packetswitching&networks

Packet Switching & Networks

A Data Communication Historical Series

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Packet Switching & Networks (ca 2003):

Block by Block data transmission has been in use since the late 1950’s when the IBM punched card devices were used to transmit information based on an eighty-character punched card. Other block by block communications systems came into use and gradually through technical advances grew into the Packet Switching networks. One of the first Packet Switched Networks was the ARPA-Network (Advanced Research Projects Administration Network). This Packet Switched network was first implemented in 1969 for the U. S. Department of Defense.

Figure 1 provides a Geographic Map of the ARPA Network in early 1974. Figure 2 is a Geographic Map of another Packet Switched Network, Telnet, at the end of 1975. There were many more Packet Switched Networks, but these two are shown to illustrate that these Networks have been around for some time and in 1974-1975 ARPA-Net used all land-based facilities, while Telnet used both land based and satellite facilities. All local connections or users would connect to the closest or most convenient Packet Switch Exchange. Any user can be connected to an Exchange via a telephone connection (typical) and would be charged a fee based on connection requirements and quantity of data and network usage. These networks are designed to be shared by a multitude of unrelated users, similar to the telephone system except data would be transmitted and received.



Figure 1

Packet Switched Networks perform the necessary conversion of each shared user communication (message) into individual, equal-sized Packets. These Packets are then sent individually, along with any other user Packets, to their destination through the network, and the entire message is reassembled when all the Packets are received. Error and lost Packet tests are performed and the necessary retransmission of Packets is accomplished when necessary.

In Figure 2 the black and open circles are microwave dishes that represent the Packet Switching Exchanges (PSE). All local connections, Data Terminal Equipment (DTE) would be connected to the Packet Switching Exchanges via predetermined lines (circuit) and equipment.



Figure 2

A typical Packet length for the early network systems was about one kilobyte, (thousand characters). A large message may be divided into thousands of individual Packets. The beginning of a Packet is called the ‘header’ and contains the following information:

* Source: The address of the computer sending the Packet.
* Destination: The address of the destination (receiving) computer.
* Length: The length of the Packet in bytes.
* Number. The total number of Packets in the complete message.
* Sequence: Sequential numbers are assigned to each Packet so the Packets, when received, can be reassembled and a missing Packet can be identified.



Note: The above Packet configuration represents the early systems and does not represent the Packet configuration used within the present-day Internet.

The header provides the information each Packet Exchange (Router) needs to forward Packets (message units) to their destination. A destination (receiving) device can request the retransmission of missing Packets, since packet framing (header and trailing) information provides the number of total Packets and sequence numbers for each Packet.

For additional reliability, Packet headers also contain an error correction code, which is a number representing a mathematical combination of the rest of the Packet data. If a single bit of the Packet data is changed in transmission, calculation of the error correction code by a Packet Exchange won't match the code transmitted with the message (data), and the Packet will be discarded and a request made for retransmission.

In later Packet Switching systems, including the Internet, Packet sizes may vary from 64 bytes to 4096 bytes, with 128 bytes being a default size on most networks. Both maximum Packet size and Packet level framing may be negotiated between the connecting DTE (Data Terminal Equipment) during a call set up.

The International Telecommunication Union-Telecommunication (ITU-T) Protocol Standard X.25, plus derivatives, was established in the beginning to create standard operating procedures for the movement of information in a Packet switched environment. The X.25 Standard(s) is covered later in this page.

Packet Switching - Public Data Network (PDN):

A Public Data Network was established and is operated by a governmental administrative agency specifically for transmission of data. There are two main types of PDN, ‘Circuit

Switched’ and ‘Packet Switched’:

In a circuit switched data network each connection established is a direct physical line connection between the calling and called equipment. Exclusively, for the duration of the call, the two subscribers use this direct connection. The main feature of such a connection is that it normally provides a fixed data rate line, and both subscribers operate at the same transmission rate (bps).

