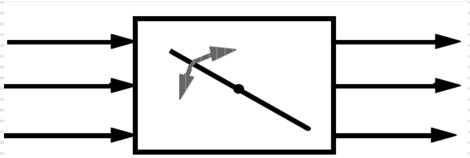
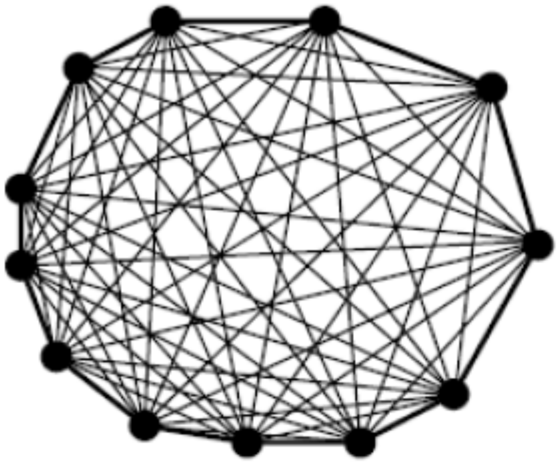
Circuit Switching and Packet Switching

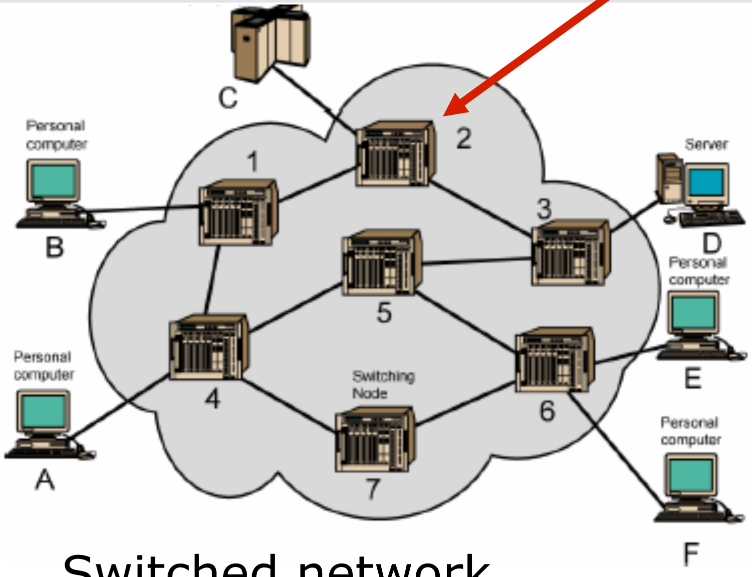
Switched Network

- Physically separate path for each pair of communicating end systems
- Using switches we can reduce the number of paths





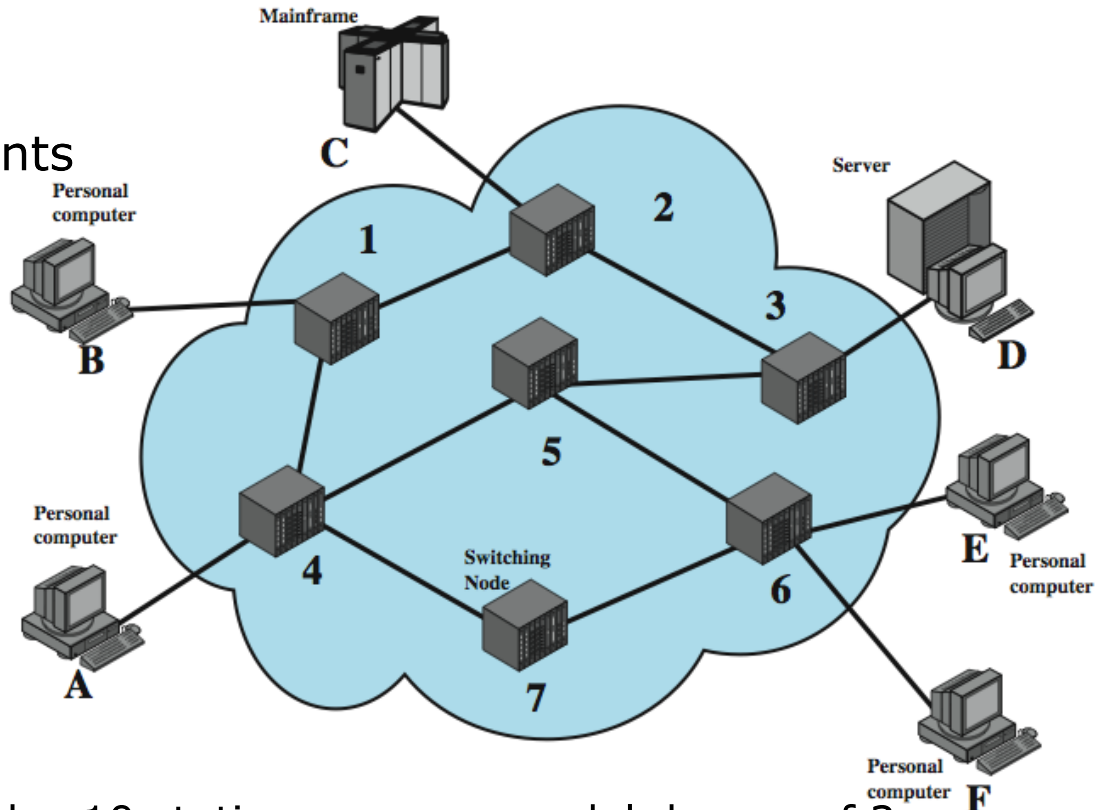
Point-to-point network



Switched network

Switched Network

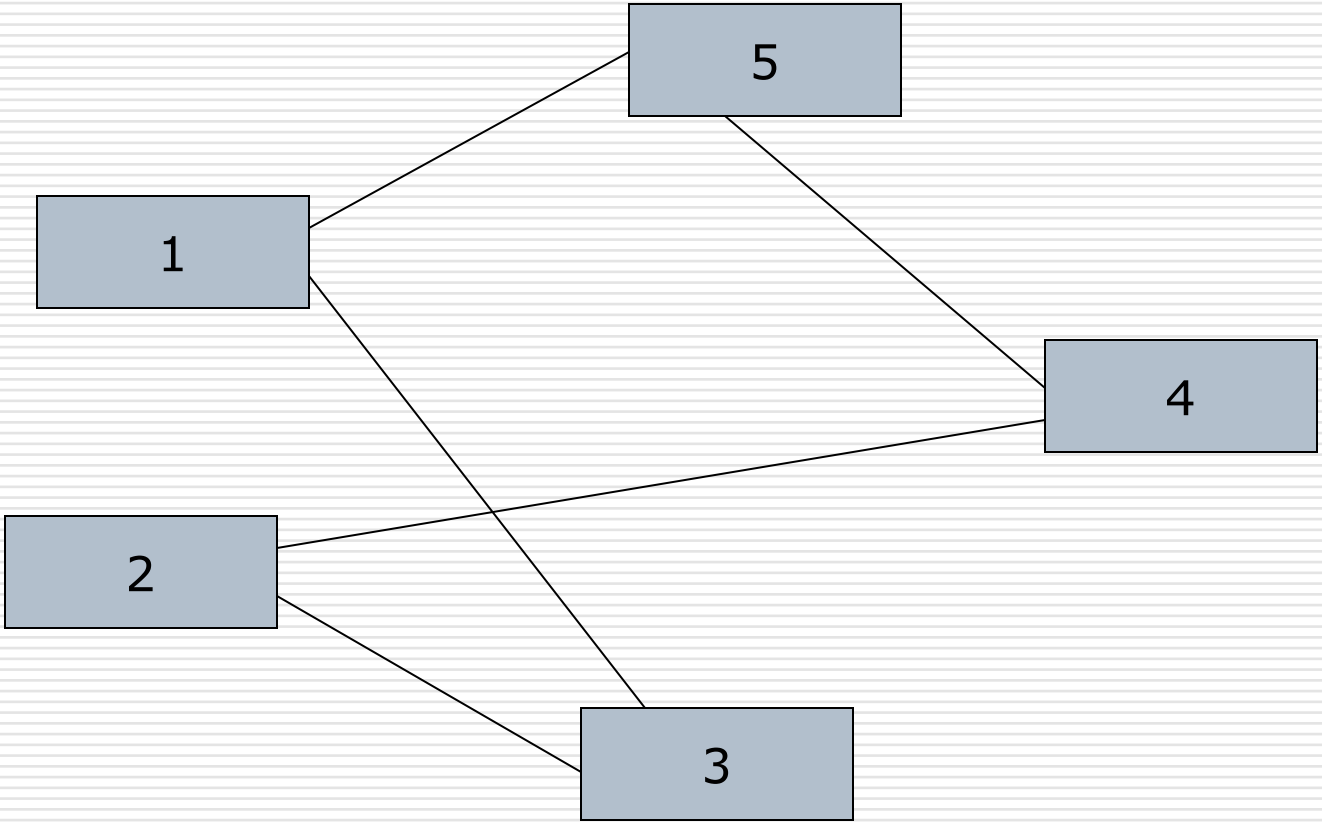
- Stations
- Switch nodes (N)
- Nodes can be access points
- Transmission links
- Nodal degree
- Number of links



Max. number of links:
N(N-1)/2

Example:
Design a network with 5 nodes 10 stations average nodal degree of 2.
How many links are required? What will be the nodal degree for a full mesh?

