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PACKET SWITCHED DATA NETWORKS: AN INTERNATIONAL REVIEW

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ABSTRACT

The historical development of packet switching technology in the late sixties and the events which led to the implementation of the first packet switched military communications system, ARPANET, are outlined. The development of the US data networks TYMNET and TELENET in the early seventies and other North American networks, DATAPAC and INFOSWITCH in Canada and SCT in Mexico, is reviewed. The status of national and international packet switched networks in Western Europe and Southeast Asia is also examined and the following networks are described: RETD (Spain), TRANSPAC (France), DATEX-P (West Germany), DATANET (Netherlands), PSS (United Kingdom), the Nordic Packet Switched Data Network (Scandinavia), EURONET (European Community) and the D50 network in Japan. The linking of networks within and between the three major networking sites in North America, Western Europe and Southeast Asia and the impact of packet switching technology on online information retrieval are briefly discussed.

1. INTRODUCTION

The two fundamental approaches used in communications networks are pre-allocation and dynamic allocation of transmission bandwidth. In circuit switched systems such as telephone and telex networks a fixed bandwidth is pre-allocated from caller to receiver for the duration of a call. Dynamic allocation techniques have been used in telegraph systems since the turn of the century and involve dynamically allocating bandwidths, one link at a time, for messages being transmitted over a network.

Packet switching technology has evolved only in the last 15 years or so and is based on dynamic allocation principles. In a packet switched network data to be transmitted are divided into packets which are stored and transmitted from source to destination, on a link by link basis, by intelligent packet switching exchanges (PSEs) or nodes. The adoption of well established dynamic allocation methods for the implementation of packet switched networks in the late sixties resulted from

developments in computer technology rather than a major innovation in communications technology. With the advent of the computer it became possible to use dynamic allocation in real time communications. As computers became smaller, cheaper and more powerful, dynamic allocation systems became more and more attractive from the point of view of economy, reliability and flexibility.

The impetus for packet switched networking came, not from the telecommunications administrations (PTTs) which were content with pre-allocation (circuit switched) systems for data communications, but from the computer industry which provided the necessary technology and from the data user community who generated an increasing demand for improved data communications. According to Baran (1977:459) the initial motivation for the development of packet switched networks was 'the need for military survivability'. The late fifties and early sixties was an era when the Americans and Russians had developed intercontinental ballistic nuclear missile systems and the technology of offence was far in advance of defence technology. This led to a highly unstable situation since the greatest chance of survival lay with an attacker rather than a defending nation. As an efficient, highly reliable communications system is a vital element in any defence system it is not surprising that in the early sixties dynamic allocation systems came under scrutiny in the context of military communications. The dynamic allocation approach, the distribution of processing throughout a network by means of intelligent nodes and the inclusion of a certain level of redundancy, results in a communications system that is more reliable than its component parts. These were the elements of a fully distributed packet switched system first described by Baran in 1964 in a report on military communications commissioned by the US Air Force (Baran, 1964). A packet switched network was the obvious solution to the problem of reliability and survivability in military communications since it could be designed to operate even in circumstances where half the communications links had been destroyed. An important spin off, which was not vital in the military context, was to shape the future of public data networks in the seventies and eighties. It was the fact that packet switching offered considerable economic (as well as performance) advantages over conventional circuit switched systems.

For unknown reasons the Air Force shelved the Baran report but, as has often happened in the history of science and technology, the idea was taken up independently by at least two other organizations—the Advanced Research Projects Agency (ARPA) of the Department of Defense in the USA and the National Physical Laboratory (NPL) in Britain. The ARPA project resulted in the first packet switched network, ARPANET, in 1969 (see Section 3.1) and a single node network was introduced four years later at the NPL (see Section 4.5).

The chronology of the introduction of packet switched networks throughout the world is summarized in Table 1. The first networks began to appear in North America in the early seventies. With the exception of Spain, which installed RETD in 1971, networks were not introduced in Europe until the late seventies and at the present rate of development most European countries will have packet switching technology by the mid-eighties. All existing networks listed in Table 1 are briefly described below (Sections 3–6). Private dedicated networks such as those used exclusively by airlines and banks are not included in this review. Examples include SITA (Société Internationale de Télécommunications Aéronautiques), an airline network which was established in 1949 and adopted packet switching in 1971 (Kroneberg, 1977; OECD, 1979), and SWIFT (Society for Worldwide Interbank Financial Telecommunications), an international network for banks (Lapidus, 1976).

Table 1. Introduction of some packet switched data networks

Network			Official launch date	Country/countries
National	*International*			
ARPANET		Actual launch date	1969	USA
TYMNET			1971	USA
RETD			1971	Spain
TELENET			1975	USA
	SCANNET*		1976	Nordic countries
DATAPAC			1977	Canada
INFOSWITCH			1978	Canada
TRANSPAC			1978	France
D50			1979	Japan
	EURONET		1980	European Community
DATEX-P			1980	West Germany
DATANET			1980	Netherlands
	NPSDN†		1980	Nordic countries
SCT			1981	Mexico
PSS			1981	United Kingdom
—		Planned launch date	1982	South Africa
—				Belgium
—				Australia
—				Austria
—				Luxembourg
EDWP				Switzerland
—			1983	Ireland
—				Finland
—				Portugal
—			1984	Denmark
—				Greece
—				Italy

* Superseded by NPSDN.
† Nordic Packet Switched Data Network.

Developments in national and international telecommunications, particularly in the area of standardization, have been shaped by international organizations such as the International Telecommunications Union (ITU) and Conférence Européene des Administrations des Postes et Télécommunications (CEPT). Both organizations were founded to encourage international cooperation and harmonization in telecommunications. Comité Consultatif International Télégraphique et Téléphonique (CCITT) is part of the ITU and is responsible for standardization and tariff structures in telephony, telegraphy and data transmission. The CCITT series X and V recommendations on data transmission are being accepted and implemented internationally. Examples of CCITT recommendations relevant to packet switched networks include the following:

1. X.3 packet assembly/disassembly facility (PAD) in a public data network.
2. X.25 (introduced in 1976) interface between data terminal equipment and data circuit terminating equipment for terminals operating in the packet mode on public data networks.
3. X.75 (introduced in 1978) terminal and transit call control procedures and data

transfer systems on international circuits between packet switched data networks.

Another international organization, the Commission of the European Communities, has also played an important role in network development by instigating the establishment of an international packet switched data network in Europe (see Section 5).

2. A REVIEW OF REVIEWS

Early reviews of data networks include those of Kirstein (1976), Bunch and Alsberg (1977), and Tomberg (1977). Kirstein's paper confirms that many of today's networks were on the drawing board in 1976. Bunch and Alsberg (1977:183) focused on packet switched networks, 'the dominant access route to today's online information systems', and examined network configurations (e.g., star, ring, distributed control and completely connected networks) and performance criteria (e.g., delay, bandwidth, reliability and cost). In a review of the status of European networks in 1977 Tomberg (1977:220) opened with the remark 'the state of Europe is that Europe is not a state . . . but 34 countries (in Western Europe, 24)' and he outlined some of the technical and political problems arising in international networking. He examined local networks (ARIANE and CYCLADES in France, now superseded by TRANSPAC, and DIMDINET in West Germany); international networks carrying financial data (DATASTREAM, MONITOR and VIDEOMASTER); research networks (ESANET and SCANNET, both of which are now superseded); American networks which had been extended to Europe (CYBERNET, CYPHERNET, MARK III and TYMNET); and the then planned European network, EURONET. He concluded with the caveat that the information user community may ultimately lose control of developments as the initiative for networking is taken over from database suppliers by brokers, from brokers by national authorities and from national authorities by intergovernmental authorities.

In a paper on the evolution of packet switching Roberts (1978) described the reapplication of basic dynamic allocation techniques and discussed the future of packet satellite, packet radio and digital voice networks. Mathison (1978), in a wide ranging review of the commercial, legal and international aspects of packet communications concluded that only one public packet switched network would be introduced in each industrialized country within a few years. He suggested that these networks would continue to be regulated and would be interconnected to form an international packet switched communications system similar to the international telephone and telex systems.

