CS343: Data Communication

Switched Communication Network

by

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Switched Communication Network

- Broader aspect – interconnecting many devices beyond a local area
- There is not a direct link between every possible pair of nodes
- Some nodes connect only to other node
  - Main task: switching of data
- Other nodes have one or more stations attached
  - Main task: switching data, accept and deliver data
- Nodes are not concerned with the content of the data
- Stations may be computer, telephone, any communicating device
- Node-station links are generally dedicated P2P links
- Node-node links are usually multiplexed (using TDM, FDM)

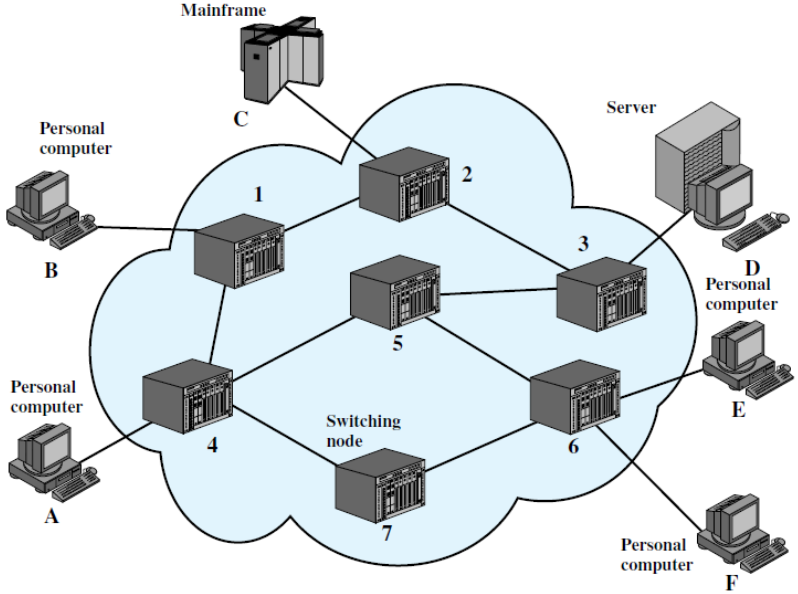


Figure 10.1 Simple Switching Network

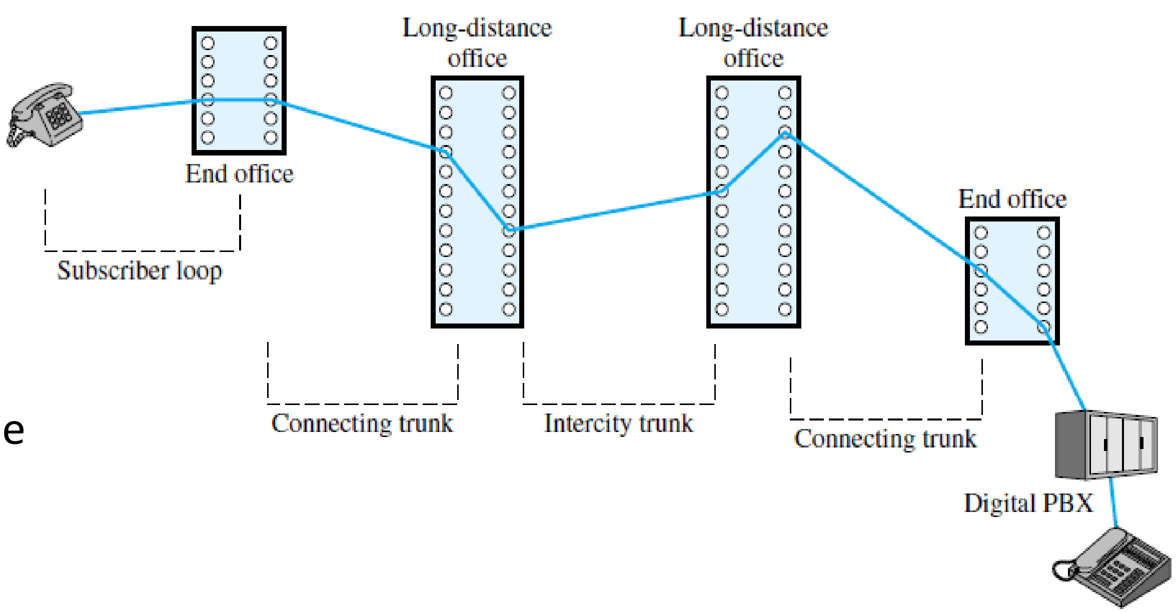
Why Switching?

- Interconnecting many devices – forms the Switched Network
- A switch transfers signals from one input port to an appropriate output.
- A basic problem is then how to transfer traffic to the correct output port.
- Solution:
  - In the early telephone network, operators closed circuits manually.
  - In modern circuit switches, this is done electronically in digital switches.
- If no circuit is available when a call is made, it will be blocked (rejected).
- When a call is finished a connection teardown is required to make the circuit available for another user.
- So, the basic function of any switch is to set up and release connections between transmission channels.
- Two different switching technologies over the network:
  - Circuit switching
  - Packet switching

Circuit Switching

Circuit Switching Network

- This has been the dominant technology for voice communications
- It is well suited to the analog transmission of voice signals
- It implies that there is a dedicated communication path between two stations
- Path is a connected sequence of links between network nodes
- It involves three phases
  - Circuit establishment
  - Data transfer
  - Circuit disconnect



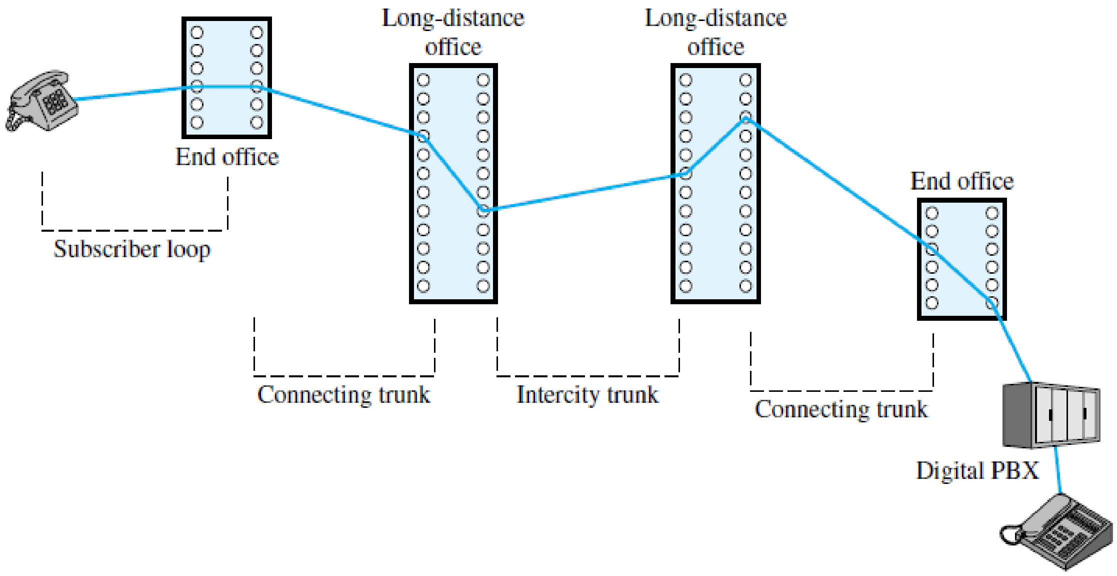
The best-known example of a circuit-switching network is the public telephone network.