Example



Communications Network

- a collection of nodes and links
- nodes may connect to other nodes only, or to stations and other nodes
- network is usually partially connected (not a full mesh)
  - some redundant connections are desirable
- switching technologies
  - circuit switching
  - packet switching

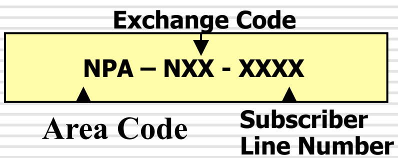
Circuit Switching

- uses a dedicated path between two stations
  - path is reserved for the single pair of end users
- has three phases
  - circuit establish
  - data transfer
  - circuit disconnect
- inefficient
  - channel capacity dedicated for duration of connection
  - if no data, capacity wasted
  - inefficient use of the path if there is bursty traffic
- set up (connection) takes time – setup time
- once connected, transfer is transparent

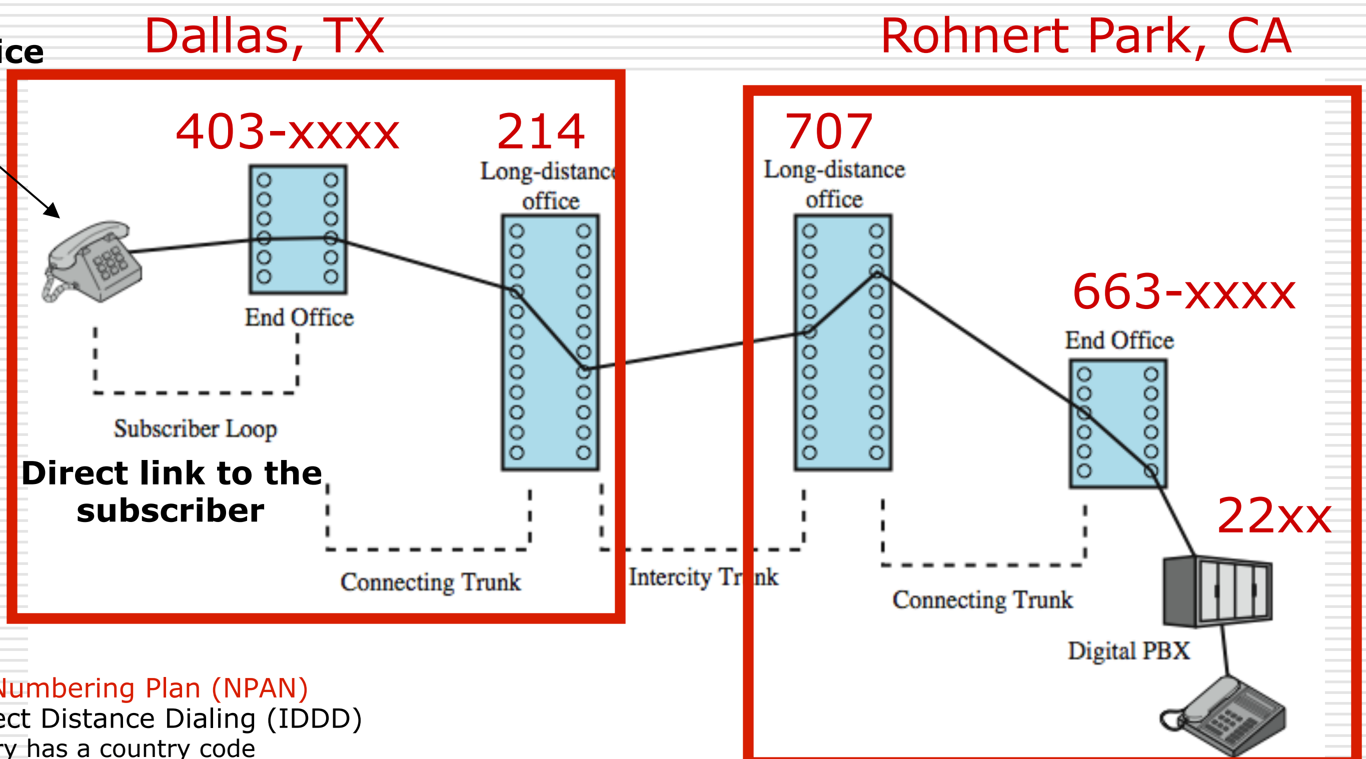
Public Circuit Switched Network

Thousands of users May be connected directly to the end-office

caller number: 214-403-2211



Check out the Geographical [NPAs Plan.]

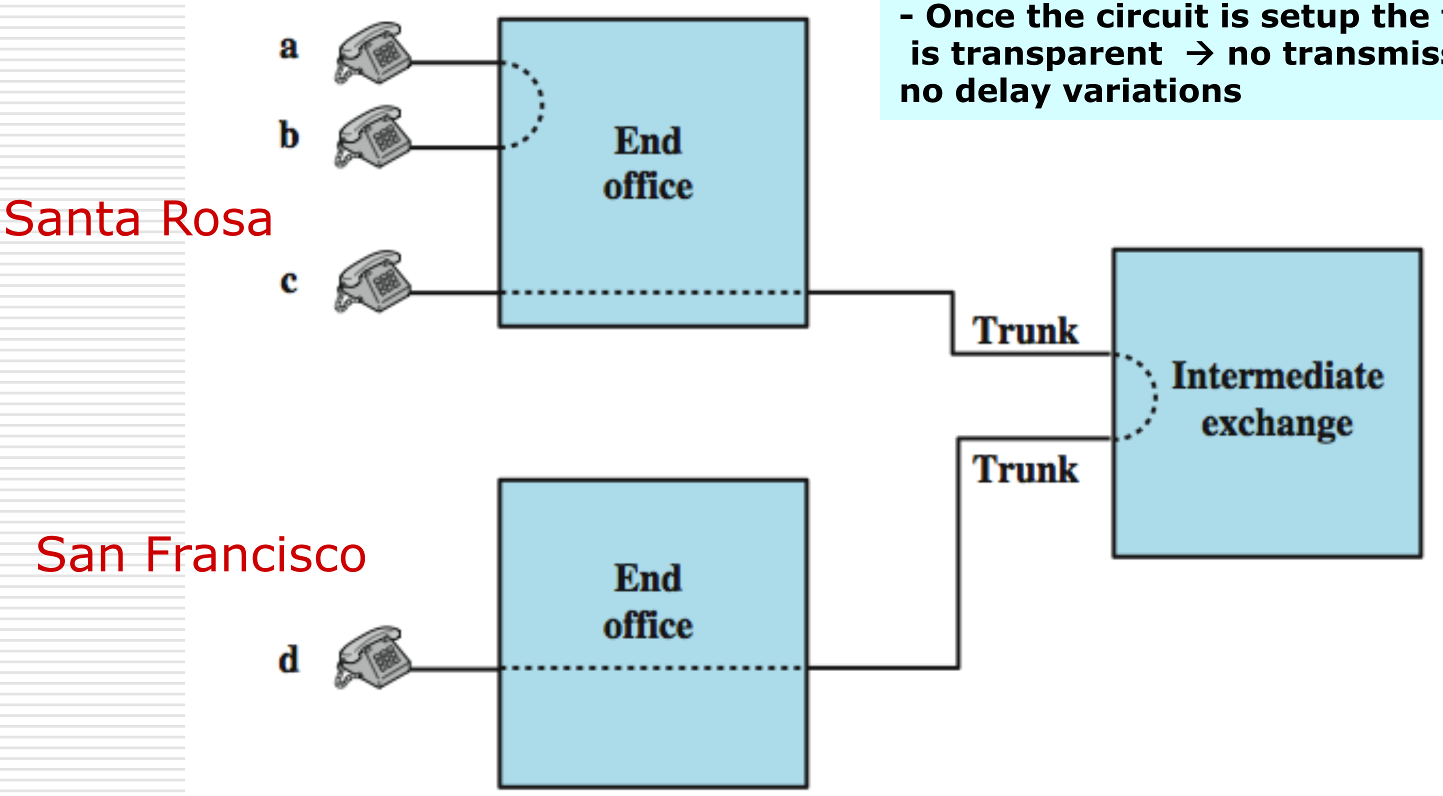


Called user number: 707-663-2211

- North American Numbering Plan (NPAN)
- International Direct Distance Dialing (IDDD)
  - Each country has a country code
  - To access the country code you need a notification code (0 or 011)

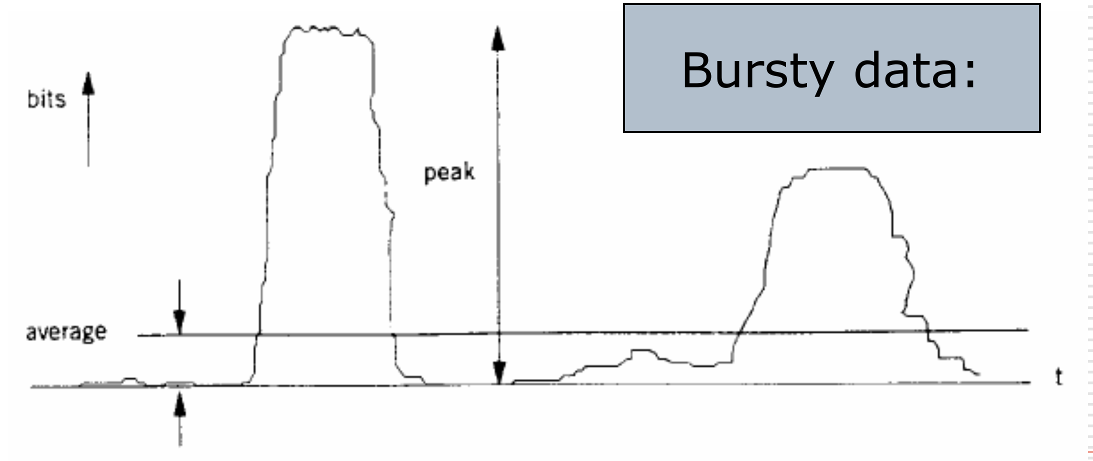
Circuit Establishment

- **Once the circuit is setup the transmission is transparent → no transmission delay and no delay variations**



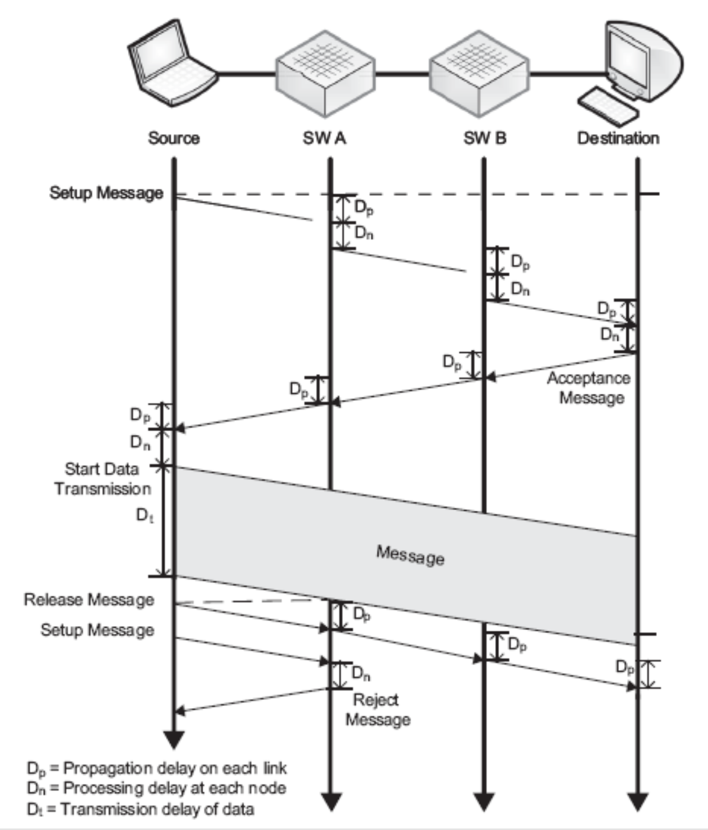
Circuit Switching Inefficiency

- Assume set-up time is 150 msec and the data length is 1000 bytes transmitting at 64Kbps.
  - Only takes 125 msec to transmit the data!
- Not efficient when data occurs in bursts separated by idle periods