A paper by Pouzin in 1979 briefly reviewed the characteristics of the networks EDS (West Germany), Nordic net (Scandinavia), RETD (Spain), TYMNET and TELENET in the USA, DATAPAC (Canada), TRANSPAC (France) and EURONET (Europe). Cardarelli (1979) reported on standards and development plans relating to European public data networks in a paper based on a study by the Eurodata Foundation. The Organization for Economic Cooperation and Development (OECD), as part of its programme of work on information, computer and communications policy, commissioned Logica Ltd. of London to undertake a study on the usage of international data networks (OECD, 1979). The research team investigated some 30 private and public data networks based in Europe. The report

sketches out a broad outline of international data communications traffic, the reasons for its appearance and growth, and issues which may require international coordination and agreement. The most widely used applications using international networks were found to be in the areas of company management, banking, credit control and travel reservations. All these categories involve sensitive personal and corporate data and require a high level of security and protection. Some of the issues examined in the study include the privacy of transborder data and national interdependence resulting from the international flow of data.

Cawkell (1980), having noted that in 1866 it took 67 minutes for Queen Victoria to send a 90 word message to President Buchanan, has briefly traced the development of telecommunications through analogue and digital transmission, packet switched networks and satellite communications. He also touched on text processing and message systems and explored regulatory, political and social issues in information technology and communications.

The Eurodata project (Eurodata Foundation/Logica, 1979) carried out in 1979 is by far the most comprehensive study to date on data communications. It was commissioned by 17 PTTs in Western Europe to examine the status and probable development of data communications in Europe in the period 1979 to 1987. The results of the study were prepared by the Eurodata Foundation, representing the PTTs, and the main contractor for the project, Logica Ltd. The report is presented in eight modules, consisting of over three thousand pages of text and costing in excess of £20000 per copy (the minimum subscription is £1000). It includes a comprehensive overview of data communications in Europe in the 1980s; basic forecasts of network termination points, data terminals and data communications traffic; and details of markets for terminals, data communications computers, processors and modems. Fortunately brief summaries of the conclusions have recently been published in several (less expensive) sources (CEPT/Eurodata, 1981; *Eurodata Foundation Yearbook*, 1981; *Euronet Diane News*, 1981a, b). In terms of overall growth it is predicted that there will be a four-fold increase in demand for data transmission services in Western Europe up to 1987. To meet these needs it is expected that the PTTs will provide public packet switched services throughout Europe by 1984 and circuit switched data networks by 1986. In the long term it is anticipated that digital transmission facilities, which will be developed as digital voice networks are introduced, will transform the data communications market and will support a wide range of applications requiring high speed data transmission. A survey of plans for the installation of public data networks by the individual member PTTs of CEPT has recently been published (CEPT/Eurodata, 1981; *Eurodata Foundation Yearbook*, 1981).

3. NORTH AMERICAN NETWORKS

3.1 United States

3.1.1. ARPANET

The US Department of Defense (DOD) was responsible for the design of the first ever operational packet switched network, ARPANET, when it sponsored a research programme in the late sixties to advance the state of the art of computer networking for military defence purposes. ARPANET emerged in late 1969 as an

experimental packet switched network and after an initial experimental phase in which it expanded rapidly, responsibility for its operation was handed over in 1975 to the Defense Communications Agency (DCA). According to the most recent information brochure (Defense Communications Agency, 1980:1) ARPANET is currently 'an operational, resource sharing inter-computer network linking a wide variety of computers at ARPA sponsored research centres and other DOD and non-DOD activities' throughout the United States and also in Hawaii, Norway and England. Use of the network is restricted to those involved in the conduct or support of official US government business. Authorized ARPANET users are classified (in order of decreasing priority) as DOD users, non-DOD US government activities and non-government US government activities. In certain circumstances non-US activities may be provided indirect access, subject to DCA approval, through the facilities of an authorized user.

The network configuration is based on the 'ARPANET backbone' comprising a large number of geographically dispersed packet switching nodes interconnected by wideband 50 kbit/s communications links provided by common carriers. A packet switching node may consist of an interface message processor (IMP), a terminal interface processor (TIP), a pluribus IMP or a pluribus TIP. IMPs and TIPs are store and forward packet switches which can accommodate up to four host computers (IMP) or three host computers and 63 terminals (TIP). A pluribus IMP is a multiprocessor based packet switch which can support in excess of 18 host computers, depending on configuration. A pluribus TIP is similar to a pluribus IMP but can also accommodate 63 terminals. Each host computer is linked to the network by means of an IMP or TIP which is usually located on the same premises as the host computer.

Terminals may be connected to the network by a direct line to a TIP or by dialling in to a TIP. Host computers communicate with each other by sending and receiving messages which vary in length from 96 to 8159 bits. The first 96 bits (i.e., the leader) are control messages between a host computer and its node (i.e., IMP or TIP). Control bits carry information on destination (node, host, internetwork address, priority, etc.) and message identity. The remainder of the message is the information being communicated from one host computer to another. Typically a sender host dispatches a message to a receiver host via its own (sender) node. The latter breaks up the message into a number of packets (not exceeding eight), each having up to a maximum of approximately 1000 bits. The node then distributes the packets through the network in the direction of the node of the receiver host. On arrival at the receiver node the packets are reassembled to form the original message which is then sent on to the receiver host. A network control centre based in Cambridge, Massachusetts exercises overall control over the network by detecting failures in communications links and packet switching nodes, by monitoring host and line traffic and by collecting data relating to IMP/TIP performance.

A detailed, technical description of the routing algorithm for ARPANET has been published by McQuillan *et al.* (1978, 1980). The recent ARPANET Information Brochure (Defense Communications Agency, 1980) already referred to offers a more general, less technical description and cites another report (AD-A026 900) providing a bibliography of publications about ARPANET. Although now somewhat dated a review of the characteristics of ARPANET by Frank and Chou (1974) is also a useful source. Kuo (1979) has briefly reviewed three defence packet switched networks in the United States, namely ARPANET, AUTODIN II and WIN.

3.1.2. TYMNET and TELENET

Rinde (1978) has described the emergence of TYMNET since it was established as a packet switched network in 1971. It is currently owned by Tymnet Incorporated which is a subsidiary of Tymshare Incorporated, a remote computing services company. TYMNET uses packet switching technology which differs markedly from that used in TELENET, and indeed the difference between the two technologies has stimulated considerable discussion concerning a strict definition of packet switching. In contrast to TELENET, which is packet-orientated and operates in the manner of ARPANET, TYMNET is said to be character-oriented with each packet containing data originating from several user messages. The routing algorithm also differs in the two networks. TELENET establishes a dynamic routing algorithm for each packet whereas TYMNET dynamically establishes a fixed optimum (minimum cost) path through the network at the time a user logs in to connect to a host computer. The path from user to host is selected by a network supervisor program each time a user logs in and the path is maintained until the user–host connection is broken. The technique is explained by Rinde (1978) and an interesting discussion on the differences between the two networks and the implications for network users, mainly in terms of cost, is presented by Smith and Moulton (1978).

In 1971 when the network supervisor program was introduced TYMNET had 30 nodes. By 1978 it had 300 nodes on three continents, connecting 140 host computers. Harcharik reported in 1979 that TYMNET had more than 450 network nodes, nearly 125000 miles of leased communications circuits and, at peak loads, approximately 5000 active circuit terminations.

