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PLANNING TO USE PUBLIC PACKET NETWORKS

Last month we discussed how the new 'personal' micro computers will probably accelerate the movement to distributed systems. Many will be used both as stand-alone processors as well as intelligent terminals for network use. Hence, user organizations will be faced with a continually growing demand for data communication network services, to serve the micros, the minis, and the other levels of distributed processing. Further, the variety of brands of computers to be tied to the network probably will increase. How best can the needed communication services be provided? Most large users are making extensive use of leased circuits for their data communications. But public packet switched networks, about which we have been writing for several years, are now becoming viable options. This is the first of four reports on aspects of distributed systems and the automated office, and how network services will impact them. We think these subjects deserve your serious attention.

Electricite et Gaz de France (EDF-GDF) are two public companies that control electricity production and distribution as well as gas distribution, providing power to over 20 million homes and employing 120,000 people. As one would expect, EDF-GDF has been making extensive use of computers for engineering, scientific, and business applications. But this use of computers is now undergoing a rather interesting change.

At the present time, the company has computers located in seven cities in France, plus terminals in hundreds of other locations. The computer centers are tied together by a leased line network. But the data communication services are closely tied to the applications they serve; a change in one generally will cause a change in the other.

The people at EDF-GDF are currently gaining experience with six distributed processors. Eventually, this may lead to about one hundred processors serving thousands of terminals. But to operate in such an environment, they see that a very different kind of data communication service is needed. The current dependence between the data communications and the application programs cannot be tolerated. Each application system cannot have its own special data communications service.

What EDF-GDF seeks is a data communication service with the following characteristics. First, it should serve all users and all traffic types with a common network. Second, it should be transparent to all users (in the same way that the telephone network is transparent for voice telephone calls, acting almost as if the speakers are talking face to face). Third, the service should be independent of the application programs, the computer hardware, and the systems software that are used. Fourth, the service should be designed so that any terminal can access any relevant application.

Further, any node of the network must be able to handle a mixture of traffic in a common manner, say the people at EDF-GDF. The types of traffic that must be handled include bulk (file) transfer, batch transfer, and interactive traffic. Moreover, the traffic must be handled on a priority basis, with interactive messages receiving the highest priority. Real-time process control applications have been excluded from this project and will continue to use their own dedicated communication services.

The general approach

The company has selected TRANSPAC, a packet switched network being installed by the French PTT (post, telephone, and telegraph), as the basis of their network. TRANSPAC has been under development since 1971 and will begin commercial operation later this year. We will have more to say about TRANSPAC shortly.

The company has designed 'stations' to interface with the network, for providing a common access to the network for all its users. In fact, if a terminal must access another terminal at the same location, they communicate through the station to which both are attached, so that common procedures are used throughout.

Some stations will handle mainly business traffic (interactive and bulk transfers), others will handle mainly scientific traffic (batch transfers), and some will handle a mixture. Hence, stations must be able to handle such mixtures of traffic.

The stations in turn will interface with the X.25 synchronous protocol (to be discussed below) used on the TRANSPAC network. So a station must be able to handle signals of teleprinter and display terminals as well as X.25 synchronous transmissions.

The stations will be using several levels of EDF-developed protocols for handling the traffic. These include:

Network access procedures. The MART (Module Access Reseau TRANSPAC) module provides communication link management, matching between links and virtual calls, network call control, packet protocol, virtual call set-up and disconnect, and block fragmentation and re-assembly. (We will be discussing some of these concepts later in this report, in case they are not familiar to your.)

An international standard for packet networks has been established, called X.25, which includes the 'virtual call' discipline for these networks. This discipline uses the concept of a defined routing, from source node to destination node, for all packets transmitted. In concept, it is very similar to a telephone circuit; it is a virtual circuit from source to destination. The virtual circuit may be set up on a permanent basis (like a 'hot line' telephone) or on a temporary basis (like a dialed telephone call).

A communication link *uses* a virtual circuit, so that a virtual circuit may handle more than one communication link. For example, if there are several terminals at one location that are communicating with a host processor at another location, each terminal would be using its own communication link, but all of these links could be handled by the same virtual circuit, in the same way that terminals share a common telephone circuit today.

So the company's network access protocol sets up virtual calls and assigns communication links to the virtual calls.

Block handling protocol. The next higher level of protocol that the company has developed deals mainly with flow control. First, it is responsible for establishing and disconnecting communication links. Once a link has been set up, this protocol module (which they call MCC—Module of Communication between Correspondents) checks to see that all blocks in a message have been sent or received. Blocks may be up to 2,000 characters in length. This MCC module handles block acknowledgement and error recovery.

