Circuit Switching and Packet Switching

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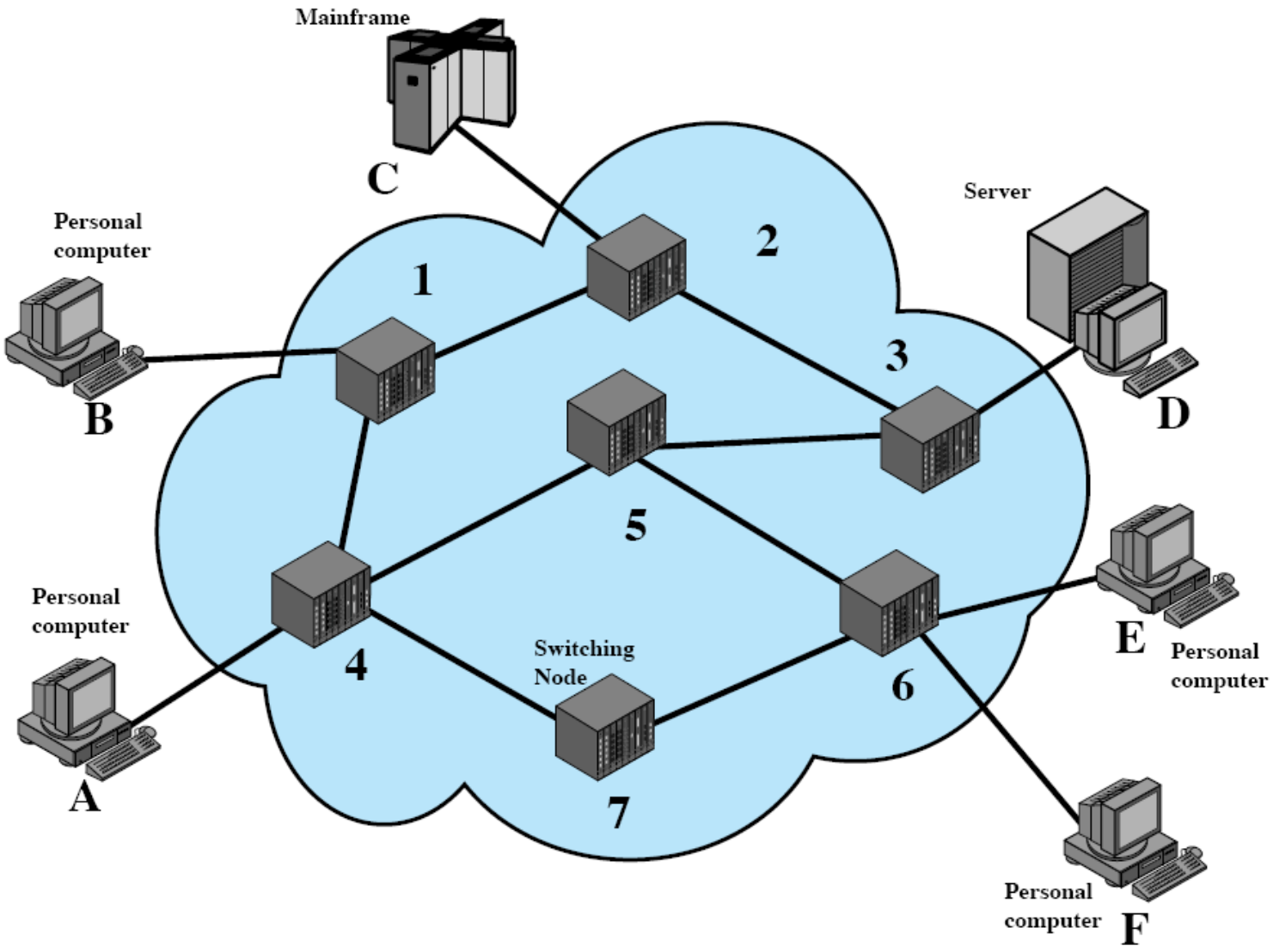
Background and History

- We have focussed on technologies for transmission over communication links
- Communication networks have multiple communication links
- In networks, switching is often used:
  - Data moves from one nodes (or switches) to another, until it reaches the destination
- Since the invention of telephone in late 1800's, circuit switching has been dominant technology for voice communications, and during computer era, also for data
- In 1970's, packet switching was developed: now the most effective means for long-distance data communications, e.g. the Internet

A Switched Network



Switched Networks

- Source transmits data through a network of switching nodes and finally to destination
  - Switching nodes do not care about content; main purpose is to forward the data until it reaches destination
- Devices attached to the network are called stations
  - Computers, terminals, telephones, …
- Switching devices are called nodes
  - Nodes connected to one another in some topology by transmission links
  - Stations attach to nodes
- A collection of nodes and connections is called a *communications network*
- Network is usually partially connected
  - Some redundant connections are desirable
  - Some nodes only connect to nodes (that is, not connect to stations); usually the links use multiplexing (TDM, FDM)
- Two different switching technologies
  - Circuit switching
  - Packet switching

Circuit Switching

Concept of Circuit Switching
Space Division Circuit Switches
Time Division Circuit Switches