Cont...

- Examples of circuit switching networks
  - Public telephone network
  - Private branch exchange (PBX) system
  - Data switch system

- In circuit switching, the path is established before data transmission begins.
  - Sometimes less efficient as channel capacity remains unused
  - There is connection establishment delay prior to data transfer

- Architectural components in public telecommunication network
  - Subscribers
  - Subscriber line
  - Exchanges
  - Trunks



Circuit Switching Concepts

- Function of the **digital switch**
  - provide a transparent signal path between any pair of attached devices
- The **control unit** performs 3 general tasks
  - establishes connections
  - maintain the connection
  - tear down the connection
- The **network interface** element represents
  - Functions and hardware needed to connect digital devices
- Blocking or non-blocking
  - Blocking occurs when the network is unable to connect two stations because all possible paths between them are already in use
- Switching techniques internal to a single node
  - Space Division Switching
  - Time Division Switching

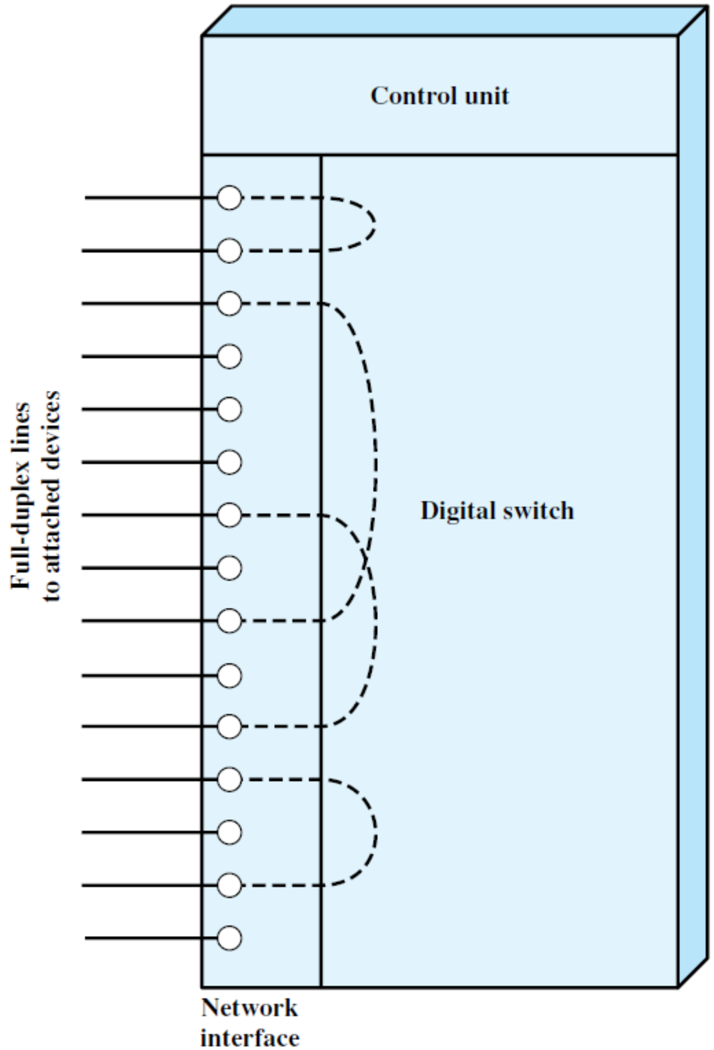


Figure 10.4 Elements of a Circuit-Switch Node

Space Division Switching

- Originally developed for analog signal
- the signal paths are physically separate from one another (divided in space).
- The basic building block of the switch is
  - a metallic crosspoint OR semiconductor gate that can be enabled and disabled by a control unit.
- Interconnection is possible between any two lines by enabling the appropriate crosspoint.
- Limitations:
  - crosspoints grows with the square of the number of stations
  - crosspoints are inefficiently utilized
  - single point failure (loss of crosspoint)

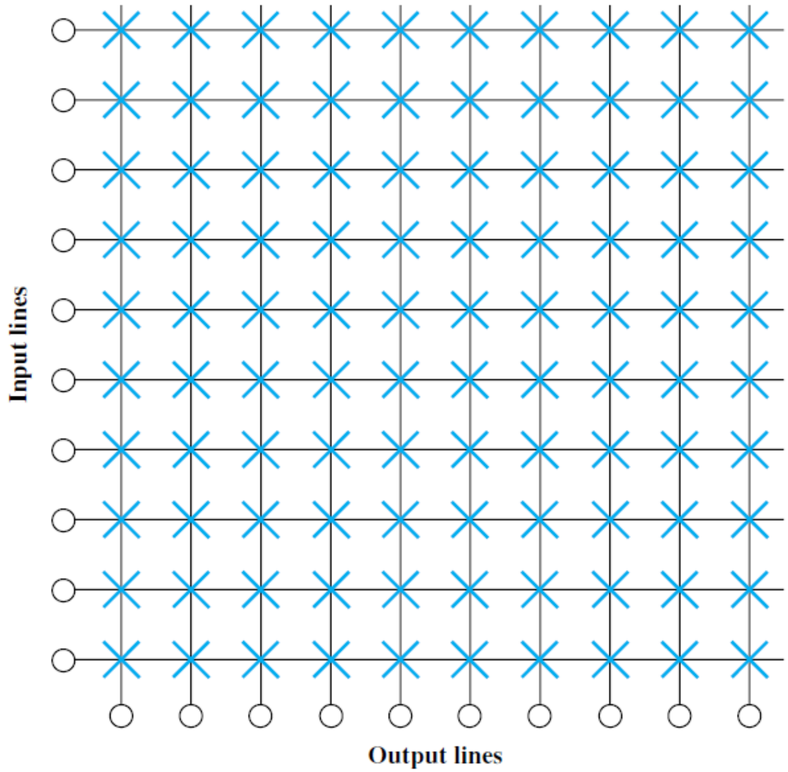


Figure 10.5 Space Division Switch

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- To overcome these limitations, multiple-stage switches are employed
- the total number of crosspoints for 10 stations is reduced from 100 to 48.