TELENET was introduced commercially in August 1975 and is currently owned by GTE Telenet Communications Corporation. Since its inception it has mushroomed across the United States and its rapid expansion is clearly evident from the literature. In 1978 Smith and Moulton claimed that local access to TELENET was available in 80 American cities, in 1979 the number had increased to 170 (Roberts, 1979) and in 1980 Wessler reported that TELENET interconnected some 250 cities in the USA. Wessler also indicated that in 1980 the network was serving a wide range of subscribers including public computing services (30 per cent), manufacturing and industrial firms (30 per cent), service industries such as banking, insurance and transportation (30 per cent) and government and public bodies (10 per cent). Use of the network was initially limited to linking computers and low speed terminals (75 to 1200 bit/s) but as CCITT recommendations were introduced in the latter half of the seventies high speed synchronous communication was introduced between devices having the appropriate software. Computer manufacturers and software suppliers such as IBM have since begun to introduce X.25 network interfaces to enable users to fully exploit the high speed facilities of packet switched networks. Network owners such as GTE Telenet are also producing standard interfaces that will, for example, convert IBM 2870/3780 protocol to X.25 (Fox *et al.*, 1980). According to Wessler (1980) high speed 1.5 Mbit/s carrier lines as well as satellite communications facilities were scheduled to be introduced on TELENET in 1981.

TELENET and TYMNET are both known as 'value added networks' (VANs) because the network owners lease transmission lines from common carriers such as the American Telephone and Telegraph Company (AT&T) and add their own switching and communications processing facilities to the network. Thus, although AT&T uses line switching the value added networks, TELENET and TYMNET, are minicomputer-based and microprocessor-based packet switched networks. These

networks, because they use packet switching technology, can support simultaneous use by a large number of customers by interleaving packets of data originating from (and destined for) many users of the network. They are also relatively cheap, error-free and reliable and network users pay on a line usage and distant independent basis. By providing VAN facilities to customers the owners of TYMNET and TELENET are *de facto* specialized common carriers. This arrangement appears to be unique to the United States since in Europe and in other countries data networks are usually provided and controlled by the PTTs. This is currently an emotive issue and pressure is being exerted on PTTs to abandon monopolistic practices and to allow a degree of free enterprise in the development and operation of data networks (see for example Parker, 1978; MacDonald *et al.*, 1981; *Monitor*, 1981; Tomberg, 1981).

Commercial organizations in the United States were quick to recognize the potential of value added networks. The cost of building and operating dedicated transmission networks had seriously hindered the development of the online database market in the late sixties (an account of the telecommunications difficulties experienced by Tymshare Incorporated from its foundation in 1966 is given by Rinde, 1978). When TYMNET and TELENET were introduced in the early to mid-seventies it is not surprising that host operators (i.e., organizations offering information retrieval services based on one or more databases stored on a 'host' computer) were among the earliest users. Some of the first VAN users in this category were Lockheed Information Systems (offering the Lockheed DIALOG service), Systems Development Corporation (offering the SDC ORBIT service) and the National Library of Medicine (offering the NLM MEDLARS/MEDLINE service based on Index Medicus). Small commercial computer bureaux, attempting to compete on a national level with larger companies, were also quick to exploit the new networks. Many larger companies already had their own dedicated networks in operation and tended to be slower than smaller companies and host operators in making use of packet switched networks. However, as the trend in business gradually moved towards automation and distributed data processing these companies began to use TELENET and TYMNET and also to install compatible private packet switched networks where necessary.

The next logical phase in the development of data networks was to establish inter-network links thus extending labyrinths of nodal connections within and across national boundaries. TYMNET uses the Tymnet designed internally switched interface system (ISIS) for internetworking. The ISIS hardware is known as the 'Tymnet engine'. The software enables a node to serve as a multipurpose device, including acting as a gateway to other networks using CCITT X.75 (Harcharik, 1979). TYMNET and TELENET are linked to each other in New York. International links to networks outside the United States are established through the New York international gateway operated by three international record carriers—ITT Worldcom, RCA Globcom and Western Union International (WUI). In 1980 Peters reported that US packet switched networks were connected to some 30 countries including Canada and Mexico in North America, France, Spain, Sweden and the United Kingdom in Western Europe and Japan, Australia and New Zealand in Southeast Asia.

3.1.3. ACS

A new packet switched network, ACS (Advanced Communications Service), offered

by AT&T may soon be competing with TYMNET and TELENET (Pouzin, 1979). The network, consisting of a series of switching centres linked by 56 kbit/s analogue or digital trunks, was originally expected to connect 137000 customer terminals and computers by 1983. This forecast now seems dubious since, according to Krass (1980), ACS has been 'a thorn in AT&T's paw for years' and its introduction has been subjected to long delays because of technical difficulties. Long term forecasts predict that by 1990 the total revenue generated by American packet switched data services will be of the order of $1.8 billion and AT&T are hoping, perhaps optimistically, that the ACS slice of the market will be in the region of $500 million.

3.2 Canada

The Canadian Radio and Telecommunications Commission (CRTC) is the federal regulatory authority for telecommunications in Canada. Data communication services are provided primarily by two competing national common carriers. One is the Trans Canada Telephone System (TCTS) which is an affiliation of individual telephone companies throughout Canada, established to provide a full range of nationwide communications services. These affiliate companies include Bell Canada and several other companies owned by the provincial governments. In 1972 TCTS pooled its data communications expertise and established the Computer Communications Group (CCG), the aim of which was to plan, develop, coordinate, market, operate and maintain all TCTS national data services and products. (It is interesting to note that separate groups or companies were also set up in the late seventies by the European PTTs when they were introducing packet switched networks, for example, Transpac Ltd., in France.)

The other common carrier providing national data communication services is Canadian National Railways and Canadian Pacific (CNCP) Telecommunications. This is a cooperative organization of the two major railway companies, Canadian National Railways (CN) and Canadian Pacific Ltd. (CP). CN Telecommunications, in addition to providing a nationwide data communications service jointly with CP Telecommunications, operates telephone services in Northwestern Canada and in some areas of Newfoundland. It is not surprising that there is keen competition between the two carriers and one serious bone of contention has been the prohibition by TCTS of access to CNCP facilities over the public switched telephone network (PSTN) (see Carleton, 1979).

Teleglobe Canada is another organization which plays an important role in Canadian and international telecommunications. The company operates the Canadian International Data Switching Exchange, which is an international gateway for the interconnection of Canadian data networks with those in other countries throughout the world.

3.2.1. DATAPAC

DATAPAC is a public switched data communications network operated by the Computer Communications Group of TCTS. It was first publicly announced in late 1974 and by November 1976 an initial network with nodes in Calgary, Montreal, Ottawa and Toronto had been fully installed for the purpose of comprehensive field trials. DATAPAC eventually went into commercial operation on 15 June 1977. It

has been described by McGibbon (1979) as a virtual-call based store-and-forward backbone network consisting of packet switchers (approximately 13 Canadian designed and manufactured SL-10 nodes in 1979) connected by 65 kbit/s digital trunks and controlled by a network control centre located in Ottawa. The network supports synchronous and asynchronous communications facilities.

DATAPAC services are described under the headings Datapac 3000, 3101, 3201, 3203, 3303 and 3304.

Datapac 3000 was the first interface developed for DATAPAC in support of general purpose synchronous hosts and terminals and is compatible with CCITT X.25 (referred to by the Canadians as SNAP—standard network access protocol). It is typically used by intelligent synchronous terminals and host mainframe computers which are accessed by other services. Data rates are 1.2, 2.4, 4.8 and 9.6 kbit/s.

Datapac 3101, the second interface to be developed for DATAPAC, supports asynchronous character mode teletype compatible terminals operating at data rates of 110, 300, 600 and 1200 bit/s and enables them to communicate with X.25 host computers. Datapac 3101 is compatible with CCITT X.3, X.28 and X.29. A packet assembler/disassembler (PAD) or, in Canadian terminology, a network interface machine (NIM) must be used to connect the terminal's protocol and data formats to X.25. Access may be over the public switched telephone network (PSTN) or via a dedicated line.