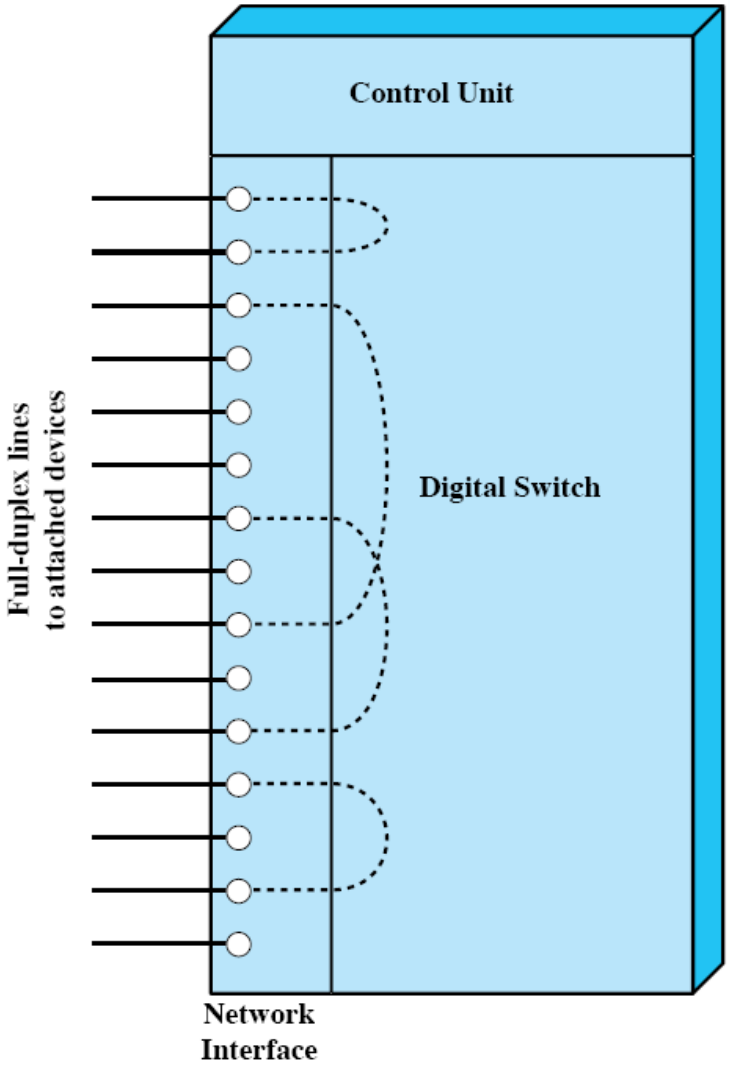

By pressing keys,

Circuit Switching

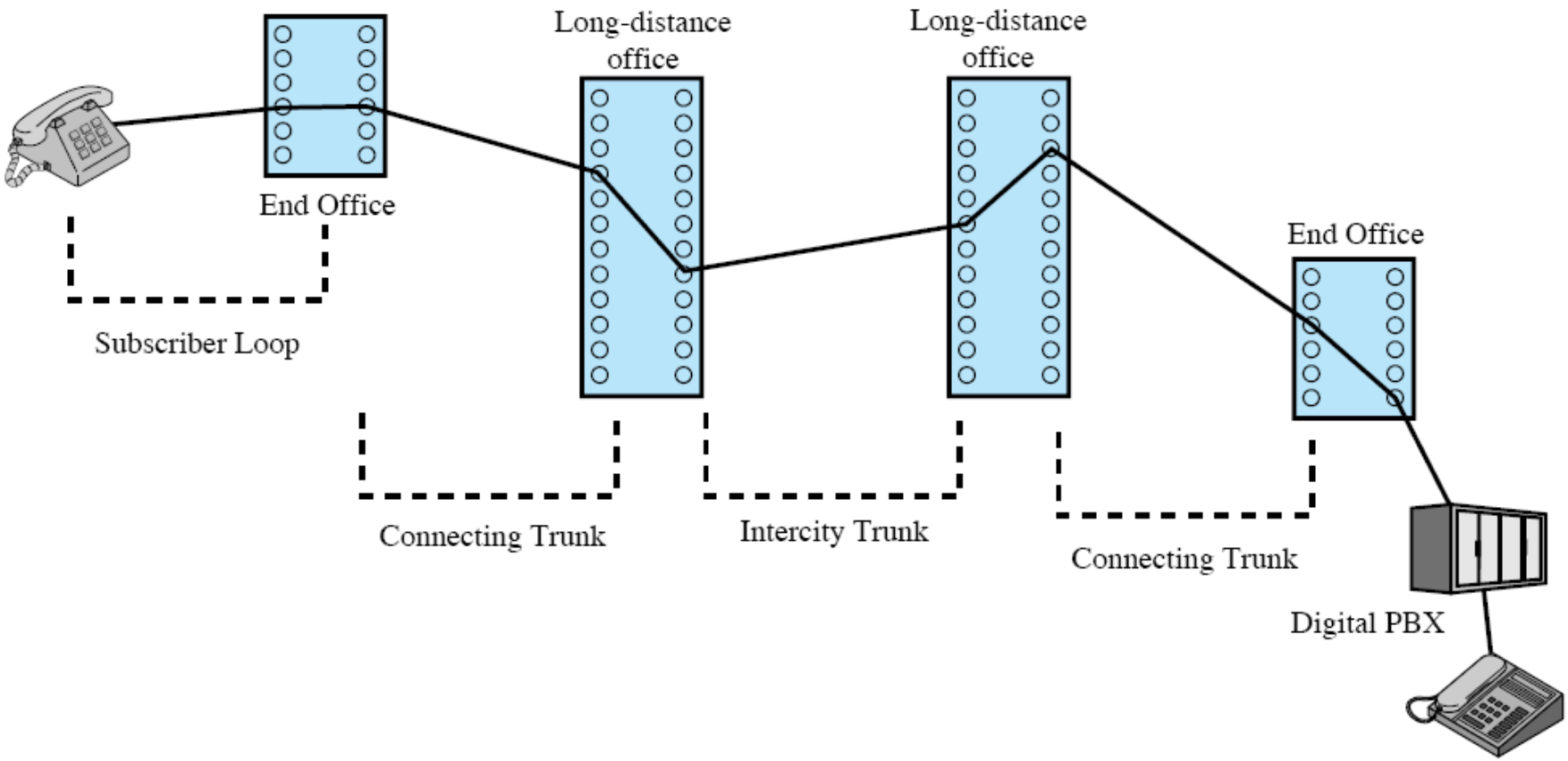
- Uses a dedicated, physical path between two stations
- Three phases in circuit switching:
  - Circuit establishment: before any data is sent, must create a circuit (including allocating resources for the circuit)
  - Data transfer
  - Circuit disconnect: after certain time, circuit is terminated, and resources are freed
- Characteristics:
  - Inefficient for data traffic
    - Channel capacity dedicated for duration of connection
    - If no data, capacity wasted
  - Set up (connection) takes time
  - Once connected, transfer is transparent
    - Only delay is propagation (delay at nodes is negligible)
    - Guaranteed resources (capacity)
- Applications:
  - Developed to handle voice traffic, but also used for data
  - Public telephone network; Private telephone networks (PBX); private data networks

Circuit Switching Elements

- Today's circuit switched networks are comprised of switches
  - Aims to provide transparent signal path between any pair of attached devices
    - Usually full-duplex
  - Network interface allows different network devices to connect (e.g. TDM E1 or E3 signals)
  - Control unit manages the connection
  - Digital switch determines the connectivity of lines
    - Space division switching
    - Time division switching
    - And combinations …



