufacturers, the common carriers, and the users. Finally, we discuss in section 6 some areas for future studies, and give in section 7 a list of recommended actions for solving some of the problems discussed in the present study.

2. OVERVIEW OF NETWORK ACCESS PROTOCOLS

We give in this section an outline of access protocols to packet-switched networks. After describing the data communication services offered by such networks, we explain the different logical levels of protocols through which the user's data pass when being exchanged between the communicating processes or terminals. This exposition is the background for the detailed comparison of the Datapac and Infoswitch protocols in section 3. The section closes with a short discussion of compatibility and standardization issues for protocols and interfaces.

2.1 Typical communication services offered by packet-switched data networks

Packet-switched data communication technology makes it possible that many users share dynamically the given transmission capacity, which results in substantial savings of transmission costs. In order to achieve this dynamic sharing, the user's data is packetized into fragments of variable length. Such a fragment, together with a header, makes up a data packet which is sent through the network. The header specifies control functions and addressing information to enable the data to be delivered to the appropriate destination.

A datagram service is a service, offered by a network, which allows the user to send individual data packets through the network. The user specifies in each packet the complete destination address and the network is responsible for delivering the packet without any error. The rate of packet loss is small. This service seems to be easy to implement and very useful for building up higher-level services for computer - computer communications [7]. However, this service is not offered by the Datapac and Infoswitch networks.

A virtual call service is a service modelled after the traditional telephone service. A virtual call, also called virtual circuit, is a bi-directional association between two subscribers of the network over which all data transfer takes the form of packets. Before the data transfer can take place, a virtual call must be established. In this aspect, a virtual call resembles a switched telephone connection; however, transmission line capacity is allocated (and charged for) only when packets are actually transmitted.

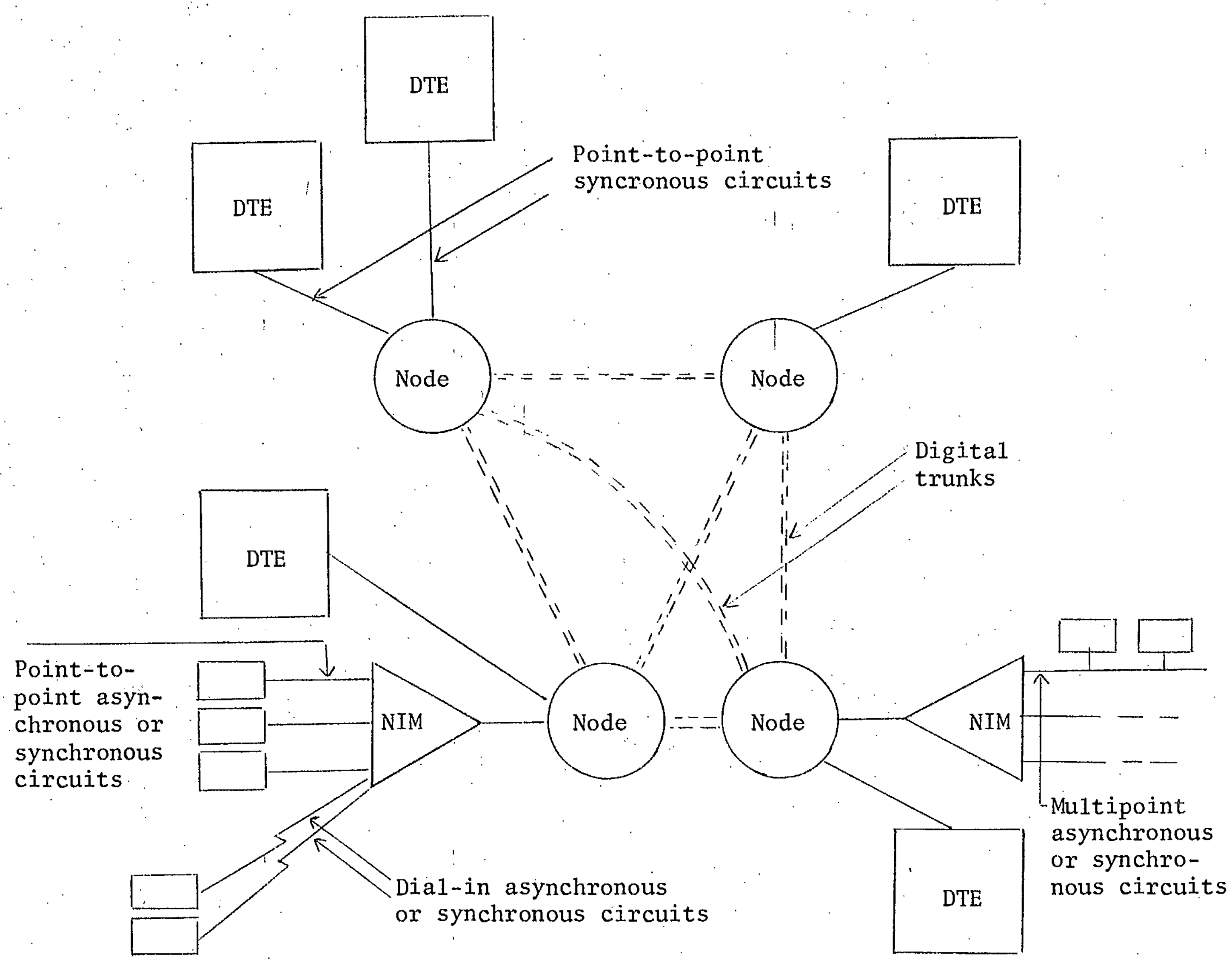
Some networks also provide for permanent virtual circuits which function like virtual calls, except that they are permanently established between a pair of subscribers. This is analogous to point-to-point private lines.

2.2 Interfaces to a packet-switched network

Figure 1 shows a typical configuration of user equipment and carrier equipment connected together to form a data processing network. The interface between the user equipment, also called data terminal equipment or DTE, and the carrier supplied communication subnet, in particular the data circuit-terminating equipment or DCE, can be of different kind.

The most general interface is a multi-access interface with a packet-mode access protocol, which is typically used between the DCE and DTEs such as computers or terminal controllers. Such an interface allows the simultaneous establishment, through the same physical connection with the network, of several virtual calls or permanent virtual circuits with different distant DTEs. A single-access interface, allowing at most one virtual call or circuit, can be used between the DCE and an intelligent terminal. These packet-mode interfaces require that the DTE packetize the data, add the header information in the packets and follow the access protocol of the communication network.

Most kinds of terminal equipment have their own communication interface which is different from the network packet interface. For certain kinds of terminal equipment, such as computers and programmed controllers, it is



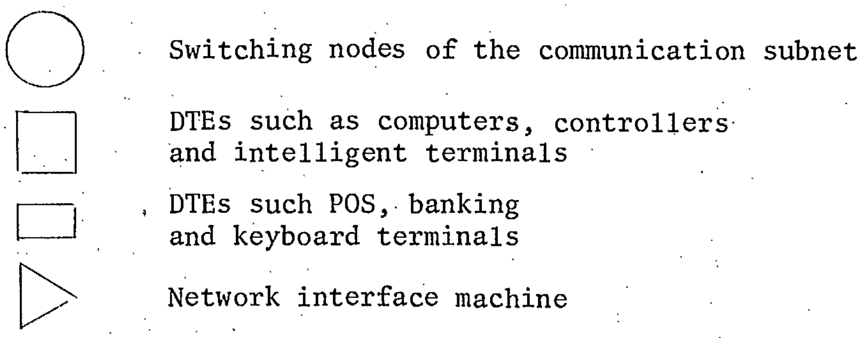


Figure 1: Typical configuration of a data processing network.

possible, although sometimes not easy, to adapt the given communication interface to the packet interface of the network. Another way to connect non-compatible terminals is by using an adaptation unit, sometimes called network interface machine or NIM. Such a unit is connected, on the one side, to the network through a packet interface and, on the other side, it presents the interface of the terminals. As indicated in figure 1, such network interface machines can be built for a variety of different terminals. Normally, the carrier supplies network interface machines for the most frequently used terminal interfaces. However, in other cases, the role of the network interface machine could be played by the user-owned terminal controllers or concentrators which connect to the network through the packet-mode interface.

2.3 The different logical levels of communication protocols

The procedures for data communications through a packet-switched network are usually structured as several logical levels of protocols. Each level has to perform a particular function and, in order to do this, it relies upon the functions of the next-lower protocol level. Figure 2 shows the typical situation. Starting with the lowest level, we distinguish the following levels of protocols:

- electrical (or physical) level interface procedure
- link access protocol
- packet level protocol
- end-to-end protocol (communication access method)
- communication between application programs or between an application program and a terminal user.

2.3.1 Network access protocols

The network access protocols specify the conventions that a DTE must follow for sending or receiving data through the communication network. For each

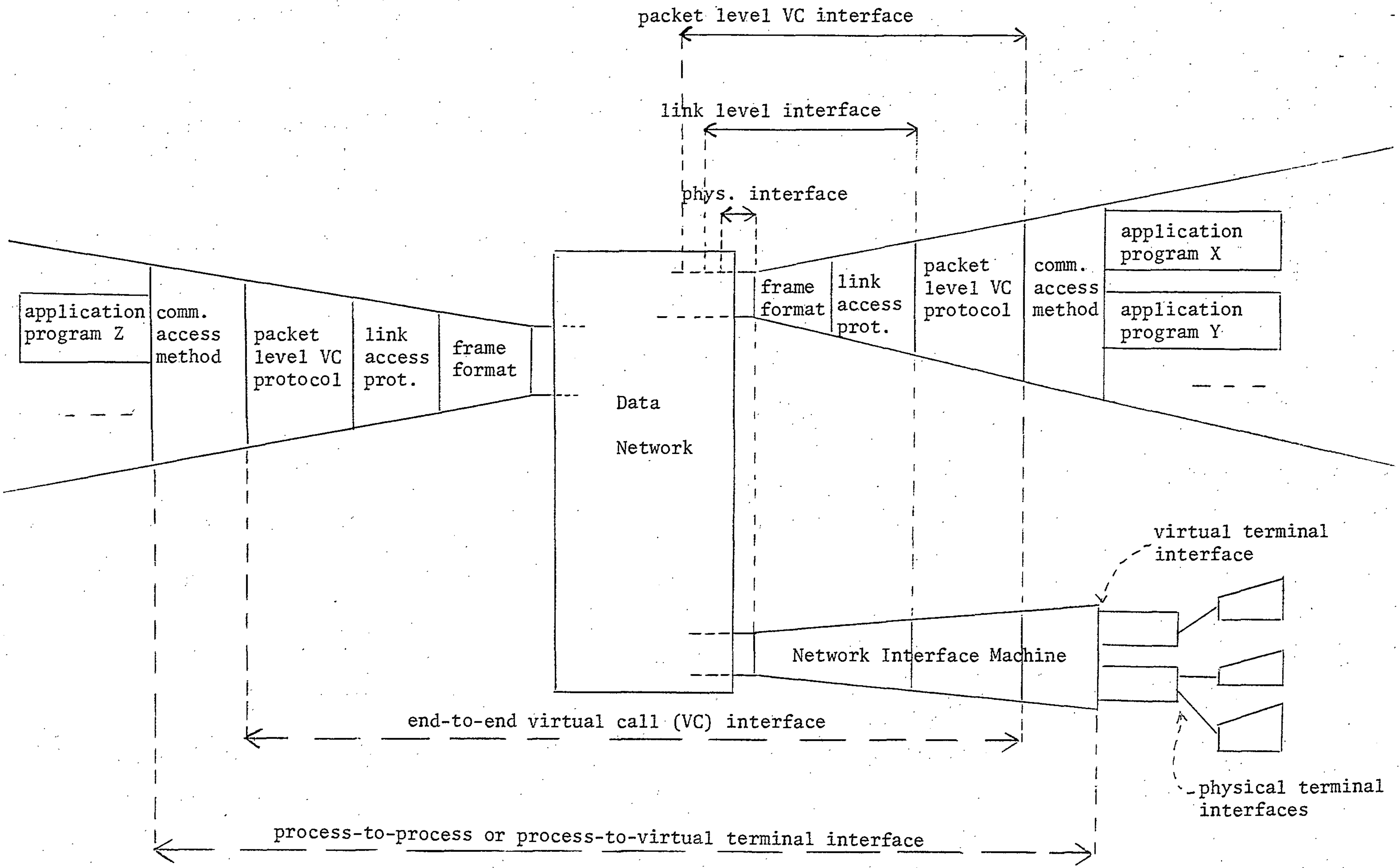


Figure 2: Diagram of logical relationships of different protocol levels.