Advantage:
- increasing crossbar utilization
- increasing reliability as multiple paths between two endpoints

Disadvantage:
- more complex control
- may be blocking (single stage crossbar switch is strict sense nonblocking)

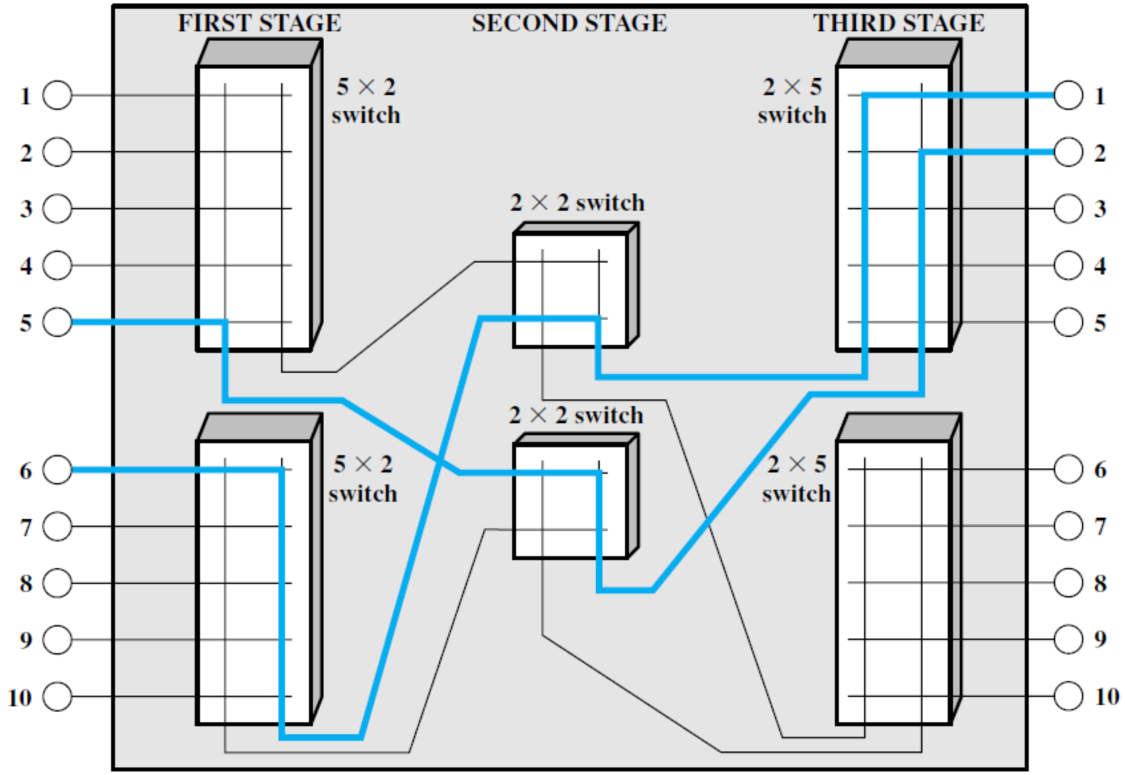
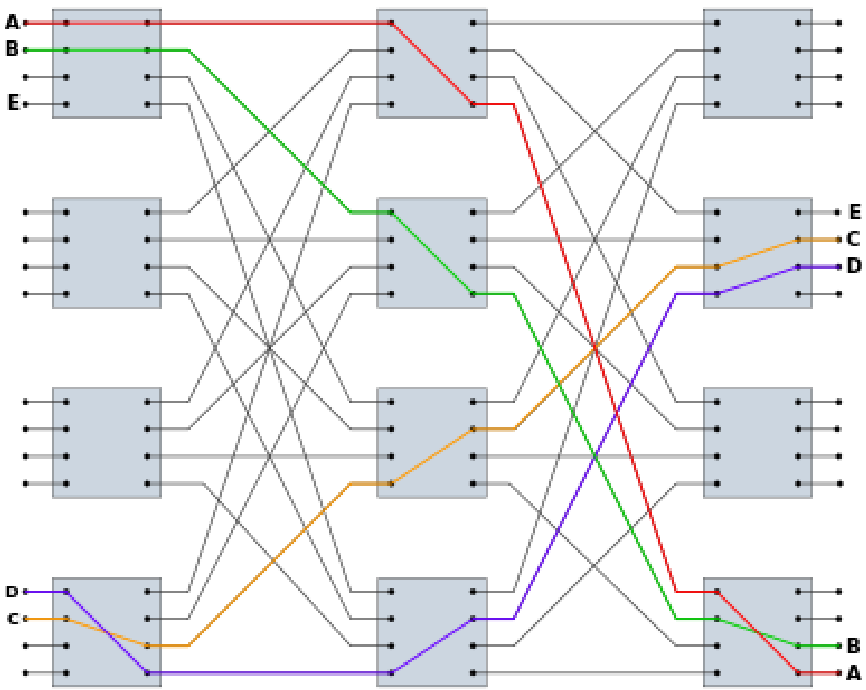


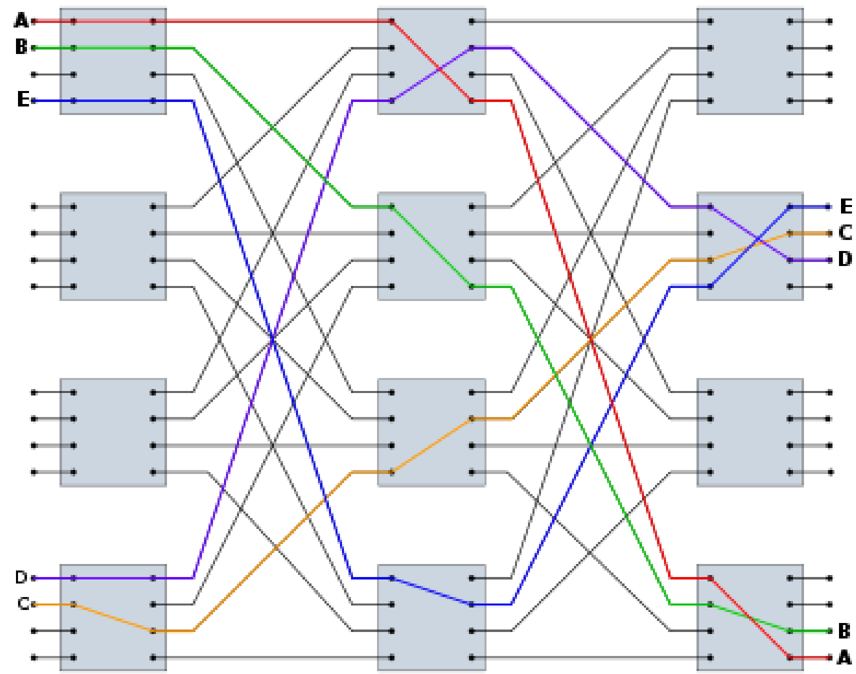
Figure 10.6 Three-Stage Space Division Switch

Blocking vs Non-blocking

- *strict-sense non-blocking* meaning that an unused input on an ingress switch can always be connected to an unused output on an egress switch, *without having to re-arrange existing calls*



Signals A, B, C, D are routed but signal E is blocked even though output port in egress switch remains unused.