Public Circuit Switched Network

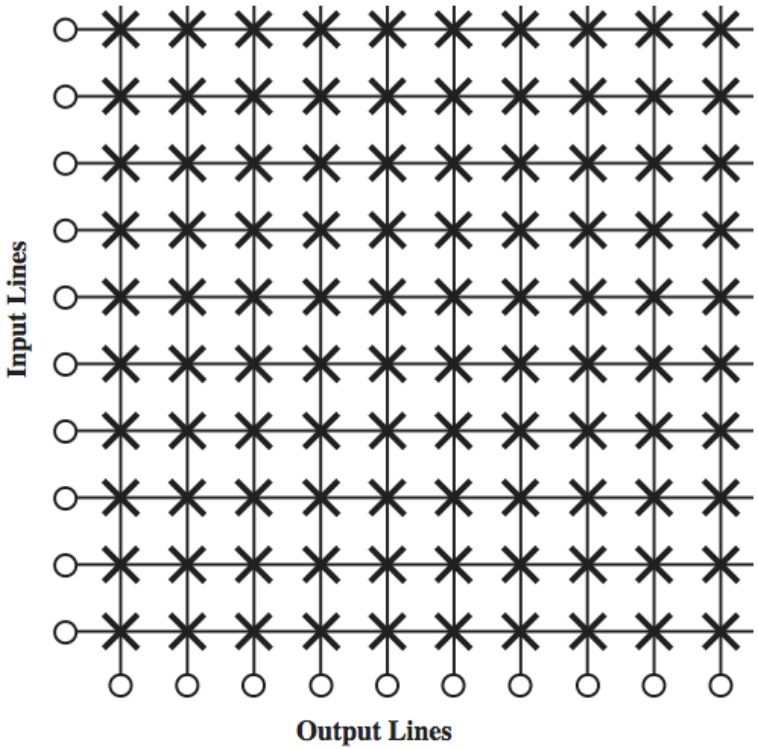


Blocking or Non-blocking

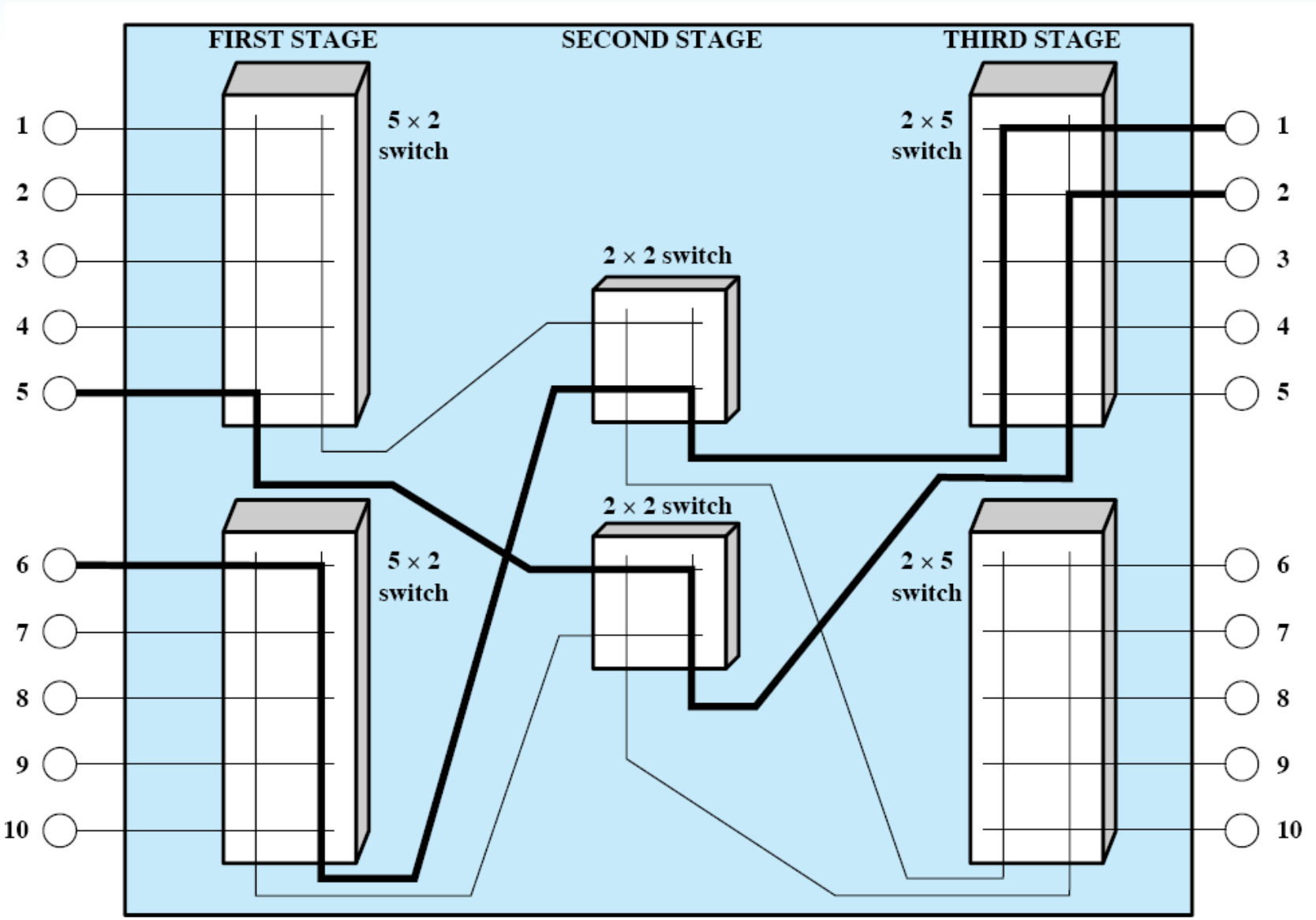
- Before we look at switching techniques …
- Blocking network
  - Blocking is possible: may be unable to connect stations because all paths are in use
  - used on voice systems
- Non-blocking network
  - permits all stations to connect at once
  - used for some data connections

Space Division Switch

- Signal paths are physical separate from each other
  - Divided in space
- Control unit enables/disables cross-points
  - Usually semiconductor gate
- Example shows 10 full-duplex I/O lines
  - Any input can connect to any output
- Limitations of crossbar switch:
  - Number of cross-points grows with square of number of stations (e.g. 100) - costly
  - Cross-points inefficiently utilised – only 10 out of 100