Terminal protocols. The station is designed to be able to use a Virtual Terminal Protocol, a standard procedure for serving classes of terminals, for interactive, batch, or bulk transfers. Interface hardware and/or software may be needed, of course, to convert any particular terminal type to agree with the virtual terminal protocol. But a new terminal type may be added to the network generally by just providing this interface. At first, however, EDF-GDF will not provide users with such a protocol. Instead, all CRT terminals will be intelligent and will be programmed to interface with the processors.

Developing the concepts

The company has been conducting research and development on these network concepts since 1974, as described in Reference 1. When the TRANSPAC network becomes operational a few months from now, EDF-GDF will begin putting them into pilot operation.

The first step in their project, completed in early 1975, was to represent two stations and a computer center on an IBM 370/145 running under VM 370. They began their first simulations of network operations in this manner.

The second step, conducted during 1975, was to take the terminal station software out of the 370 and put it into a Cii MITRA 15 mini computer. At this point, there still was no packet network involved but communications between stations was simulated and different protocol requirements were investigated.

The third step, which was completed in early 1977, involved taking the host station software out of the 370 and putting it into a front-end processor (a Systems Engineering Laboratories SEL 86). Also, they began using the PTT's experimental packet network, RCP, operating under a virtual circuit protocol.

The fourth step, which they expect to complete late this year, is to begin pilot operation with the TRANSPAC network, serving six outlying computer centers and terminals at some locations. The bulk transfer protocol and the batch transfer protocol programs were completed earlier this year, and they hope to have the interactive protocol completed by November. With all of the development work that has already been done, they hope and expect that this step will go relatively smoothly. They will then be ready to begin productive use of the network and to expand the number of processor and terminal sites.

Eventually, EDF-GDF foresees a processing center in each of France's geographic departments, plus national centers at Clamart, near Paris, and Issy-les-Moulineaux. Their network control center will also be located at Issy-les-Moulineaux. While they expect some center to center data flow, the main flows will be from terminals to centers and then from centers to the national centers.

EDF-GDF plans to use TRANSPAC for a large part of the data communications. However, in some instances, leased lines will be used where they are less expensive—for short distances and heavy traffic. But the same block handling protocol will be used in either case, thus providing users with a common communication service. EDF-GDF feels that TRANSPAC can provide, in addition to some standardization, an economical and evolutionary means for communicating between computers and terminals spread all over the country.

Transpac

As mentioned earlier, the French PTT became interested in packet network technology in 1970 and in 1971 decided to build an experimental packet network. This RCP network was put into operation in January 1975 with three nodes, at Paris, Rennes, and Lyon. A second Paris node was later added to the network, and last year a fifth node, with an X.25 interface, was connected. The RCP network is considered semi-experimental; it is in operational use, with a variety of host computers, and eight hours per day of availability is guaranteed. It can be accessed by leased lines to the nodes, or by dial-in to the nodes from the Telex network or the telephone network.

Last year, RCP was used in an interesting demonstration, given in conjunction with the IFIP Congress in Toronto in August and the SICOB Conference and Exhibition in Paris in September. A trans-Atlantic connection was made with the Canadian Datapac network, using the X.25 protocol. A variety of computer types and terminals in France were put into communication with a variety of computer types and terminals in Canada, as a convincing demonstration of the practicality of public packet switched networks.

In addition to this work of the PTT, research in packet networks was also going on at IRIA, on an experimental packet network developed under Project CYCLADES.

Based on their own early work and that of IRIA, the French PTT decided in 1973 to go ahead with a public packet network, which they named TRANSPAC. The goal that was set was to have this network in operation with 12 nodes in 1978. Now, five years later, the network is slated to begin operation this fall.

One of the critical decisions facing the network designers early-on was: should the network use the virtual call discipline or the datagram discipline? We described the virtual call discipline above. In the datagram discipline, each packet contains the complete address of its destination and may follow any route through the network, depending upon instantaneous traffic loads. Thus, two sequential packets of a block may follow very different routes through the network and the second packet may, in fact, arrive ahead of the first packet. Software is thus needed to put the packets back into their normal order and to make sure that all have been received.

There has been, and there still is, considerable debate on the pros and cons of these two disciplines. Suffice it to say that the French PTT favored the virtual call discipline and found that all other PTTs that were considering public packet networks felt the same way. About this time, the virtual call discipline was proposed as an international standard for packet networks, as a part of X.25, so the decision became easy. TRANSPAC would use the virtual call discipline.

TRANSPAC may be accessed in several different ways and in a number of different speeds. It may be accessed from the public Telex network at a speed of 50 bits per second (bps). It may be accessed by two-wire leased lines or from the public telephone network at speeds of 110, 150, 200, or 300 bps, asynchronous operation. With four-wire access, speeds of 600 or 1200 bps asynchronous or 2.4, 4.8, 9.6, 19.2, or 48 kbps synchronous can be used.