Datapac 3201 and 3203 were introduced in 1978 to support communications terminals in the retail industry for credit checking and point of sale applications and to meet the needs of the consumer loan industry. The main application of Datapac 3201 is in supporting access by NCR electronic cash registers and point of sale terminals to retailers' host computers. McMahon (1980) has described how DATAPAC is used by a leading shoe retailer with 106 outlets across Canada. By linking each store to a central computer the company is able to operate an up to date sales reporting and inventory control system. Datapac 3203 serves the consumer loan industry by providing an interface for a DMC 8901 terminal or other terminals using a particular IBM 2740 protocol.

Datapac 3303 and 3304 have been described in detail by Tagg and McGibbon (1979). These services are designed to accommodate synchronous terminals having relatively fixed protocols, for example the IBM 3270 display station terminal family and other manufacturers' emulators as well as remote job entry terminals. Both of these data services were introduced to minimize changes required by end users and hence to promote usage of the network in a period when new protocol standards were emerging.

3.2.2. INFOSWITCH

In 1975 CNCP Telecommunications announced plans for the design, development and implementation of a new hybrid digital public data network, INFOSWITCH, which was to provide both digital circuit switching and digital packet switching services (Carleton, 1979; McCrum, 1979). Field trials began in late 1976 and the service was launched commercially in mid-1978.

The first phase of the network consisted of four nodes in Edmonton, Montreal, Toronto and Vancouver, each node using the Siemens System EDX with PDP-11 type central processing equipment. Nodes were connected by 56 kbit/s 'INFODAT' point-to-point digital transmission links. The network was later extended using

concentrators having the same operational capabilities and providing the same services as the nodes. According to McCrum (1979) basic services including Infoexchange, Infogram and Infocall.

Infoexchange is a digital circuit switched service suitable for bulk data transfer where the communicating devices operate at identical data rates. The network establishes a point-to-point path for the exclusive use of the subscriber for the duration of the call.

Infogram is an end-to-end X.25 packet transmission service intended for intelligent data terminal equipment (DTE). The service can also support asynchronous terminals by means of a concentration option which allows intercommunication with the host Infogram connections over multiple simultaneous virtual connections on a single synchronous link (Carleton, 1979).

Infocall is a packet mode service aimed primarily at low data rate users having code and speed compatible terminals. In the case of synchronous transmission blocks of data are transmitted unaltered from sender to receiver terminals. In asynchronous operation data are packetized at the entry point in a manner which best facilitates an acceptable response time on the network.

Shortly after their introduction Canadian networks were extended to other North American and European countries. DATAPAC was linked to TYMNET and TELENET in 1977. The link-up was established by means of enhanced X.25 interfaces over 9.6 kbit/s lines and was in commercial operation by May 1978 (McCrum, 1979). The library of Memorial University of Newfoundland was accepted by TCTS as a trial user of the extended network and in January 1978 it became the first Canadian library to access US host computers using the DATAPAC/TELENET link (Clinton, 1978a). DATAPAC is also linked to IPSS in London by means of the Teleglobe Canada International gateway and other international links are being established as new networks emerge in other countries. In 1979 Carleton disclosed plans to connect INFOSWITCH to TYMNET and was optimistic regarding links to other countries, particularly France, West Germany, Spain and Israel.

3.3 Mexico

3.3.1. SCT

The SCT (Secretaria de Comunicaciones y Transportes) data network in Mexico became operational in February 1981 and is based on packet switching equipment supplied by GTE Telenet (*GTE Telenet Report*, 1981). Initially the network served five major cities in Mexico but is expected to be extended to 20 cities by the end of 1981 and by 1983 users in approximately 50 cities will have local access. A synchronous X.25 service is available and asynchronous terminals are also supported. The latter operate at 110–300 bit/s and 1.2 kbit/s and may be connected via leased lines or over the PSTN. Under an agreement between GTE Telenet and SCT the Mexican network was linked to TELENET early in 1981.

4. NATIONAL NETWORKS IN WESTERN EUROPE

The major national public packet switched data networks that have emerged in Europe are summarized in Figure 1. These include RETD in Spain, TRANSPAC in

France, DATEX-P in West Germany, DATANET in the Netherlands and PSS in the United Kingdom. Two international European networks, EURONET and the Nordic Packet Switched Data Network (NPSDN) have also been recently established (see Figure 1) and are described in Section 5. Most networks in Europe are being gradually interconnected by means of international gateways such as those presently located in London, Paris and Frankfurt.

4.1 Spain

4.1.1. RETD

The first public data network in Europe to employ packet switching techniques was RETD (Red Especial de Transmision de Datos) set up in 1971 by the Spanish telephone company CTNE (Compañía Telefonica Nacional de España). The network was originally based on packet switching nodes in Madrid and Barcelona which were accessed via network entry points (concentrators) (OECD, 1979). In the last decade the network has been gradually extended throughout the provinces and there has also been a move towards CCITT standards. By the end of 1979 RETD consisted of five nodes, 36 concentrators and a network management centre and there were 31 host computers and almost 8000 terminals in operation (Cuenca, 1980). Much of the older equipment installed in the early seventies is being gradually replaced by new purpose built packet switching equipment (the replacement programme which began in 1978 is referred to by Cuenca as the TESYS-5 Project).

The tariff structure consists of three elements: an installation charge depending on the distance to the nearest concentrator; a fixed monthly charge related to connection circuit type and distance from the concentrator; and a traffic volume charge depending on the type of service, when the network is used and the geographical location. RETD is already connected to TYMNET and TELENET in the USA, DATAPAC and INFOSWITCH in Canada, TRANSPAC in France and a link to EURONET is expected before April 1982.

4.2 France

4.2.1. TRANSPAC

The French were engaged in research on packet switching from the early seventies and eventually two experimental packet switched networks emerged. RCP (Réseau à Commutation par Paquets) was implemented in 1973 and made available to users in 1975 by CNET (Centre National d'Etudes des Télécommunications) and CCETT (Centre Commun d'Etudes de Télévision et Télécommunications). This network served as a testbed for TRANSPAC, the existing public data network. The second experimental network, CYCLADES, was developed by IRIA (Institut de Recherche d'Informatique et d'Automatique) and was used for online information retrieval from databases offered by several host operators (see Tomberg, 1977).

Following a comprehensive testing programme on RCP complete specifications for a new public packet switched network, to be named TRANSPAC, were drawn up in 1974. In April 1976 the SESA Company (Société d'Etudes et Systèmes d'Automation) was contracted to build TRANSPAC to CCITT standards and a new

company (named Transpac) was formed in 1978 by the French Government to operate and market the network. The company is 72 per cent state owned and the remaining 28 per cent of shares belong to a group of users (UTIPAC). TRANSPAC

