UNIVERSALLY SHARED PACKET SWITCHED DATA NETWORKS

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ABSTRACT

This paper discusses the evolution of Universal Data Networks and outlines the technology that makes them possible. Specifically, Canada's Datapac Network. Why it was developed, how it operates, and the impact it will have on Data Communications users as it evolves.

PARTAGE UNIVERSEL RESEAUX DE DONNEES "PACKET SWITCHED"

RESUME

Cette étude discute de l'évolution des réseaux de données universels "Universal Data " et analyse leurs technologies. Plus précisément le réseau "Datapac" du Canada. Nous étudions leur raison d'être, comment ils opèrent et l'influence que peuvent avoir ces réseaux chez l'opérateur des systèmes de données de communications.

UNIVERSAL SHARED NETWORKS

INTRODUCTION

The impact of the computer on many facets of society today has resulted largely from the applications of the technology of communications to that of data processing. In the space of little more than two decades, we have seen the development of increasingly sophisticated computer communications systems that now form one of the foundations of many of our business, government, academic and other institutions.

In the years and decades to come, these systems will become even more vital, as they become more universal and more available. A result of the continuing evolution of data communications technology. The most significant development, in Canada and in many other countries around the world, is the emergence of truly universal data networks, that can be accessed by many users for many purposes. Just as the telephone network is for voice communications, so will a Universal Data Network be for Data Communications.

In this presentation, I will endeavor to trace the development of universal data networks and outline the technology that is making them possible. Specifically, I will discuss Canada's Datapac Network, why it was developed, how it operates and what impact it will have as it evolves.

ANALOGUE

To appreciate the significance of the developing universal data networks, it may first be helpful to view them in the context of what preceded them. The first data communications systems, some two decades ago, used the telephone voice network. The telephone network is an invaluable resource. It is capable of bringing computer power to wherever there is a telephone. There are, however, problems with it that make it unsuitable for large-scale computer communications systems.

One of the major problems being noise. If we were, for example, to examine the human ear we would find it to be a magnificent terminal. It can filter out extraneous noise and accept only the relevant information. Computer terminals are not that discerning. Extraneous noise can be read as meaningful data and errors can result. In addition, there are technical limitations in terms of speed of transmission, call set up times and technical interfaces.

Point-to-Point

The first real services specifically designed for data were point-to-point private line analogue systems with a circuit connecting each terminal to its host computer. The economics and technical limitations of these early systems restricted teleprocessing to a few very specialized applications. The largest single restriction was that such systems required vast amounts of data flow to make them economically justifiable. The user payed a flat rate for the transmission media whether or not it was being used. Even the more efficient systems transmitted data only a small portion of the time. The cost of analogue point-to-point private lines were an obstacle to the development of a national data communications system. As distances grew, costs became more and more prohibitive. A solution had to be found. In fact, two solutions were devised to handle the two major emerging applications for data communications.

Circuit Switched

One solution applied to batch type operations and applications which enables the sender to have access to more than one computer or terminal. This solution is called circuit switched communications through specially conditioned data facilities. The circuit is switched through a dedicated data switcher and is in use only for the duration of the call. In this situation, users buy only the transmission speed or bandwidth needed and are charged on a pay as you use basis. In circuit switching the user shares network facilities, including transmission lines and switchers with other users. The result is a lower cost while providing the range of transmission speed required by data processing networks. However, circuit switching is not without drawbacks. The original switched circuit networks are analogue and thus incapable of delivering the degree of accuracy implicit to digital transmission. Also, circuit switched networks have relatively long call set up times which make them inappropriate for interactive applications. In circuit switched services, the charges are based on connection time. Because data transmission is typically a series of bursts with gaps in between, time-based systems means the user pays as much for the gaps as for the meaningful data. For some applications, circuit switched systems may remain suitable. But, for most requirements they are not the optimum solution.

Multipoint

The second solution was designed to meet the needs of wide-spread organizations operation inquiry/response systems. In these applications, response time is critical. Lower costs and higher accuracy were also prerequisites to the expanding computer communications market. The answer was the development of multipoint and multidrop networks. A multipoint network consists of terminals in several locations communicating with a computer along a single communications link. In a multidrop network, several terminals in one region are connected to a remote computer through one communications channel. Many networks are not exclusively multipoint or multidrop but a combination of both.