link between a DTE and the network, three levels of protocol are distinguished:

a) The physical or electrical interface specifies how the wire connections to the circuit-terminating equipment, i.e. modem, can be used to exchange sequences of bits of information with the network.

b) The link access protocol provides, at the link level interface, a reliable means for communication between the DTE and the network. The protocol ensures that the control information for virtual calls and user data contained in packets (belonging to the next higher level of protocol) are accurately exchanged between the DTE and the network. Usually, the protocol includes a mechanism for error detection and for retransmission of erroneous or lost packets.

c) The packet level protocol specifies the manner in which the DTE can establish, maintain and clear virtual calls through the network. It also specifies the manner in which control information and user data are structured into packets. The packet header contains control and addressing information. We note that a single physical access link to the network (controlled by a link access protocol) can support numerous virtual calls and permanent virtual circuits to other DTEs at the same time.

It is important to note that the virtual call interface provided by the packet level protocol has two different roles: it serves for communication between the DTE and the network concerning virtual calls and data transfer, and it serves also for end-to-end communication, through a virtual call, between the local DTE and one or several distant DTEs.

2.3.2 End-to-end protocols

The lowest level end-to-end communication facility, in the case where the communication network offers the virtual call service, is the virtual call interface mentioned above. However, as an end-to-end interface, it is not very satisfactory. In fact, it can be used as a base for implementing more appropriate end-to-end protocols which are used for the communication between application programs and users. We mention only the following two categories of end-to-end protocols:

a) Process-to-process protocols provide a means for communication between several application programs at different locations.

b) Interactive terminal protocols provide the basic conventions for the communication between a person at an interactive terminal and an application program.

At the side of the application program, the end-to-end protocol is implemented in the host computer by the communication access method. The corresponding protocol at the terminal side is implemented either in the network interface machine or in the terminal itself.

Because of the large variety of different terminals, it is useful to define a standard set of functions that can be realized by most interactive terminals. Such a set is called a virtual terminal. The network interface machine in figure 2 implements, in addition to the physical, link and packet level procedures, a protocol for communication with a virtual terminal. This virtual terminal interface is then adapted to the different types of physical terminals that are connected to the interface machine. An advantage of using a virtual terminal interface is that the application program at the other end of the communication path need not make the distinction between the different types of physical terminals and all their particularities. Instead, it sees all of them as standard virtual terminals.

2.4 Protocol implementations

Communication protocols are implemented partly by specialized hardware, such as line controllers and partly by software on micro-, mini, or large-scale computers. Figure 3 shows the typical DTE configurations for a host computer and for a micro-processor based controller of interactive terminals.

2.5 Compatibility and standards

Most computer networks in use today are a collection of host computers, concentrators and terminals connected to one another by leased or dialed-up physical circuits. The communication procedures used between the components of such a network are normally the conventions developped by the computer manufacturer for the equipment. Typically, all the components of a computer network are built by the same manufacturer. Some of these communication procedures although technically not the best, became de facto standards due to their widespread utilization.

There are two main reasons why these different communication conventions can coexist:

- Users that have a computer network can be convinced (how much choice do they really have?) to only use the equipment of <u>one</u> manufacturer.
- The communication medium, rented from the common carrier, consists of physical lines with a simple standard interface.

The advent of packet switching has a direct impact on the second point above. Packet-switched data networks not only furnish the equivalent of physical lines, but also offer very flexible concentration facilities and, in many cases, terminal control equipment for a variety of terminals. Traditionally, these functions have been provided by user-owned equipment

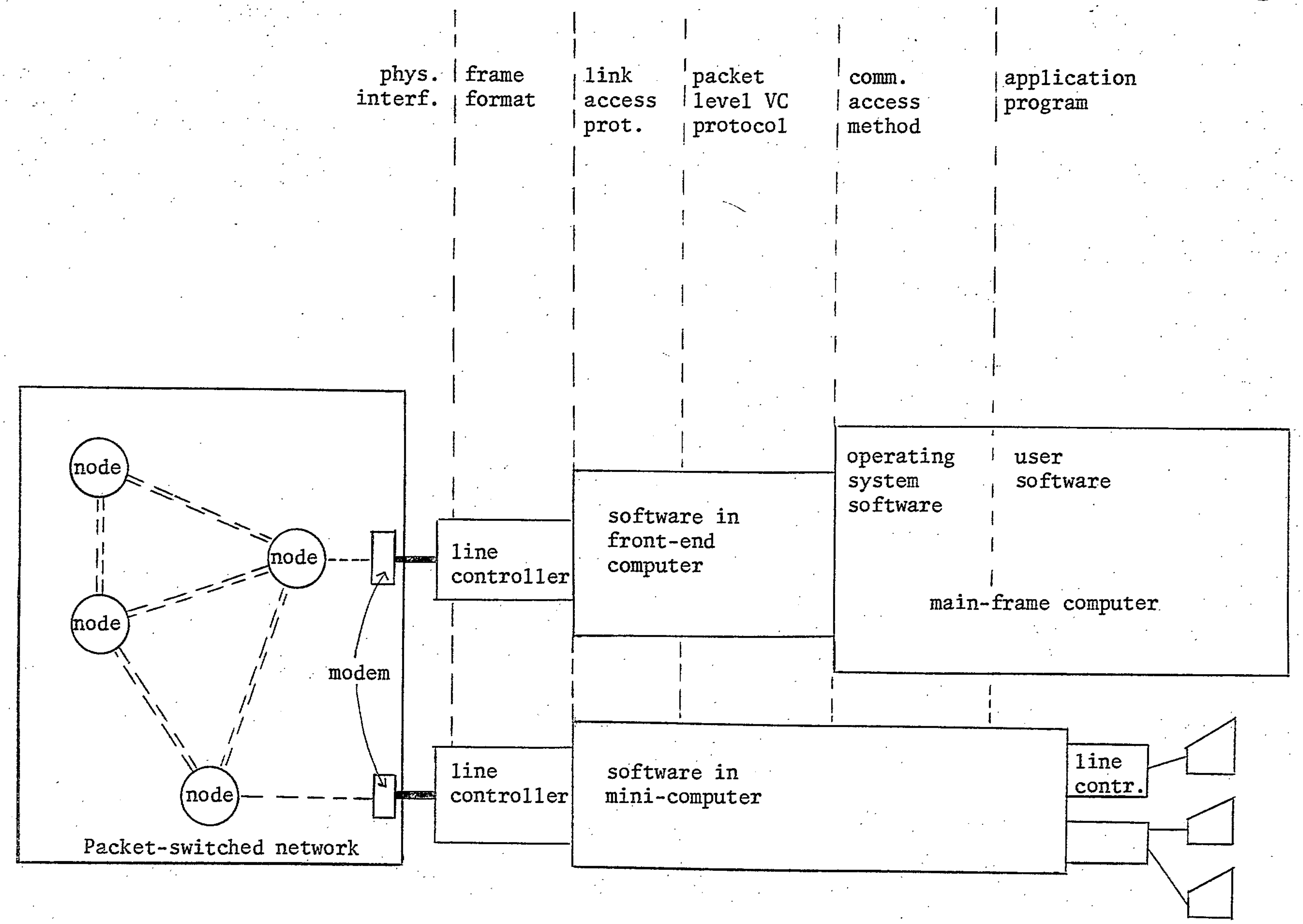


Figure 3: Diagram of a typical realization of different levels of protocols in the user's equipment.

compatible with the communication procedures of the host computer. In packet-switched data networks, however, these functions are provided by the network, and the user equipment has to comply with the network communication protocol, or adapt its own protocol to that of the network.

Instead of going further into this subject, we mention the article "Compatibility or Chaos in Communications" by Sanders and Cerf in Datamation [6] in which these issues are discussed. The adaptations of the given communication protocols of host computers and terminals to the protocols of the network are not always simple. A paper by Pouzin [7] points out the conflict between the computer manufacturers and the common carriers, and also between these two and the user. The question comes up whether anyone speaks for the user?

Clearly, generally accepted standards for communication protocols would be much welcome by the user. The International Telegraph and Telephone Consultative Committee (CCITT) will vote in September on the proposed standard X-25 which specifies the link and packet level protocols for the access to data networks providing a communication service of virtual calls. There are other areas in computer communications where standardization would be useful, in particular end-to-end protocols such as internetwork host-host protocols [5] or protocols for interactive terminals. Different areas of possible standardization in packet switching have been studied by an ad hoc group for the US ANSI [4].

3. COMPARISON OF THE ACCESS PROTOCOLS FOR THE DATAPAC AND INFOSWITCH DATA NETWORKS

We give in this section a detailed comparison of the network access protocols of the two Canadian packet-switched data networks, Datapac and Infoswitch. The main part of the section deals with the packet-mode interface to the networks, i.e. the Standard Network Access Protocol (SNAP) of Datapac and the Infogram service of Infoswitch, respectively. We also consider the interactive terminal interfaces, i.e. the Interactive Terminal Interface (ITI) of Datapac, implemented by a carrier provided Network Interface Machine (NIM), and the asyncronous Infocall service of Infoswitch. Finally, we characterize CNCP's syncronous Infocall service which has no corresponding service in Datapac. In this section, we try to make the comparison without any evaluation. In section 4, we give an indication of what the differences in the protocols mean to the user and how they affect the compatibility of the networks.

3.1 Comparison of the multi-access packet-mode interfaces

A comprehensive description of a network access packet interface is contained in TCTS's document on Datapac [2]. This description applies in large parts also to CNCP's Infogram service. Since Datapac's SNAP is based on the proposed international CCITT standard X-25, we mention the X-25 proposition in all the cases where we find a difference between the Datapac and Infogram protocols that is accommodated for by this standard, or where the Datapac protocols do not directly follow the X-25 proposition.