3 Stage Space Division Switch

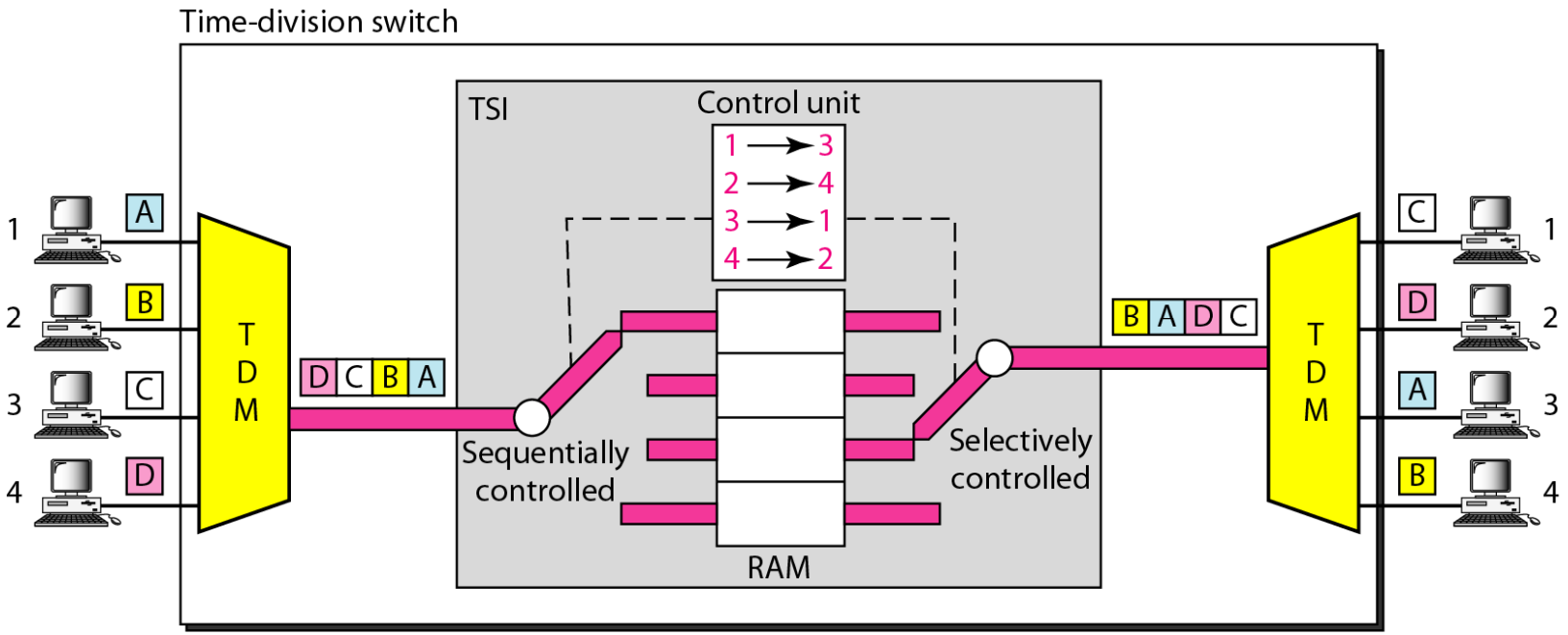


Multiple Stage Space Division Switch

- Overcome limitations of single stage switch:
  - Use multiple switches to connect an input to an output
  - Each individual switch has smaller number of inputs/outputs
  - Advantages:
    - Number of cross-points reduced (e.g. 100 to 48)
    - More than one path between input and output, increasing reliability in the event a cross-point fails
  - Disadvantages:
    - More complex control needed
    - May be blocking
- Blocking example:
  - Single stage switch is non-blocking (always path available to connect input to output)
  - Example 3 stage switch is blocking
    - Bold lines show paths in use; hence input 10 cannot connect to 3, 4 or 5
  - A multiple stage switch can be made non-blocking by increasing number or size of intermediate switches (but increases cost)

Time Division Switching

- Modern digital systems use intelligent control of space and time division elements
- Use time division multiplexing in the switch, e.g. Time Slot Interchange (TSI)
  - The TSI, depending on the path needed, will interchange the data in time slots from the input signal with time slots in the output signal
- Current circuit-based switches can use time-space-time switching



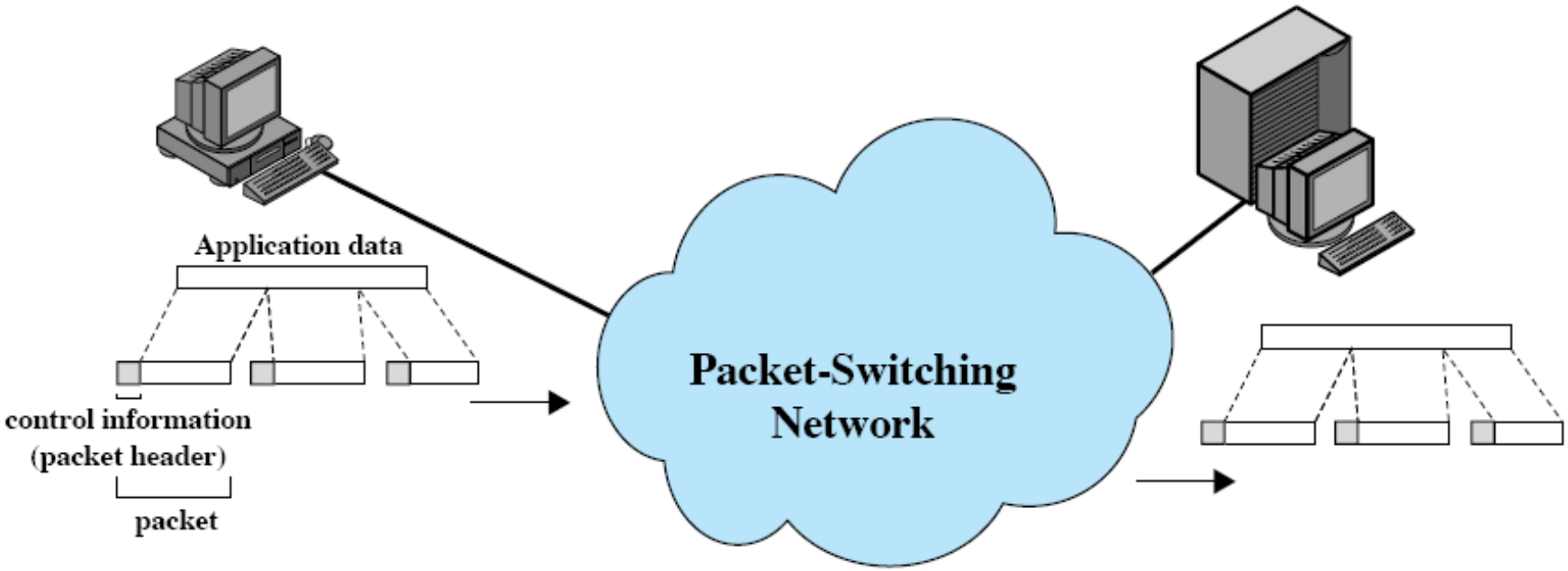
Packet Switching

Concepts of Packet Switching
Datagram Packet Switching
Virtual Circuit Packet Switching
Circuit Switching versus Packet Switching