Packets may be up to 32 bytes (which they call 'octets') or 128 bytes in length; both maximum lengths are available. It is up to user software to fragment blocks into packets and reassemble the blocks at the destination.

Charges for the use of TRANSPAC within France are completely distance independent. Charges are based on the method and speed of access, plus a connection charge, plus a packet volume charge.

The people at TRANSPAC foresee their network connecting to other public packet networks in the not distant future. These include networks in Belgium, Netherlands, Spain, U.K., Canada, U.S., and Japan. For multi national computer users, it means that high quality packet communications will become available in numerous industrialized countries in the near future.

Hughes Aircraft Company

Hughes Aircraft Company, with headquarters in Culver City, California, is owned by the Howard Hughes Medical Institute, a non-profit medical research foundation. HAC is a large manufacturer of electronic and industrial products and employs some 35,000 people. Plants and research centers are located in Southern California, between Santa Barbara on the north and Carlsbad in the south (about 200 miles). In addition, the company has a plant in Tucson, Arizona. HAC since its inception has been very heavily involved in the development and manufacture of sophisticated electronics equipment, such as airborne fire-control radar, air defense control systems, the first lunar landers, and the development of synchronous communications satellites.

Because of the high technology involved in its products, HAC is very engineering oriented. And because computing is an important support service for engineering, the engineers have had a big voice in the selection of computing equipment to meet their specific needs. The result has been that a variety of computers are in use, including IBM 370s, Amdahl 470s, Honeywell 66/70, DEC PDP-10 and PDP-11, Hewlett Packard HP1000 and 3000, Burroughs B1726, and Xerox Sigma 9. In all, 20 computers are in use in 13 separate installations, not including an increasing number of mini computer installations.

The company's main computer center, consisting of two Amdahl 470s and a Honeywell 66/70, is in Fullerton, California, just south of Los Angeles. As might be expected with the several computer centers, data communications has continued to grow at a fast rate. In particular, more and more lines have been requested into the

Fullerton center. In most cases, the data communications services are closely tied to the applications. Even though some of the leased lines have some available capacity, other applications may not be able to use those same lines because of incompatible disciplines.

So, in mid-1977, the corporate director of computing and data processing initiated a project to study HAC's future needs for data communications. He wanted a study made of the different options available to the company and the pros and cons of each option.

One of the requirements was, of course, that the data communications service be able to serve a variety of computer types. Corporate management was unlikely to force one standard computer type on the various users.

Another requirement was that the communications network be able to handle growth both in volume and in number of applications. In order to handle this growth economically, it was recognized that the network should be application independent, serving all applications on a common basis.

One of the options available to HAC was to build a private data communications network, using leased lines, and based on one or more of the new network architectures offered by the computer manufacturers. These architectures include IBM's SNA and DEC's DECNET. But analysis showed that this approach would have difficulty in meeting HAC's needs. Each architecture favored the manufacturer that developed it; interfaces for the other makes of computers are not provided, in general. Further, the architectures are not compatible with each other; it would be difficult to try to inter-connect two or more of these networks.

Another option available to HAC was to obtain flexible front end processors, such as those made by COMTEN and CCI. While these front end processors tend to favor IBM equipment, they can be interfaced with other brands of computers and with a variety of terminal types. This was a viable alternative, as far as HAC was concerned.

A third option was to use a public network such a Telenet or Tymnet. By the nature of their business, these networks must interface with a variety of computer types and terminal types. This also was considered to be a viable alternative.

A fourth option that was considered is really a variation of the third one. In this case, packet switching equipment and software would be purchased or leased from the public packet carrier and put on HAC premises. For the bulk of the data communications, lines leased by HAC would inter-connect the nodes of its private network. But where distances were long and traffic volumes not great (as in the case of communications with numerous district offices around the country), then the public packet network could be used. Further, the public packet network could be used for backup and for handling peak load conditions.

After some months of study, the project recommended to the director of computing and data processing that the fourth option be selected by having Telenet furnish necessary hardware and software for a Hughes private packet network. A phased schedule for Telenet implementation, with appropriate benchmarks, is being established for evaluation of service.

Some of the Telenet features that appeal to HAC are the following. Telenet is well qualified in serving large numbers of all brands of computers and terminals, and has been subjected to the day-to-day grind of solving problems that only an operating communications carrier has experienced. Because of its own needs, Telenet has developed and is using software to gather and process statistics on line utilization and error rates, for dynamic network management. They have the software to gather actual usage data for the equitable distribution of data communications costs to users. The private packet network provided by Telenet will be able to set up all communications calls within the private network and will not be dependent upon the public network.