DIGITAL

These systems met the demand for fast response transaction processing. Then with the introduction of the Dataroute digital network, low cost, high accuracy nationwide data communications became a reality. The Dataroute network, introduced in February 1973, was the world's first nationwide digital data transmission system operating commercially. Because digital transmission is more accurate, the dataroute is able to offer error performance up to 10 times superior to that of analogue systems. The dataroute will remain the basic backbone of new network services and will continue to provide low cost, high accuracy performance for those applications which continue to operate in a private line environment.

But multipoint systems also have some basic flaws. They have a relatively low facility utilizations. In the order of 10 percent of capacity. In addition when the circuits are not being used, they are not available for others since these are really private line arrangements. Such networks also raise contention problems. That is, several terminals each trying to communicate with the data base at the same time. This requires the installation of communications control programs to organize traffic flow. As I am sure you are aware, programs take-up valuable mainframe and front-end capacity and add to the overhead of the database operation.

Both multipoint and switched systems do not fully utilize the capabilities of the computer, the terminals or the people operating them. When one terminal is transmitting to/or receiving from the computer, all the others are effectively closed down because the link is only used for one transaction at a time. The inefficiencies inherent in these systems coupled with the large anticipated growth in inquiry/response business applications made apparent the need for new and more efficient data networks.

Up to the mid - 1970's the development of Computer Communications systems was primarily on a private basis, with relatively little demand for circuit switched services. The result is that there are many private systems across Canada, each serving the particular requirements of its users. However, many of them cover the same locations, and most of them are used only to a fraction of full capacity. And most important, to a degree, are totally incompatable.

DATAPAC

The solution to this problem became obvious. What the data communications industry required was a UNIVERSAL, SHARED, INTELLIGENT NETWORK. Just as a common user network made possible the growth of voice communications in Canada, so could a single universal shared intelligent network extend the benefits of computer communications to the broadcast range of Canadians in the years to come.

A universal network will permit access to many users large or small for a wide variety of applications. A shared network means the maximum utilization of scarce resources. With the more efficient use of the network, such capabilities as alternate routing, network diagnostics and dynamic allocation of bandwidth become economic. An intelligent network will perform many of the communications functions which today take up costly mainframe of front end capacity. In the future it will be easily adaptable to new requirements through the programable logic built into the network.

Universal-shared-intelligent - those are the key words. With such a system users will have access to many other users and applications through a single terminal, paying primarily on the basis of the amount of data sent through the network. Many of the information moving requirements of the future can only be met by a universal network connecting many users and many data bases. Electronic funds transfer systems, for example, will depend for their effectiveness on the interaction of financial institutions, retail stores and credit organizations in one interconnected system. Datapac is designed to be just such a network.

Essentially, Datapac is a national data network designed to accomodate MANY USERS, MANY USES, MANY types of equipment and to undertake a number of communications functions. It has the potential of interconnecting an almost limitless universe of data terminals and data bases. The Datapac network is built around nodal switches, with digital transmission facilities linking these switches. It provides a range of services to match the varying characteristics, such as response time and volume, that define the many applications for data communications. It is a multi-application network, with provisions for handling inquiry/response, time sharing, bulk transfer, data retrieval and data collection functions, among others.

Packet Switching

Of the many technologies employed in the Datapac network, it is the technology of packet switching that represents the area of greatest innovation, and that makes possible many of the benefits of a universal network. Similarly, most of the intelligent networks emerging in other countries are built primarily on the technology of packet switching.

Unlike circuit switching, packet switching never physically links both ends of a communications path. That is, it does not require dedicated bandwidth to be set up betweeen a pair of communicating devices. Instead, all information is passed through the switching system in the form of discreet units called packets. The network facilities are required and paid for, only while the packets are actually being transmitted.

In addition to the data field which is transparent to the network, a packet consists of a header which specifies control functions and an address indicating the terminal or terminals to which the packet is to be delivered. To provide error control on the local access line, a Frame Check Sequence is appended to the packet.

Node. The switching nodes themselves are specialized computers that decode the instructions contained in each packet header, check it for accuracy, and route it to the destination address and perform the communications functions indicated, such as flow and error control. Packet switching, as used in the Datapac network will make possible a range of functions and benefits that were not possible before.