Packet Switching

- Circuit switching was designed for voice
  - Resources are allocated for the duration of the circuit
    - Important for voice, which requires short and constant delay
    - Can design a circuit-switched network for high utilization, given statistics about the number of users and their calling patterns
- Data traffic is different from voice traffic
  - For typical computer users, much of the time the line is idle
- Circuit switched connections require both devices transmit/receive at same data rate
  - This limits the utility of the network which may contain a wide variation of hosts and connections
- Packet switching was designed for data
  - Data transmitted in small packets (e.g. up to 1000 or 2000 bytes)
    - Each packet has data and a header – control information that can be used to indicate the destination
  - Packets are received, stored briefly (buffered) and past on to the next node, until it reaches destination

Packet Switching



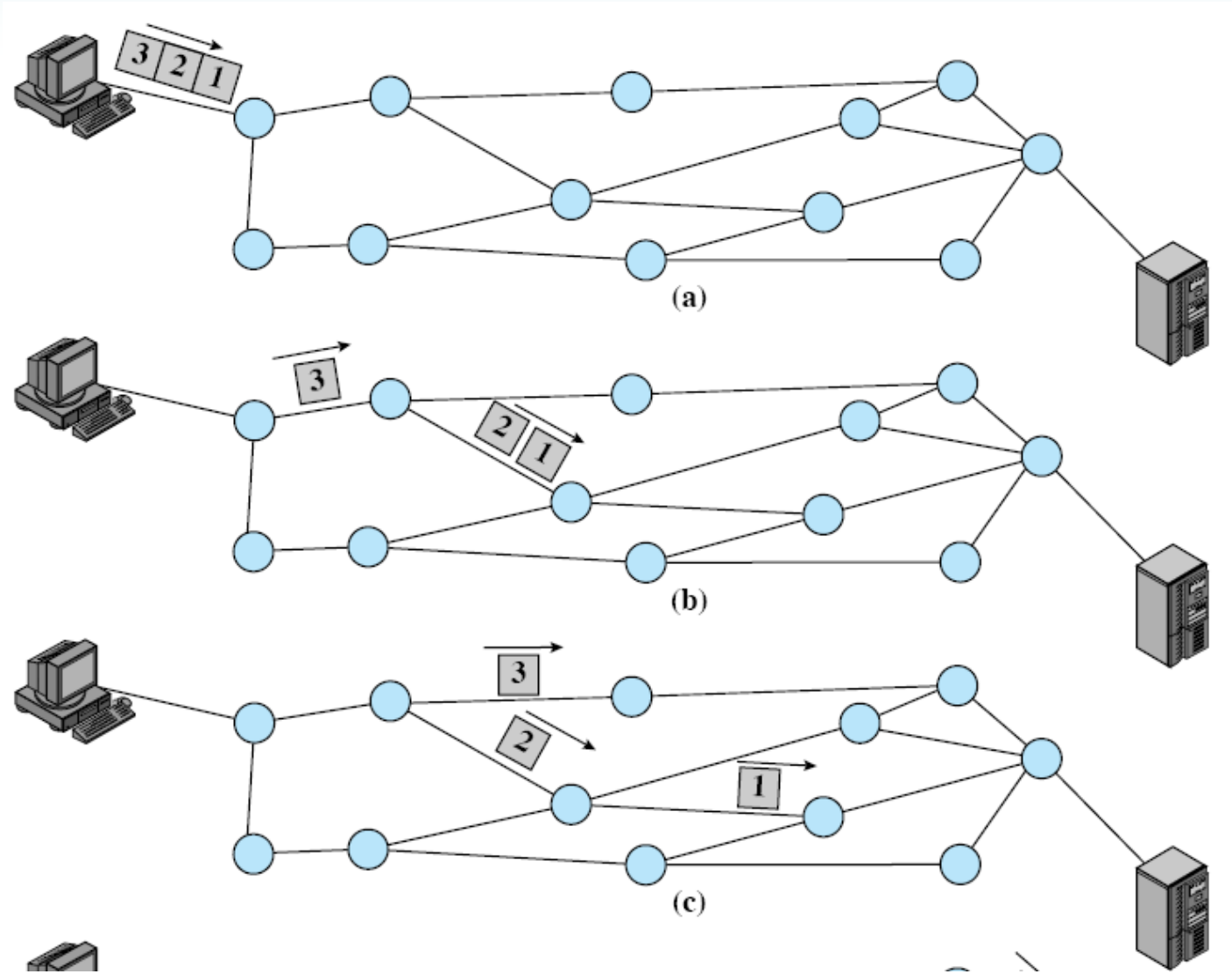
Advantages of Packet Switching

- Line efficiency is greater
  - A single node-to-node link can be shared by many packets over time
    - Packets are queued up and sent as fast as possible over link
  - In circuit switching, TDM is inefficient when connections are idle
- Data rate conversion
  - Two stations with different data rates can communicate
- Non-blocking
  - In circuit-switched, if no circuits, calls are blocked
  - In packet-switched, packets are still accepted, but delay increases
- Priorities
  - Packets can be given priorities, and those with higher priorities transmitted first (giving them less delay)

