Packet Switching Networks
Packet Switching (Basic Concepts)

- Packet switching technology has evolved over time.
  - basic technology has not changed
  - packet switching remains one of the few effective technologies for long-distance data communication.
Problems with Circuit Switching

• Network resources are dedicated to a particular connection.
• Two shortcomings for data communication.
  – In a typical user/host data connection, line utilization is low.
  – Provides facility for data transmission at a constant rate.
    • Data transmission pattern may not ensure this.
    • Limits the utility of the method.
Packet Switching :: essential idea

- Data are transmitted in short packets (~ Kbytes).
  - A longer message is broken up into a series of packets.
  - Every packet contains some control information in its header (required for routing and other purposes).
Store-and-forward Concept

• **Basic idea:**
  – Each network node receives and stores the packet,
  – determines the next leg of the route, and
  – queues the packet to go out on that link.

• **Advantages:**
  – Line efficiency is greater (sharing of links).
  – Data rate conversion is possible.
  – Even under heavy traffic, packets are accepted, possibly with a greater delivery delay.
  – Packet priorities can be used.
Switching Technique

- As mentioned earlier, a packet switching network breaks up a message into packets.
- Two contemporary approaches for handling these packets:
  - *Virtual Circuit*
  - * Datagram*
Virtual Circuit Approach

- A preplanned route is established before any packets are sent.
- *ControlRequest* and *ControlAccept* packets are used to establish the connection.
- Route is fixed for the duration of the logical connection (like circuit switching).
  - Each packet contains a virtual circuit identifier as well as data.
  - Each node on the route knows where to forward packets.
Virtual Circuit (contd.)

• A *ClearRequest* packet issued by one of the two stations terminates the connection.

• *Main characteristics*:
  – Route between stations is set up prior to data transfer.
  – A packet is buffered at each node, and queued for output over a line.
  – A data packet needs to carry only the virtual circuit identifier for effecting routing decisions.
  – Intermediate nodes take no routing decisions.
  – Often provides sequencing and error control.
Datagram Approach

• Each packet is treated independently, with no reference to packets that have gone before.
• Every intermediate node has to take routing decisions.
  – Every packet contains source and destination addresses.
  – Intermediate nodes maintain routing tables.
• Problems:
  – Packets may be delivered out of order.
  – If a node crashes momentarily, all of its queued packets are lost.
Datagram (contd.)

- **Advantages:**
  - Call setup phase is avoided (for transmission of a few packets, datagram will be faster).
  - Because it is more primitive, it is more flexible.
  - Congestion/failed link can be avoided (more reliable).
Effect of Packet Size on Transmission Time

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• There is a significant relationship between packet size and transmission time.

• Illustrative example:
  – Assume there is a virtual circuit from station X through nodes a & b to station Y.
  – Message size is 30 octets, packet header is 3 octets.
  – 1-packet message ==> total 99 octet times
  – 2-packet message ==> total 72 octet times
  – 5-packet message ==> total 63 octet times
  – 10-packet message ==> total 72 octet times
Comparison of Circuit & Packet Switching

• Three types of delays are encountered:
  – **Propagation Delay**: time taken by a signal to propagate from one node to the next.
  – **Transmission Time**: time taken by the transmitter to send out a block of data.
  – **Node Delay**: The time it takes for a node to perform the necessary processing as it switches data.
Event Timing for Circuit and Packet Switching

(a) Circuit switching
(b) Virtual circuit packet switching
(c) Datagram packet switching

Call request signal → propagation delay → Call accept signal → processing delay → Call request packet

User data

Acknowledgement signal

Nodes: 1 2 3 4

link  link  link

Pkt1  Pkt2  Pkt3

Pkt1  Pkt2  Pkt3

Pkt1  Pkt2  Pkt3  Pkt3

Pkt1  Pkt2  Pkt3

Pkt1  Pkt2  Pkt3

Pkt1  Pkt2  Pkt3

Acknowledgement packet

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External and Internal Operation