The following comparison is structured according to the different logical levels of protocols involved. However, we concentrate on the packet level protocols which determine the data communication service provided by the networks. We note that the following comparison is based on preliminary documents [1 , 2 , 3] and personal discussions with the parties involved. The final protocols of the networks may possibly be somehow different.

The main results of this comparison are summarized in the tables 1 and 2. Table 1 shows the different link access protocols available for the networks, together with the adopted frame formats. Table 2 deals with the packet level protocols for virtual calls. The table indicates similarities and differences between the functions provided in both networks, and the ways these functions are implemented by the respective protocols. A detailed discussion is contained in the following subsections.

3.1.1 The physical interface

This interface is the same for Datapac and Infogram (interface to syncronous modems, RS-232-C standard of the Electronic Industries Association).

The transmission speeds to be supported are 1200, 2400, 4800 and 9600 bps on both networks. In addition, higher speeds are forseen in the future.

3.1.2 The link access protocol

a) Protocols

Datapac provides only one link access protocol. It is a completely balanced full duplex HDLC kind of protocol with asyncronous response mode in which both the DTE and the DCE contain a primary and a secondary function and are capable of establishing the link.

Infogram provides initially the following three link protocols and more different protocols could possibly be provided if necessary.

(1) The "Standard CNCP Link Access Protocol" is an unbalanced full duplex HDLC kind of protocol with asyncronous response mode in which the DTE is the primary and the DCE is the secondary station. Only the DTE can establish the link but both DTE and DCE can initiate data transmission over the established link.

(2) The "CNCP SDLC Link Access Protocol" is a subset of the IBM SDLC protocol. The protocol is similar to the standard CNCP protocol above. The DTE is the primary.

Table 1: Available frame formats and link access protocols

link access protocol	available in Datapac	available in Infoswitch
symmetrical HDLC (proposed standard X-25)	- with HDLC frame format - with BSC frame format (transparent mode)	
CNCP HDLC (primary in DTE)		with HDLC frame format
CNCP SDLC (subset of IBM's SDLC, primary in DTE)		with HDLC frame format
Infogram BSC (subset of IBM's BSC)		with BSC frame format

Table 2: Comparison of the packet level protocols in the Datapac and Infoswitch networks

Protocol function	Similarity of service provided	Similarity of procedure elements	Service provided only in Datapac	Service provided only in Infoswitch	Comments
1. Call establishment and clearing				—	-both networks use the concept of logical channel numbers (LCN)
call establishment	similar	different	-transfer of user data -address of the calling DTE for incoming calls	-network chosen LCN -no call collisions on a given LCN	-call progress signals are similar (see Table 4)
permanent virtual circuits			-provided		-equivalent to a permanently established virtual call
clearing a virtual call	same	same			
initialization of the network-DTE interface			-use of "restart" packets		
optional user facilities	similar				-see Table 3
2. Data transfer					
max. length of data packets	same	—			-different for Datapac's priority class of traffic
packets delivered in order	same	—			
flow control, including resetting	same	same	-network generated resets are accompanied by the resetting cause		-there is no end-to-end flow control, only flow control for each network-DTE interface
additional facilities	different		-more data bit -data qualifier bit -interrupt packets		

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additional facilities	different		-more data bit -data qualifier bit -interrupt packets		

(3) The "Infogram BSC Link Access Protocol" is a subset of the IBM BSC protocol.

X-25 proposes the Datapac link protocol but leaves for further study other kinds of protocols such as protocols with half duplex and/or normal response mode as well as different allocation of primary and secondary functions, which includes the Infogram protocols (1) and (2).

b) Packet frame formats

We note that the disposition of the different fields of information within a frame is determined by the packet and link level procedures. Here we are concerned only with the following two aspects of the frame formats:

(i) The order of bit transmission is the same in Datapac and Infogram. User data consists of a sequence of octets (bytes of 8 bits). The octets are transmitted sequentially, the least significant bit first. We note that the X-25 proposition allows for user data of arbitrary size (arbitrary number of bits).

(ii) Two different methods can be used for obtaining frame synchronization, transparency and error detection with the Datapac and Infoswitch networks:

1 - The HDLC method with flag sequences, bit stuffing and CRC also used by SDLC; this is the only method included in X-25.

2 - The BSC method with SYNC characters, "Transparent Mode of Operation" and frame check sequence. Different versions of BSC frame formats exist for character codes EBCDIC and US-ASCII.

For the same HDLC link access protocol, the Datapac network provides two options for the frame format: the HDLC format and a BSC format for EBCDIC character codes (called "Frame Structure for Character-Oriented

Transmission Modes"). The Infogram service provides for each link protocol the appropriate frame format, i.e. the HDLC format for the protocols (1) and (2) and a BSC format with character codes EBCDIC or US-ASCII for the protocol (3).

3.1.3 The packet level protocol

In the first two subsections, we compare the virtual call interface provided by the two networks, that is, the communication service provided to the user. In the third subsection, we point out some additional differences in the protocols; but these differences are only different means for obtaining the same user interface.

3.1.3.1 The call establishment interface

a) Similarities

Datapac and Infogram both offer virtual call connections as described in section 2.1.

In both networks, the address of the destination DTE for the call to be established is given as a decimal number. The address identifies the DTE link to the network.

Call establishment and clearing are similar in both networks except for the following points.

b) Differences

Datapac offers permanent virtual circuits.

The maximum number of simultaneous virtual calls (including permanent virtual circuits) per network link is 4096 (16 groups of 256 virtual calls each) in Datapac; but for Infogram it is 256 (and can be extended to 1024).

In Datapac, user data (up to 16 octets) can be transferred during the call establishment phase to the destination DTE.

In Datapac, the network furnished the address of the calling DTE for incoming calls. In Infogram, this information is not available.

The optional user facilities available in both networks are compared in Table 3. We note that X-25 contains a proposition for optional user facilities which is not definitive, but left for further study.

In the case that a call can not be established, the network returns a call progress signal. These signals are quite similar in both networks. They are compared in Table 4.

Subscriber addresses in Datapac are 8-digit numbers. In Infoswitch, they are normally 7-digit numbers, a 3-digit area code followed by a 4-digit subscriber number. For inter-network and international data traffic, both networks' administrations intend to follow the proposed CCITT plan.

3.1.3.2 The interface for data transfer

a) Similarities

The user data in a data transfer packet, sent over an established virtual call, consists of a variable number of octets with a maximum length of 256 octets (in Datapac, this limit applies for normal priority traffic). X-25 proposes a maximum length of 128 octets and allows 256 as an additionally supported maximum length. X-25 does not restrict the data size of a packet to multiples of octets; any number of bits are allowed.

Table 3: Optional User Facilities

User facility	Announced to be available ? Datapac	Announced to be available ? Infogram	Remarks
closed user group	yes*	yes	the concepts of a closed user group are not the same in both networks; but it seems they are equivalent
reversed charging	yes*	no	
flow control window size between 1 and 7	yes	yes	
abbreviated addressing	no	yes	X-25 leaves this facility for further study
priority class of traffic	yes*	no	X-25 does not include this facility
hot line	no	yes	for a single access interface only
collective number group	no	yes	automatic subaddressing among the members of the group by the rotary or by the homing method
camp on	no	yes	

* additional information must be provided by the calling DTE for each call to be established

Table 4: Call Progress Signals

The corresponding signals are

in Datapac	in Infogram
number busy	called subscriber is busy
number refusing collect calls	—
network congestion	originating network node congested* no circuits
invalid call (invalid facilities)	—
access barred	correspondence with this subscriber is not permitted
local procedure error	local procedure error* no more logical channels available*
not obtainable	subscriber's number has been changed the called party is not or is no longer a subscriber incorrect address number
remote procedure error out of order	out of order called subscriber is out of service
—	absent subscriber, office closed
—	called subscriber busy, camp on

* possible network response to a call request packet

The sequential order in which data packets arrive at the destination DTE is identical to the order in which they were sent by the source DTE. (This is not explicit in the protocol specifications.)

The procedure for flow control, including resetting, is the same in both networks.

b) Differences

In Datapac, the user can indicate by a more data bit in the control field of a full data packet that more data, transmitted in the following packet(s), belongs to the same logical unit of information. In Infogram, this bit is not used. We note that the standard X-25 does not require the network to consider the "more data bit" in the case of a national network with only one single maximum user data length.

In Datapac, interrupt packets can be sent over virtual calls. Containing one octet of user data, they travel faster than normal data packets and are not subject to the flow control of data packets.

In Datapac, a data qualifier bit in the control field of a data packet can be used to distinguish between two levels of data transfer. This facility is used in Datapac for the implementation of the Interactive Terminal Interface (see section 3.2).

Datapac provides a higher priority class of traffic as an optional user facility. For those virtual calls that belong to this class, the maximum size of user information in data packets is 128 octets.

Although the resetting procedure for virtual calls is logically the same in both networks, there is the following difference. In Datapac, an incoming reset indication packet furnishes some information about the resetting cause.

Datapac includes a procedure for restart, i.e. a simple means for reinitializing the user-network interface to the state it was in when service was initiated.

3.1.3.3 Protocol details

a) Similarities

The flow control procedure for data transfer over an established virtual call is the same in both networks, including the procedure for resetting the data flow.

The clearing procedure of an established virtual call is the same in both networks.

Both networks use logical channel numbers (LCN) for identifying the different virtual calls (and permanent circuits) of a DTE. The choice of an LCN is the local affair of the network-DTE interface. The LCNs used at the two ends of a given virtual call are not related.

b) Differences

The differences in the virtual call interface described in the two preceding subsections necessitate certain differences in the packet level protocol. We do not mention these differences here, but concentrate on additional differences that are not caused by differences in the user interface.

Packet formats are different in both networks, except for the fields used for flow control. Most of the differences are related to differences in the virtual call interface and the protocol.

Packet transmission through the link access protocol is at a rate of one packet per frame in both networks. However, Infogram provides also an option for transmitting several packets per frame. X-25 leaves this possibility for further study.

The call establishment procedure is different in both networks. In Datapac, the DTE chooses a new logical channel number (LCN) and sends one "call request" packet to the network, including the LCN and the address of the called DTE. The network's response is either a "call connected" packet or a "clear indication" packet with a clearing progress signal (see Table 4). This is a single exchange of messages.

In Infogram, the call establishment procedure is similar to the procedure for the telephone and consists of a double exchange of messages. The DTE sends a "call request" packet and receives (normally) a "proceed to address" packet, including the LCN chosen by the network. Then the DTE sends an "address" packet, including the address of the called DTE, to which the network responds by a "call connected" packet or a call progress signal.

In Datapac, it can happen that an incoming and an outgoing call collide on the same LCN, i.e. the procedure must handle this case of call collision. In Infogram, this situation can never occur, since the LCNs of both incoming and outgoing calls are chosen by the network.

In Datapac, optional user facilities are related to additional information to be coded by the DTE into the call request packets. In particular, such additional coding must be furnished in the call request with a closed user group DTE. In the case of Infogram, such additional coding is not required.