In a Packet switched data network all data to be transmitted is first assembled into one or more message units, called Packets, by the sending (source) DTE (Data Terminal Equipment); packets include both the sending and the receiving DTE network addresses. The Packets are then forwarded by the sending DTE to its local Packet Switching Exchange (PSE). On receipt of each packet, the PSE inspects the destination (receiving) address contained in the packet. Each PSE contains a routing directory specifying the outgoing links to be used for each network address. On receipt of each Packet, the PSE forwards the Packet on the appropriate link at the maximum available bit rate. As each Packet is received at each intermediate PSE along the route, it is forwarded on the appropriate link interspersed with other Packets being forwarded on that link. At the final PSE the Packet(s) is passed to the destination (receiving) DTE.

To prevent delays and ensure that the network has a reliably fast transit time, a maximum length is allowed for each Packet. This maximum length division into appropriate size Packets is accomplished by the Transport layer protocol within the DTE. In turn, the packets will be reassembled into a single message at the destination (receiving) DTE.

Transport Layer is the name of the layer in the Open System Interconnection (OSI) network that is responsible for the end to end transmission integrity through a network. Another function of this layer is data flow control and transmission speed matching.

X. 25 + Standard:
X.25 is an International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) protocol standard for WAN (Wide Area Networks) communications that defines how connections between user devices, Data Terminal Equipment (DTE), and network devices, Data Circuit-terminating Equipment (DCE), are established and maintained. X.25 design criteria allow systems to operate effectively regardless of the type of systems connected to the network. It is typically used in the Packet-Switched Networks (PSN) of common carriers, such as the Telephone companies. The X.25 standard was established in the middle 1970's and has been used and proven to be reliable since the mid 70’s.

X.25 MLP (Multi-Link Procedure):
The Multi-Link Procedure: defined in ITU-T norm X.25-84. Its function is to distribute the Packets among the available lines, each line operating according to the single line procedure, and restore the sequence of the Packets on the remote side for transfer to the Packet layer.

X.29
ITU-T recommendation that defines the format for control information in the terminal-to-PAD interface used in X.25 networks.

X.75
ITU-T specification that defines the signaling protocol between two PDN(s) (Public Data Network), X.75 is essentially an NNI (Network/Network Interface).

The X.25 protocol encompasses the first three layers of the OSI 7-layered architecture as defined by the International Organization for Standardization (ISO):

* Layer 1: The Physical Layer is concerned with electrical connections or signaling. It includes several standards such as V.35, RS232 and X.21.
* Layer 2: The Data Link Layer, which is an implementation of the ISO HDLC (High-Level Data Link Control) standard called Link Access Procedure Balanced (LAPB) and provides an error free link between two connected devices. LAPB is a bit-oriented protocol derived from HDLC.
* Layer 3: The Network Layer, which provides communications between devices connected to a common network. In the case of X.25, this layer is referred to as the X.25 Packet Layer Protocol (PLP) and is primarily concerned with network routing functions and the multiplexing of simultaneous multiple connections over a single line connection.

X.25 and TCP/IP (Transmission Control Protocol / Internet Protocol) protocols are similar because they are both Packet switching protocols, but they differ in some areas, for instance:

* TCP/IP has only end-to end error checking and flow control, while X.25 is error checked from node to node.
* TCP/IP has a much more complicated flow control and window mechanism than X.25, to compensate for the fact that a TCP/IP network is completely passive.
* The electrical and linkage levels are tightly specified in the X.25 specifications, while TCP/IP is designed to function over many different kinds of media, with many different types of link service, such as: Ethernet, Frame relay, X.25, FDDI (Fiber-Distributed Data Interface), etc.

X.25 PLP permits a DTE user on an X.25 network to communicate with a number of remote DTE(s) simultaneously. Connections can occur on logical channels of two types:

* Switched Virtual Circuits (SVC): A SVC connection is similar to a telephone call connection; a connection is established and data are transferred and then the connection is released. Each DTE on the network is given a unique DTE address, which can be used much like a telephone number.
* Permanent Virtual Circuits (PVC): PVC is similar to a leased line in that the connection is always present. The logical connection is established permanently by the Packet Switched Network administration. Therefore, data may be sent without a call setup.