Interestingly, the packet technology appears to make the most efficient use of the leased lines for the Hughes network, even though the route mileages of this network are low due to its concentration in Southern California.

Perhaps most importantly, given Hughes' successful use of many makes of computers and terminals, the Telenet approach provides the company with a private network that will support just about any front-end processor or terminal that Hughes organizations desire to use. New computers, front-end processors, and terminals—and even new nodes—can be added without a traumatic redesign of the network.

Looking not too far down the road, the people at HAC can see the day when engineers and others within the company will want to use their own micro computers for routine smaller functions. And these people will probably want to be able to tie into the company network when the need arises, so as to be able to access services on the larger computers. "That is when we will really be thankful we have an application independent communications utility," they said.

Telenet

Telenet Communications Corporation, with headquarters in Washington, D. C., was the first U.S. packet switched common carrier. Its tariffs became effective in August 1975. Telenet was also the first U.S. packet network to implement the X.25 service. Its nationwide network now provides communications for over 190 U.S. data centers whose users are spread throughout North America and in Western Europe, Puerto Rico, and Hawaii.

As indicated, Telenet is a public packet carrier. This means that it must serve users in other countries by way of public packet switched services offered by telecommunications agencies in those other countries. Service to Canada is provided by inter-connecting the Telenet network to the Trans-Canada Telephone Service's Datapac network. The U.K. Post Office has purchased Telenet equipment in order to provide the needed packet switching interfaces (as has the Hawaiian Telephone Company). In Mexico, Telenet interfaces with Teleinformatica de Mexico. And for crossing the oceans, Telenet has arrangements with three international record carriers, RCA Global Communications, ITT World Communications, and Western Union International.

The Telenet public network is expanding rapidly, in the number of U.S. cities served, in the number of other countries served, and in the number of user organizations served. So the figures given above will quickly become obsolete. For instance, it possibly will not be long before Telenet users in the U.S. communicate regularly with terminals connected to public packet networks in France, Italy, Spain, Belgium, Netherlands, Hong Kong, and Japan. And with public packet networks in operation in other countries, computer to computer communications can take place, not just terminal to computer.

In addition to the public packet network, Telenet has other offerings. It can sell or lease its hardware and software, for use as on-site nodes for the public network or for private network use, as HAC is doing. It can provide network management or network maintenance for private networks that use Telenet equipment. It offers a 'Hotline' packet service, which is the functional equivalent of a point to point leased line. When a terminal is turned on, the Hotline service automatically establishes the virtual circuit to the pre-established destination. And Telenet is now offering TELEMAIL, a terminal to terminal message service.

Terminal access and speeds. One way by which terminals can access the Telenet network is by way of the nearest Telenet central office. Three options are available for performing this: by dial-in over the telephone network to a public network port (including the use of In-WATS), by dial-in over the telephone network to a private port, and by a leased line to a private port. Private ports are assigned to specific customers and are not shared among customers as are the public ports.

Another way by which terminals can access the Telenet network is by having a Telenet Processor (TP) on the customer's site. In effect, this processor becomes a node of the network. Several TP models are available, the smallest of which handles seven asynchronous terminals, and the largest handles up to 480 asynchronous and synchronous terminals. The terminals may operate at 50 to 300 bps or 1200 bps, under a variety of protocols, including X.25. The TPs are also used to interface customer computers to the public network.

The terminal protocols that Telenet presently provides include their own Teletype-compatible asynchronous protocol, an IBM 3270 and 2780 bi-sync protocol (in private Telenet-furnished systems), and the X.25 synchronous protocol. The X.25 interface may require special hardware and software for controlling the terminals and does require an X.25 software interface in the host computer.

The most commonly used speeds are: 50 to 300 bps fixed speed asynchronous operation; 110 to 300 bps adaptive speed asynchronous operation; and 1200 bps asynchronous. The X.25 synchronous operation is expected to grow rapidly; Telenet will be offering this protocol throughout the U.S. by the end of this year.

Tariffs. For U.S. domestic use, tariffs are distance independent; the charge for transmitting across a city is the same as transmitting across the country. Charges are based on the access speed used and the number of packets transmitted. At the 300 bps speed, the charges average out to about $3.50 to $4.00 per hour. Significantly, at 1200 bps, the rates are the same for public dial-in access. (To these charges must be added the cost of modems and telephone service.)

For international use, distance-dependent charges do enter the picture. At the least, the charges vary by country. In some cases, the services of international record carriers are used, the latter generally offering lower end-to-end rates for the user. Finally, one or more supra-national packet networks, such as EURONET, may be linked to Telenet in the future, extending packet service to another set of Western European countries.

For more information about Telenet services, see Reference 3.