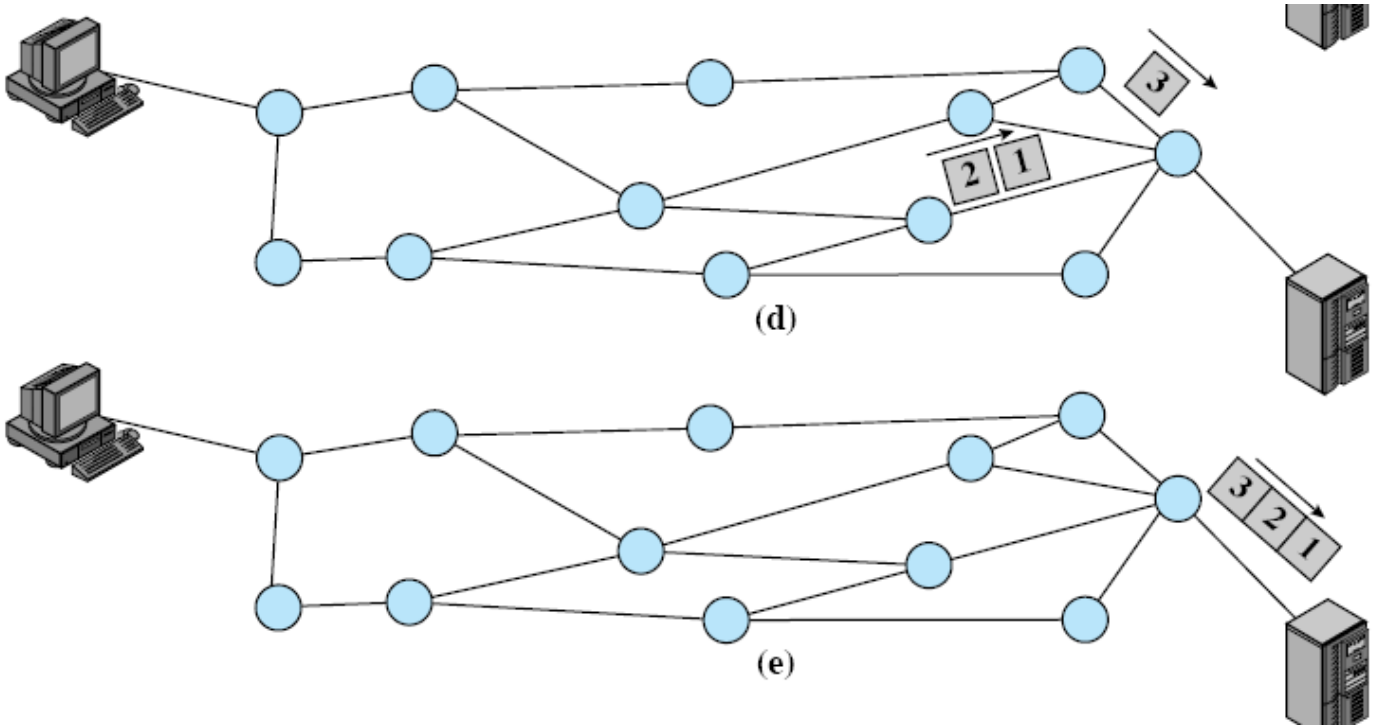
Packet Switching Techniques

- Stations break long message into packets
- Packets sent one at a time to the network
- Packets can be handled in two ways
  - Datagram
    - Each packet is treated independently by the network, with no consideration of where they have gone before
    - Packets from a message may not follow some path/route
    - Packets may arrive at destination out of order and may be lost (e.g. if a switching node crashes)
  - Virtual Circuit (VC)
    - Preplanned route/path is established before packets sent
    - Once have a path, packets between source and destination are all sent on that path
    - Similar to circuit-switched networks, but:
      - Not a dedicated physical path
      - Packets from one VC may share line with packets from other VCs (hence efficiency advantage still exists)
    - Network can provide sequencing and error control
    - Requires call setup phase (delay at start)