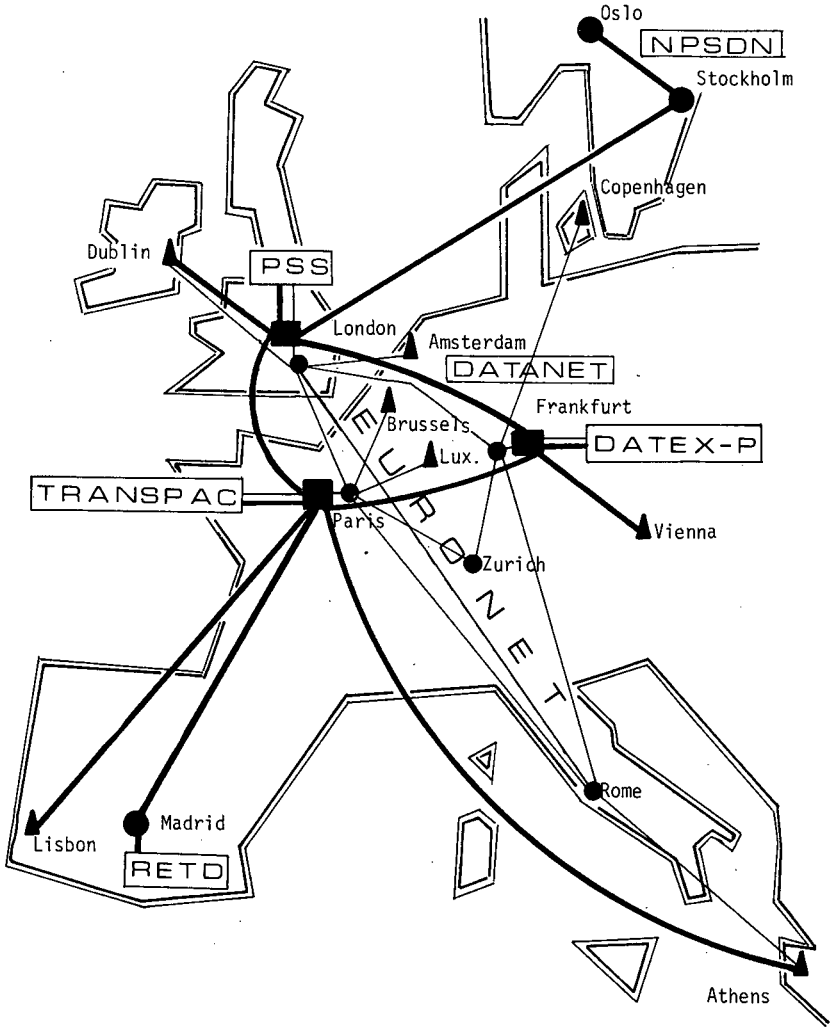

FIG. 1. European data networks and some existing and proposed interconnections (■ = international gateway—London, Paris, Frankfurt; ——— = public network link; ——— = EURONET link; ● = EURONET switching exchange; ▲ = remote access facility; ● = other switching exchanges)

finally became operational in December 1978 based initially on four switching nodes and by the end of 1980 there were 19 packet switching centres throughout France.

TRANSPAC supports both packet mode and character mode terminals. Packet

mode terminals are connected to the network by dedicated lines and operate at data rates of 2.4, 4.8, 9.6, 19.2 and 48 kbit/s. Character mode terminals may be connected by dedicated lines (at data rates of 600 and 1200 bit/s), via the PSTN (at data rates of 110 to 300 bit/s) or by means of the telex network (at data rates of 50 bit/s). The tariff structure is distance independent. A user possessing a dedicated line is charged a rental which depends on the data rate of the line. Other charges include duration charges for calls and data volume charges. In cases where access is over the PSTN there is a local call charge, irrespective of distance or duration, provided a unique number is used to automatically connect the caller to the nearest TRANSPAC access point. In some circumstances it is possible to make direct calls to other access points but the caller must pay the normal long distance telephone charge. A full description of TRANSPAC is given by Despres and Pichon (1980) and other useful papers have been published by Platet (1980) and Trottin (1981).

NTI, the French international gateway, has been described by LeRest *et al.* (1980). Located in Paris it serves to connect TRANSPAC to other data networks worldwide. For example, the French network is already connected to TYMNET and TELENET via NTI and the New York gateway operated by ITT, RCA and WUI. TRANSPAC is also connected via NTI to EURONET, RETD and DATAPAC and there are international links to Amsterdam, Brussels, Copenhagen, Dublin, Frankfurt, London, Luxembourg and Rome. In 1980 Despres and Pichon indicated that other networks emerging in Europe, as well as D50 in Japan, would soon be linked to TRANSPAC.

4.3 West Germany

4.3.1. DATEX-P

The Deutsche Bundespost has installed an Integrated Telegraph and Data Network (IDN) providing data subscribers with a wide range of communications facilities operating at low, medium and high bit rates (Kaiser, 1979). There are two networks for the transmission of digital information, DATEX-L, a public circuit switched data network, and DATEX-P, a public packet switched data network. According to Hillebrand (1980) the decision to introduce DATEX-P was taken in December 1978 and a subscriber working group was set up in May 1979. The service was opened in late 1980 and was scheduled to be available for testing by users in July 1981. The proposed first stage network configuration (scheduled for 1980) consisted of a data collection centre, a network control centre, 18 SL-10 packet switching exchanges and an international gateway. Like most other packet switched networks DATEX-P tariffs are distance independent and are based on a fixed monthly charge plus use related charges.

Planned services are designated Datex P10, P20, P32 and P33.

Datex P10 is the basic service supporting X.25 synchronous transmission (at data rates of 2.4 to 48 kbit/s) for connection of packet mode terminals.

Datex P20 will support CCITT recommendations X.3, X.28 and X.29 for the connection of simple character mode terminals at speeds of 300 and 1200 bit/s.

Datex P32 and Datex P33 are for the connection of data stations and data processing systems which are compatible with IBM 3270 and Siemens 8160 respectively.

Interlinking of DATEX-P to other networks via the international gateway in Frankfurt is shown in Figure 1.

4.4 Netherlands

4.4.1. DATANET

Development of the Dutch packet switched data network, DATANET, was initiated in 1976 by the Dutch PTT in cooperation with a small group of 'early users' (Drukarch and van den Burg, 1980). The objective of the first stage (DATANET 1 or DN1), implemented in mid-1981, was to meet the short term requirements of the early user group. It is intended to gradually extend the capacity and functions of the network over the next few years and to eventually offer it as a public service. Initially only X.25 connections operating at speeds of 2.4, 4.8, 9.6 and 48 kbit/s were made available and users were expected to provide their own X.25 adaptation facilities. The range of connections is being extended by the installation of a PAD to enable small and medium sized companies to exploit the network.

The initial configuration of DATANET 1 was based on three packet switching exchanges (PSEs) located in Amsterdam, Arnhem and The Hague, 57 packet data satellites (PDSs) (i.e., concentrators) distributed throughout the country and a network operation and management centre (NOMC) near Amsterdam. A subscriber is connected to a PDS via an X.25 interface, the PDSs are connected to the PSEs, and the PSEs are all interlinked and have direct lines to the NOMC. The NOMC functions include supervision and operational management of the network, network debugging, maintenance test activities, statistics processing and handling of billing data.

The characteristic feature of DATANET according to Drukarch and van den Burg (1980) is the distribution of intelligence by means of PDSs. Although it is not unusual to separate the data switching function and that of setting up the call most other systems do not have the PDS remote from the controlling exchange.

4.5 United Kingdom

4.5.1. PSS

Work on packet switching in the UK began in the late sixties at the National Physical Laboratory (NPL) when an experimental packet switched network was designed by Davies and co-workers in 1967 to link computer equipment on the NPL's London site (Davies *et al.*, 1967; Jackson, 1981). The single node network became operational in 1973 and probably influenced the British Post Office (BPO) in its decision to introduce a public data network. An outline proposal for a BPO experimental packet switched service (EPSS) was introduced in 1972 but it was not until April 1977 that EPSS became operational with PSEs in London, Manchester and Glasgow. The configuration, development and some operational aspects of the network are outlined in a paper by Hadley and Sexton (1978).

EPSS served as a test facility for the BPO, the data processing industry and data users by providing an opportunity for the appraisal of the economic and technical aspects of a public network. Some 40 organizations operating in such diverse fields as commerce, computer industry and services, research, government and banking cooperated in the EPSS Project and the heaviest users appear to have been universities, polytechnics and research centres (OECD, 1979).

In the five year period taken to develop EPSS to operational level (1972–77)

international CCITT standards began to emerge. As these were not compatible with EPSS protocols the BPO was forced to reconsider its original plan to develop EPSS into a public network (Cross, 1978; Feldman and Mildenhall, 1978). Development of a public packet switching service (PSS), based on CCITT recommendations and designed to replace EPSS, was initiated in 1978. The network became operational in September 1980 on an experimental basis and was initially based on nine PSEs connected by 48 kbit/s trunk circuits, at Birmingham, Bristol, Cambridge, Edinburgh, Glasgow, Leeds, London, Manchester and Reading. PSS was officially opened for customer operations in August 1981 and is expected to have three additional PSEs at Liverpool, Newcastle and Slough by the end of 1981. The network management centre is located in London (Medcraft, 1980).