Planning for data communications

It is generally only the larger organizations that have one or more people assigned to the function of planning for the overall use of telecommunications services. These services include the telephone, Telex or TWX, facsimile, and data. Even when one or more persons are assigned to this function, they may depend heavily upon help from the telecommunications agencies. In only a small percentage of user organizations, we gather, are these people actually doing the whole planning function themselves.

Our discussion is this report is concerned with planning for data communications, and in particular, considering the use of public packet networks in this planning. It should be noted that, in most organizations, data communications charges represent only a small percentage (say, 5% or so) of the total telecommunications charges paid by the organizations. Typically, voice telephone charges far outweigh data communications charges.

But most medium and larger size organizations are finding their data communications charges growing. Further, the data communications services they are using may well be inflexible and closely tied to the specific applications for which they were installed. The networks have evolved; they have not been planned. Leased lines are used where the traffic volume is high; dial-up services are used for the lower traffic links. Different terminal protocols are used for different applications. It may not be possible to share communication circuits among several applications because of the differences in protocols and speeds. These are only some of the difficulties that are being encountered but they give an idea of the problems.

Thus, even though data communications represents a small percentage of overall telecommunications expenses, we think it deserves more attention than it has been receiving. Now is a good time for users to think in terms of a 'data communications utility' to serve *all* applications.

A typical approach. If an organization begins to think in terms of a 'data communications utility' for serving all applications, typically the first thing that comes to mind is a private network, because of the problems of using many switched telephone networks at other than the lowest speeds. This approach has been encouraged by the computer manufacturers, because they can more easily control the computer equipment connected to a private network.

If the organization has standardized on one or a very few brands of equipment—say, one brand of CPU and associated equipment, plus two or three brands of terminals—this approach can make a lot of sense. The economics can be even more appealing if most of the locations are within a small geographic area, so that leased line charges will be relatively low.

But if the organization has—or foresees having—a variety of equipment brands, then this approach begins to be less attractive. This approach tends to favor the manufacturer who supplies the network components; IBM's SNA favors

IBM equipment, for instance. The other manufacturers favor their own equipment but generally will also support some IBM equipment and common asynchronous terminals. It would be rather difficult to connect, say, IBM, Univac, Honeywell, and Burroughs computers on the same private network. As mini and micro computers enter the picture, the difficulties of trying to serve all of them will increase.

Another option: public networks. Public data networks now offer a viable alternative to private networks. These public data networks are those installed by the telecommunication agencies and providing *switched* data services. There are two forms of switching being used: circuit switching and packet switching. (We have discussed this general subject in our February 1975 and July 1976 issues.)

Circuit switching. For speeds up to 9600 bps, users can use at least some of the public telephone switched networks in the world. At 300 bps, service seems to be reasonably reliable on the networks in most industrialized countries, we are told. As transmission speed increases toward 9600 bps, error rates increase significantly on all telephone networks—and some become unusable well below this speed. For practical purposes, 9600 bps represents an upper limit on speed on the *switched* telephone networks.

Some telecommunications agencies have decided to provide reliable switched data services over a wide range of speeds by building special circuit switched networks. The Bell System offers a high-speed Dataphone Switched Digital Service, as well as a 50 kbps switched service to a few U.S. cities. The West German EDF data network is a circuit switched service. And the Nordic Data Network, installed by the PTTs of Denmark, Norway, and Sweden, is a circuit switched service.

The point to emphasize is that, as transmission speeds exceed 1200 bps, the existing telephone switched voice networks prove more and more troublesome. In order to provide switched service at speeds over 9600 bps (and even lower, in many cases) special switched digital networks must be built.

Packet switching. Packet switching technology can provide a wide range of transmission speeds at very low error rates over existing analog telephone facilities. The reason is that the packet network uses leased wide band transmission trunks (say, 56 kbps or higher) where noise problems are less. It avoids the telephone switching system and instead does all of the routing switching by computer technology. At each node, the error detection code of each packet is checked; if an error is detected, retransmission of the packet is requested. When digital data services *are* available, such as the Bell System's DDS or Canada's Data Route, the packet network can make use of those services, reducing the retransmission problem.

Because transmissions are made in standard formats, a variety of terminal types and computer types can be interfaced to a packet network by converting their outputs into the standard packet format. And because high speed trunks are used, the delay time for the transmission of a packet is small; most of the delay is the switching time in the nodes. For reasons such as these, many of the world's telecommunication agencies have seen packet switching as a way to provide high quality public data networks in relatively short time and at relatively low capital investments.

The emerging public networks

While our main discussion in this report will deal with public packet networks, we will set the stage by describing some work that compares circuit switching versus packet switching for data networks. We will then get into a brief discussion of the types of protocols involved, including the X.25 protocol previously referred to.