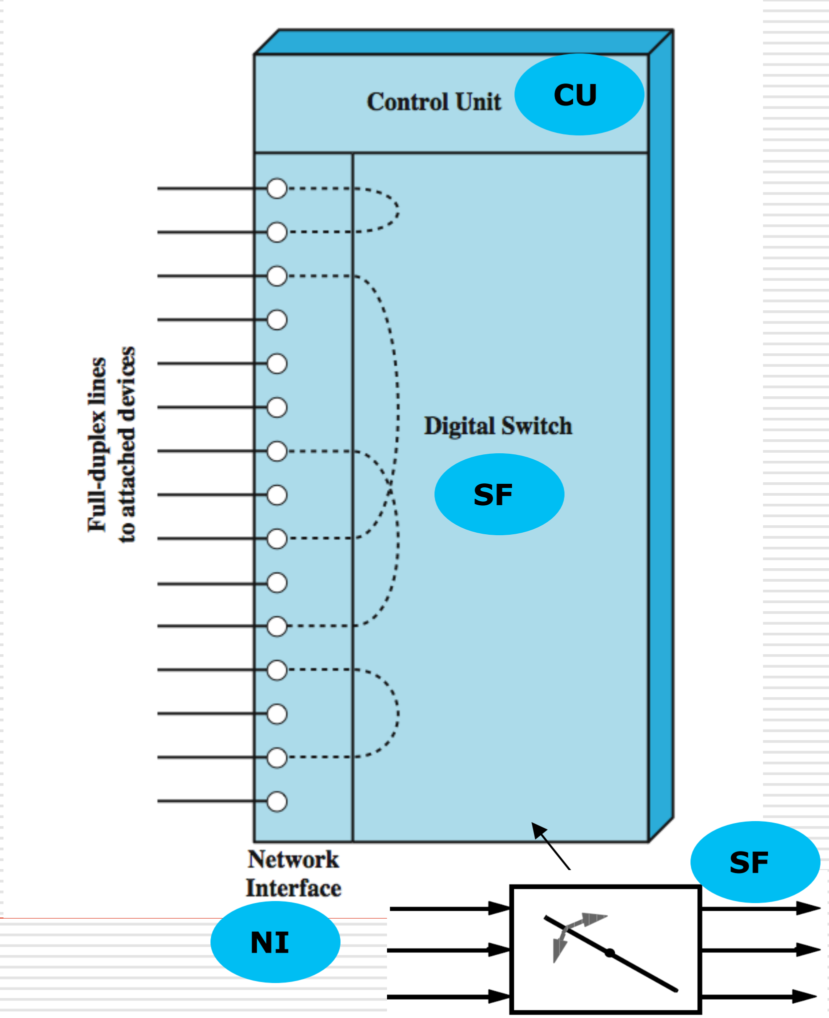
Event Timing

- Assume R=2.5Gbps
- N=4 (intermediate nodes)
- Message length L=1000Kbit
- Control Message length L' = 10 bit
- Data Transmission Delay = L/R (sec)
- Control Message Transmission Delay = L'/R (sec)

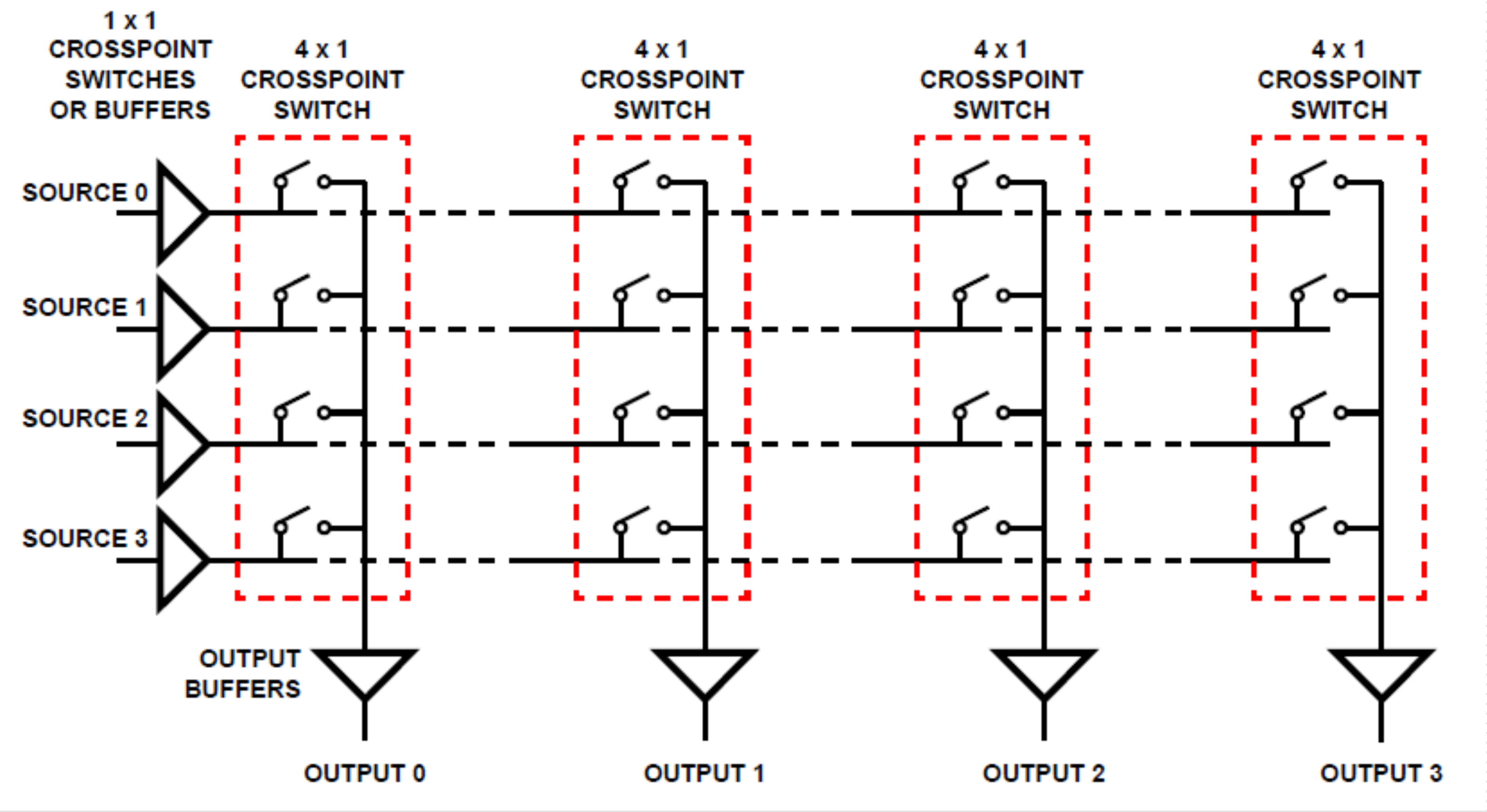


Circuit Switch Elements

- NI allows connecting to digital or analog lines
- CU sets up the switch fabric (SF)
- SF is the hardware that actually causes switching



Switch Fabric using Crosspoints



This is a non-blocking Switch

Blocking or Non-blocking

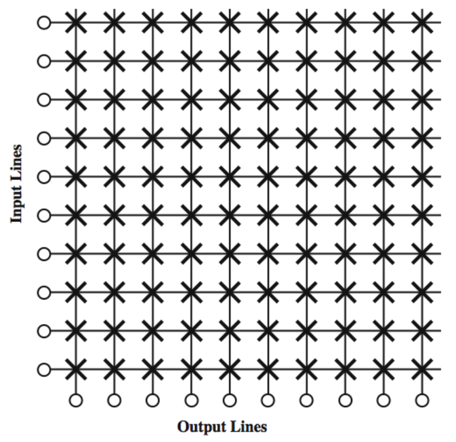
- non-blocking network
  - permits all stations to connect at once
  - used for some data connections
- blocking network
  - may be unable to connect stations because all paths are in use
  - used on voice systems
- non-blocking is cheaper
  - not everyone can make a call at the same time

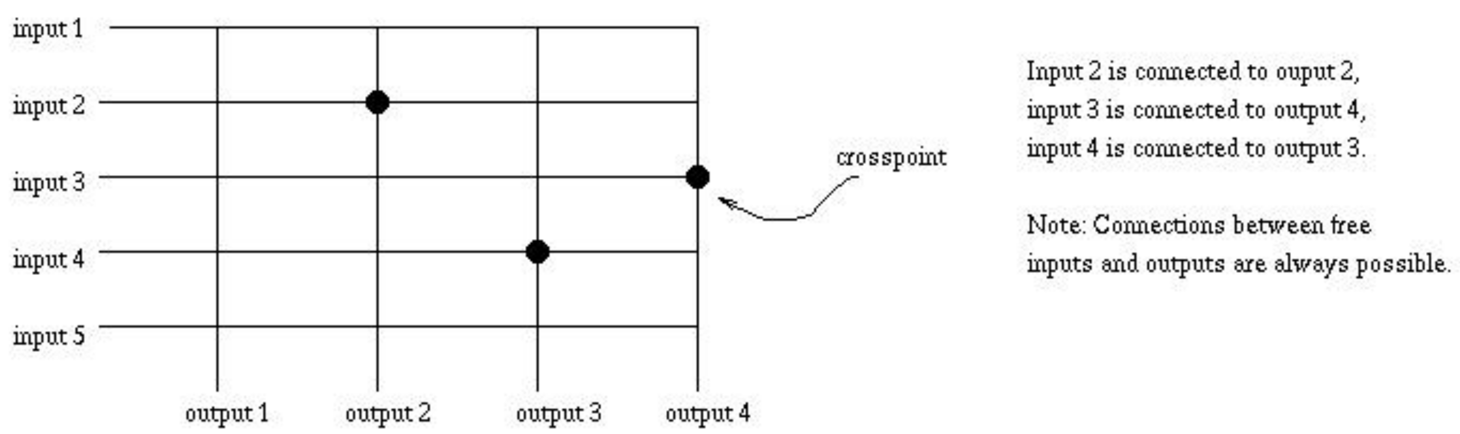
Switching technologies:

- Space Division Switching
- Time Division Switching

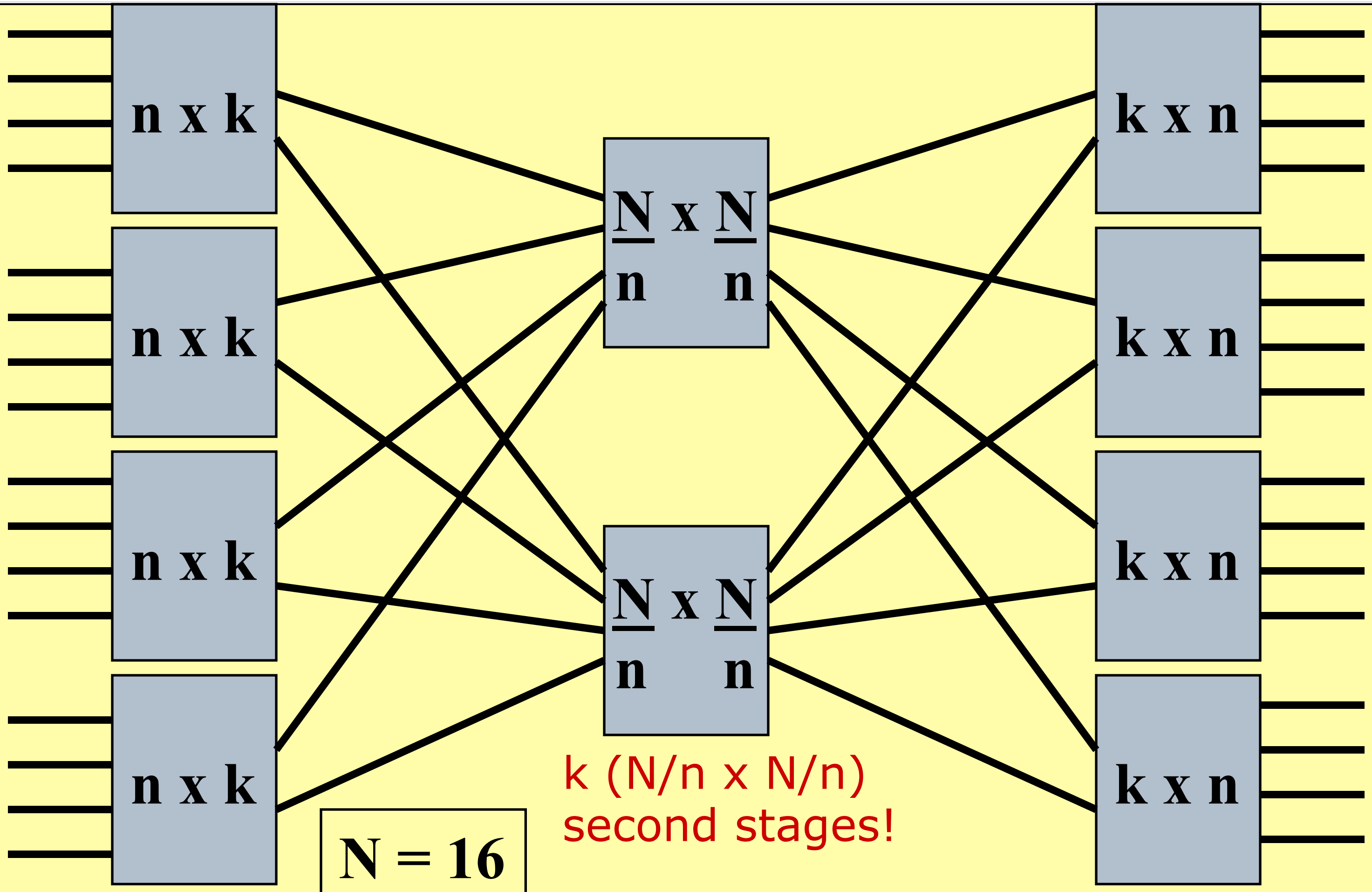
Space Division Switch - Non-blocking

- NxN crosspoints
- For 10^6 users, a crossbar would require 10^12 crosspoints (N^2)





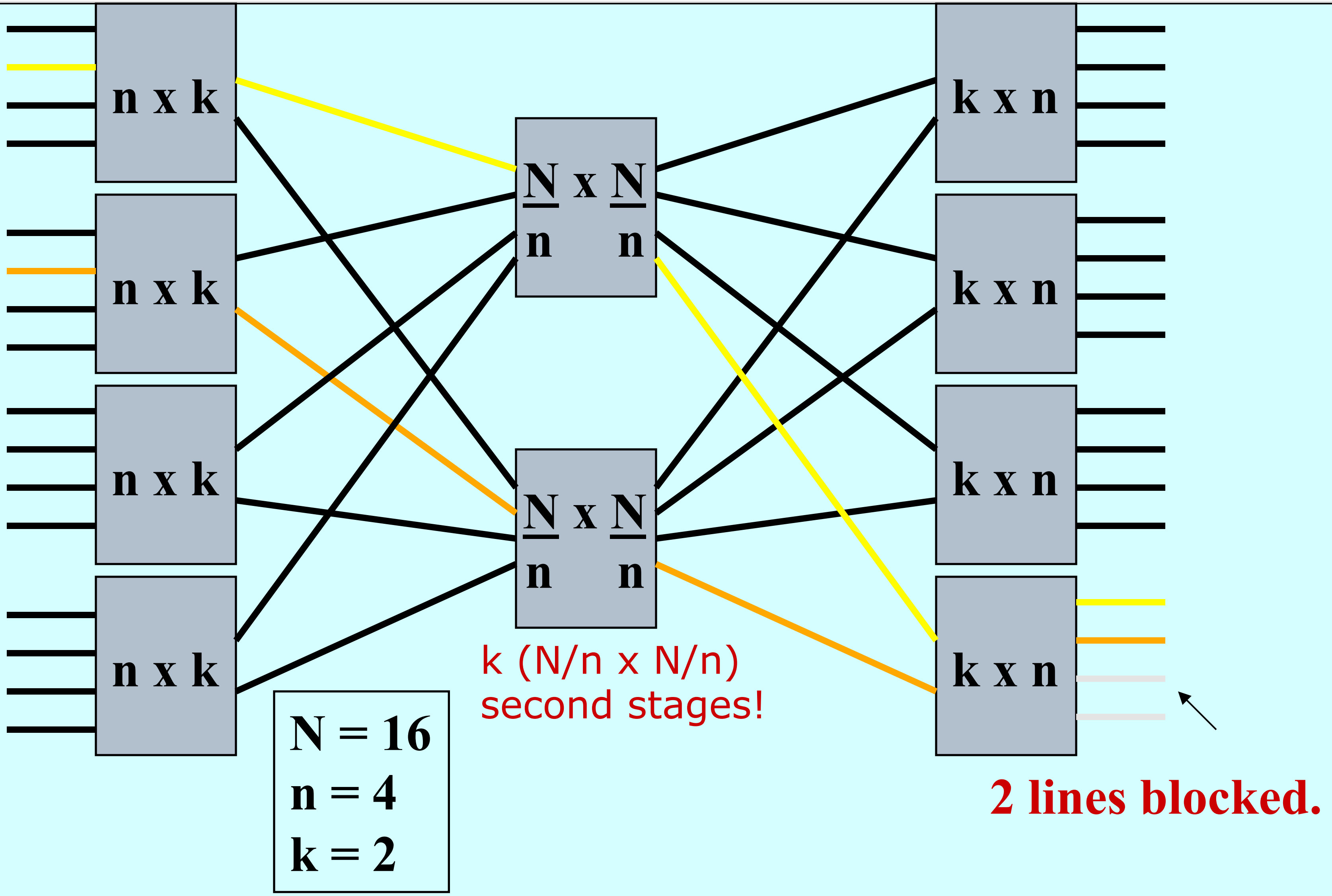
Multiple Stage Space Switch -



N = 16
n = 4
k = 2

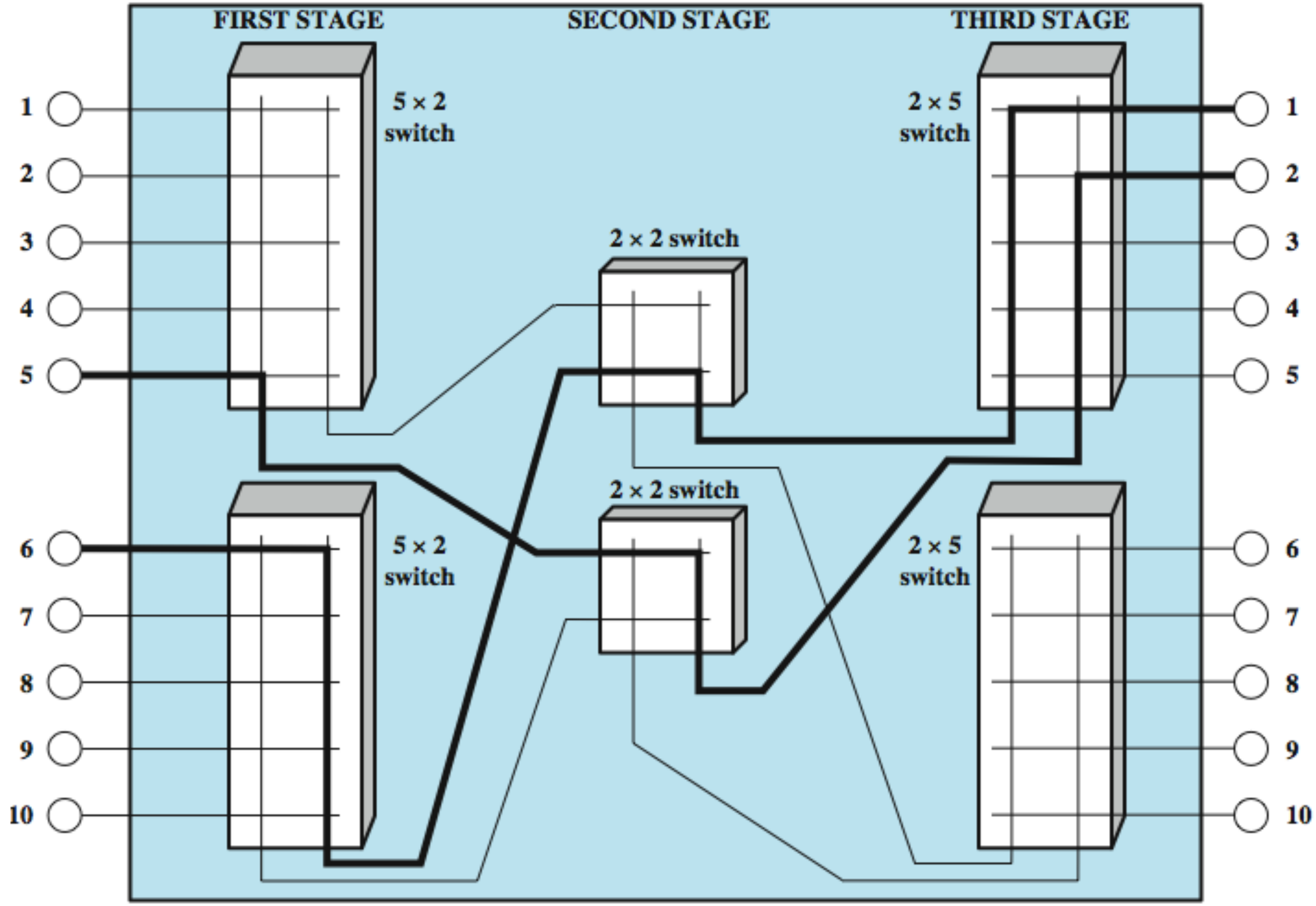
16x16 Rectangular Array: 256 crosspoints
Three Stage Switch: 96 crosspoints

Blocked Calls are possible...