PSS supports both packet mode and character mode terminals. Packet mode terminals are directly connected via a 'Dataline' to the nearest PSE and operate in the usual 2.4–48 kbit/s range. Character mode terminals are connected through a PAD by means of a 'Dataline', or over the PSTN using the 'Datel' service, at data rates up to 300 bit/s and at 1.2 kbit/s. PSS tariffs are dependent on connection time and on the volume of data transmitted but are independent of distance. Users of character mode terminals who are connected over the PSTN incur normal telephone charges in addition to PSS charges.

It has recently been announced (*Data Processing*, 1981) that a PSS-IPSS gateway will be provided by January 1982. PSS links to Australia and Japan via TYMNET, and two way links to Hong Kong and Spain are scheduled for the end of 1981. A gateway to EURONET is also planned for mid-1982 (see Figure 2).

4.5.2. IPSS

The world's first public intercontinental packet switching data service, the International Packet Switched Service (IPSS) having an international gateway in London, was introduced by the BPO in December 1978. It followed the successful operation of the transatlantic Database Access Service (DBS) which afforded UK customers access to databases in the United States (Medcraft, 1980). DBS had been operated on a trial basis by the BPO in conjunction with WUI, TYMNET and TELENET from 1977 in response to mounting pressure from database users. As the response to DBS indicated that there was a clear market need for a data link with the United States the BPO decided to implement a packet switched service which would conform to all CCITT recommendations.

IPSS supports packet mode terminals (connected directly to the London gateway and operating at 2.4, 4.8 and 9.6 kbit/s) and character mode terminals (connected to the London gateway directly or over the PSTN). When PSS is linked to IPSS all UK access to IPSS will be via PSS, thus considerably improving access to IPSS by users of character mode dial-up terminals.

IPSS is already connected to the North American networks described in Section 3 above and will also serve as a gateway to Europe and the rest of the world. Existing and proposed link-ups are summarized in Figure 2.

4.6 Republic of Ireland

In the Republic of Ireland an experimental packet switched network is being

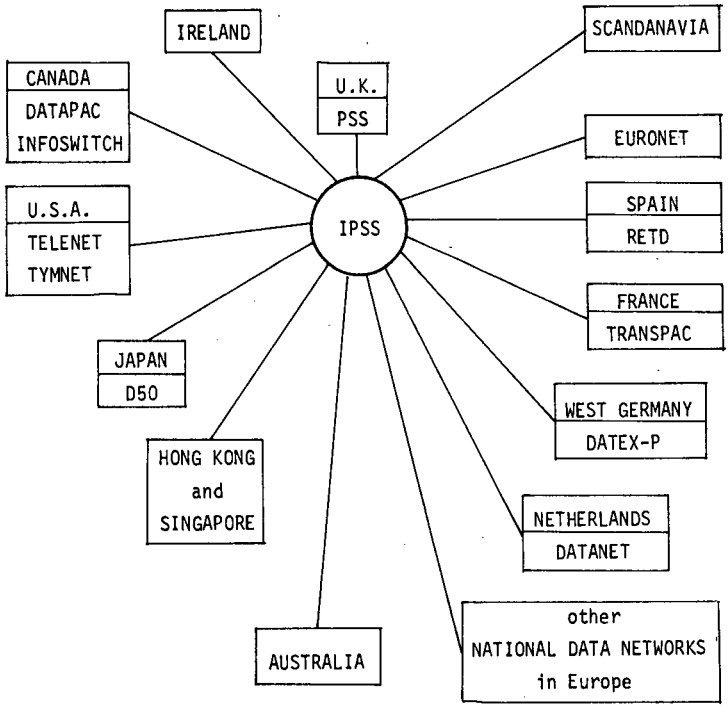

FIG. 2. IPSS: some existing and proposed interconnections (Sources: 1. Medcraft, 1980; modified and updated; courtesy of Online Publications Ltd., UK. 2. *Data Processing*, 1981)

installed under the auspices of the National Board for Science and Technology (NBST) with the cooperation of Trinity College Dublin (TCD), University College Dublin (UCD) and the PTT (Jennings, 1980). The network will be fully operational by February 1982 and will consist of a single PSE in Dublin with X.25 links to EURONET and to the TCD and UCD computers.

The PTT plans to implement a public packet switched network by 1983. The network will be based on the Dublin PSE, which will provide international access to other networks, and a number of multiplexors sited throughout the provinces. Links have already been established with EURONET and, since December 1981, with IPSS.

4.7 Other European countries

The Swiss data network, EDWP (Elektronisches Datenwahlnetz mit Paketvermittlung), planned for 1982, is described by Pitteloud (1981).

Packet switched public data networks are planned in most other countries in Western Europe and all are expected to be installed by the mid-eighties (see Table 1). Details of PTT plans are available in the Eurodata Foundation Yearbook (1981) and, in less detail, in the CEPT/Eurodata Foundation (1981) publication on public data networks.

5. INTERNATIONAL NETWORKS IN WESTERN EUROPE

5.1. Nordic Packet Switched Data Network (NPSDN)

The Nordic Cooperative Organisation for Applied Research (NORDFORSK) established the first international packet switched data network in Denmark, Finland, Norway and Sweden when it installed SCANNET (Scandinavian Network) in August 1976 (see Tomberg, 1977; Abrahamsson, 1979). As the Nordic PTTs were planning to introduce a Nordic Public Data Network (NPDN) (see below) sometime in 1980/81 they reluctantly gave permission to NORDFORSK to establish SCANNET as a private experimental network for online database searching on condition that it would switch over to public communications facilities when available.

The basic SCANNET configuration consisted of nodes in Copenhagen, Gothenburg, Helsinki, Oslo and Stockholm connected by leased telephone lines operating at data rates of 2.4 kbit/s. The nodes were NORD 12 mini-computers with ports for incoming user calls at speeds of 110, 300 or 1200 bit/s. In 1979 there were 250 organizations using the network and access was available to more than 15 databases. It had always been the intention of the SCANNET steering committee to establish international links with other packet switched networks. According to Abrahamsson (1979) however, the Nordic PTTs considered it undesirable to permit a private experimental network like SCANNET to become involved in global networking, and they set about providing packet switching facilities intended specifically for the provision of international access to databases. The outcome of discussions between the PTTs and the SCANNET steering committee was the establishment by the PTTs in 1980 of a Nordic packet switched data network (NPSDN) to enable online users to access databases in Scandinavia, North America and Europe. These developments are well documented (see for example Abrahamsson, 1979; Gronlund, 1979; *Online Review*, 1980a, 1981; *SCANNET Today*, Winter 1980-81).

The new network is based on packet switching facilities provided on the PSTNs (DATAPAK in Sweden and NORPAK in Norway). The network configuration is centred around two interconnected PTT nodes, one in Stockholm (DATABAS 300/1200) and another in Oslo (NORPAK) (see Figure 1). Multiplexors in Helsinki and Copenhagen are connected to DATABAS 300/1200. Access to TELENET and TYMNET is available via DATABAS 300/1200 and a link to PSS in the United Kingdom is expected by 1982 (see Figure 1). The Oslo node is connected to an experimental packet switched data network, UNINETT, operated by a group of Norwegian universities. The original SCANNET nodes now act as front end processors to the PTT nodes and can no longer be accessed directly. The status of the original Gothenburg node is not clear and it may be abolished now that tariffs are distant independent (*Online Review*, 1980a). The DATABAS 300/1200 node in Stockholm is to be extended to provide a public packet switched service which will facilitate a wide range of applications other than database access.

The Nordic packet switched data network, NPSDN, referred to above should not be confused with the Nordic Public Data Network (NPDN) (described in detail by Svendsen, 1980) which also came into operation in 1980. The NPDN is a circuit switched data network which is normally considered to be a single international Scandinavian network. It is however composed of four independent interconnected national circuit switched data networks operated and maintained by the individual PTTs in Denmark, Finland, Norway and Sweden. It is possible that in the future packet switching facilities will be introduced on the NPDN.