Circuit vs. packet switching

Kirstein (Reference 4) gives a good overview of the newly emerging public data networks, and a comparison of the existing tariffs for data communications. Using the existing telephone facilities (either dial-up or leased lines) for data communications, the following are the typical operating speeds, he says. For asynchronous operation, the most common speeds are 200 bps full duplex and 600 bps half duplex, with 48 kbps half duplex also being available. For synchronous operation, the most common speeds are 2.4, 4.8, and 48 kbps half duplex, he says. But these are only the *most common* offerings; the actual offerings of any particular PTT can be quite different.

Now compare these common speeds and line disciplines with the recommendations of CCITT, the international telecommunications standards committee. CCITT recommends 200 bps asynchronous and 600 bps, 2.4, 9.6, and 48 kbps synchronous operation, says Kirstein.

How does one get international *switched* data communications services using the switched telephone network? It is a problem, as these figures indicate. Most users of international services thus resort to leased line private networks. There are also problems of wide differences in tariffs. Kirstein points this out vividly in his paper. David Butler, quoted in Reference 5, points out further that these tariffs are constantly changing, and so frequently that his firm had to give up publishing a report on European communications tariffs.

Rosner (Reference 4a) has reported on an analysis he made of circuit switching versus packet switching on a large hypothetical network. One half of the traffic on the network was assumed to be short messages, where a rapid response was desired. The other half of the traffic was long messages. Earlier studies of circuit switching versus packet switching, he said, had always involved a single type of traffic.

Rosner's study led him to conclude that "clearly...a common user data network can be more efficiently and cost effectively implemented using packet switching rather than circuit switching. This result appears to be valid over a broad range of assumptions and traffic loads-...(but) because of the overhead requirements of packet switching, long messages are best handled in circuit switched networks."

Grubb and Cotton (Reference 4c) have analyzed effective data transfer rates. As an example, the ARPA Net has an internode signalling rate of 50 kbps. But due to internode control processes (checking packets, acknowledging, retransmission, etc.), the effective internode transfer rate is about 40 kbps. If one is interested in transferring large volumes of data (bulk or file transfer) over the ARPA Net, the effective end-to-end transfer rate will be much less than 40 kbps, say the authors. Due to several end-to-end protocols that are needed, plus the load on the host computer, the effective transfer rate will be somewhere between 4 kbps and 10 kbps.

While these figures apply to the ARPA Net, somewhat similar figures probably apply to other types of networks such as circuit switched public data networks and private networks. Further, the figures are important not just for the transfer of large files but also for the down loading of programs in some distributed systems. Transmitting not-large programs to outlying terminals might require up to several minutes each, annoying if it must be done often.

The data communications analyses that we have studied convey the following message to us. Packet switching compares very favorably with circuit switching, particularly when a good portion of the traffic is interactive. The international X.25 standard packet protocol provides the beginnings for both domestic and international standard packet communication. Yes, the switching times in packet networks impose a non-trivial overhead. But packet networks compare favorably with circuit switched networks over a wide range of traffic loads.

We think the upshot can be stated bluntly: packet switched networks are where the action is. They have just too many good features not to be seriously considered by organizations that use data communication services. In addition, the arrival of public packet networks has brought this technology within reach of *many* users.

In short, you ought to be looking seriously at the use of packet switched data communications.

Types of service and protocols

By 'types of service,' we mean the variety of ways that users will want to use the network. And by 'types of protocols,' we mean the levels of procedures that will be needed for supporting the types of service.

Types of service

Even in those organizations that have imposed rather strict company standards on the computer types and terminal types that will be used, interest is growing in new types of both of these. There is a wide range of terminal types now on the market, and the capabilities of mini and micro computers are becoming impressive. Let us briefly list the types of terminals, processors, and data transfers that networks will surely have to handle.

Types of terminals. *Intelligent terminals* provide full local programming capability and, very possibly, mass storage for files. *Quasi intelligent terminals* provide little or no local programming capability, but do perform formatting and editing functions. The programs for these functions must be developed elsewhere and may be 'down loaded' to these terminals. *Non intelligent terminals* are the equivalent of teleprinter terminals, with no formatting, editing, nor (generally) error detection capabilities. Terminal types also include keyboard and display terminals, batch terminals, or combinations of these.

Users will want to be able to attach all of these types of terminals to their networks.

Types of processors. Even where organizations have decided to centralize 'all' data processing, the pressures for some forms of distributed processing are growing. Mini and micro computers will be showing up in more and more places in organizations. And most of these eventually will want to have data communications capabilities.

A true distributed system will involve a hierarchy of processors, or a network of essentially equal level processors, or a combination of both. The hierarchy structure will usually consist of a main CPU and associated front-end processor, two or more regional processors at the second level, local site processors or controllers at the third level, and terminals at the fourth level. The network structure probably will consist of a set of co-operating processors that can call on each other's services in the performance of their tasks. Either structure might also include personal work stations that use rather powerful micro computers, as we discussed last month.