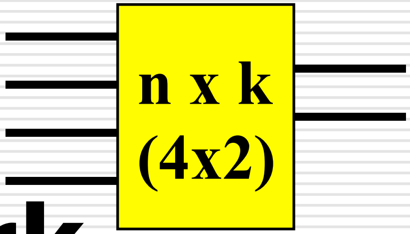


3 Stage Space Division Switch

N = 10
n = 5
k = 2



3 lines blocked.



… also called **Clos Network**

- if k = 2n-1 or greater nonblocking switch
- If k < 2n-1, blocking can occur
- ….. the higher k value the more crosspoints are required for the crossbar switch! (for each additional k we add n more crosspoints!)
- Example: suppose that 1000 users using 10 input per input module. How many second stages are required in order to have a non-blocking switch?

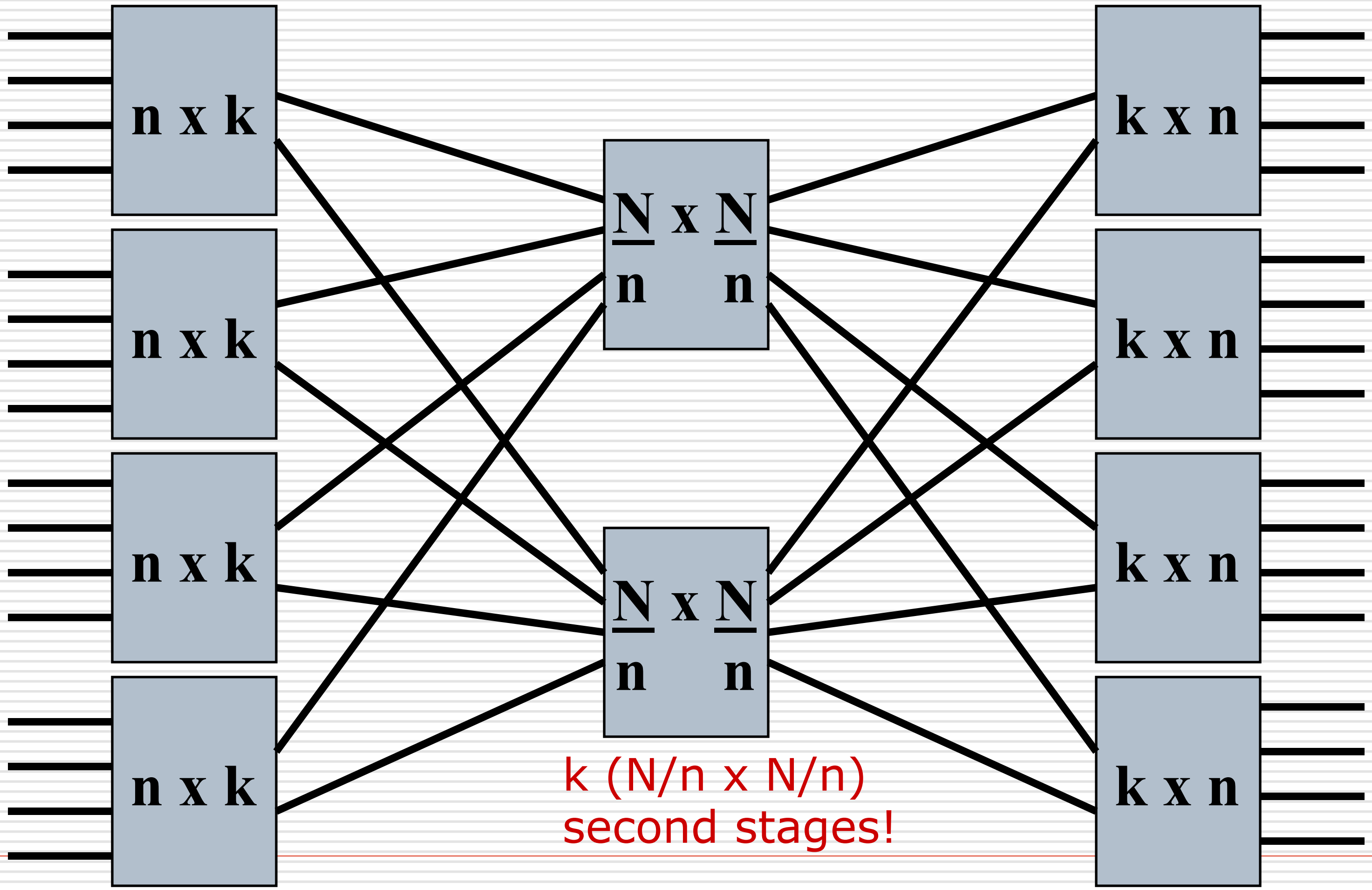
Example - Solution

- **N=1000, n=10;**
- **There are N/n = 1000/10 = 100 switches at the first and third stages.**
- **At the first stage, there are 10 x k and at the third stage**
- **There are k switches in the second stage**
- **The second stage will have k switches of size 100 x 100.**
- **If k = 2n-1=19, then the resulting switch will be nonblocking.**
- **If k < 19, then blocking can occur.**

- **In the case of a full 1000 x 1000 crossbar switch, no blocking occurs but 1,000,000 (a million) crosspoints are required.**
- **For n=10 and k=19, each switch at the first stage is a 10 x 19 crossbar which requires 190 crosspoints and there are 100 such switches.**
- **Same for the third stage.**
- **So the first and third stages use 2x190x100=38,000 crosspoints altogether.**
- **The second stage consists of k=19 crossbars each of size 100 x 100 because N/n=1000/10 = 100.**
- **So the second stage uses 190,000 crosspoints.**
- **Altogether, the Clos construction uses 228,000 crosspoints**

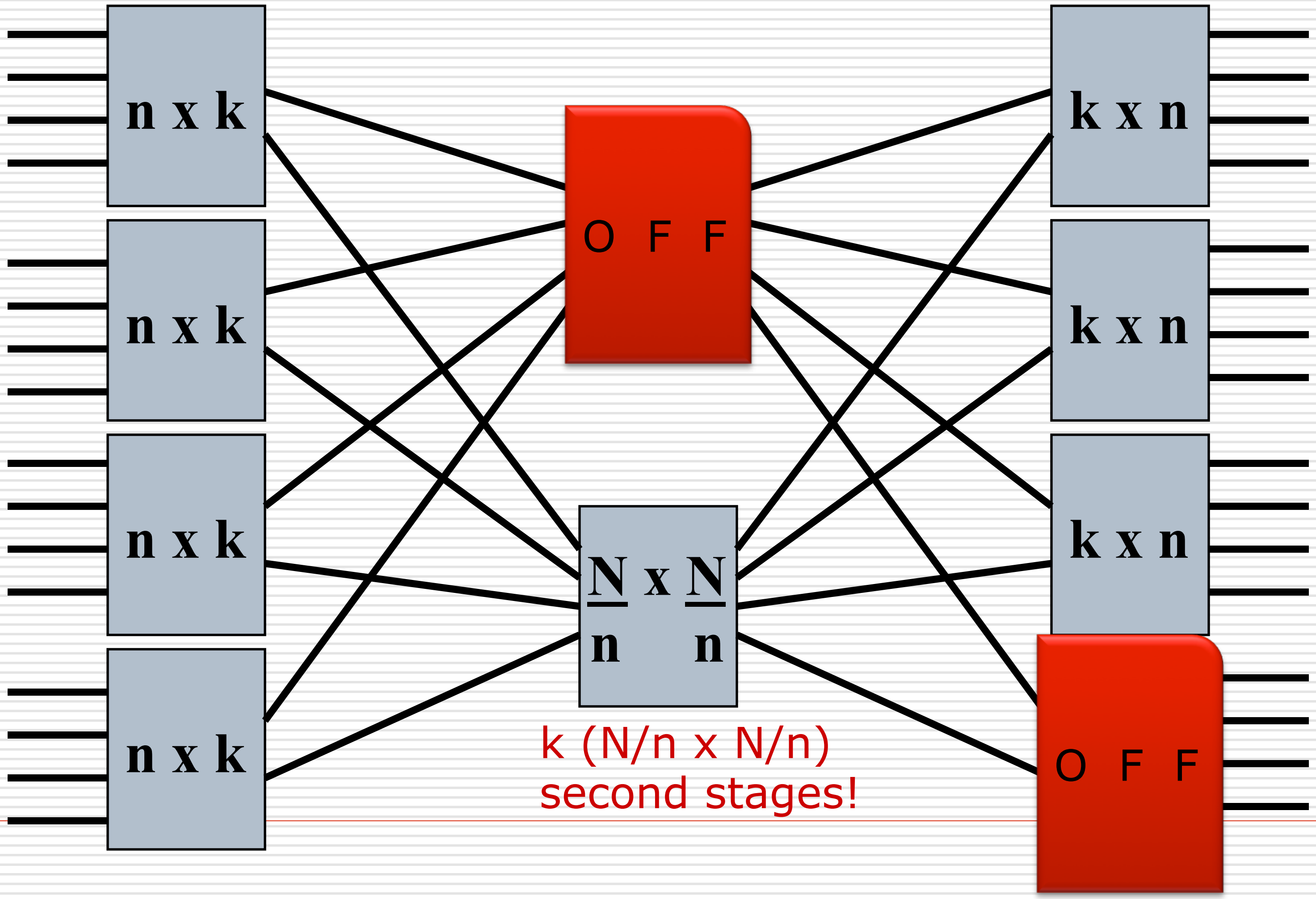
http://people.seas.harvard.edu/~jones/cscie129/nu_lectures/lecture11/switching/clos_network/clos_network.html