To establish a connection on a SVC, the calling DTE sends a ‘Call Request Packet’, which includes the address of the remote DTE to be contacted. The destination (receiving) DTE can accept or reject the call. The ‘Call Request Packet’ includes the sender's DTE address, as well as other information that the called (receiving) DTE can use to decide whether or not to accept the call. A call is accepted by issuing a ‘Call Accepted Packet’, or cleared (refused) by issuing a ‘Clear Request Packet’.

Once the originating DTE receives the Call Accepted Packet, the virtual circuit is established and data transfer may begin. When either DTE wishes to terminate the call, a Clear Request Packet is sent to the remote DTE, which responds with a Clear Confirmation

Packet.

The destination for each packet is identified by means of the Logical Channel Identifier (LCI) or Logical Channel Number (LCN). This allows the Packet Switched Network (PSN) to route each Packet to its intended (addressed) DTE.

X.25 relies on HDLC LAPB (High-Level Data Link Control - Link Access Procedure Balanced) to get data from node to node through the X.25 network. An X.25 Packet makes up the data field within an HDLC frame. Also at the X.25 level additional flow control and slotting (positioning) of Packets are provided for each Logical connected Channel. Packet sizes may vary from 64 bytes to 4096 bytes, with 128 bytes being a default size on most networks. Both maximum Packet size and Packet level framing may be negotiated between

DTE(s) during a call set up.

The X.25 protocol provides for a ‘virtual high-quality digital network’ at low cost. There can be tremendous savings in cost when multiple parties share the same infrastructure (network). In most parts of the world, X.25 is paid for by a monthly connect fee plus packet charges. There is usually no holding charge, making X.25 ideal for organizations that need to be on line all the time. Another useful feature is speed matching. Because of the store-and-forward nature of Packet Switching, plus excellent flow control, DTE(s) do not have to use the same line speed. For instance, a host computer can be connected at 56kbps and communicate with numerous remote sites operating on lines at 19.2kbps.

Networks and the Internet:

With the advent of the personal computer (PC) in the early 1980s terminals took on a more important role. Terminals became pre-processing centers and, in some cases, provided concentrator points for other terminals. The server devices (computers) provided an efficient method of allowing terminals to share common processing programs and common devices. The 1980s saw the rise of the Bulletin Board System (BBS) where the public could make a dial up connection, via a MODEM, to a BBS and then download free software, participate in discussions, play on-line games, etc. Making a Connection to a BBS was similar to connecting to a present-day Internet site, except there wasn’t a feature that allowed a transfer to another BBS site without disconnecting and then dialing a new number. In the early 1990s the BBS operations were booming and by the middle 1990s some even offered Internet connections.

The major advancements in Internet activity in the middle 1990s resulted in the demise of the BBS near the end of the 1990s. Some converted to web sites, but web site development could be expensive so most of the BBS operations just disappeared. Chat rooms and other interaction media came alone with the Internet development and new meeting places and services were available.

Of course, along with the good Internet and E-mail features some not so good features were also introduced and these create many problems for Internet users. This ease of interaction created by the Internet between individuals and companies helped bring along the system destroying virus / worms and the overwhelming ‘Spam’ mail along with a few fraudulent acts, including ‘Spy ware’.

Networks:

Data communication Networks have been around since the Morse code days if one considers the fact a network is simply a method of connecting devices together so they can communicate with each other. Networks of terminals and paper tape switching systems followed the Morse code days and then the computerized data communication-switching system was implemented. The computerized systems provided the platform for the Packet switching environment. Regardless of the system components the major concern was increasing the efficiency of the network systems. These continuing switching system upgrades included the Internet Router systems, which utilize Packet switching.

Local Area Network (LAN):

With the arrival of Time-sharing ‘Server’ systems, which provided both program sharing and terminal interconnection functions, the sophisticated communications Network was born. Network systems in existence today provide high-speed local connection facilities between terminals and computers and also can be connected to long distance telephone and high-speed data communication facilities. These local network systems, with servers, are referred to as LANs (Local Area Networks). The LAN in turn can connect to any outside (distant) LAN or other network systems, such as Packet Switched Networks or the Internet.