Again, many users will want to be able to interconnect processors in such a manner.

Types of data transfer. As we have indicated earlier, users will want the following data transfer capabilities: *bulk (or file) transfer* in which hundreds or thousands (or more) of records are to be transferred; *batch transfer* in which tens to hundreds of records are to be transmitted; *transaction transfer* in which a single transaction is transferred very promptly and for which a prompt response may be required; and *interactive transfer* which may involve query and response, data entry and editing response, text input and editing response, and computer message systems. Most users will have need for these types of data transfer.

These, then, are the major types of service that users in general will demand, we believe. Any given organization might try to restrict the variety of types actually used. But in a general population of users, all of these types will be desired.

Thus, procedures will be needed for handling all of these types of service.

Types of protocols

To indicate how this subject of protocols for supporting the various types of service might be approached, we will single out the work of the Study Group on Distributed Systems, of the ANSI (American National Standards Institute) SPARC committee. The study group is chaired by Charles W. Bachman, widely known for his pioneering work on data base management technology.

This study group has postulated the following six levels of protocols:

Level 1, the physical control level. This level of protocol adapts the input data stream to the specifics of the transmission media on the input end and converts back at the output end.

Level 2, the link control level. This is the point to point, or intermediate node to intermediate node level of control. It checks to see that individual packets are received correctly at each intermediate node point. Examples of this level of protocol include the data link protocol used in X.25 (HDLC) and IBM's SDLC.

Level 3, the transport (or network) control level. This control level provides end node to end node procedures. It assures that all of the packets that make up a block of data have been received and in the right sequence, and then acknowledges to the transmitting end node that the block has been received. The X.25 protocol is an example of this level of procedure. However, it does not provide end-to-end assurance and does not demultiplex several messages which may be sharing the virtual call.

Level 4, the message (or session) control. This level of protocol is concerned with user process to user process control. While Level 3 deals with the end point *nodes* of the data communications network, Level 4 deals with the end point *user sites*. Level 4 thus must acknowledge that the complete messages have been received at the destination user sites.

Level 5, the presentation control. This is the level of protocol that adapts the particular hardware and software being used to the standards of the network. While data may be transmitted on the network under a synchronous discipline and at a speed of, say, 56 kbps, the Level 5 protocol would have to adapt it to, say, a character at a time (asynchronous) operation of 300 bps for running a typewriter-like terminal.

Level 6, user control. This level of protocol is designed to permit processes in two user work stations to exchange data and thus to cooperate in the solution of some problem. This level of protocol will often be user-specific. There will also be some standard protocols developed within certain industries, such as banking and airlines.

Two basic concepts. The study group has identified two concepts that appear over and over again in network protocols.

Fragmentation and re-assembly concept. This concept occurs at the interfaces between levels two, three, and four. Briefly, each of these levels has its own data transfer 'unit'; the unit for level 4, for instance, might be a 'record,' while the unit for level 3 might be a 'packet.' So level 4 must fragment records into packets, before passing them on to level 3 for transmission. At the receiving end, level 4 must re-assemble the packets into records. The same concept applies between levels 2 and 3.

Multiplexing concept. Again, this concept can occur at the interface between levels two, three, and four. To illustrate, a point-to-point link at level 2 may be used by numerous virtual calls. In turn, a single virtual call may support a number of sessions, when their end points are the same pair of nodes. So the multiplexing for level 2 may use a series of queues, with one data transfer unit being drawn from each queue in sequence. However, there would be no reserved or empty slots; if a queue is empty, the system just goes to the next queue. The data transfer units are labelled, of course, so that they can be properly de-multiplexed at the receiving end and prepared for re-assembly.

Notice that this concept can provide the priority function. Bulk, batch, transaction, and interactive sessions would provide different data streams, flowing into different queues. Bulk queues would normally be 'full' while interactive queues often would be 'empty.' When an interactive message arrived and was fragmented, its first fragment would be transmitted within the next commutator cycle. One fragment would be transmitted each cycle.

Let us see how this work of the study group fits into international standards work.

The push for international standards

Actually, we have been told, the big push for standards for distributed system networks has come mainly from the Europeans. The need to interface the various national public data networks is urgent in Europe. And the U.S. has been accused of 'dragging its feet.'

The key agency for international standards is the ISO—the International Standards Organization. The British Standards Institute urged ISO to set up a special sub-committee for distributed system network standards, in order to move this subject ahead rapidly. Normally, it takes six to ten years to get standards developed and adopted, and BSI felt that this amount of time could not be tolerated for these particular standards. Nor does it *have* to take that long; the X.25 standard was developed in three years, we understand. In order to co-operate with this effort, the U.S. American National Standards Institute set up the SPARC Study Group on Distributed Systems to work with the new ISO sub-committee.