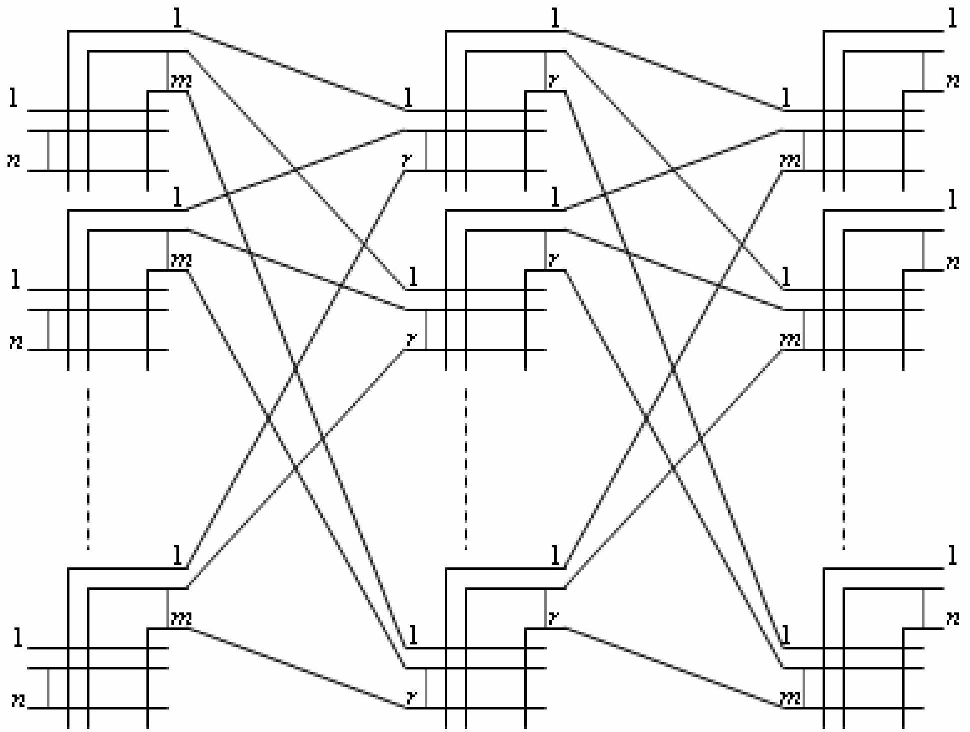


After D, in purple, is rerouted, signal E can be routed and all the additional signals plus E are connected

Clos Networks

- Clos networks are defined by three integers *n, m, r*. Three stages: ingress, middle, egress
- *n* represents the number of inputs which feed into each of *r* ingress stage crossbar switches.

- If there are a total of *N* input lines , then *r=N/n*
- Each ingress stage crossbar switch has *m* outlets, and there are *m* middle stage crossbar switches.
- There is exactly one connection between each ingress stage switch and each middle stage switch.
- There are *r* egress stage switches, each with *m* inputs and *n* outputs.
- Each middle stage switch is connected exactly once to each egress stage switch.



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Property: If $m \geq 2n-1$, the Clos network is *strict-sense non-blocking*

Home task: Prove the strict-sense non-blocking property of the Clos network.

- What is the total number of crosspoints in the three stages non-blocking Clos network?
  - Ans: $(2n - 1)(2N + r^2)$
- Explanation:
  - Each first stage matrix has n input lines and $(2n-1)$ output lines, so it has $n(2n-1)$ crosspoints.
  - There are (N/n) first stage matrices, where N is the total input lines.
  - So the total crosspoints in the first stage = $N(2n-1)$.

  - By the same argument, there are $N(2n-1)$ crosspoints in the third stage.

  - Each second stage matrix has r inputs and r outputs, for a total of $(N/n)^2$ crosspoints.
  - Second stage has at least $(2n-1)$ matrix.
  - So, there are a total of $(2n-1)\,(N/n)^2$ crosspoints in the second stage

  - Hence, Total crosspoints = $2N(2n-1) + (2n-1)\,(N/n)^2 = (2n-1)[2N+(N/n)^2] = (2n - 1)(2N + r^2)$

Blocking Prob. Estimation

- Poisson arrival process with rate λ
- Service times X are exponentially distributed with parameter μ, so $E[X] = 1/\mu$
- We define ratio, $\rho = \lambda / \mu$

- Let us make use of the small time δ approximation
- In a small δ interval, we have probability roughly $\lambda\delta$ of having an arrival and $1 - \lambda\delta$ of having no arrival
- If there is a customer in the system, then we have probability roughly $\mu\delta$ of having a departure and $1 - \mu\delta$ of having no departure

- The blocking probability of a (n x m) switch matrix

$$P_B = \frac{{}^{n}C_{m}\rho^{m}}{\sum_{j=0}^{m} {}^{n}C_{j}\rho^{j}}$$

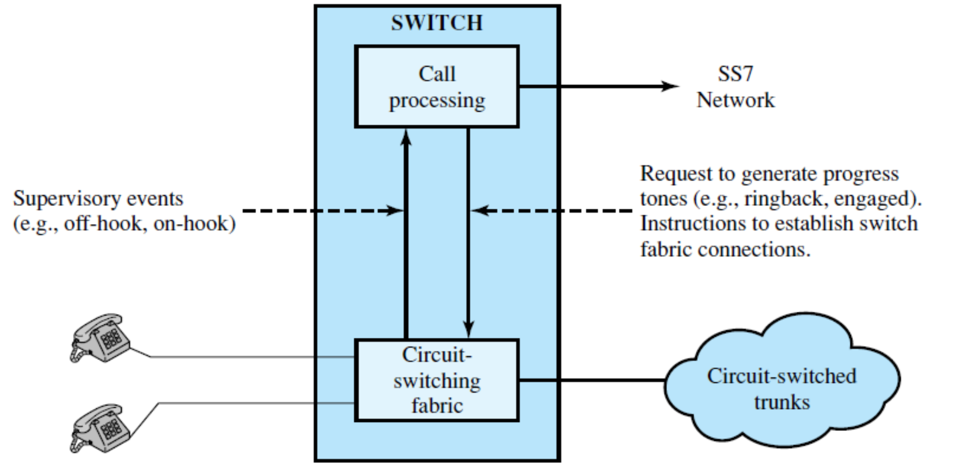
Home task: Prove the blocking probability of a (n x m) switch matrix.