The term Server is used to identify a common shared computer that is connected to a group of terminals and stand-alone computers. The original Server computers were strictly used in a LAN (Local Area Network) environment to provide data storage, shared programs and terminal connection facilities. In the early 1980’s a single Server unit could easily be overloaded because of the limited disk space; a disk capacity of 120 megabytes was considered a large capacity disk. The cable connections between units were normally twisted pairs, shielded and unshielded, and used digital interface devices, a MODEM type unit. Transfer rates were in the kilobyte to megabyte ranges.

Today the Server capability is almost unlimited because the connection facilities, software and hardware, can be configured to support just about any size high-speed system.

A couple of popular LAN network configurations are illustrated in the following Figures. Figure 3 shows a network connected in a network configuration called a ‘Ring’ network. Figure 4 shows a ‘Star’ configured network.



Presently, in addition to a LAN, anyone can connect to the World Wide Web (WWW) since it is a public oriented communication service. All that is required to connect to the Internet is telephone line or something like a Digital Subscriber Line (DSL) that provides a high-speed digital connection. To support the internet connection a computer system, Personal Computer (PC) or larger, with the necessary protocol (interface) software and some type of MODEM or digital driver is required. The Internet, which is part of the World Wide Web, is basically a conglomeration of different networks, various types of equipment (hardware / software), facilities and a Packet Switched Network.

So as described above a Local Area Network is a group of computers and associated devices that share a common communications line or wire-less link and typically share the resources of a single processor or server within a small geographic area, usually within an office building. Normally, the server has applications and data storage that are shared in common by multiple terminals and computer users. A local area network may serve as few as two or three users or hundreds of users and could be connected to the Internet. A couple of present LAN connection and configuration technologies would include the following:

Ethernet:

An Ethernet LAN typically uses coaxial (coax) cable, twisted pair wires or fiber optic cables. Ethernet is also used in wireless LAN operation. The most commonly installed Ethernet systems are called 10BASE-T and provide transmission speeds up to 10 mbps (megabits per second). Devices are connected to the cable and compete for access using a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol. Fast Ethernet or 100BASE-T provides transmission speeds up to 100 megabits per second and is typically used for LAN backbone (common connection) systems, supporting workstations with 10BASE-T cards. In addition, Gigabit Ethernet (1000 megabits per second) and 10-Gigabit Ethernet (10 billion bits per second are available. Refer to the Ethernet Section for additional information.

Token Ring:

In a Token Ring network computers are connected in a ring or star topology and a bit or token-passing scheme is used in order to prevent the collision of data between two devices attempting to send messages at the same time. The Token Ring protocol is probably the second most widely used protocol on Local Area Networks after Ethernet. Token Ring technology provides for data transfer rates of either 4 or 16 megabits per second. Briefly, it functions in the following manner:

1. Empty information frames are continuously circulated on the ring.
2. When a computer has a message to send, it inserts a token in an empty frame (this may consist of simply changing a 0 to a 1 in the token bit part of the frame) and also inserts a message and a destination identifier in the frame.
3. The frame is then examined by each successive workstation. If the workstation sees that it is the destination for the message, it copies the message from the frame and changes the token back to 0.
4. When the frame gets back to the originator, it sees that the token has been changed to 0 and that the message has been copied and received. It removes the message from the frame.
5. The frame continues to circulate as an empty frame, ready to be taken by a workstation when it has a message to send.

Wide Area Network (WAN)

A Wide Area Network could be a telephone access system or data computer systems separated by significant distances, such as those located in different buildings, cities or countries. This would involve the use of the Internet or long-distance connecting lines, with bit per second speeds dictated and controlled by the connection speed rate requirements or restrictions. One or more LAN networks could be connected to the WAN.

Packet Switched Networks are a nationwide or worldwide network of mostly digital high-speed connecting lines (circuits) and Packet processing computers, these computers being designated by such terms as, Nodes, Packet Switching Exchanges and Routers.