The coding of addresses is different in both networks. In both cases, binary coded decimal numbers (4 bits per digit) are used. However, Datapac uses a variable length field and an octet for indicating the field length whereas Infogram uses a fixed size field which contains a variable length string of digits with an end delimiter.

3.2 The interactive terminal interfaces

The packet-mode interfaces can be used to access the data networks by host computers, terminal concentrators or intelligent terminals that contain the necessary logic to follow the access protocols. Datapac, as well as Infoswitch, provides, in addition to the packet interface, an interactive terminal interface which offers access to the network for simple typewriter-like terminals as used in timesharing, inquire-response and message applications. In Datapac, this access is called the "Interactive Terminal Interface" or ITI,and in Infoswitch, it is called the "asyncronous Infocall service".

The asyncronous Infocall service provides the basic functions of a virtual call communication between the interactive terminal and another DTE on the network. The Interactive Terminal Interface to Datapac is different; it provides in addition a particular end-to-end protocol for terminal handling.

3.2.1 Differences in scope

The scope of the interactive terminal interface is different in the two networks. In Infoswitch, the role of the asyncronous Infocall service is the implementation of virtual calls with interactive terminals. The functions handled by this basic virtual call interface for interactive terminals are the following:

- establishment of the connection with the network (this function corresponds to the link access protocol in the packet interface),
- establishment of an outgoing or incoming virtual call,
- termination of such calls,
- character input/output through an established call, including appropriate strategies for assembling input characters into packets and basic flow control between the network and the terminal.

These functions resemble those of the packet interface and can be directly translated into the packet level access protocol of the network.

In Datapac, the scope of the ITI includes this basic virtual call interface for interactive terminals, but includes, in addition, some conventions for end-to-end communication between the interactive terminal and a host computer. These conventions specify a virtual terminal, i.e. they represent an end-to-end standard protocol for communication with all the terminals that are connected to the network through the ITI interface. The functions provided by this end-to-end protocol are the following:

- transmission of BREAK signals as interrupts,
- flushing the stream of input characters,
- flushing the stream of output characters,
- setting the parameters of the virtual terminal.

Since, in the Infoswitch network, the interactive terminal interface only contains the basic virtual call functions, a computer that communicates via a virtual call through the network with another DTE sees basically no difference whether the other DTE is connected to the network by the packet interface or by the interactive terminal interface (asyncronous Infocall service). However, in Datapac, the computer would see a difference. If the DTE is connected to the network by the interactive terminal interface (ITI), the computer has not only to follow the packet access protocol for the virtual call, but also the higher level end-to-end conventions for the virtual terminal.

The end-to-end conventions for the virtual terminal in Datapac are implemented by using the interrupt packets, and the data qualifier bit in data packets as provided by Datapac's virtual call packet interface.

3.2.2 The basic virtual call interfaces

Infoswitch provides two different methods for call establishment and termination for an asyncronous terminal, the "supervisory circuit" method and the "character" method. In the first method, a call request is automatically generated when the terminal is connected to the network; and an established call is cleared by disconnecting the terminal from the network. In the "character" method, particular character sequences are used for establishing and clearing a call. The first method allows transparent character input/output over the established virtual call, which is not possible with the second method; the second method allows the establishment of several consecutive virtual calls without disconnecting the terminal from the network.

The Datapac ITI call establishment and termination procedure is similar to the "supervisory method".

The strategies for assembling input characters into data packets are similar in both networks. Typically, a data packet is sent when the packet becomes full, or when a carriage return (CR) or BREAK signal is entered. CNCP offers optionally several alternative assembling strategies, for instance forming data packets with a fixed number of characters, which could be useful for certain types of applications.

3.3 The syncronous Infocall service of CNCP

The Infoswitch network offers a spectrum of different services for data transmission. The services resemble one another in that they provide basic data transmission over dialed-up connections. For the Infoexchange service, these connections are digital syncronous circuits; for the other services, they are virtual calls with packet-switched transmission. The syncronous and asyncronous Infocall services represent single access interfaces for virtual calls, and the Infogram service represents a multi-access interface. The Infogram and asyncronous Infocall services can be used for communication via virtual calls between a host computer and several asyncronous terminals. These services are similar to those offered by Datapac and are discussed in the preceding subsections.

The syncronous Infocall service has no correspondence in the Datapac network. This service offers virtual connections with a minimum amount of network access protocols. An established connection provides end-to-end full-duplex packet transmissions between the two DTEs involved.

3.3.1 Characteristics of the syncronous Infocall service

The establishment of virtual connections and their clearing in the syncronous Infocall service follows the same protocol as in the Infoexchange service for digital circuits. The call establishment procedure is logically similar to the call establishment protocol of Infogram and consists of the following two exchanges: "call request" sent by the DTE, followed by "proceed to address" sent by the DCE, and "address sequence" followed by "ready for data". Once established, the connection provides transparent transfer of data packets between the two connected DTEs, simultaneously in both directions.

Options for different data packet formats are available. Typical packet formats are BSC and HDLC, as mentioned in section 3.1.2 (b). Infocall packets do not contain any header information; the whole information content of a packet is user data; and there are no control packets. The only protocol convention used during the data transfer phase is the packet format which is essential for distinguishing between user data to be transmitted, and idle line signalling.

3.3.2 Comparison with other data communication services

Although the syncronous Infocall service is said to provide virtual calls, which are also provided by the Infogram service, it is to be noted that the characteristics of the Infocall virtual connections are quite different from the virtual connections provided by Infogram and Datapac, as discussed in section 3.1.3.

The following points are the most important differences:

a) Infocall is a single access interface.
b) There is no link access protocol. Therefore, the possible transmission errors introduced by the link between the DTE and the network must be recovered by an appropriate protocol between the two DTEs involved.
c) There is no flow control; the only restriction is the finite capacity of the physical link to the network.

The above points represent, in fact, similarities between the syncronous Infocall service and real switched circuits, such as provided by CNCP's Infoexchange service and TCTS's Dataroute. However, there are the following points that distinguish Infocall connections from switched circuits:

d) The transmission delay is longer than in real circuits due to the queuing delay at the nodes.
e) The error rate between network nodes is very low (lower than for digital circuits) due to inter-node packet retransmission. However, the link between the DTE and the network may in turn introduce transmission errors.
f) All data transmitted must be embedded in transmission frames (packets) of a certain format and with some maximum length.
g) The tariff is charged by amount of information transmitted and not by connect time.

3.3.3 Applications for the Infocall service

The main application of the syncronous Infocall service seems to be for private computer networks where the virtual connections of Infocall can be used instead of leased or dialed-up syncronous circuits. Most present-day systems that use point-to-point lines for data transmission could use this service without much change. They would use the same DTEs with the same communication protocols as used for real circuits. Several Infocall interfaces are available with different packet formats, to be chosen according to the protocol used by the DTEs.

For a system built around real circuits for data transmission, the syncronous Infocall service provides packet-switched communication with a minimal amount of change. However, it introduces additional transmission delay. This additional delay could cut down the throughput efficiency of the communication, particularly at high transmission capacities and when half-duplex protocols are used between the connected DTEs.

The syncronous Infocall service seems to be a compromise for users of real circuits and does not provide all the flexibility and efficiency that is available with packet-switching. In particular, it does not provide any concentration facilities.

4. COMPATIBILITY ISSUES

After having elaborated, in section 3, on the similarities and differences of the two data networks, Datapac and Infoswitch, we discuss in this section what the differences of the protocols mean to the users, and how they affect the compatibility between the two networks. The first two subsections deal with the link access and the packet level protocols for network access by multi-access DTEs, such as host computers or terminal handlers. These protocols are discussed in section 3.1. The remaining subsections deal with the issue of end-to-end protocols for communications between application programs and terminals.

We consider two aspects of compatibility for communication protocols:

- compatibility of the communication service offered, and
- compatibility of the protocols themselves, i.e. the implementations of the service.

We explain this distinction with figure 4. We consider two protocols X and Y that are used with two data networks respectively. Suppose that both protocols offer the same service, i.e. it is possible to define a user interface that is the same for both protocols. In this case we say that the two protocols are compatible as far as the service offered is concerned, because the system that interfaces to the protocols, such as higher level protocols or user applications, does not see any difference between the two protocols (as long as the right protocol is used in conjunction with the right network).

We say that protocol X is compatible with protocol Y if X can be used instead of Y for most applications. It is important to note that compatible service provided by two protocols does not imply that the protocols are compatible. For example, let us consider the different

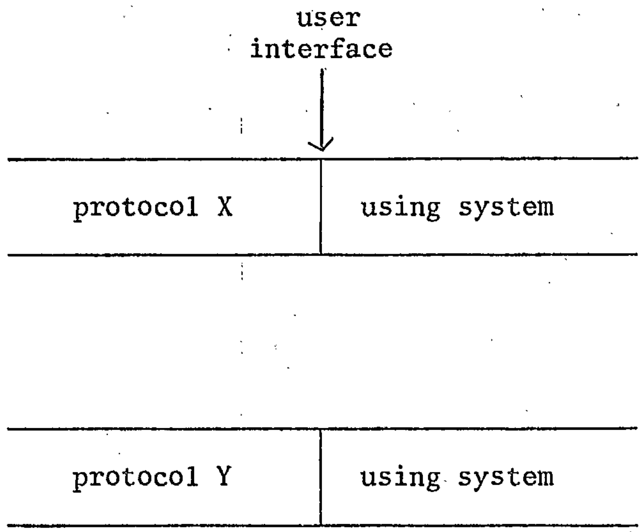


figure 4

link access protocols provided by Infoswitch. These protocols are not compatible with one another, but they offer the same service, i.e. error free communication with the network. We say that they are compatible as far as the communication service offered is concerned, and therefore it is easy to implement the same virtual call packet protocol on top of any of these link access protocols.

4.1 Compatibility of the link access protocols

The link access protocol provides an interface for the reliable exchange of data and control packets between the user's DTE and the data network. The protocol, which handles link establishment and error recovery, is based on the physical interface for serial bit transmission, and a frame format for obtaining transparency and error detection.

The functions that are usually performed by specialized hardware, i.e. the physical interface and the problems of the frame format, are the same in both networks. The physical interface is the one usually used for syncronous circuits, and there are two possible frame formats:

- The BSC frame format which is presently much used for syncronous communications (we note that for Datapac the transmission facility must be full duplex);
- the HDLC frame format which is proposed as an ISO standard, and used by IBM's SDLC communication procedures.

We conclude that, as far as hardware is concerned, the network access protocols of both networks are largely compatible with one another and with present-day standard practice.

The link access protocols, usually implemented in software, are different for both networks. Datapac offers the full-duplex HDLC link protocol included in the proposed CCITT standard X-25. Infogram offers three alternatives: a different full-duplex HDLC protocol, a subset of IBM's SDLC and a subset of the half-duplex BSC protocol (again for IBM).

One of these link protocols must be implemented in the user's DTE. Which one is chosen depends on the options provided by the network, and on the particular DTE. All of these link protocols provide essentially the same service: error-free communication with the network. This service is used by the packet level protocol for establishing and using virtual calls.