Softswitch Architecture

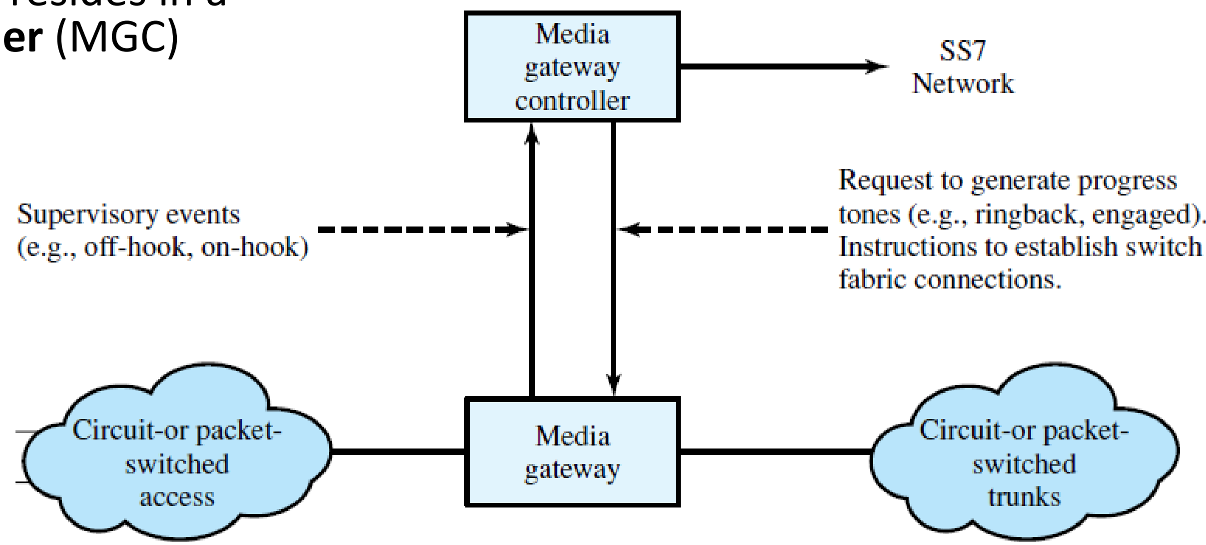
- a softswitch is a general-purpose computer running specialized software that turns it into a smart switch

- In softswitch,
  - the physical switching function is performed by **media gateway** (MG)
  - the call processing logic resides in a **media gateway controller** (MGC)

- It physically separate the call processing function from the hardware switching function.



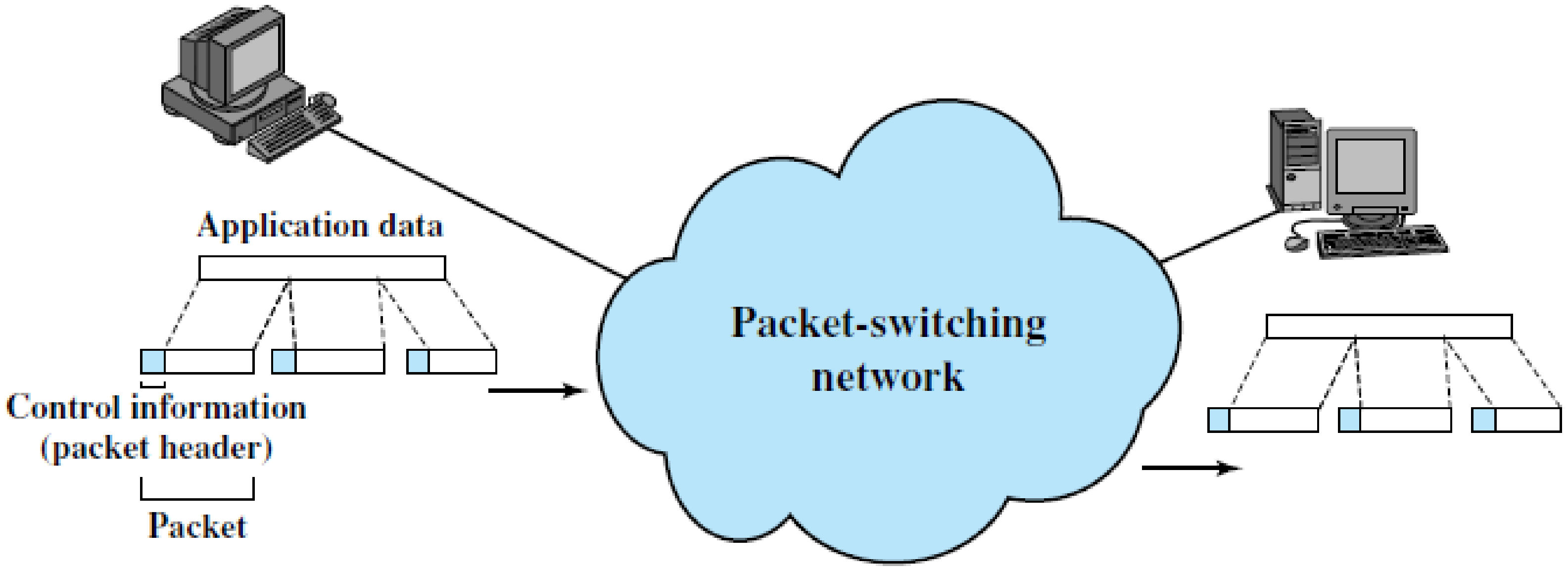
(a) Traditional circuit switching



(b) Softswitch architecture

Packet Switching

Packet Switching



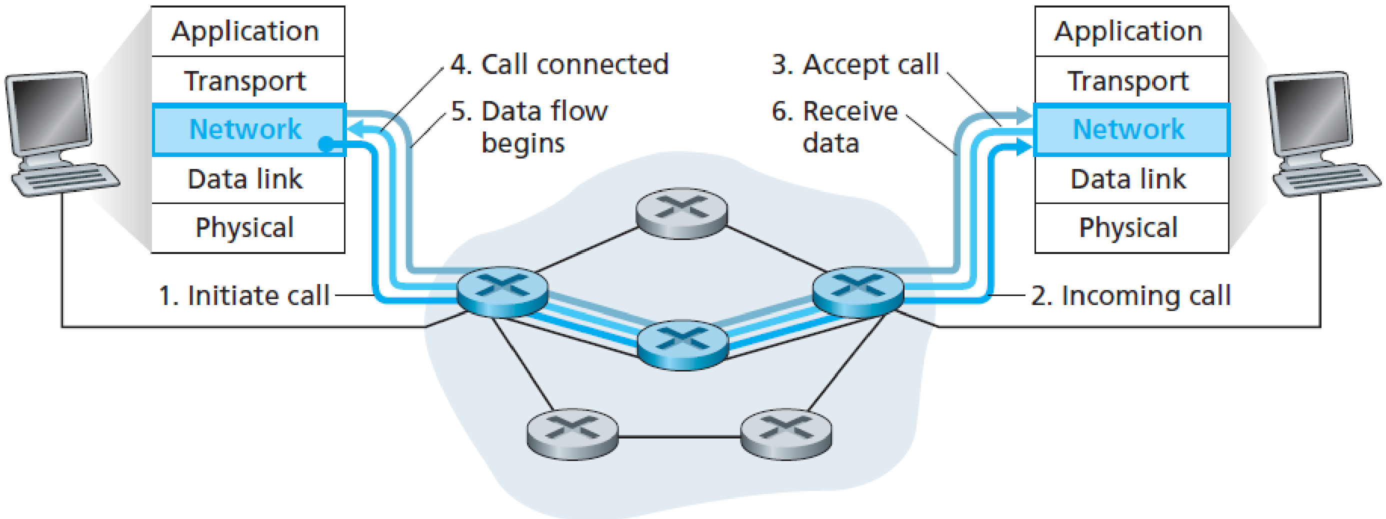
- Advantages of Packet Switching over Circuit Switching
  - Higher line efficiency, because a single node-to-node link can be dynamically shared by many packets over time
  - Two end stations of different data rates can exchange packets
  - Under heavy traffic condition, circuit switching refuses connection, but packet allows with higher delay
  - Priorities can be applied