Power Consumption In Modular Design



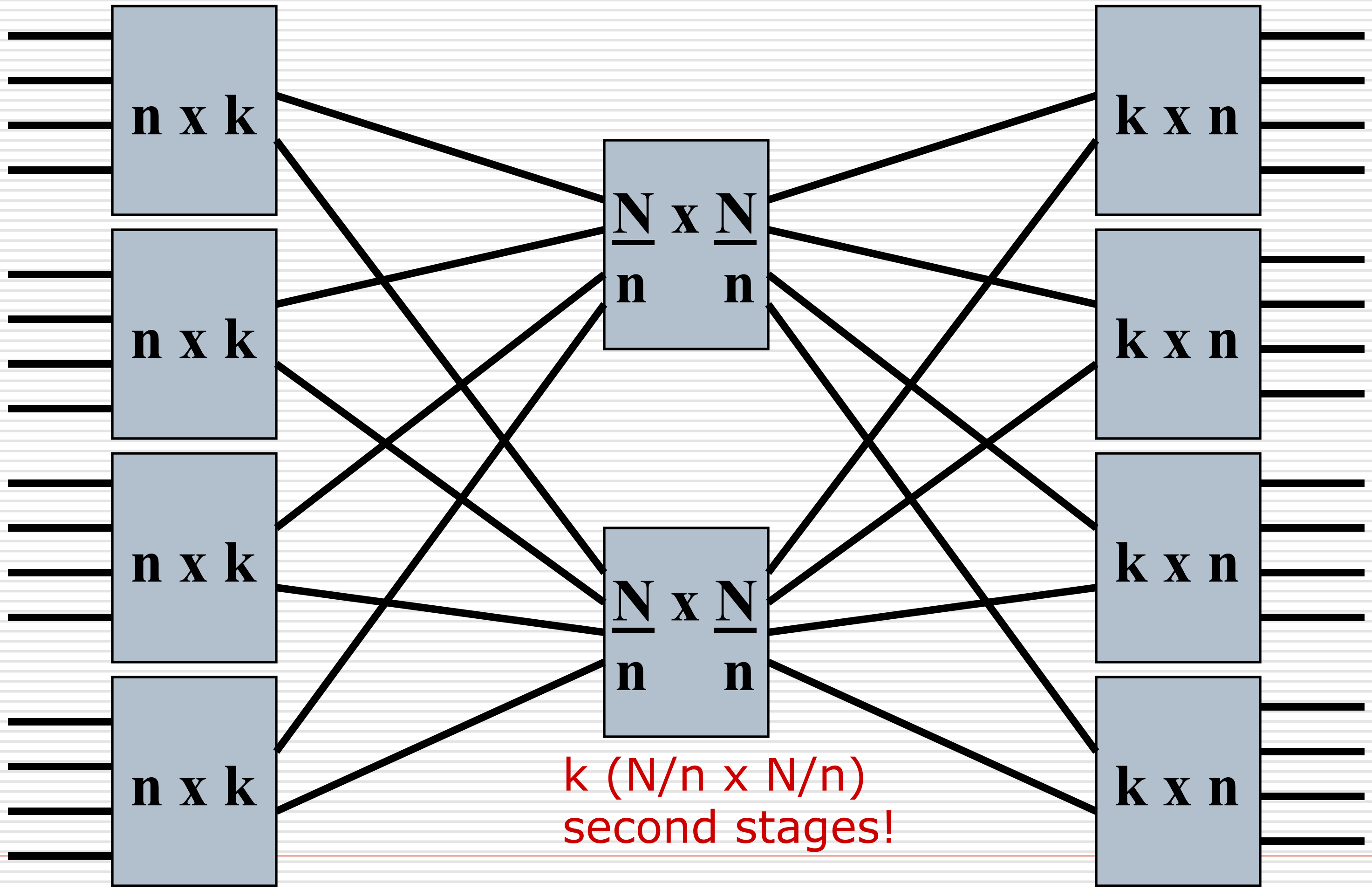
k (N/n x N/n)
second stages!

Power Consumption In Modular Design - Power Efficient Architecture



k (N/n x N/n) second stages!

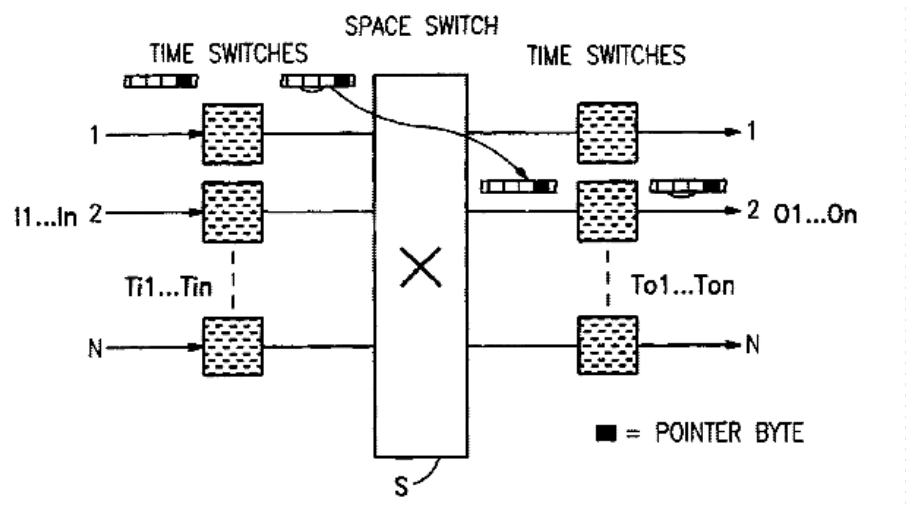
Example (Remember)

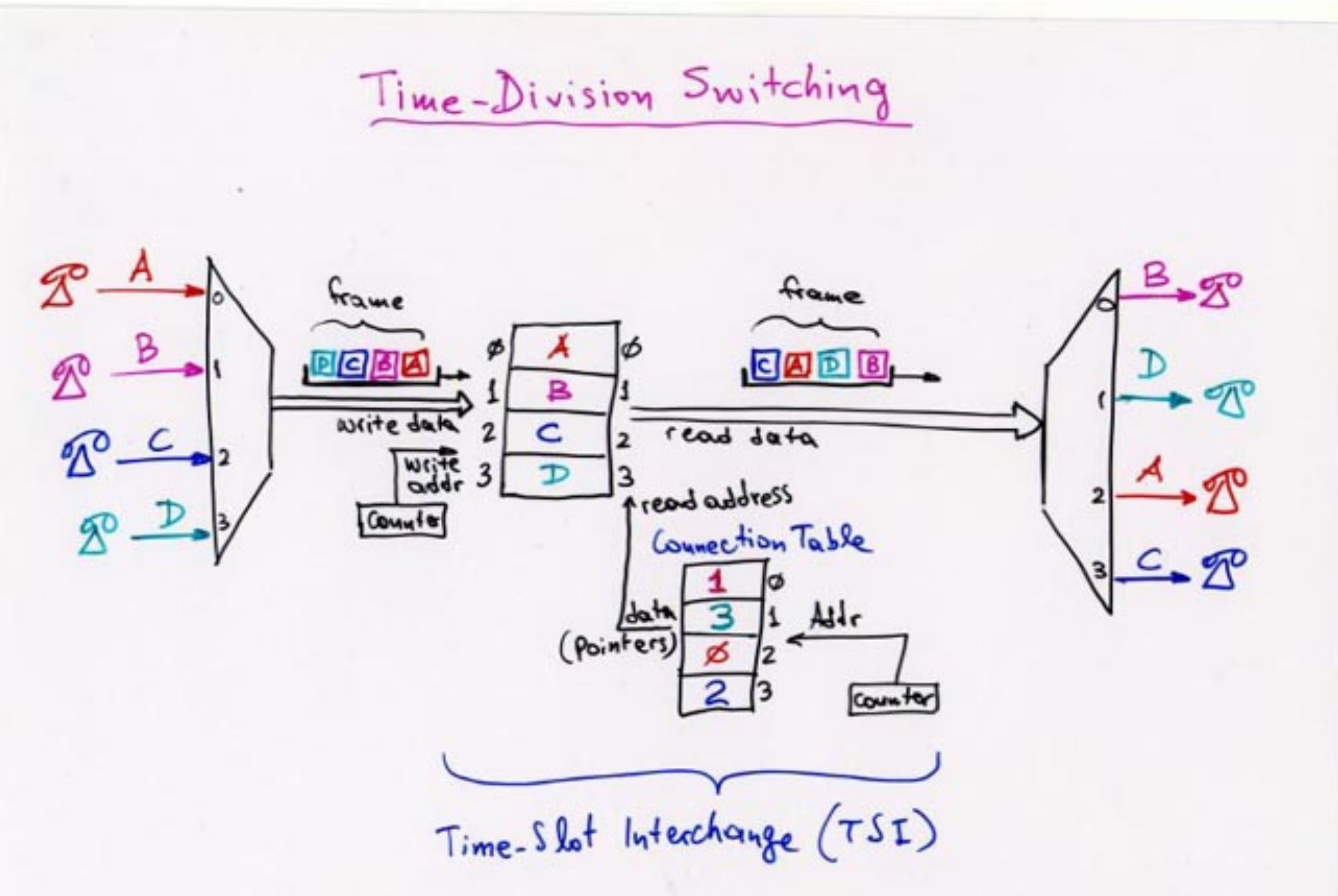


k (N/n x N/n)
second stages!

Time Division Switching

- modern digital systems use intelligent control of space & time division elements
- use digital time division techniques
  - set up and maintain virtual circuits
  - partition low speed bit stream into pieces that share higher speed stream
  - individual pieces manipulated by control logic to flow from input to output





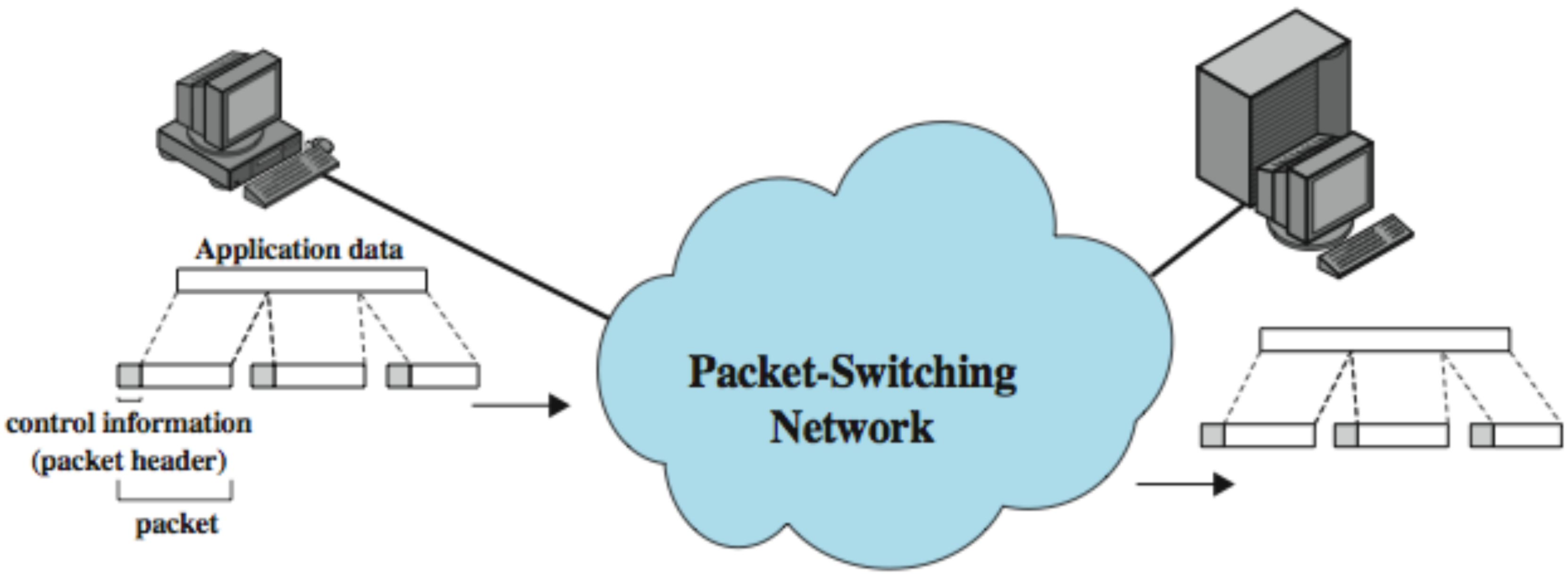
Remember: This is circuit switching which uses time slots (TDM)!