In order to simplify an eventual change of the link protocol for a given DTE, and to improve the modularity of the protocol software design, it would be very useful to use a standard, well defined interface between the link level and packet level protocols, an interface independent of the actual link protocol used. Unfortunately, such a specification is not contained in the international standard specifications. Further work should be done in this area.

4.2 Compatibility of the multi-access packet protocols

a) The basic virtual call service

CNCP's Infogram service and TCTS' SNAP access to Datapac offer a similar service for data communications. Both networks offer a basic service of packet-switched virtual calls between the DTEs connected to the network. Each DTE can use several virtual calls simultaneously. A DTE can establish a virtual call by providing the address of the called DTE, use an established call for data transfer, reset the flow control, i.e. eliminate any data packets in transit, or clear the call. Data transfer is provided simultaneously in both directions in the form of packets of data of variable size, with a maximum size of 256 octets. Data packets are delivered by the network in the same order in which they were sent.

As far as this basic service is concerned, both networks are compatible. However, there are non-compatible additional facilities offered which we discuss below. Also the protocols that provide the basic service are not compatible. Although certain functions, such as the flow control of data packets, the resetting and clearing of a virtual call, are implemented the same way in the protocols of both networks, there are many aspects that are different.

Since the basic virtual call communication service is used by the end-to-end protocols of the user's applications, it would be useful to define an interface between the same basic virtual call service provided by both data networks and the higher level protocols of the user. As in the case of the interface between the link and packet level protocols, such an interface specification would improve the modular structure of the communication software in the user's DTE, and would simplify the adaptation of a DTE to both networks. Such an interface will include the following actions that can be called upon by the higher level protocols of the user:

- to establish a new virtual call,
- to send the next data packet on an established virtual call,
- to receive the next data packet on an established virtual call,
- to reset the data flow on an established virtual call,
- to clear a virtual call.

Such an interface could be used to build higher level end-to-end and application protocols that are compatible with both data networks. Further work is needed in this area.

b) Additional facilities

In addition to the basic virtual call service discussed above, TCTS offers a number of facilities that are not necessary for most applications, but can be useful on certain occasions. These facilities are not directly offered by CNCP (according to the preliminary specifications [1]). In the following, we discuss the different additional facilities one by one, point out for what purpose each facility can be used, and show how the same facility can possibly be obtained in the CNCP network.

Permanent virtual circuits

As indicated by the name, permanent virtual circuits are used where the user wants permanent connections between different DTEs. Except possibly for tariff, a permanent virtual circuit is equivalent to an established virtual call. Therefore one could use virtual calls instead of permanent virtual circuits. However, the establishment of a virtual call could be delayed due to a busy condition of one of the DTEs involved. This seems to be the only difference.

The address of the calling DTE

For an incoming call, the address of the calling DTE is provided by the Datapac network. This facility is useful for obtaining some security and user identification. In the case of a time-sharing system, for example, the billing could be based on the calling address information provided by the network. However, this information is not sufficient for virtual calls established through dialed-in connections to Datapac. In general, the calling address information must be supplemented with explicit terminal and user identification in order to obtain high security. If the calling address information is not provided by the network, there is no other reliable method for obtaining it.

User data in call establishment packets

In Datapac, up to 16 octets of user data can be transferred during the call establishment phase to the destination DTE. For example, this facility can be used for subaddressing, i.e. the calling DTE indicates, in the user data field, with which particular subsystem or service of the called DTE it wants to communicate. Before accepting the call, the called DTE will verify that the requested subsystem or service is available.

In the Infoswitch network, the same function can be realized by an appropriate end-to-end protocol, implemented on top of the virtual call interface. For instance, such an end-to-end protocol could foresee an initial data packet to be sent over each established virtual call, which serves for subaddressing and setting of other end-to-end parameters. If this initialization is not successful the virtual call will be cleared.

The more data bit

In Datapac, the user can indicate by a "more data bit" in the control field of a full data packet that more data, transmitted in the following packet(s), belongs to the same logical unit of information. This facility is useful for the fragmentation of large data units into several data packets and their reassembly at the destination DTE. It is also useful in internetwork data traffic, if the data of a packet is considered a logical unit, and the maximum packet size is different in the networks involved.

In the Infoswitch network, the same facility can be obtained by using an appropriate end-to-end protocol. For instance, one could possibly reserve one octet at the beginning of each data packet for this and other functions of the end-to-end protocol.

In the case of virtual calls with interactive terminals, one uses normally the convention that a logical unit of data is terminated by the special character CR (carriage return). This is another form of end-to-end protocol for indicating the size of the logical units of information.

Interrupts

In Datapac, interrupt packets can be sent over virtual calls. Containing one octet of user data, they can travel faster than normal data packets and are not subject to the flow control of data packets. This facility is used by TCTS' conventions for the Interactive Terminal Interface (see sections 3.2 and 4.4). However, this facility seems to be essential only when an important message must be communicated to the destination DTE and the latter does not accept any more data packets from the network.

For example, this situation can occur when a user on a terminal wants to interrupt an application program that loops without reading, and the input buffers in the DTE are full of characters to be read by the program.

In the Infoswitch network, this problem can again be solved by an appropriate end-to-end protocol which ensures that at least one data packet, for end-to-end flow control and interrupt information, can be received anytime by each DTE. Another possibility would be to use two virtual calls between the DTEs in question: one for data transfer, and the other for interrupt information.

The data qualifier bit

In Datapac, a "data qualifier bit" in the control field of a data packet can be used to distinguish between two levels of data transfer. One level could be used for the transfer of user data, and the other for the exchange of control information for an end-to-end protocol. The facility is for example used this way by the conventions of TCTS' Interactive Terminal Interface (see section 3.2 and 4.4).

In the Infoswitch network, as mentioned earlier, an end-to-end protocol could be implemented by reserving one octet of data at the beginning of each data packet for the control information of the end-to-end protocol.

4.3 End-to-end protocols

Different end-to-end protocols have been implemented by computer manufacturers for the communication between application programs (process-process communication protocols) and between a terminal user and an application program (process-terminal communication protocols, or virtual terminal conventions). For increasing the compatibility of the computing systems of different manufacturers it would be useful to adopt common standard end-to-end protocols. Such protocols could also be used for internetwork traffic. Different end-to-end protocols for communications between heterogeneous computing systems have been implemented on several computer networks, and some end-to-end protocols have been proposed as standards [5] .

As discussed in section 4.2, the Datapac SNAP protocol contains certain facilities for end-to-end communications that in the case of Infoswitch would be implemented in a higher level end-to-end protocol. However, the SNAP facilities are not complete; for instance, there is no end-to-end flow control. For this reason, also with Datapac, the user has to implement, on top of the virtual call service, a higher level end-to-end protocol.

What kind of end-to-end protocol will be implemented in the DTE, by a particular network user would depend on the data communications application and on the operating systems used in the DTEs. We believe that the adoption of standard conventions for end-to-end communication could largely increase the compatibility of different application systems and different computer systems. More work should be done in this area.

As far as the compatibility between Datapac and Infoswitch is concerned, we note that, whatever end-to-end protocol is implemented in the user's DTEs connected to Infogram, the same end-to-end protocol could easily be implemented when the DTEs are connected to Datapac, because the basic virtual call service of Infogram is also provided by Datapac's SNAP (see section 4.2 a)). However, it would be much more difficult for a given end-to-end protocol, implemented in the DTEs using all the additional facilities (see section 4.2 b)) offered by Datapac, to be adapted to CNCP's Infogram service, because the additional facilities used are not directly offered by Infogram, but instead must be incorporated into the end-to-end protocol implemented by the user. We conclude that a user who is interested in using both networks for providing a given end-to-end communication facility, may prefer, for the implementation of this facility, to use only the basic virtual call service offered by both networks, and to ignore the additional facilities offered by Datapac.

4.4 Interactive terminal conventions

In many data communication applications, a computer communicates with interactive terminals. When using a packet-switched data network, the computer would normally access the data network through a multi-access protocol as discussed above and would exchange data through virtual calls with interactive terminals. In the case of intelligent terminals, the packet mode protocol for network access would be implemented in the terminal for direct connection to the packet-switched network. In the other case, the terminal would be connected to the network via an interface for asyncronous terminals; CNCP provides for this purpose the asyncronous Infocall service; TCTS provides the Interactive Terminal Interface (ITI) to Datapac. The scope of these two terminal interfaces are quite different.

CNCP provides the basic virtual call service, as discussed above, for asyncronous terminals with different options for packet assembly strategies (usually, but not always, one line of text is sent as one data packet). The ITI of Datapac provides, in addition, a certain end-to-end protocol for terminal handling. It includes conventions for handling packet assembly, break signals for host interruption or output flushing, and a procedure for parameter setting.

It is important to note that the ITI conventions of Datapac include an end-to-end protocol, implemented on top of the Datapac virtual call packet level protocol, that must be followed by the host computer communicating with the terminal. At the side of the asyncronous terminal, this end-to-end protocol is implemented in the carrier-provided network interface machine (NIM).

We believe that it would be very useful to have standard conventions for communicating with interactive terminals; these conventions are sometimes called a virtual terminal interface. Much work is presently being done in this area by different organizations. Hopefully, these efforts will converge to an internationally agreed standard.

Meanwhile, TCTS is developing and implementing their ITI conventions which are incompatible with the end-to-end protocols for interactive terminals implemented by other organizations. In particular TCTS' ITI is incompatible with CNCP's asyncronous Infocall. The latter includes essentially only the basic virtual call service (see section 4.2 a) and no additional end-to-end conventions. The incompatibility is noticed mainly by the host computer that talks to the interactive terminal at the other end of the network. In the case of Infoswitch, it sees a normal virtual call connection over which characters are exchanged. Some additional conventions about carriage returns, etc. must be followed. In the case of Datapac, the computer sees, at the other end of the virtual call, a terminal handler. Some of the data packets exchanged over the virtual call connection are not exchanged with the physical terminal, but with the NIM terminal handler.

We think that the provision of an asyncronous basic virtual call interface to Datapac, such as CNCP's Infocall service, would increase the compatibility of both networks. More work must be done in this area of virtual terminals before any definite solution can be suggested.

5. SUMMARY AND CONCLUSIONS

5.1 The data communication facilities offered by the Datapac and Infoswitch networks

In addition to the traditional data transmission facilities in the form of analog or digital, leased or dialed-up circuits, TCTS and CNCP plan to offer, in the near future, transmission facilities in packet-switched technology. To the user, packet-switched technology is characterized by the facts that data is sent and received in the form of packets, the tariff charges are determined mostly by the number of packets transmitted (and not by connect time) and the interface to the network, including a packet-mode access protocol, is more involved than the simple interfaces to leased or dialed-up circuits.

CNCP presents its data transmission network under the name Infoswitch, which includes four services:

- Infoexchange,
- syncronous Infocall,
- asyncronous Infocall, and
- Infogram.

Infoexchange is a service of dialed-up or permanent digital circuits similar to TCTS' Dataroute, the three other services are based on packet switching. The syncronous Infocall service provides packet-switched virtual circuits with a user interface very similar to digital circuits. The Infogram service is a network interface for host computers, terminal handlers and concentrators which allows the establishment, through the same physical connection to the network, of several simultaneous, packet-switched virtual calls to different terminals on the network. The network access protocol for this service includes, in addition to the physical interface, a link access protocol that ensures correct communication with the network and a packet level protocol that handles the different virtual calls. This network access protocol must be implemented on the data terminal equipment (DTE) that uses the Infogram data communication service. The asyncronous Infocall service provides simple network interfaces for asyncronous interactive terminals, compatible with the Infogram service.