5.2. *EURONET*

On 24 June 1971 the Council of Ministers of the European Community passed a resolution which outlined a basic policy for the coordination of activities in the field of scientific and technical information within the member states. This resolution has resulted in three Action Plans for scientific and technical information and documentation in Europe. The First Action Plan, covering the three year period 1975–1977, was adopted by the Council of Ministers in March 1975 and was supported by a total budget of $9 million. The Plan authorized the Commission of the European Communities to develop, *inter alia*, an international data network extending to all member states to provide improved, distance independent access to a wide range of databases and information services. The implementation of the network, to be named EURONET, was to require the cooperation of the nine PTTs, a large number of host operators, database producers and online users, the European Commission and its consultative Committee for Information and Documentation on Science and Technology (CIDST).

The French PTT, acting on behalf of the nine PTTs, signed a contract with the Commission in December 1975 to build the network. In June 1977 the PTTs subcontracted a consortium of European software companies to implement the network using TRANSPAC packet switching technology and incorporating CCITT standards. The Second Action Plan, covering the period 1978–1980, was approved in October 1978. It had a budget allocation of $11 million and provided for the full development of EURONET into an operational service. In November 1979 the network was made available for testing to hosts and users and it was finally opened for commercial use throughout the European Community in March 1980.

The development of EURONET has been extensively covered in the literature (an online search by the author of the PASCAL database yielded 64 references to EURONET over the period 1979–1981). Examples of papers include those of Vanautryve (1981), Davies (1980), Mahon (1980) and Kelly (1979). According to Davies (1980) the network configuration at the opening date consisted of four packet switching exchanges in a central ring circuit (from Frankfurt to London to Paris to Rome to Frankfurt) and five remote access facilities (RAFs) at Amsterdam, Brussels, Copenhagen, Dublin and Luxembourg. The PSEs were connected by 48 kbit/s lines and there were also 48 kbit/s lines from the Paris PSE to Brussels and from the London PSE to Amsterdam. Dublin was linked to the London PSE and Luxembourg to the Paris PSE by 9.6 kbit/s lines. The network management centre was located in London. The proposed configuration in 1982 is shown in Figure 1. An additional PSE has already been established in Switzerland (Zurich) with links to the Frankfurt and Paris PSEs (*Euronet Diane News*, 1980). Connections will also be made to Austria (Vienna), Greece (Athens), Portugal (Lisbon) and Spain (Madrid). A 9.6 kbit/s link will be installed between the London and Rome PSEs and all other lines will operate at 48 or 72 kbit/s.

EURONET is already connected to TRANSPAC in France and is expected to have linked into other public data networks such as DATEX-P in West Germany and PSS in the United Kingdom by 1982. These developments will be in line with the Third Action Plan of the European Communities (approved in 1981) which aims to transform EURONET into a public data network by 1983 (*Euronet Diane News*, 1981c). Hitherto EURONET, like SCANNET, has been made available primarily for online searching of databases and as such is not a public network. By the end of 1983 however the network will devolve completely to the nine PTTs of the

community member states and will eventually be superseded by interconnected national public packet switched data networks.

Shortly before EURONET became operational the European Commission turned its attention to the promotion of services on the network. A EURONET launch team was established to promote the network and the concept of EURONET DIANE was introduced. EURONET denotes the telecommunications facility and DIANE (Direct Information Access Network for Europe) represents the service aspect (i.e., the supply and distribution of information using EURONET as a vehicle). When the network was launched in 1980 there were approximately 15 host computers, offering more than 90 databases, connected to the network. The latest Euronet Diane Directory (1981) lists 36 hosts and almost 300 databases, indicating a rapid expansion in services. Other services now available include a common command language, which is being adopted by an increasing number of hosts, and a free enquiry service.

Despite the continued barrage of criticism directed at EURONET (it was originally unrealistically scheduled to open in 1977 and when it was eventually launched in 1980 some irritating access problems were encountered by users) it has been a unique and remarkable exercise in international cooperation. It will be seen in the future, long after it has ceased to exist as a separate entity, as the major catalyst in the advancement of data communications in Western Europe.

6. NETWORKS AND GATEWAYS IN SOUTHEAST ASIA

6.1 Japan

6.1.1. D50

Packet switching first got underway in Japan when the DDX (Digital Data Exchange) project was initiated by the Nippon Telegraph and Telephone Company (NTT). The project produced two prototype systems, DDX-1 and DDX-2. The latter has been described by Iimura *et al.* (1978). In May 1978 the D50 public packet switched network was installed on an experimental basis in seven cities—Tokyo, Fukuka, Nagoya, Osaka, Saporo, Sendai and Yokohama. It became commercially operational in 1979 and is expected to be available in 100 cities by 1982, and all over Japan by 1987 (Ishino and Mizusawa, 1979).

D50 supports packet mode and character mode terminals and is compatible with CCITT recommendations (X.25 for packet mode and X.3, X.28 and X.29 for access over the PSTN). It is connected to North American networks through the ICAS (International Computer Access Service) node in Tokyo (*Online*, 1980) and there is also a link to Australia.

6.2 Australia and New Zealand

According to Morrison and Cuzens (1978) long-term telecommunications policy in Australia was outlined by Telecom Australia in its report '*Telecom 2000*' (published in 1976) and in a follow up report entitled '*Outcomes from the Telecom 2000 Report*' July 1978. Another report, '*Data Communications: 1978 Overview*', also published by Telecom Australia in October 1978 indicated a growing need for

specially designed public facilities for data transmission (data modems in privately leased circuits increased from approximately 250 in 1970 to 14500 in 1978).

Poussard (1978) indicated that data communications services being considered in 1978 by Telecom Australia included a dedicated link service and circuit switched, packet switched and transaction switched services. More recently Peake (1981:12) stated that 'Telecom Australia (has) announced that a packet switching data network would be operational by 1982'.

Australia, because it is geographically isolated, has always placed high priority on international communications. In April 1979 the Overseas Telecommunications Commission (OTC) established a packet switched service known as MIDAS (Multimode International Data Acquisition Service) to facilitate access to overseas databases (*Australian Special Libraries News*, 1978; *Online Review*, 1980b). MIDAS is linked to TYMNET, TELENET, DATAPAC and INFOSWITCH in North America and also to networks in Europe and Japan. The introduction of the service was a significant development for Australian users mainly because telecommunications charges, now distance independent, were reduced from $A200/hour in 1978 to $A25–$30/hour in 1979 (Peake, 1981). There are plans to extend MIDAS and to establish two-way links to other networks, making Australian databases available to overseas searchers.

Access to databases within Australia is available on AUSINET, a national system set up under the auspices of the National Library of Australia, and on the CSIRONET computer network operated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Middleton, 1981). Some user reactions to AUSINET are described by Bays (1979) and Cayless (1979).

In 1979 the New Zealand Post Office announced the introduction of OASIS (Overseas Access Service for Information Systems). Links were established in 1980 with TELENET and TYMNET and there are plans to connect to other services in Europe, and Southeast Asia (*Online Review*, 1980c).

7. SUMMARY OF INTERNATIONAL INTERNETWORKING

The international gateway established in New York by ITT, RCA and WUI made the packet switching facilities of North American networks available to the rest of the world. In the mid-to-late seventies there were virtually no packet switched networks outside North America and traffic was one way, i.e., users outside America could search host computers such as those of Lockheed, SDC and the National Library of Medicine but Americans were unable to search European databases. As packet switched networks began to emerge in Europe international gateways like IPSS in London and NTI in Paris were installed to facilitate the interconnection of networks. As indicated above international gateways have also been recently established in Japan, Australia and New Zealand. The global situation in 1982 is summarized in Figure 3. Most packet switched networks are linked via gateways in North America, Europe and Southeast Asia. In some cases only one way links exist but most will be upgraded in the near future to accommodate two way communications. The situation in Europe is changing rapidly and most European countries are expected to install packet switched data networks by 1984 (see Table 1). As the individual pieces of the European jigsaw slot into place EURONET, as already mentioned, will disappear from view and European networks will evolve as one large network. Similar developments will probably occur in Japan, Australia

and New Zealand. The overall result will be the emergence of three major interconnected networking sites as depicted in Figure 3.