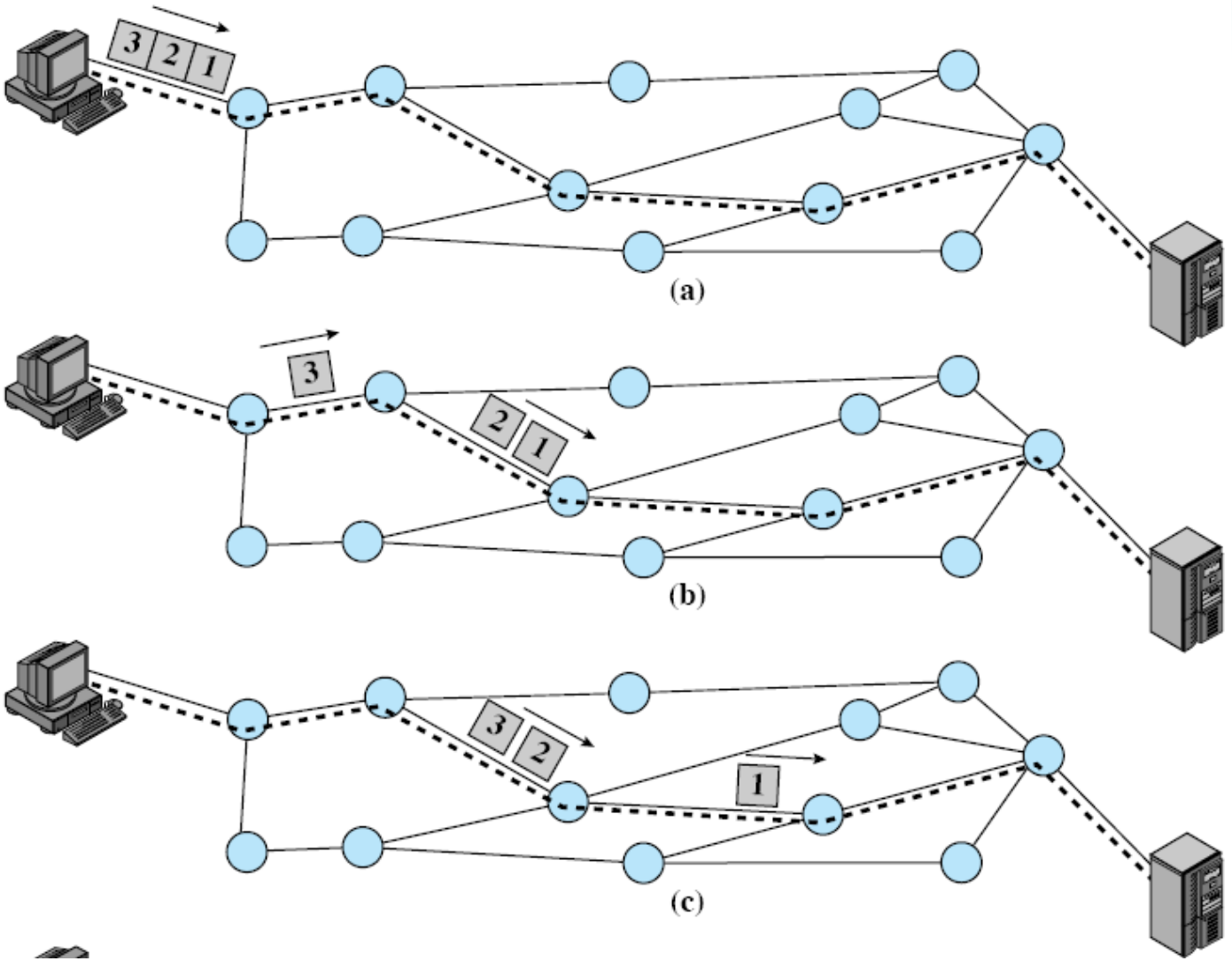
Packet Switching: Datagram



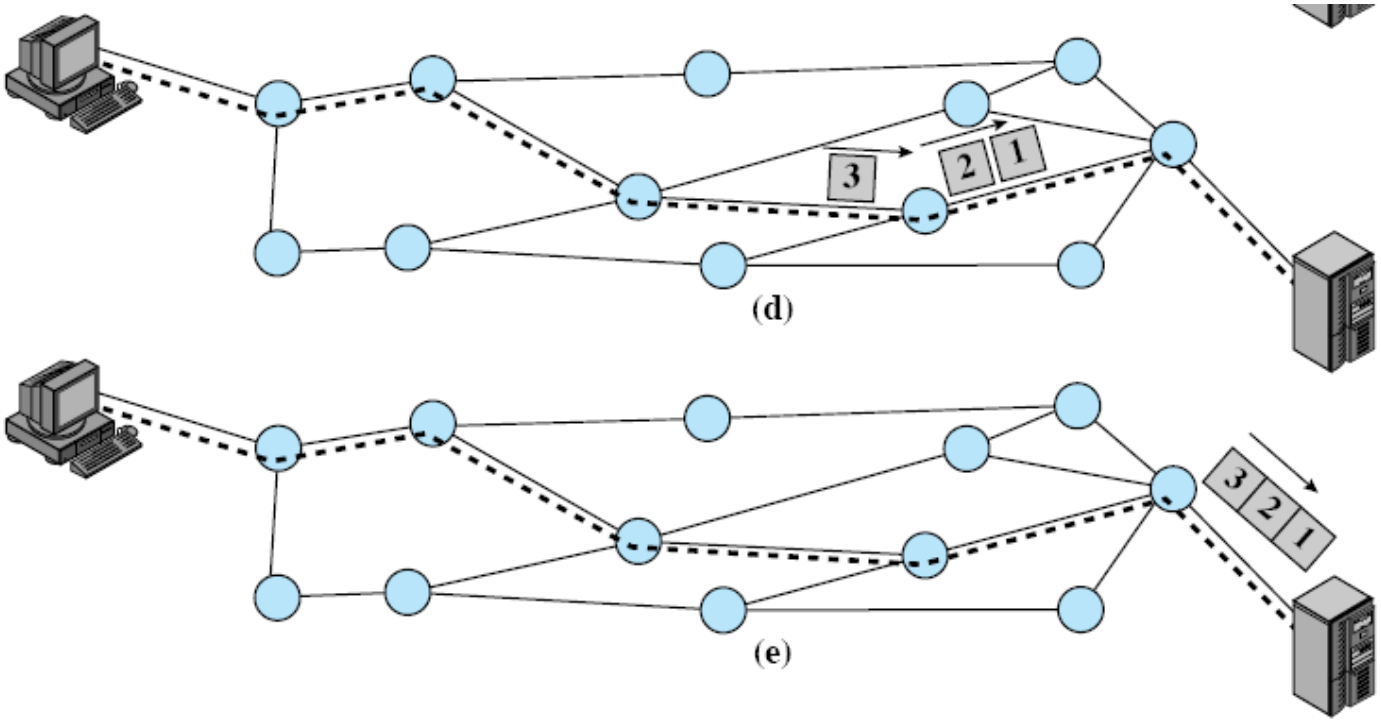
Packet Switching: Datagram



Packet Switching: Virtual Circuit

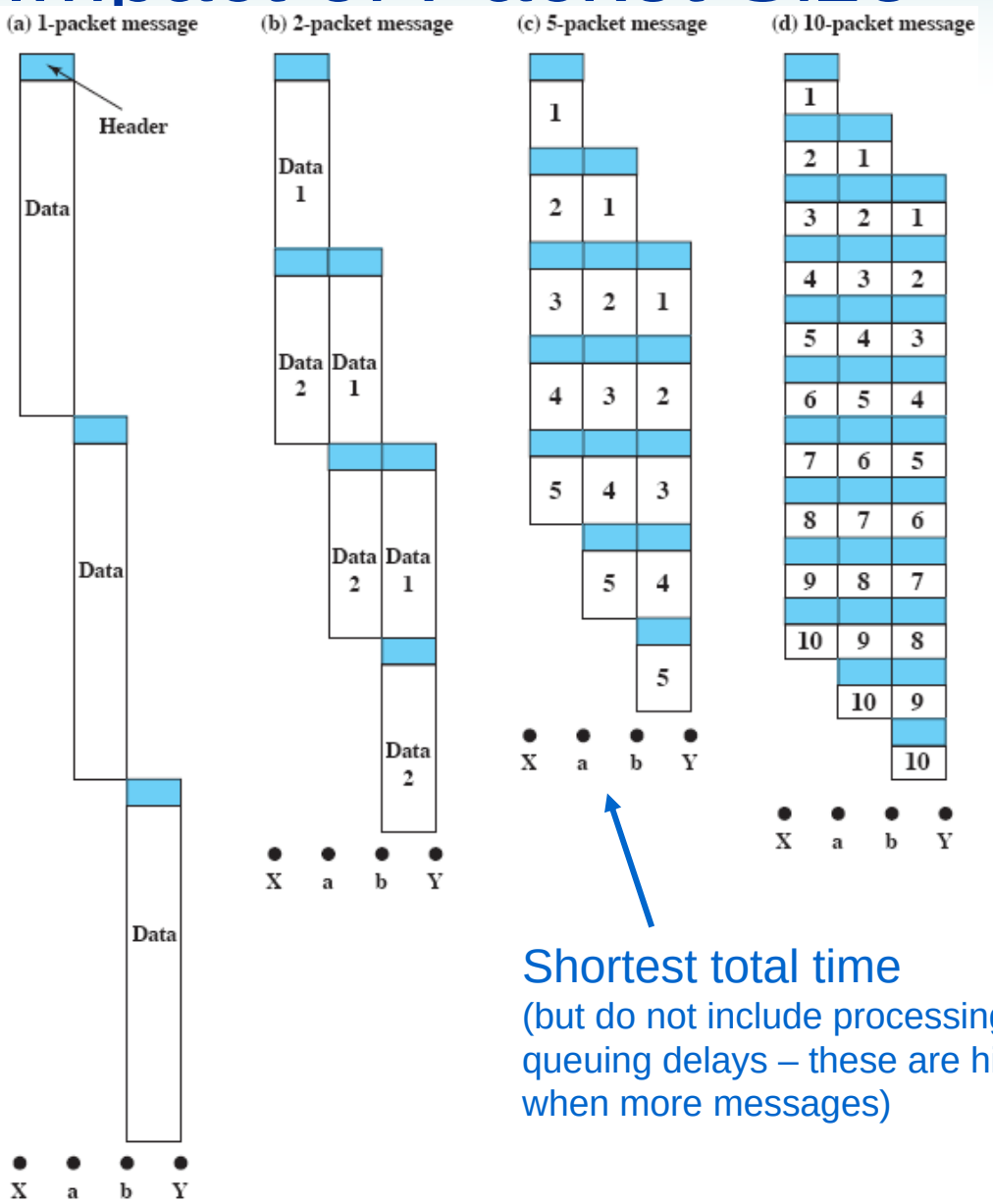


Packet Switching: Virtual Circuit



Impact of Packet Size

- Assume virtual circuit connection between X and Y (via a and b)
- Message is 40 bytes plus 3 bytes of header



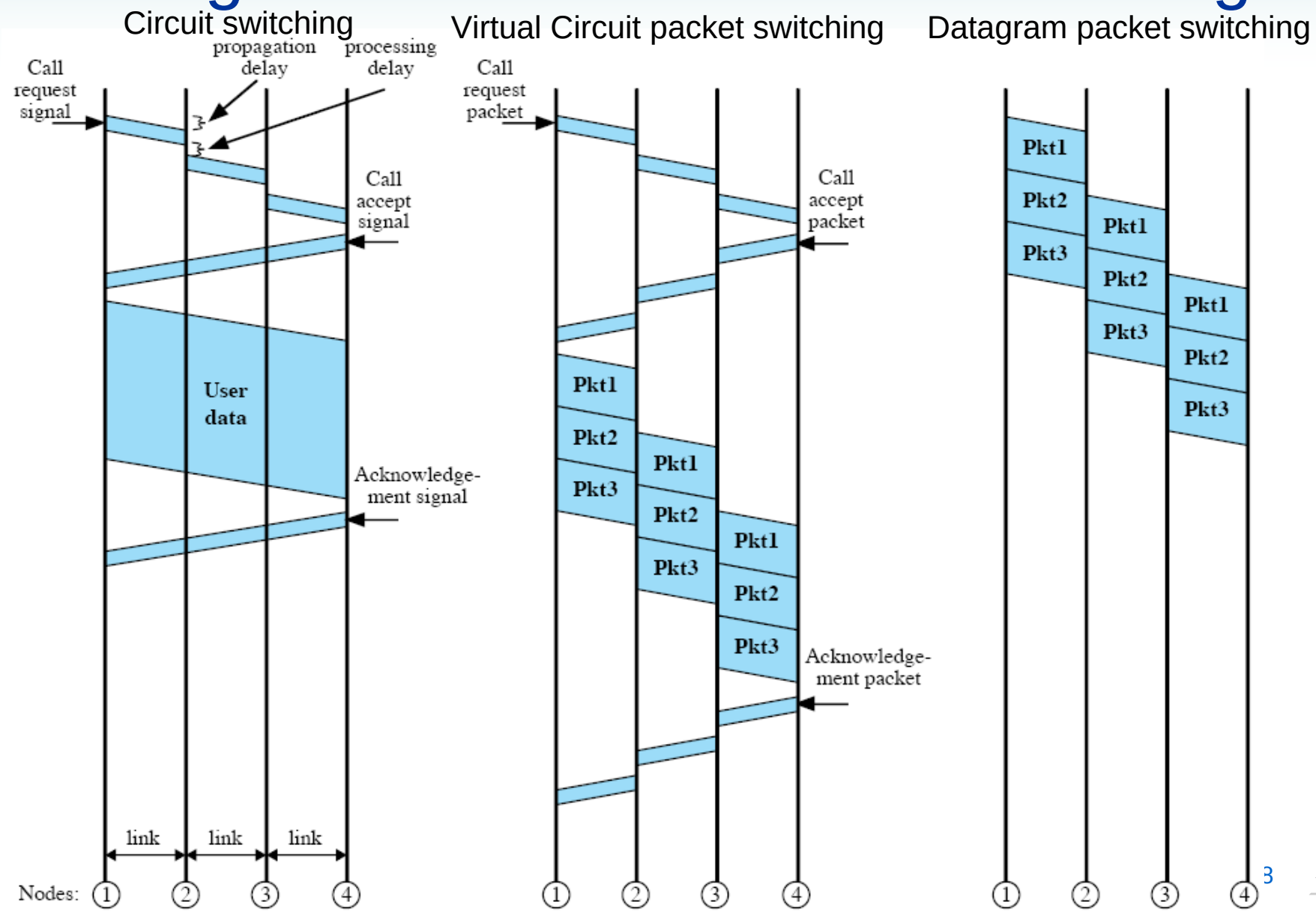
Shortest total time

(but do not include processing and queuing delays – these are higher when more messages)

Circuit Switching vs Packet Switching

- Performance metrics of interest:
  - Propagation delay: time it takes a signal to propagate from one node to the next
    - Generally very small; Negligible
  - Transmission time: time it takes for transmitter to send out block of data
    - E.g. 1second to transmit 10kb block at 10kb/s
  - Node delay: time it takes for node to process/switch data

Timing in Circuit and Packet Switching



Circuit Switching vs Packet Switching

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
Path 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 individual packets
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