TCTS calls its packet-switched data network Datapac. The services offered are similar in nature to CNCP's Infogram and asyncronous Infocall. Datapac's standard network access protocol (SNAP) is similar to, but different in many aspects, from the Infogram network access protocol. It is based on the internationally proposed standard X-25 which will be voted by the CCITT in September 1976. The planned interface for asyncronous terminals, called Interactive Terminal Interface (ITI), includes in addition to the usual virtual call conventions, a particular end-to-end virtual terminal protocol.

The main characteristics of the packet-mode access protocols of both networks are summarized in the tables 1 through 4 of section 3.

We note that none of these networks provides the packet-switched datagram service. Although at present most data communication users who are interested in packet-switching services prefer virtual calls to datagrams, it is probable that for certain future applications datagrams would be better suited [7]. Experience with the announced virtual call services and further studies are necessary for determining how important the datagram service is as a public data communication facility.

5.2 Alternatives for network (inter-) connections

Given two public data networks that offer packet-switched communication facilities in Canada, a number of companies consider the possibility of using both networks for their data communication applications. Depending on the degree of collaboration between the two carriers, different situations can be envisaged, ranging from separate user systems using different networks until integrated user systems that use both networks for different geographical regions within Canada. We discuss in this section the impact of simultaneous user connections to both networks, of inter-network gateways, and of the tariff for inter-network communications on the different kind of user systems, and on the availability of network access and back-up service. The problems related to the compatibility of the access protocols will be discussed in section 5.3.

The main results of these considerations are shown in Table 5. For each of the different user systems, which are explained in more detail below, the table shows whether the system can be realized with a connection to one network alone or to both networks, and in the presence or absence of inter-network gateways. The possibility of using the second data network as back-up facility is also considered. The results are discussed in detail below.

The user systems we consider are data processing networks and are implemented on one or several host computers and a number of interactive terminals. We suppose that each terminal is permanently connected to a given data network, and each host computer is either connected to one network, or has an alternate connection to both networks, i.e. a single network interface unit that can be connected to each network in turn, or has two simultaneous interfaces to both networks.

The first kind of user system is a system for a single application using a given data network for the communication needs. It requires some of the resources of the given host computer, as shown in figure 5(a) , and communicates with terminals and/or other host computers that are connected to the same data network. We consider two cases concerning the communication protocol compatibility:

- The communication protocols of the application are tailored to the network access protocols of the data network used; we say the system is "one-compatible".
- The communication protocols of the application are designed such that they can be easily adapted to the access protocols of either network (see section 5.3); we say the system is "bi-compatible".

It is clear that for such a system a single network connection is sufficient

Table 5: Network (inter-) connections for different kinds of user applications

The user's data processing systems			The system could be realized with a single connection to one network	The system could be realized with an alternate connection to both networks	The system could be realized with simultaneous connections to both networl
single application system using one network		"one-compatible"	yes	yes	yes
		"bi-compatible" (2)	yes	yes (1)	yes (1)
multiple applications system	alternate use of networks	"one-compatible" applications		yes	yes
		"bi-compatible" applications (2)	with gateways (3)	yes (1)	yes (1)
	simultaneous use of both networks	"one-compatible" applications			yes
		"bi-compatible" applications (2)	with gateways (3)	with gateways (1) (3)	yes (1)
"partitioned system" using both networks for different geographical regions (2)			with gateways (3)	with gateways (1) (3)	with gateways (1) (3)

Notes:
(1) The second data network can be used as back-up facility for data communications between hosts that have connections to both networks. In the presence of gateways this back-up facility can be extended to terminal-host communications.
(2) The use of standard end-to-end protocols would facilitate communication between different user systems.
(3) It is important for these applications that the inter-network communication facility is offered at a tariff that is close to the tariff for communications within one network (low extra cost for inter-networking).

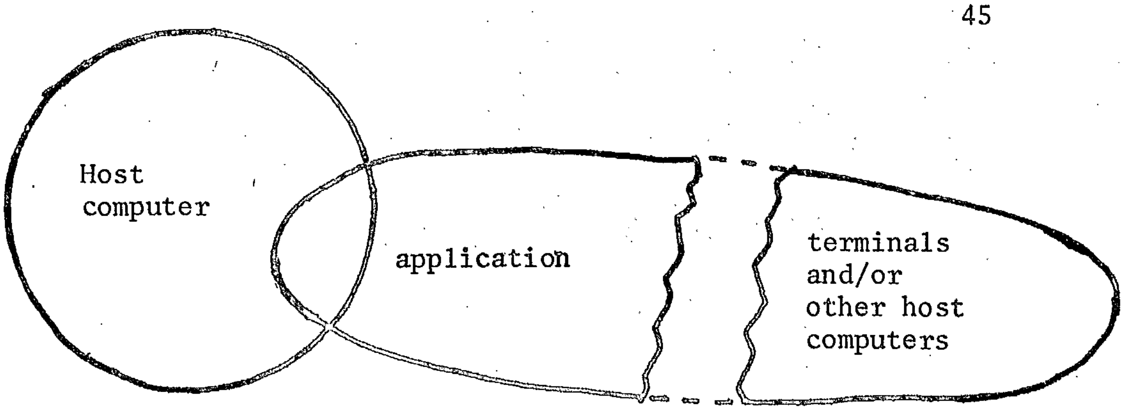


Figure 5 (a)

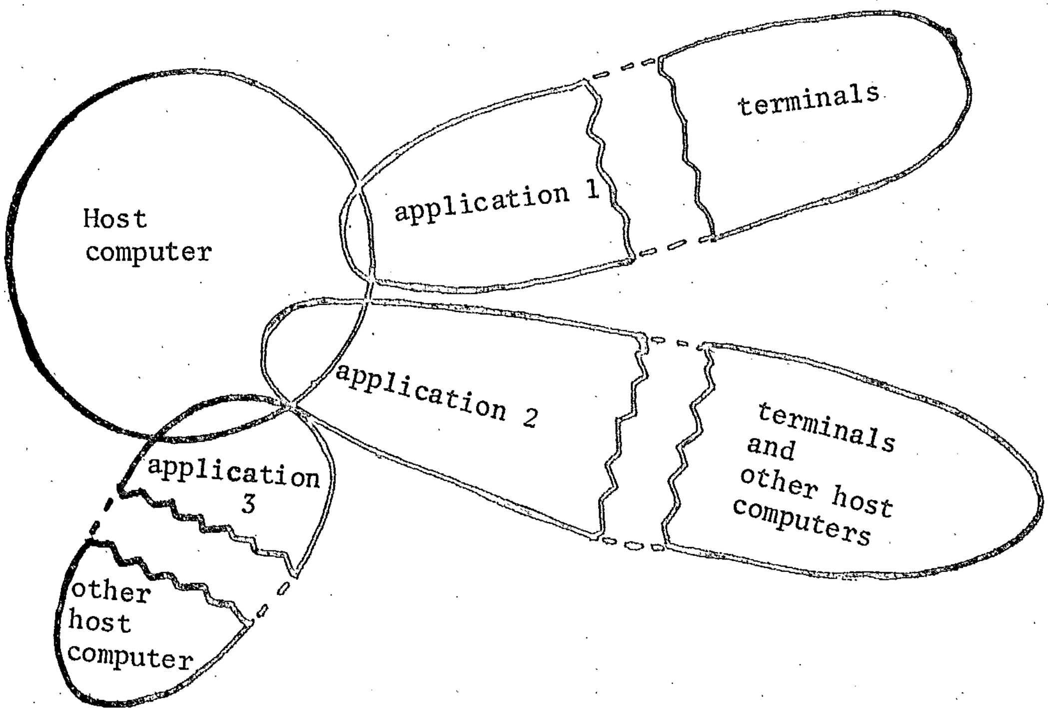


Figure 5 (b)

(as indicated in Table 5). In the case of a "bi-compatible" system, and a host connection to both networks, we assume that the host computer contains the communication software for interfacing with both networks, so that the second network could serve as back-up facility.

The second kind of user system consists of several applications such as those discussed above (see figure 5(b)). For each application, the corresponding terminals and/or other host computers are connected to a particular data network, which is used for the application. Each network is actually used by some application. We consider two categories of systems:

- systems for which an alternate schedule for the use of the networks can be established; for instance a banking system with a subsystem for on-line banking, used during the day and implemented on one data network, and a subsystem for batch data transmission between host computers, used during the night and implemented on the other data network.
- systems for which a simultaneous use of both data networks is essential; for instance in the presence of two on-line subsystems using different networks for communication.

In the first case, an alternate connection of the host computer to both networks is sufficient (as indicated in Table 5), whereas in the second case the host computer needs simultaneous access to both networks, which can be obtained through a simultaneous connection to both networks, or through inter-network gateways. As above, we also distinguish the two cases of "one-compatible" and "bi-compatible" subsystems.

The third kind of user system, which we call "partitioned system", is a system that uses both data networks for the same application such that different geographical regions of Canada are covered by different networks. We suppose that such a system would be designed for using inter-network data traffic.

Inter-network data traffic would typically be implemented as virtual call connections that originate at a subscriber's DTE in one network and terminate at another DTE in the other network. An inter-network addressing scheme as for international traffic could be used, or a uniform Canadian assignment of subscriber addresses in both networks. The technical problems could be solved, for example by using gateways between the two networks. The main problem is one of tariffs. A uniform billing scheme where the user does not see any artificial cost for network interconnection would be preferable.

One use of inter-network traffic is for back-up purposes. We suppose that the networks are connected by gateways, and that the user's host computer has an alternate or simultaneous connection to both networks. If now the local node of the network used by the application fails then the communication with the distant terminals and/or host computers can probably be maintained through newly established virtual calls through the other network, unless the terminals are connected to the failing node. More details are given in the appendix.

It is important to note that the inter-network tariff structure is of great importance for the feasibility of many applications. All those applications marked "with gateways" in Table 5 rely on an inter-network tariff with low extra-costs, i.e. the tariff for an inter-network virtual call communication is close to the tariff for virtual calls within one network. Such a tariff is particularly important for the applications using both networks for different geographical regions ("partitioned systems").

Tariffs, within one network, that are largely independent of the distance, represent another case for inter-network tariffs with low extra-costs. High extra-costs would penalize inter-network traffic in no relation to the distance involved: a virtual call between two Montreal subscribers of Datapac and Infoswitch, respectively, would cost about twice as much as a virtual call between Montreal and Vancouver.

A more detailed discussion of the relation between the different user applications and the network (inter-) connection patterns is given in the appendix. It is not clear from this study what network (inter-) connection pattern would be most appropriate. We believe that the answer to this question depends largely on the kind of systems the Canadian data communications users intend to implement. Further studies of this question would be useful.