In a paper outlining the problems of developing countries in online information retrieval Hoover (1980) suggests that 'the ICAS line from Japan, the MIDAS line from Australia and the OASIS line from New Zealand [and presumably the North American and European gateways] invite the possibility of nodes in cooperating less developed countries to tie them to the outside world'. He also notes that an increasing number of developing countries, such as Kenya for example, now have satellite telecommunications nodes in service. Unfortunately however the rate determining factor in establishing international links between developing countries and the rest of the world is usually the local telephone services which are often unreliable or nonexistent. Hoover suggests that the telex network be used initially to

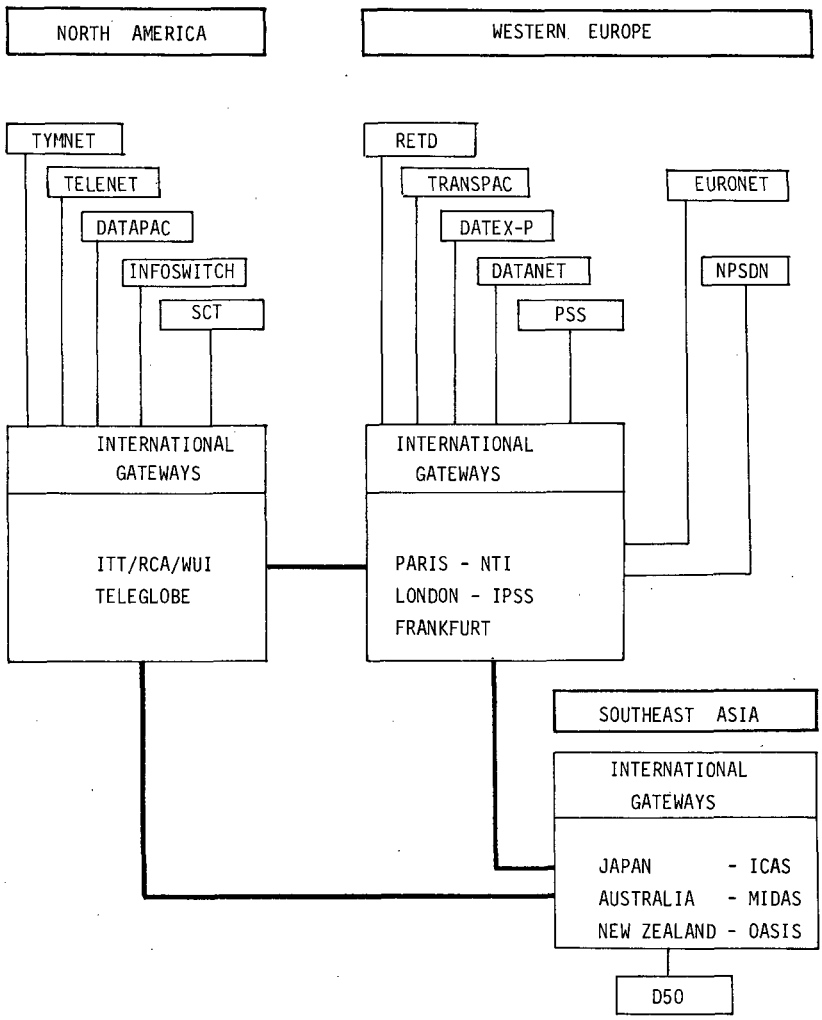

FIG. 3. Global internetworking

establish slow (6 cps) communication links for online services to train and familiarize users with online systems. The more difficult problem of planning general telecommunications policies in developing countries is tackled by Cleevely and Walsham (1980).

8. IMPACT ON ONLINE INFORMATION RETRIEVAL

Interactive information retrieval from commercially available databases dates from the early seventies when the technologies of computer hardware, software and telecommunications had reached the stage where remote online access to a central host computer was economically feasible. Software development was pioneered in the late sixties by the American companies Lockheed and Systems Development Corporation (SDC). DIALOG software developed by Lockheed was operational by 1970. It was installed under contract at the National Aeronautics and Space Administration (NASA) and was later adopted by the European Space Agency (ESA) in Rome as the RECON/QUEST software for its online information retrieval service, IRS. SDC software, ORBIT, was acquired by the US National Library of Medicine for its MEDLARS/MEDLINE service and later by the British Library for BLAISE (British Library Automated Information Service).

From the early seventies online users in the United States had access to Lockheed and SDC databases via TYMNET, and later, TELENET. European users however were less fortunate in the range of databases and telecommunications facilities available to them. In the early-to-mid seventies European databases were restricted to specialist interest groups, e.g., databases on space technology by ESA and on medicine by the British Library and Deutsches Institut für Medizinische Dokumentation und Information (DIMDI). Although experimental packet switched networks began to emerge in Europe in the mid-seventies (e.g., EIN, CYCLADES, NPL—see *OECD*, 1979; Tomberg, 1977) online access to databases was mainly via expensive, distance dependent public telephone lines and dedicated line networks such as ESANET, BLAISE and DIMDINET until the arrival of EURONET in 1980.

The prospect of cheaper, more reliable and more flexible packet switched national and international networks in Europe was one of the many factors which stimulated the phenomenal growth of European produced bibliographic and nonbibliographic databases (a bibliographic database provides references to documents containing the information required by a user and a nonbibliographic database, i.e., a databank, provides direct information to a user). Tomberg (1979) has shown that the extent of this growth was such that by 1978 Europe had overtaken the USA as a database producer. He also pointed to the growing success of nonbibliographic databases (which increased from zero in 1972 to 609 in 1979) compared with bibliographic databases (which increased from 98 to 556 in the same period). By 1981 there were over 1400 databases in all fields of interest available in Europe and approximately 500 were accessible online (EUSIDIC, 1981). Despite Europe's dominance in database production, however, the United States continues to lead in the number of online searches being undertaken annually. In 1980 Europeans performed 500000 bibliographic searches online while some 5000000 searches were conducted by Americans (Tomberg, 1981).

The future role of telecommunications in information retrieval has been examined by several authors including Clinton (1978b), Isotta (1980) and Tomberg (1981). A broad scenario of new and improved technologies, new applications of existing

technologies, new services and new problems is predicted for the eighties. Electronic mail services are already available on EURONET (*Euronet Diane News*, 1981e). Now that data networks are actually in operation the long standing problems of document delivery are being taken seriously (Gillespie *et al.*, 1979; *Euronet Diane News*, 1981f; Norman, 1981). The inadequacy of terrestrial networks in coping with high speed applications such as document delivery is being overcome by satellite communications (Cawkell, 1979; Kelley, 1979; Raitt, 1980). The launching of ARIANE satellites from French Guiana in June and December 1981 confirmed that Europe is becoming a serious competitor in the US dominated field of satellite communications. The problems to be overcome in the next decade are formidable. A long and bitter struggle to usurp traditional PTT monopolies in telecommunications is already underway. A solution to the copyright problem is urgently needed if the full potential of computer and communications technology is to be realized. Problems of design, management and maintenance of rapidly expanding information systems, multilingual databases, efficiency of retrieval languages, standardization of hardware and software, economics of online searching, user education and training, understanding user needs, the relevance of online databases to user needs, and problems of security and privacy in national and international data transfer need to be tackled. Developments in information retrieval systems in the eighties are more likely to be influenced by political, social, legal and economic considerations than by advances in technology. It is now obvious that the new technology of data networking has precipitated rather than solved the real problems of data communications.

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