Packet Switching Techniques

- Datagram Approach
  - each packet is treated independently, with no reference to packets that have gone before
  - Connectionless

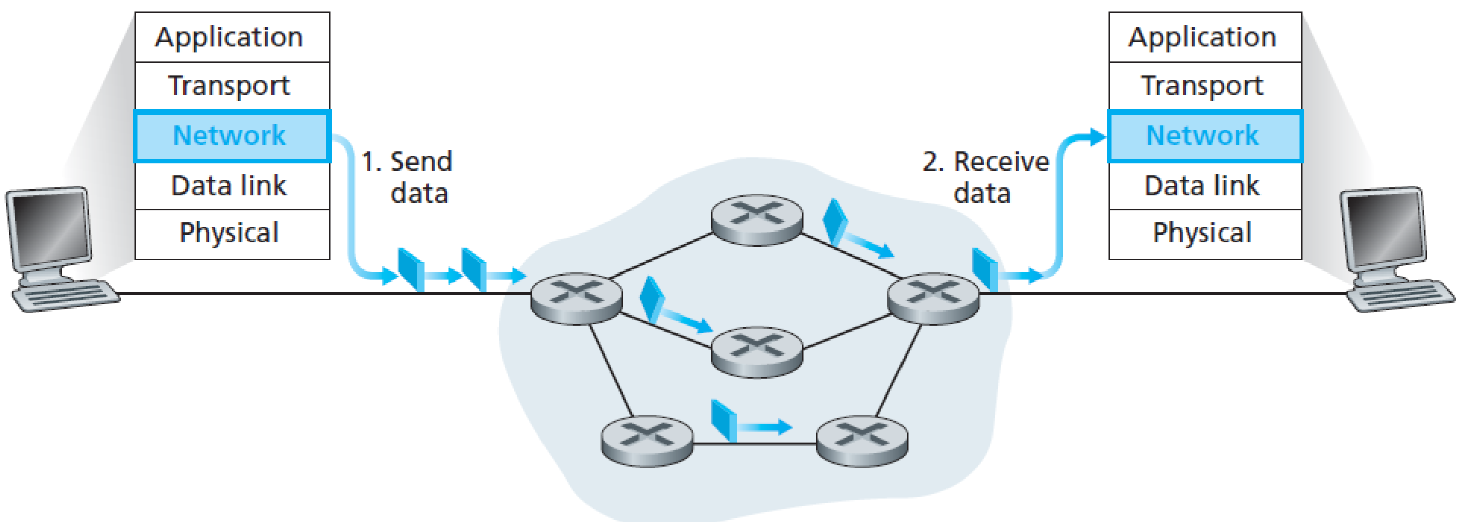
- Virtual Circuit Approach
  - a pre-planned route is established before any packets are sent. Once the route is established, all the packets between a pair of communicating parties follow this same route through the network
  - Connection-oriented