• Whether to use virtual circuit or datagram.
• Two dimensions to the problem:
  – At the interface between a station and a network node, we may have connection-oriented or connectionless service.
  – Internally, the network may use virtual circuits or datagrams.
• Leads to four different scenario (different VC/DG combinations).
Scenario 1: external VC, internal VC

- When the user requests a VC, a dedicated route through the network is constructed. All packets follow the same route.
Scenario 2: external VC, internal DG

- The network handles each packet separately.
  - Different packets for the same external VC may take different routes.
  - The network buffers packets, if necessary, so that they are delivered to the destination in the proper order.
Scenario 3: external DG, internal DG

- Each packet is treated independently from both the user’s end and the network’s point of view.
Scenario 4: external DG, internal VC

- The external user does not see any connections -- it simply sends packets one at a time.
- The network sets up a logical connection between stations for packet delivery.
  - May leave such connections in place for an extended period, so as to satisfy anticipated future needs.
X.25

• Best known and most widely used packet switching protocol standard.
  – Originally approved in 1976.
• The standard specifies an interface between a host system and a packet-switching network.
• Uses three layers of functionality:
  – Physical layer
  – Link layer
  – Packet layer
Solid line = physical link
Dashed line = virtual circuit
X.25 Layers

• Physical Layer
  – Deals with the physical interface between an attached station and the link that attaches that station to the packet-switching node.
    • User machine termed as *data terminal equipment* (DTE)
    • Packet switching node to which a DTE is attached is termed as *data circuit-terminating equipment* (DCE)
    • X.21 is the most commonly used physical layer standard.

• Link Layer
  – Provides for the reliable transfer of data across the physical link by transmitting the data as a sequence of frames.
    • Link standard used is *Link Access Protocol – balanced* (LAPB), which is a subset of HDLC.

• Packet Layer
  – Provides an external virtual-circuit service.
X.25 Interface

DTE

User Process

Packet

Link Access

Physical

X.21 physical interface

DCE

Packet

Link Access

Physical

Multi-channel logical i/f

LAPB

To remote user process
X.25 Encapsulation

Figure 10.17 from the book by Stallings
X.25 Virtual Circuit Service

- With the X.25 packet layer, data are transmitted in packets over external virtual circuits.
- X.25 provides two types of virtual circuit
  - **Virtual call**: It is a dynamically established virtual circuit using a call setup and call termination procedure.
  - **Permanent virtual circuit**: It is a fixed, network-assigned virtual circuit.
    - Data transfer occurs as with virtual calls
    - No call setup or termination is required.
X.25 Packet Format

- User data are broken into blocks of some maximum size, and a 24-bit or 32-bit header is appended to each block to form a data packet.
- Uses sliding-window protocol with piggybacking
  - Go-back-N for error control.
- X.25 also transmits control packets related to the establishment, maintenance and termination of virtual circuits.
  - Each control packet includes:
    - The virtual circuit number.
    - The packet type (call request, call accepted, call confirm, interrupt, reset, restart, etc.).
    - Additional control information specific to the type of packet.
X.25 Packet Format (contd.)

(a) Data packet with 3-bit sequence numbers

(b) Control packet for virtual calls with 3-bit sequence numbers

(c) RR, RNR, and REJ packets with 3-bit sequence numbers

(d) Data packet with 7-bit sequence numbers

(e) Control packet for virtual calls with 7-bit sequence numbers

(f) RR, RNR, and REJ packets with 7-bit sequence numbers

(g) Data packet with 15-bit sequence numbers

(h) Control packet for virtual calls with 15-bit sequence numbers

(i) RR, RNR, and REJ packets with 15-bit sequence numbers
X.25 Multiplexing

- One of the most important services provided by X.25.
  - A DTE is allowed to establish up to 4095 simultaneous virtual circuits with other DTEs over a single DTE-DCE link.
  - Each packet contains a 12-bit virtual circuit number.
    - Expressed as a 4-bit logical group number plus an 8-bit logical channel number.
  - Individual virtual circuits could correspond to applications, processes, terminals, etc.
  - The DTE-DCE link provides full-duplex multiplexing.