5.3 The compatibility of the network access protocols

A packet-mode network access protocol, such as the Infogram service or Datapac's SNAP, is a means for using efficiently the full service offered by the packet-switched data network. The protocol includes, in addition to the physical interface between the network and the DTE, a link access protocol that is responsible for error-free communication between the DTE and the network, and the packet-level protocol that allows the establishment and use of several virtual calls from the DTE to other DTEs connected to the network. Mostly used for DTEs such as host computers, terminal handlers or concentrators, the network access protocol must be implemented on the DTE. The carriers also offer a network interface for asycronous interactive terminals, in which case the access protocol is implemented in a carrier supplied network access machine.

An organization that wants to use the same DTE for communication through different networks has to implement the network access protocols of all these networks in his DTE. Therefore, it would be advantageous that all networks use the same access protocols. The common carriers try to reach an international agreement on this subject in the CCITT. However, such an agreement is not sufficient for an easy use of packet switched services. Since most computer users rely on the vendor's system software, it would be very useful that the standard be accepted by the computer manufacturers and incorporated by them in the computer system software. We come back to this point in section 5.4.

a) User systems connected to one data network

In the case of an application system using only one data network, the problems of compatibility arise between the access protocols of the data network and the communication protocols provided by the computer manufacturer, or already implemented in the application system. We mention here only two approaches to connecting host computers to data networks: (1) implementing the network access protocol in the host systems software, or (2) connecting the host through a standard host interface to a front-end computer which in turn is connected to the network and contains the software that implements the network access protocols as well as the host interface.

We do not discuss these problems here any further. More work must be done in this area for obtaining good interface facilities with packet-switched data networks for the variety of computing equipment available today.

b) User systems connected to two compatible networks

We suppose now that the network access protocols of Datapac and Infoswitch are compatible (which is not the case according to the present plans). In this case, the compatibility problems are the same as for user systems connected to one network only (see point a) above). Alternate connections to both networks can be obtained by switching the same physical interface of the DTE from one network interface to the other.

Simultaneous connections with both networks require two physical network interfaces on the DTE. However, the communication software would be the same for both connections.

c) User systems connected to two non-compatible networks

We consider now a user system connected to both Canadian public networks, which are not compatible according to the present, preliminary specifications [1,2]. In this case, in addition to problems arising for a single network connection, there are problems related to the compatibility between the different network access protocols. The sections 3 and 4 of this report deal with these problems in detail.

Both networks use the same physical interface and essentially the same packet formats. Therefore, the same line control hardware can be used for accessing both networks, one line control unit in the case of alternate connection, or two identical control units in the case of simultaneous connections.

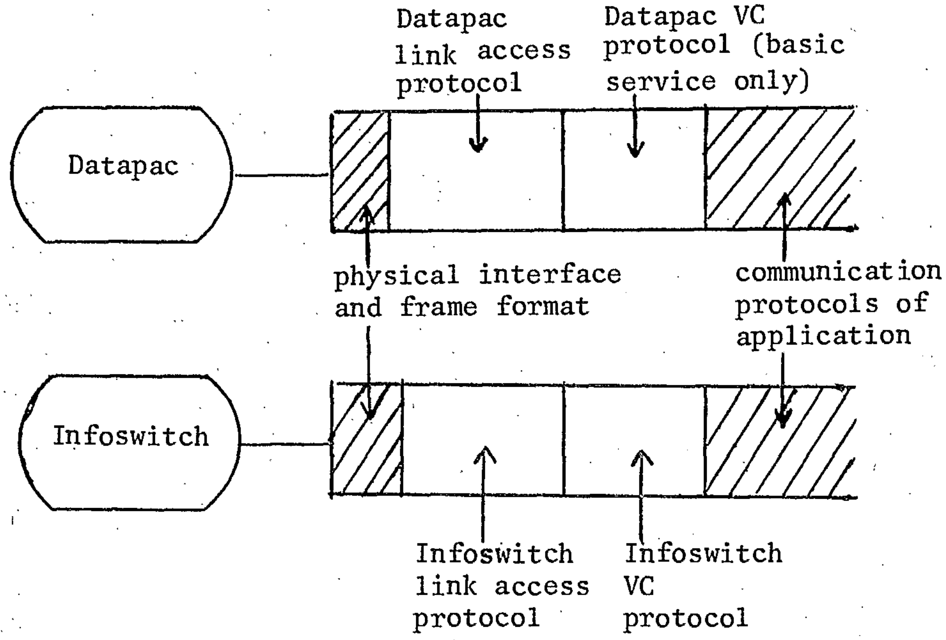
The link access protocols available for both networks are different (see Table 1). Therefore, the communication software of the DTE must include two different link access protocols. Similarly, the DTE must contain the two packet-level protocols for both networks. Although certain aspects of the protocols are identical in both networks, there is essentially a duplication of software for the same function, namely the virtual call interface to a data network.

The services offered by the Datapac and Infoswitch virtual calls are not the same (see summary in Table 2). It is important to note that both networks, Datapac and Infoswitch, offer the same basic virtual call facilities, including call establishment, data transfer with flow control between the DTE and the network, flow control reset, and call clearing. (We ignore for this comparison CNCP's syncronous Infocall service which resembles real circuits and is discussed in section 3.3.) In addition to this basic service, TCTS offers a number of facilities that are not necessary for most applications, but can be useful in certain situations. CNCP does not offer these additional facilities. They believe that such facilities are better incorporated into the end-to-end protocol which the user builds anyway on top of the virtual call communication service. Section 4.2 b) of this report contains a discussion of how important these facilities are to the user and how they can be obtained with the CNCP network where they are not provided directly.

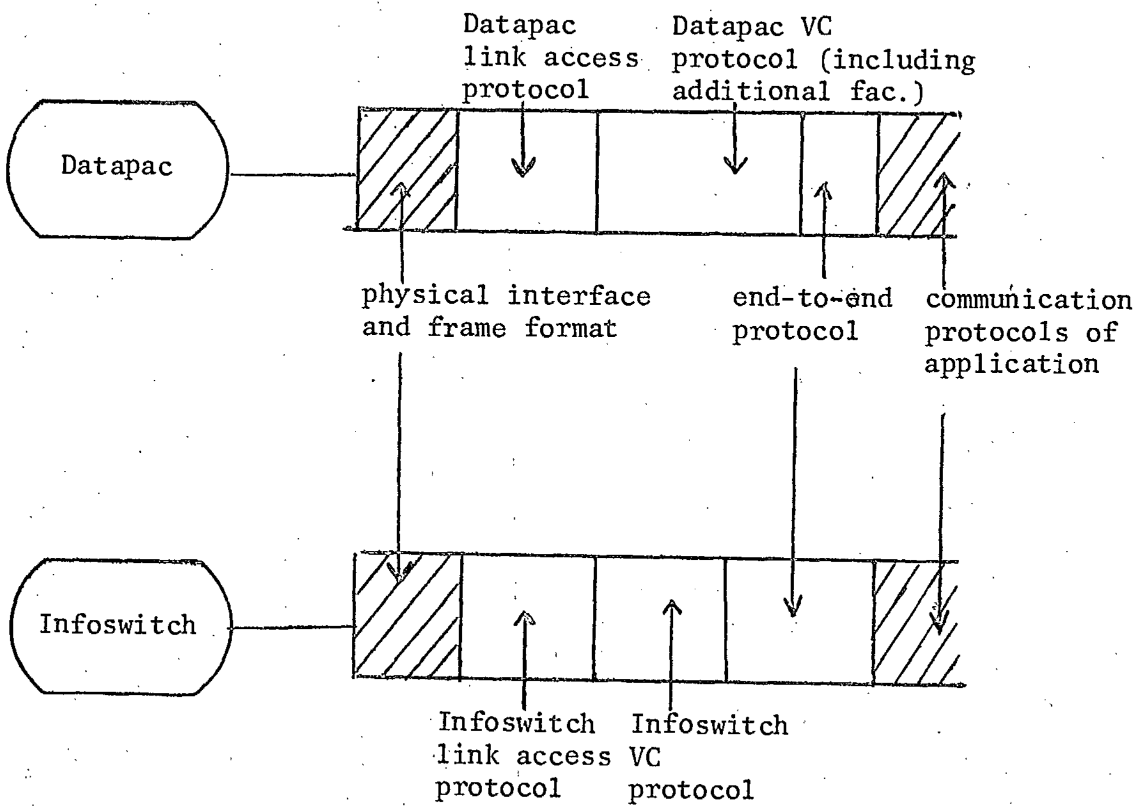
User application systems can be "one-compatible" to a given data network, or "bi-compatible" to both networks, as discussed in section 5.2. Only "bi-compatible" systems can use the second network as back-up facility. "Bi-compatible" communication facilities must also be used for inter-network traffic (see Table 5). There are at least two approaches for obtaining "bi-compatible" systems: (1) the use of the basic virtual call service offered by both networks, and (2) the use of a compatible protocol for end-to-end communication, implemented differently on the two networks. The two approaches are visualized in figure 6.

It is clear that end-to-end protocols can play an important role for the compatibility of data processing systems, data communications networks, and computer systems. We mention, as an example, the end-to-end protocol of reference [5] which has been proposed as an international standard, and which is also suitable for inter-network communications. Figure 6(b) shows the use of such a standard end-to-end protocol for obtaining "bi-compatible" application systems. The use of standard end-to-end protocols also facilitatesoccasional communication between different user systems that originally have not been designed for such communications. We can only give these general indications here. Further studies and actual experience with data communication applications would be useful in this area.

Conventions for interactive terminals, sometimes called virtual terminals, represent a particular kind of end-to-end protocol. The conventions implemented by the two Canadian networks are not compatible. CNCP's asyncronous Infocall service allows the connection of interactive, asycronous terminals for communication through virtual calls (with CNCP basic service) to host computers or other terminals. TCTS does not offer a basic virtual call service for interactive terminals. They plan to offer network access for asyncronous terminals through their Interactive Terminal Interface (ITI) which, in addition to the basic virtual call communication facility, implements certain end-to-end protocol conventions for host interruption, output flushing and parameter setting.



(a) "bi-compatible" application based on basic VC service



(b) "bi-compatible" application based on a compatible end-to-end protocol

Figure 6 : Interfacing a "bi-compatible" application to both data networks (corresponding shaded areas are identical).

At the terminal side of the communication link, this protocol is handled by the carrier provided Network Interface Machine (NIM), but at the host side it must be implemented by the user.

Both networks could be compatible, in respect to interactive terminals, if TCTS offered an unsophisticated asyncronous network interface as CNCP does. On the other hand, the development of more sophisticated standard virtual terminal conventions is very important. Much work is being done in this area, not only by TCTS, and the agreement on standards is very important because of the large investment in interactive terminal equipment.

d) User systems using inter-network communications

The problems of compatibility for inter-network traffic are essentially the same as for "bi-compatible" application systems. In the case of a single connection to one network, software duplication for the access protocols of both networks is not necessary in the DTE. However, the inter-network communication facility used must be compatible with both networks. As in the case of user systems connected to both networks, shown in figure 6, the compatible communication facility adopted could be for example the basic virtual call service or a standard end-to-end facility. These and other approaches are discussed with more detail in reference [8].

In the case of compatible network access protocols, these compatibility problems for inter-network communication would disappear, just as they do for multiple network connections.