http://archvlsi.ics.forth.gr/~kateveni/534/04a/s21_ts.html

Packet Switching

- circuit switching was designed for voice
- packet switching was designed for data
  - transmitted in small packets
- packets contains user data and control info
  - user data may be part of a larger message
  - control info includes routing (addressing) info
- packets are received, stored briefly (buffered) and past on to the next node
  - packets are queued

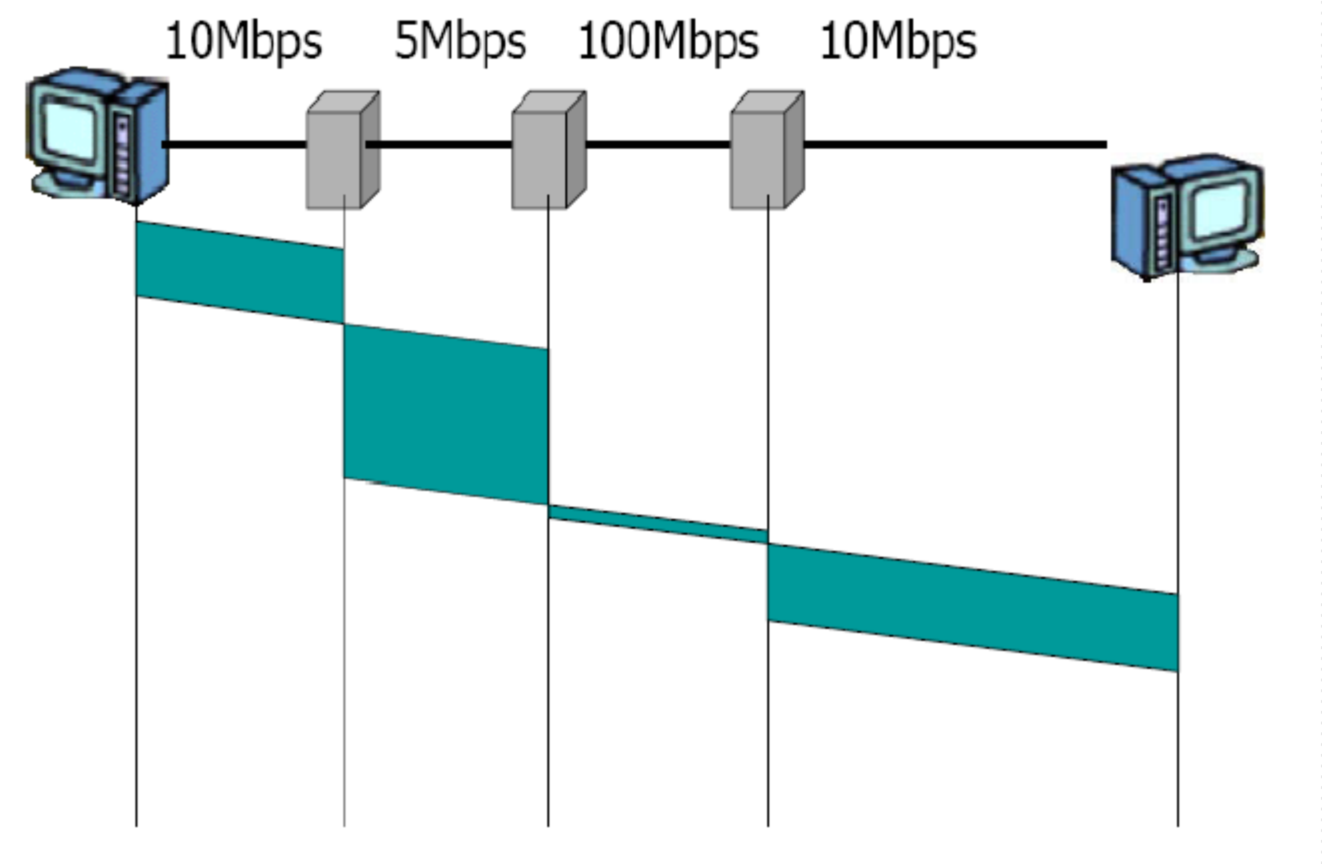
Packet Switching



Advantages

- line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- data rate conversion
  - stations connect to local nodes at their own speed
  - nodes buffer data if required to equalize rates
- packets accepted even when network is busy
- priorities can be used

Data Rate Conversion

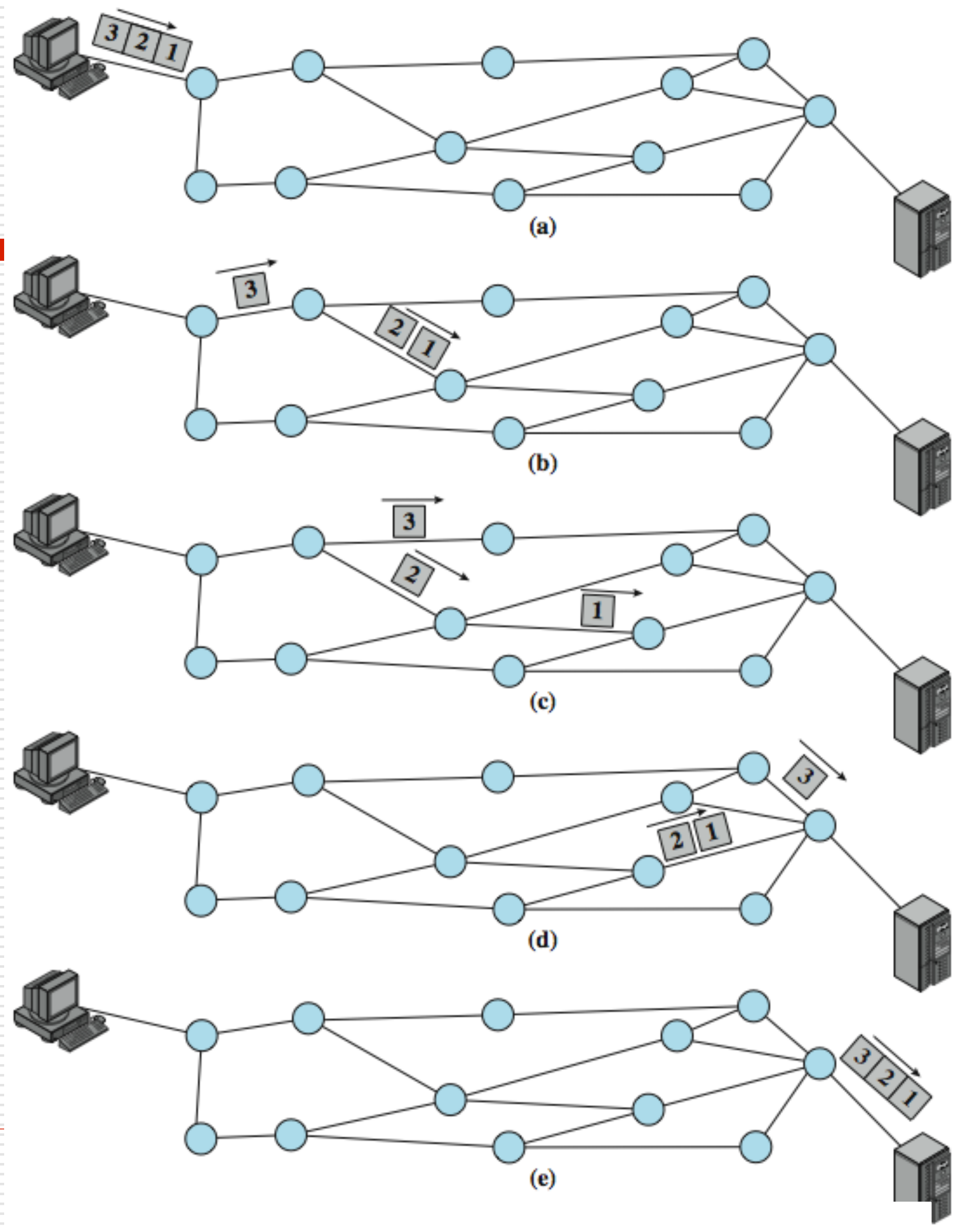


Switching Techniques

- The station breaks long message into packets
- Packets are sent one at a time to the network
- Packets can be handled in two ways
  - datagram
  - virtual circuit