By using one common, agreed standard for the format of the packet, it is possible for many types of terminals and computers built by many manufacturers to communicate with one another. The packet switching nodes accept streams of packets from many sources and dynamically interleave them on digital high-capacity inter-nodal trunks. This means a more efficient use of transmission facilities and therefore reduced investment and lower cost.

Routing. Using a system of alternate routing the switching nodes route individual packets through the network along optimum paths. In some cases, a series of packets from one terminal may be split and sent along different routes, depending upon volumes of traffic, trouble conditions, etc. At the receiving nodes they are reassembled into correct sequence and delivered to the destination. This again maximizes circuit utilization and gives a high degree of protection should one particular route become congested or interrupted. The entire transmission within the network takes only a fraction of a second.

Error Control. An integral component of the packet format is error control information. As each packet moves along the network from one point to the next, the packet is temporarily stored in a buffer as it is dispatched onwards. The receiving node verifies its accuracy by performing a set of operations on the error control information. If there is an error, the entire packet is automatically retransmitted from the last correct station. Accuracy is estimated to be in the region of one undetected packet error in 5×10^8 packets transmitted. But the sharing of error control procedures eliminates the need for each user to apply valuable mainframe capacity to what is essentially a communications processing function.

Because the switching nodes are essentially programable mini-computers, they can be instructed to undertake a variety of communications processing functions that are normally either undertaken by the host computer or not available on other systems.

Services. The intelligence inherent in a packet network such as Datapac provides users with several kinds of network operations from fully switched to closed user groups. A closed user group is essentially a private system within the matrix of the shared network. It bars access to non-authorized terminals and allows terminals within one group to communicate only with accredited terminals in that same group. Because the network and users communicate in the form of packets, it is possible for the first time to create a charging system based primarily on the amount of information sent, not on connection time or bandwidth as before. In its packet mode of operation, Datapac users will be charged primarily on the basis of number of packets sent, with less sensitivity to distance than in the past.

Diagnostics. The intelligence resident in the network allows sophisticated diagnostic systems to be built in to oversee and report on the operation of the network. In the Datapac Network, there is a National Control Centre that constantly monitors the performance of the network. In addition, critical elements in the network have backup facilities on standby ready to take over should there be any indication of deterioration of service. These are all features that can be designed into a shared network, but would be uneconomical to include in a private network.

Perhaps, most important, an intelligent universal network opens up vast possibilities for new and innovative applications. With access available to small as well as large users, and to many types of terminals and data bases, there is great potential for the development of new types of services and applications by software suppliers, hardware manufacturers, data processing providers, information banks and many others.

Protocol. The very nature of a shared, universal, intelligent network, with many users and many different types and makes of equipment, requires an agreed standard for the format of data. This standard is called a protocol. Protocols are used in a wide range of activities, from international diplomacy to electronic communications. In all cases, the intent is the same. To establish a formal set of well-defined procedures which are clearly understood by all parties so that in any given situation each party clearly understands the appropriate sequence of actions.

A packet network access protocol is a series of conventions which govern the manner in which computers and terminals format packets and manage calls, and send or receive packets to and from the network.

To implement a packet switched network that is universally available and shared by many users, it is necessary to have a protocol that is common to the network users and the communications carrier. Such a standard protocol facilitates users with a diversity of terminals, in terms of manufacture and function, to access the network and to communicate with one another.

S.N.A.P. In Canada, the Computer Communications Group of the Trans-Canada Telephone System has designated this set of standards as S.N.A.P. (Standard Network Access Protocol). SNAP, known internationally as X.25, has also been ratified by the CCITT (International Telegraph and Telephone Consultive Committee) as the agreed international standard for packet mode operation. This international agreement will facilitate the inter-working of intelligent networks in many countries, as well as make it practical for manufacturers to design their hardware to operate on such a widespread basis.

The implementation of SNAP by manufacturers and users is a necessary first step in preparing for essential world-wide communications on a packet basis without the need for costly international interface arrangements. In the near future, users should be looking to their suppliers for hardware that incorporates SNAP in order to obtain the performance, price and flexibility benefits inherent in Datapac services operating in a full snap mode.