Inter-networking is an area which became of interest only very recently. Only few experiments for interconnection of packet-switched data networks have been performed to date, and more research must be done for evaluating the different possibilities. This is an area of particular concern for Canada because of the two public networks that will be available.

5.4 The user's situation between computer manufacturers and common carriers

Most computer networks in use today are a collection of host computers, concentrators and terminals, connected to one another by leased or dialed-up physical circuits. Typically, all the components of such a network are built by the same manufacturer. The advent of packet-switching has a direct impact on this situation. Packet-switched data networks not only furnish the equivalent of physical lines, but also offer very flexible concentration facilities and, in some cases, terminal control equipment for a variety of terminals. Traditionally, these functions have been provided by user-owned equipment compatible with the communication procedures used by the host computer. In packet-switched data networks, on the contrary, these functions are provided by the network and, as far as these functions are concerned, the host computer has to comply with the network access communication protocols.

The best solution to network access would be to implement the network access protocols in the system software of the host computer or its front-end. However, only few computer users build their own system software. The large majority of users rely on the operating system provided by the computer manufacturer. If the computer manufacturers do not support the packet-mode network access protocols, these users have to use more or less awkward and inefficient adaptation methods.

To the user, the introduction of common carrier standards for data communication procedures (if internationally adopted) have the advantage that they promote the compatibility of terminal equipment, interactive terminals as well as host computers built by different manufacturers, at least as far as communication interfaces are concerned. In the future, a user may be less constrained than he is now to buy all his equipment from the same manufacturer.

Because of this situation, it is not clear whether the computer manufacturers will support the network access protocols in the system software, even when the protocols are accepted as an international standard by the CCITT. It is likely that a standard network access protocol will be supported by small computer manufacturers and be incorporated in systems for new applications because of its flexibility and efficiency. However, large computer manufacturers with much investment in specific, non-standard communication protocols may prefer to make their own standards, an attitude that, in the past, has certainly been successful for IBM.

In the meantime, since the computer manufacturers do not yet support their network access protocols, the common carriers work for the adaptation of the network access protocols to the manufacturer's communication protocols. In the same spirit, software companies may offer services for adapting the user's computing equipment to the packet-switched networks. This development, once again, favors the large computer manufacturer; in fact, most work has been done on the adaptation of IBM computers.

All these considerations show that it is very difficult to keep alive a healthy competition on the data processing market. On the one hand, this market is dominated by one large manufacturer, IBM. On the other hand, the common carriers try to get a larger share of the communication part of data processing. As far as this data communication market in Canada is concerned, there are two companies that start out with a quite unequal background.

Where do the users make their point? Do the Canadian data communication users have an opinion on the subject of packet-switching and standards? - Some certainly do.

There is also the body of federal regulations. They could have a positive impact on the Canadian developments.

We close this section with a quotation from an article by Sanders and Cerf in Datamation [6], who discuss the importance of standards in data communications, and give the following, quite optimistic out-look:

"Over the past several years there has emerged a remarkable unanimity regarding the basic structure of a standard method for accessing data communication networks. The SNA network architecture announced by IBM possesses, from the logical structure point of view, very similar attributes to many proposed standards, including the X.25 proposal discussed above. The protocols announced by Digital Equipment Corp., Burroughs, Honeywell, and others also possess very similar basic structures. There appears to be little technical justification for each of the manufacturers to support network access protocols which differ only in details.

"We are at a point where standardization at the network access level can be a practical reality. There are benefits for all in adopting network access standards. From the user's point of view, it broadens his field of choice by giving him access to a competitive marketplace. From the manufacturer's viewpoint, it opens new markets which would not be economically viable without the resource sharing advantages such standardization implies.

"There is much to be gained by all in agreeing to abide by the forthcoming network access standards. In today's world, the customer is king. By insisting that suppliers adhere to these standards, he will ensure not only his own future, but a brighter future for the industry as well."

6. AREAS FOR FUTURE STUDIES

The comparative analysis performed in this study brings up a number of areas where further studies are required for better understanding the impact of packet-switched data networks and their protocols on the user, and for promoting standards in this field. We mention here the following areas for future studies.

(1) Standards for communication protocols

Much work is presently being done on standards for packet-switched data communications. In order to actively participate in these developments, it is necessary to analyse the different standard proposals and to evaluate their impact on the users. After the possible adoption of the X-25 proposition by CCITT, much international discussion will probably center around the following issues:

- refinements of the X-25 standard, in particular the network access protocol for single access terminals;
- end-to-end protocols for process communications and inter-network traffic;
- virtual terminal protocols, i.e. conventions for interactive terminals.

In relation with the compatibility of different data networks, the end-to-end communication protocols play an important role, as indicated in the present study. More work in this area is required for better understanding and evaluating the different end-to-end protocols proposed, in view of their impact on compatibility and on the user interface.

The present study also suggests for future study the area of virtual terminal protocols. The preliminary specifications of these protocols for the two Canadian networks seem to be incompatible. Future work on this subject could be influential for increasing compatibility in this important area of data communications.

(2) Specifications of interfaces between different levels of protocols

A clear definition of the interface between the link access protocol and the packet level protocol can not be found in the standard specifications. As pointed out in this study, such an interface specification would increase compatibility because it facilitates the implementation of a given packet level protocol independent of the underlying link access protocol.

A similar case is made in section 4.2 a) for the importance of an interface specification between the basic virtual call service, offered by both networks, and the user's end-to-end protocols. Such an interface specification would much simplify the development of user applications that are compatible with the communication facilities of both data networks. We believe that work in this area would be useful to the data network user, and could promote compatibility.

(3) Transport mechanisms for inter-networking

Inter-networking is of particular concern to Canada because of its two national data networks and the importance of international data traffic. The non-compatibility of the access protocols for different data networks complicates the mechanism for data transfer between different networks. We propose in this study two approaches to the inter-connection of the two Canadian networks. Recently, standards for inter-network communications have also been proposed. More work in this area would be useful for evaluating the different inter-networking alternatives, and for promoting appropriate standards for inter-network communications.

(4) Survey of present and future user applications and data communications needs

In section 5.2 of this study, we have discussed several alternatives for network (inter-) connections. Simultaneous connections to both networks, inter-network gateways, and low extra-cost tariffs for inter-network traffic have been found of interest. In order to decide on the relative importance of the different options, more should be known about the ways the Canadian users intend to build their application systems and make use of the two data networks. Such information would also be useful for studies on the adaptation of the user's data terminal equipment to the networks.

(5) Adaptation of the data terminal equipment to the networks

There are many different approaches for interfacing the user's terminals and host computers to packet-switched data networks. The present study does not focus on these problems, but work in this area would be useful for identifying the possible solutions and helping the user to choose the best alternatives. Cost/performance analysis of different configurations using various types and combinations of manufacturers equipment and carrier services would also be useful for planning future computer-communications systems.

7. RECOMMENDATIONS

For promoting the compatibility between different data communications and processing systems and equipment, and for keeping alive a healthy competition, we propose the following lines of action:

1. Promoting standard communication protocols.
2. Allowing simultaneous connections for a DTE to both data networks.
3. Adopting a tariff for inter-network communications with low extra costs.
4. Informing data communications users about the compatibility problems of the packet-switched networks.
5. Promoting equal access facilities for different kinds of user equipment to both data networks.

Appendix: DIFFERENT NETWORK (INTER-) CONNECTIONS AND USER APPLICATIONS

This appendix is a complement to section 5.2 and Table 5. We distinguish four different situations concerning the network (inter-) connections, and discuss the different user applications that can be realized in each situation.

Network (inter-) connection I: no simultaneous connections, no gateways, but alternate connections to both networks. This is the present situation: For no obvious reason, simultaneous connections of one DTE to both data networks are not supported by the Canadian carriers. We suppose that host computers may have alternate connections to both networks, but interactive terminals are only connected to one. The following applications involving both networks can be built:

1. Multiple application systems with alternate use of the networks (see section 5.2).
2. Back-up, version (a): In the case of "bi-compatible" application systems, the alternate network can be used as back-up facility for host-host communications. All hosts involved need an alternate connection to both networks. This method does not work for host-terminal communications as long as the terminals are only connected to one network.

Network (inter-) connection II: simultaneous connections, no gateways. We suppose that the host computers that have a simultaneous connection are permanently connected to both networks. The following applications involving both networks can be realized:

1. Multiple application systems with alternate use of the networks (see "Network (inter-) connection I").
2. Back-up, version (b), like version (a) with "Network (inter-) connection I", but the switch-over to the back-up network can be performed automatically.

3. Multiple application systems with simultaneous use of both networks (see section 5.2).
4. Access to subscribers on both networks, version (a): Many users may wish to communicate, on an occasional basis, with certain other users or services. These users or services may be connected to either one of the networks. Each subscriber with a simultaneous connection to both networks can be reached, anytime, from each subscriber of each network (unless he belongs to a closed user group), as long as "bi-compatible" communication conventions are used.

Network (inter-) connection III: gateways with high extra costs for inter-network traffic: We suppose that one or several gateways between the two networks support inter-network data traffic, and the user's DTEs are usually connected only to a single network. The gateway(s) is (are) either implemented by the carriers or by an independent company using a simultaneous connection to both networks. The tariff for inter-network communication is high compared to the tariff for communication within one network (the cost is essentially the sum of the costs for communication through both networks and for using the gateway). The following applications involving both networks would be feasible:

1. /
2. Back-up, version (c): For a DTE with an alternate or simultaneous connection to both networks, this version of back-up works like version (a) above, or (b) respectively, but the presence of gateways provides the possibility of back-up for host-terminal communications, too.
3. /
4. Access to subscribers on both networks, version (b): Occasional communications with subscribers on both networks, as discussed above, is possible without that any subscriber need a double connection to both networks.

We note that multiple application systems with alternate or simultaneous use of both networks could be built using inter-network traffic. However, in most cases, this would be too expensive compared to an implementation where the DTE is connected to both networks (see "Network (inter-) connection I and II").

Network (inter-) connection IV: gateways with low extra cost for inter-network traffic: We suppose that the carriers support inter-network communications at a tariff that is close to the tariff for communications within one network. Low extra cost for inter-network traffic seems reasonable, since the tariffs of any given network are largely distance independent. We suppose that the extra cost for inter-network traffic is low enough that the extra cost of the inter-network traffic within a "partitioned system" (see section 5.2) is outweighed by the advantage of using in each geographical region the network that best covers the area and gives the best service for network access. The possible applications involving both networks are the following:

1. Multiple application systems with alternate use of networks. We note that in the case of "bi-compatible" applications a single connection to one network is sufficient.
2. Back-up, version (c), see "Network (inter-) connection III".
3. Multiple application systems with simultaneous use of both networks. Same note as for application 1.
4. Access to subscribers on both networks, version (b), see "Network (inter-) connection III".
5. Application using both networks, each one in a particular geographical region (see "partitioned system", section 5.2).

We note that an application system similar to what we call a "partitioned system" can be built using simultaneous connections, but no inter-network traffic. For instance, if all host computers of the system have simultaneous connections to both networks, then the terminals, in each geographical region, can be connected to the network that offers the best access service.

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