Virtual Circuit & Datagram Approaches



Virtual Circuit

Datagram Approach



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Datagram Approach

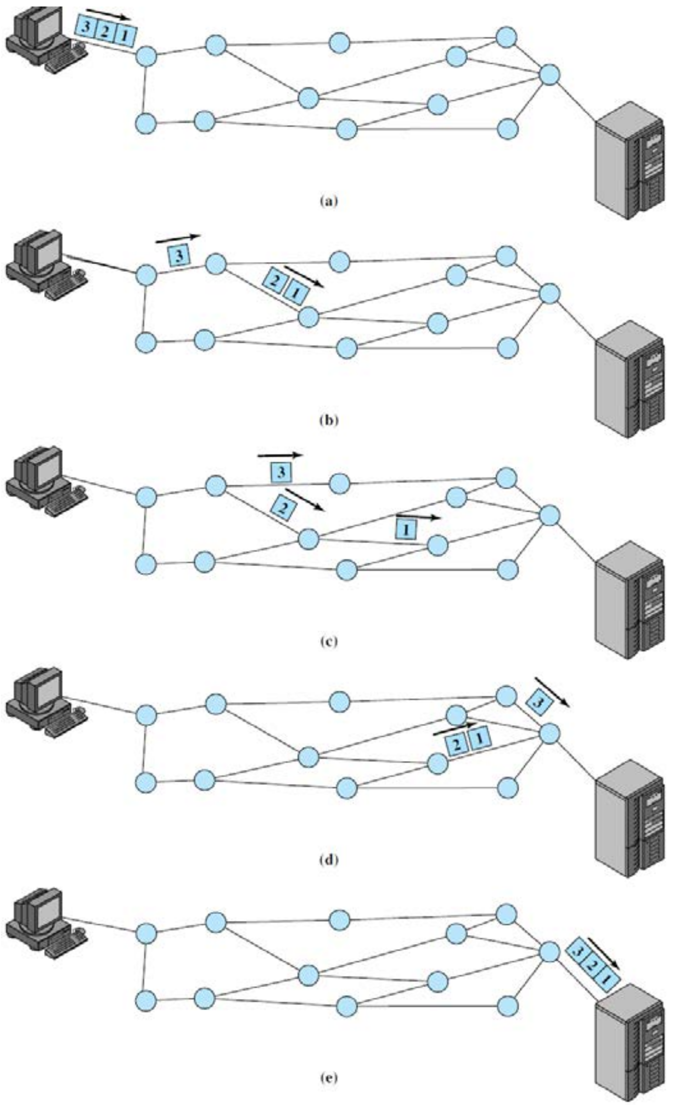


Figure 10.9 Packet Switching: Datagram Approach

Virtual Circuit Approach

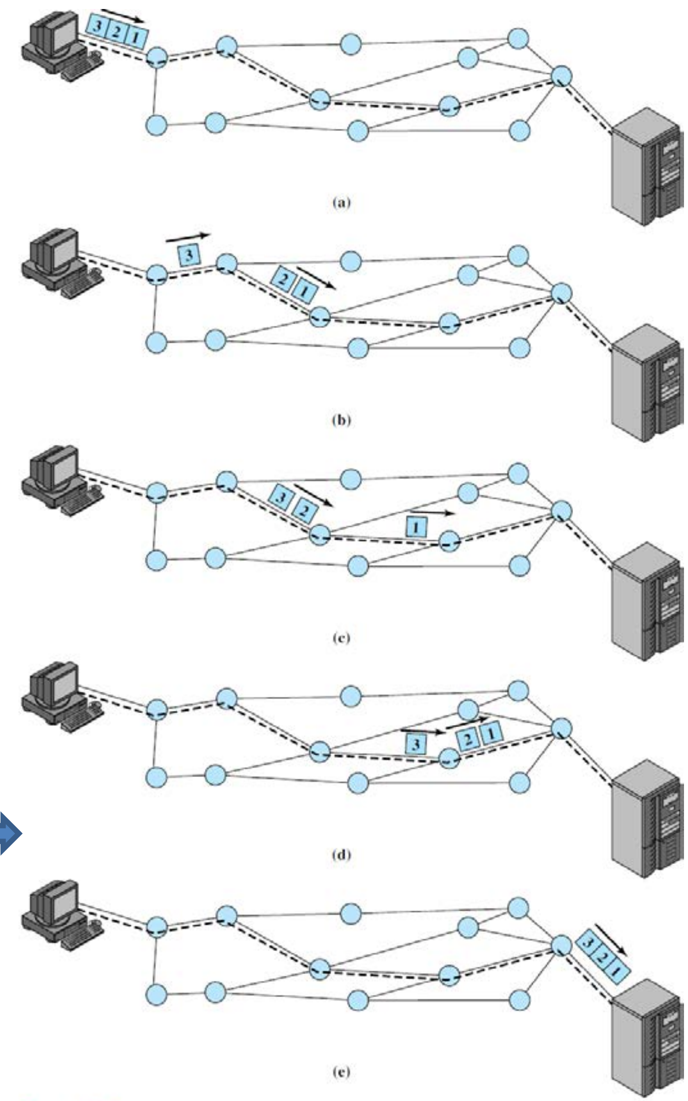
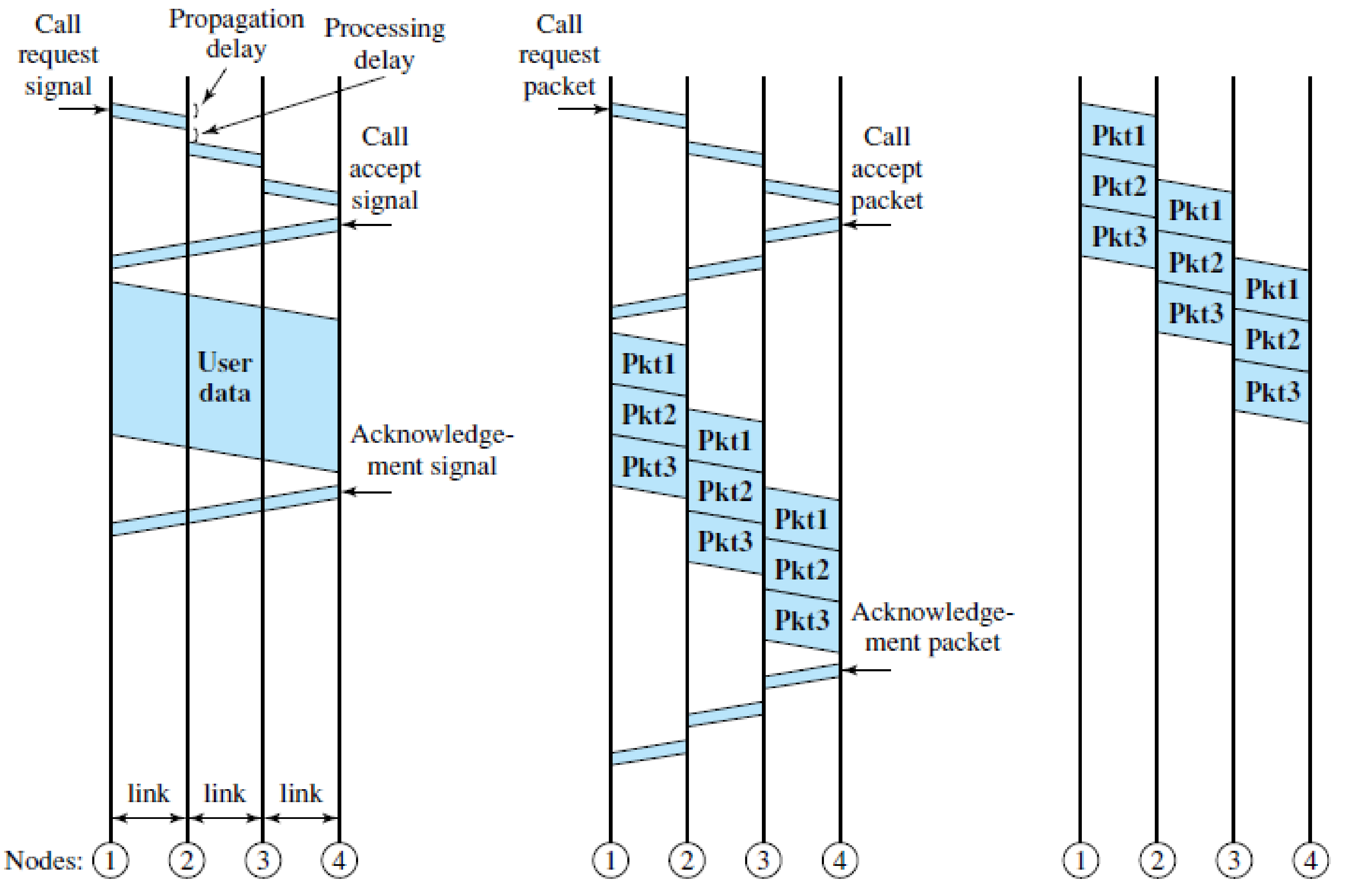


Figure 10.10 Packet Switching: Virtual-Circuit Approach

Comparison



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

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Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

Which one is better?

- Ans.: None for all condition.

- For short message
  - Circuit switching might be faster

- For long message
  - Virtual Circuit switching might be faster

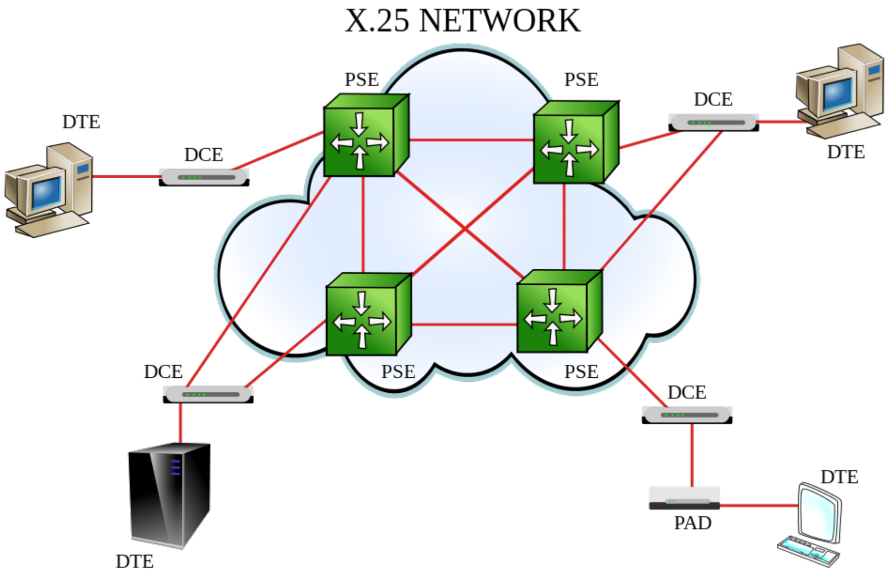
- w.r.t. average delay, flexibility, reliability
  - Datagram approach is better

Interface Standard for PSN

- Packet Switched Network (PSN) requires a certain level of cooperation between the network and the attached stations *to organize the data into packets for transmission*.