SNAP consists of three distinct levels of control procedures: the Physical Interface, the Frame Level Logic Interface and the Packet Level Logical Interface.

Physical I/F. The Physical Interface specifies the characteristics of the physical media by which a user is linked to the network. The physical interface between the datapac network and the terminal using SNAP is a digital or analogue, four wire, point-to-point, synchronous circuit. It is identical to the specifications of EIA interface RS232C.

Frame Level. The Frame Level Logical Interface specifies the use of a data link control procedure. This ensures that the control information and user data contained in the packets are accurately exchanged between the network and the sending or receiving stations. The frame level procedure adds error-detection information to the packet to ensure that transmission is accurate on the connection between the network and the user as it is within the network itself.

Packet Level. The Packet Level Logical Interface details the manner in which users establish and maintain the clear data transfer of calls through the network. This involves a well-defined set of ground rules which specify the manner in which control information and user data are structured into packets. The flexibility inherent in the packet level logical interface allows a terminal or computer to coincidentally communicate with numerous destinations by means of one physical connection to the Datapac network.

Intelligent Devices. Intelligent terminals including computers can access the network using Standard Network Access Protocol and a full duplex synchronous physical connection. The terminal itself issues and receives the data and control information in SNAP format.

Non-Intelligent Devices. Non-Intelligent terminals, which do not have the software capabilities to implement SNAP, can access the network through a synchronous or asynchronous connection to a Network Interface Machine (NIM). The NIM contains the software to convert the data into SNAP packets. A NIM is a shared communications controller which enables non-intelligent terminals to access the Datapac network.

Virtual Circuits. Data transfer through the Datapac network using SNAP is accomplished through the use of virtual circuits. These are not physical point-to-point connections as in private line or even circuit switched connections. Rather, virtual circuits are logical associations between sending and receiving stations, using the information carried in the packet header and the intelligence built into the network. The packet header in SNAP format contains a section for logical channel identification. This is a code which enables the Datapac network to recognize all the packets that go together to form a message or a stream of messages on a virtual circuit to a specific terminal. It is this concept which allows any terminal to simultaneously send and receive messages to and from several other terminals while employing only a single physical circuit to the Datapac network.

These are two types of virtual circuits: switched virtual circuits and permanent virtual circuits.

Switched virtual circuits would be used for applications in which a terminal requires access to more remote terminals than it is capable of handling concurrently. In network terms, terminals are any device connected to the Datapac network, including computers. When switched virtual service is used, a virtual circuit must first be established between the terminals. A virtual circuit is established between the terminals through the transmission of supervisory packets by the calling and called stations. After a virtual circuit is established, data is transferred by means of a data packet.

The use of permanent virtual circuits eliminates the need for call set-up as the terminals are always in the data mode. A permanent virtual circuit is a constant logical connection between two terminals.

Logical Channels. The concept of logical channels is fundamental to Datapac. With the use of logical channel numbers, one terminal can simultaneously support several switched virtual circuits, several permanent virtual circuits or a combination of both. This still requires only one physical connection to the network.

CONCLUSION

The emergence of universal, shared data networks depend largely on the development of technology, and particularly the technology of packet switching. The true significance, however, lies not in the technological advances, but in the socialogical and economical impact of such networks. The universal data network represents a radical change in direction in the evolution of information handling systems. The possibilities in terms of new and innovative applications and uses are almost limitless; the potential is only now beginning to be recognized.

The universality of networks such as Datapac will create broad new communities of interest, as application oriented services are developed. The effectiveness of any communications network depends largely on the number of users tied into that network. In a universal shared network, a broad universe of users can be linked together. The potential for the development of new applications by software providers, by equipment manufacturers, by processing suppliers and by individual users is vast. At the same time, universal networks deliver a quality and range of service not available before. In accuracy, reliability, economy and flexibility, such networks represent a dramatic improvement.

On the bottom line, it is the user who stands to benefit. And with the direction that data communications developments are taking today, it is likely that the users of computer communications will represent a rapidly increasing percentage of the population in the years to come. More and more, we rely on information in the running of our affairs. Datapac like networks emerging around the world will do much to increase the flow and accesibility of that information.