There are numerous other groups already working on specific standards recommendations in this general area. These groups include other ANSI groups, a group in the Electrical Industries Association, other groups within ISO, and a group within CCITT. But no overall structure exists for tying these efforts into a cohesive whole. Hopefully, the ideas proposed by the study group will lead toward that structure.

To illustrate the need for this overall structure, consider the X.25 standard.

Where does X.25 fit?

As we reported in our July 1976 report, the X.25 recommendations were developed under an unusually rapid time schedule in order to be presented to a tri-annual plenary session of CCITT in September 1976. It was recognized that a standard was needed and needed urgently, to allow for the development of public packet networks on an international basis. X.25 was the result.

As indicated earlier, X.25 applies to Levels 2 and 3 of the six levels described above. That is, X.25 incorporates the HDLC data link control protocol for Level 2. At Level 3, X.25 provides end node to end node virtual call control, with responsibility for seeing that all packets of a block have been received correctly (at the end node) and are in the proper sequence.

But it is clear from our discussion of the six levels proposed by the study group that X.25 does not do the whole job. Its responsibility stops with the destination node of the network. It does not assure delivery of the packets to the user, on an end-to-end basis; this will be particularly important when traffic flows internationally over several inter-connected packet networks. Nor does it assure that all blocks of a message have been received. Nor does it provide for handling asynchronous terminals.

At present, we are not aware of standards work going on at Level 4, for packet networks. The public packet networks do provide some protocols at this level, but on an individual basis. Nor do they seem so comprehensive to us as the protocols developed by Electricite et Gaz de France, described earlier.

There is some work going on within CCITT for some Level 5 protocols. Hovey (Reference 6) describes some such work for a packet assembly and disassembly facility for non intelligent teleprinter and display terminals. X.3 specifies 12 basic functions for asynchronous operation, X.28 describes the interface between the terminal and the packet assembly and disassembly facility, and X.29 provides end to end procedures for data and control information.

What the ANSI SPARC Study Group on Distributed Systems is proposing is an overall structure for data communications protocols. If that structure is accepted by the various standardization bodies involved, it would do two main things. It would point out where the gaps in standards exist. And it would define the interfaces of the different levels of protocols, so that the different standards groups could work more in harmony.

Conclusions

For the past several years, we have been discussing in these reports the newly emerging public packet networks. Our research for this report convinced us that these networks are already viable solutions for many data communications users.

It seems to us that if your organization (a) already uses or expects to use in the next few years a variety of terminal types and processor types, with a mixture of bulk, batch, transaction, and interactive data flows, and (b) has these terminals and processors spread over a fairly wide geographical area, then you ought to be looking into public packet networks. This is even more the case if your organization is doing international data communications to countries that have (or soon will have) public packet networks.

The day of the public packet network has arrived.

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2. For more information on TRANSPAC, write to Direction des Affaires Commerciales, DACI-TRANSPAC, 20 rue Las Cases, Paris, France.
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6. Hovey, R. B., "Matching teleprinters to X.25 packet switching networks," *Data Communications* (McGraw-Hill Building, 1221 Avenue of the Americas, New York, N.Y. 10020); October 1977, p. 63-69; price $2. AL

Additional reading

7. For a summary of U.S. data communications services, including packet networks, see Datapro Report *All about data communications facilities*, Datapro Research Corporation (1805 Underwood Boulevard, Delran, N.J.08075); updated report issued from time to time, ask for most recent report; price $12.

8. For good, up-to-date discussions of data communications technology, including both packet switched networks and satellite communications, see the *Proceedings of the National Computer Conference*, for both 1977 and 1978. Order from AFIPS Press (210 Summit Avenue, Montvale, New Jersey 07645); price $60 each.

9. For information on EURONET, the European international packet network, write Directorate General "Scientific and Technical Information and Information Management," Commission of the European Communities, Batiment Jean Monnet, Kirchberg, Luxembourg (Grand Duchy).

10. For an example of the discussion on datagram service for packet networks, see "ISO position on datagram service," ACM Computer Communications Review (ACM, 1133 Avenue of the Americas, New York, N.Y. 10036); January 1978.

Public packet networks are only one form of support for distributed systems. The rapid developments in micro processors, which we discussed last month, also give impetus in this same direction. Distributed network architectures, intelligent terminals, generalized application programs—these and other developments encourage the dispersion of computing power and data storage. But distributed systems also pose challenges, not only to the data processing function but also to user management and staff. Next month, we will discuss some of those challenges and steps to take to help mitigate them.

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