- This cooperation is embodied in an interface standard. The interface standard for traditional PSN are
  - **X.25**
  - **Frame Relay**

The X.25 defines the interface between a subscriber (DTE) and an X.25 network (DCE)



functionalities of X.25 :

- Packet level : virtual circuit service
- Link level : LAPB (Link Access Protocol – Balanced).
- Physical level : X.21 standard.

DTE: data terminating equipment (e.g. PC)
DCE: data circuit-terminating equipment (e.g. modem)
PSE: packet-switching exchange

X.25

- packet level provides a virtual circuit service which enables any subscriber to set up logical connections to other subscribers
- Exchanging control and user data packets

- link level provides for the reliable transfer of data across the physical link, by transmitting the data as a sequence of frames.
- Consists of the link access procedure for data interchange on the link between a DTE and a DCE

- physical level deals with the physical interface between an attached station (computer, terminal) and the link that attaches that station to the packet-switching node.
- Control the physical link between a DTE and a DCE.

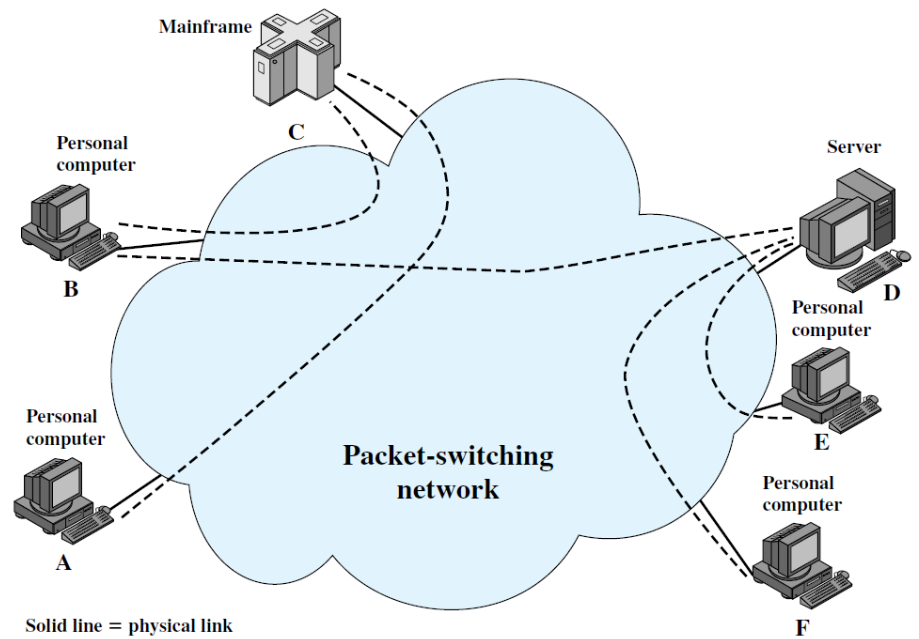


Figure 10.13 The Use of Virtual Circuits

control information in X.25 packet

- Virtual circuit number with which a packet is associated
- Send and Receive Sequence number

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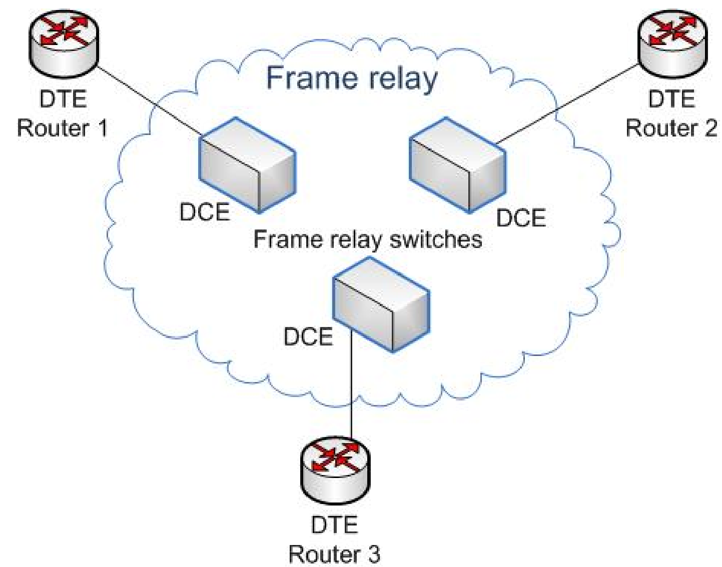
- OSI Layers & X.25 Layers
  - the OSI physical Layer corresponds to the X.25 *physical layer*
  - the OSI data link layer to the X.25 *link layer*
  - the OSI network layer to the X.25 *packet layer*

- Disadvantages of X.25
  - at each intermediate node, state tables must be maintained for each virtual circuit in X.25 (for call control)
  - At each hop the DLC protocol involves the exchange of data and ack frames (for error control/flow control)

Frame Relay

- Frame Relay offers higher performance and greater transmission efficiency than X.25

- Frame Relay vs X.25
  - Call control signaling is carried on a separate logical connection from user data. Thus, intermediate nodes need not maintain state tables
  - There is no hop-by-hop flow control and error control.
  - Multiplexing and switching of logical connections takes place at layer 2 instead of layer 3, eliminating one entire layer of processing.
  - Frame Relay is a Layer 2 protocol suite, X.25 provides services at Layer 3



- It is less expensive than leased lines and that is one reason for its popularity.
- It handles the transmission over a frequently changing path.

Asynchronous Transfer Mode (ATM)

- ATM is in some ways similar to packet switching using X.25 and frame relay.
- 1980's effort by the phone companies to develop an integrated network standard (BISDN) that can support voice, data, video, etc
- ATM is a connection-oriented packet switching technology
  - that was designed to provide the performance of circuit-switching network and
  - the flexibility and efficiency of the packet-switching network
  - uses small (53 Bytes) fixed size packets called "cells"
- Likewise packet switching using X.25 and frame relay, ATM allows multiple logical connections to be multiplexed over a single physical interface.
- Presently, wide acceptance of IP network reduces the role of ATM.
  - IP network is more scalable and less complex than ATM
  - IP supports data, voice and video traffic
  - Performance is very good

Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2017), Data and Computer Communications, 10th Ed.
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2012), Data Communication and Networking, 5th Ed.