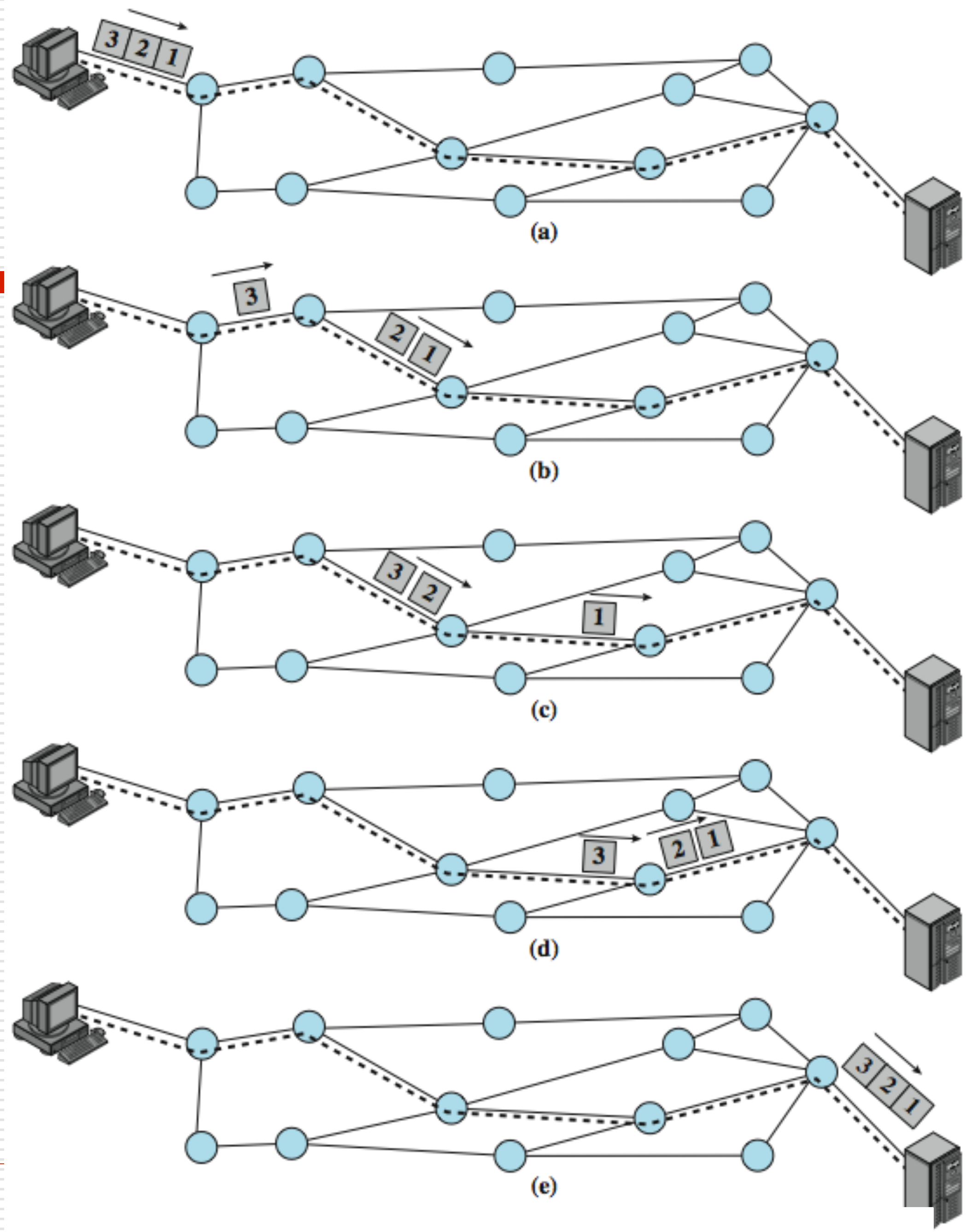
Datagram Diagram

- No pre-planned route → fast (no circuit)
- Each packet can pass through a separate path
- Reassembly is required
- Packets may experience jitter (delay variation)
- Network can provide error control
- More flexible (more primitive)
- More reliable (if a node fails circuit fails)

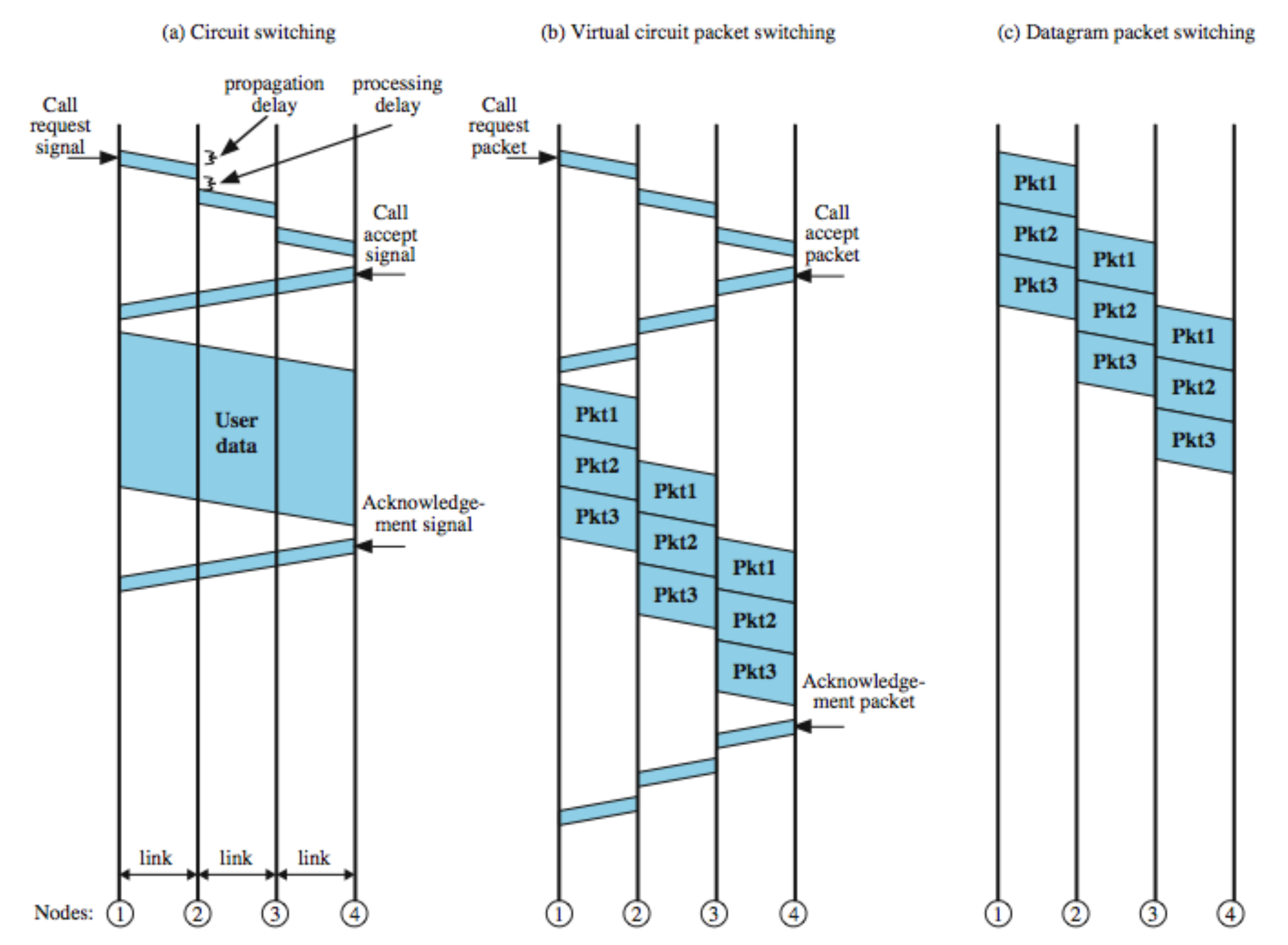


Virtual Circuit Diagram

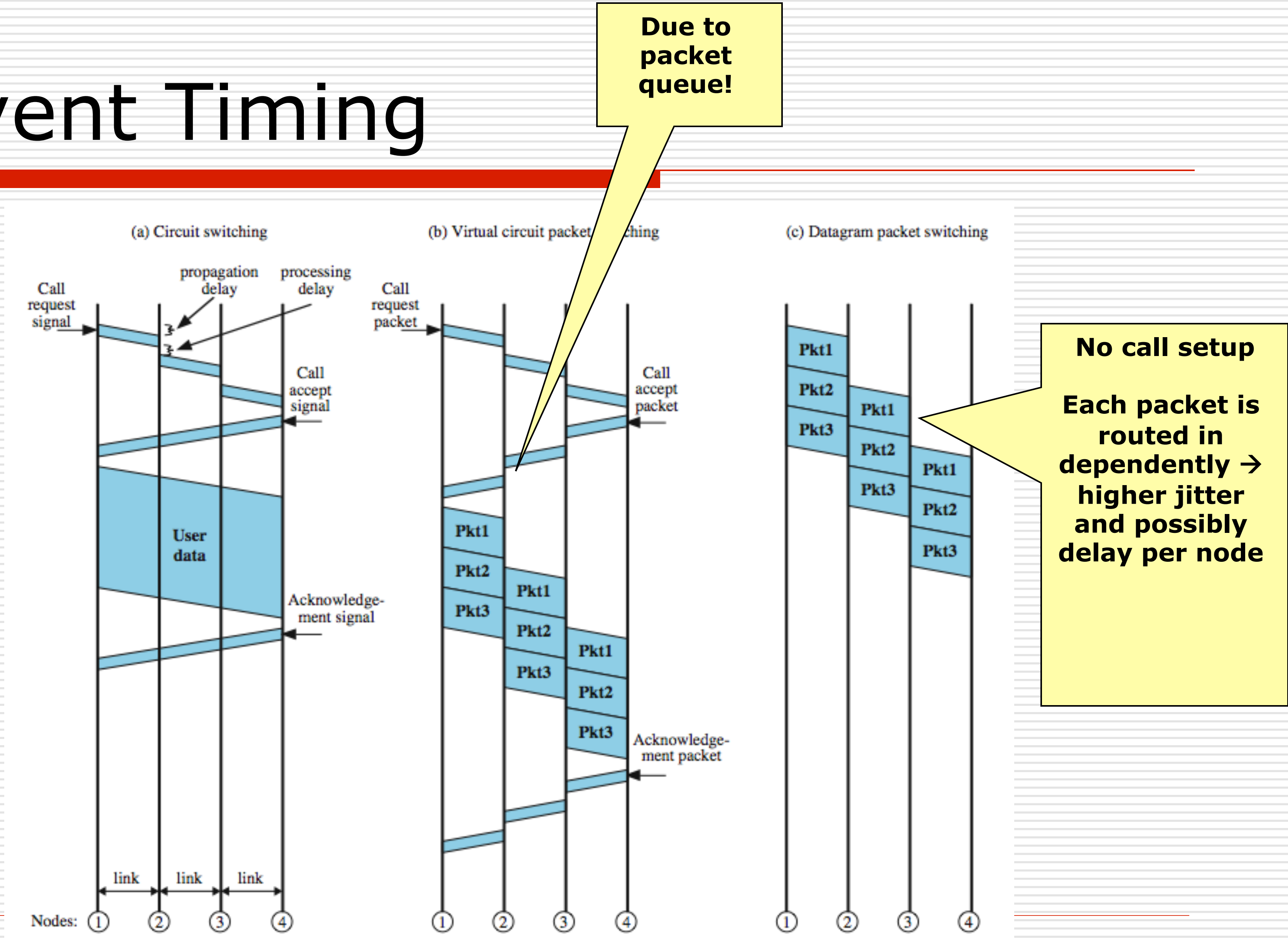
- call setup phase is required
- Fixed route (circuit switching)
- Each packet has VC ID
- No routing decisions at the intermediate nodes --> fast delivery



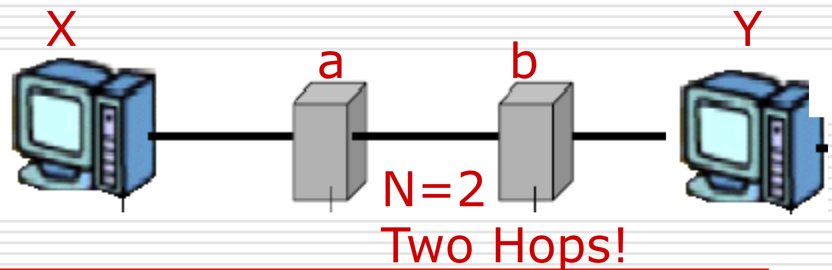
Event Timing (With ACK)



Event Timing



Packet Size and Delay



$K = Message\_length(bit)$ e.g., entire message

$P = Packet\_length(bit)$

$R = Line\_transmission\_rate(bps)$

$N = \#\, switch\_nodes\_in\_the\_path$

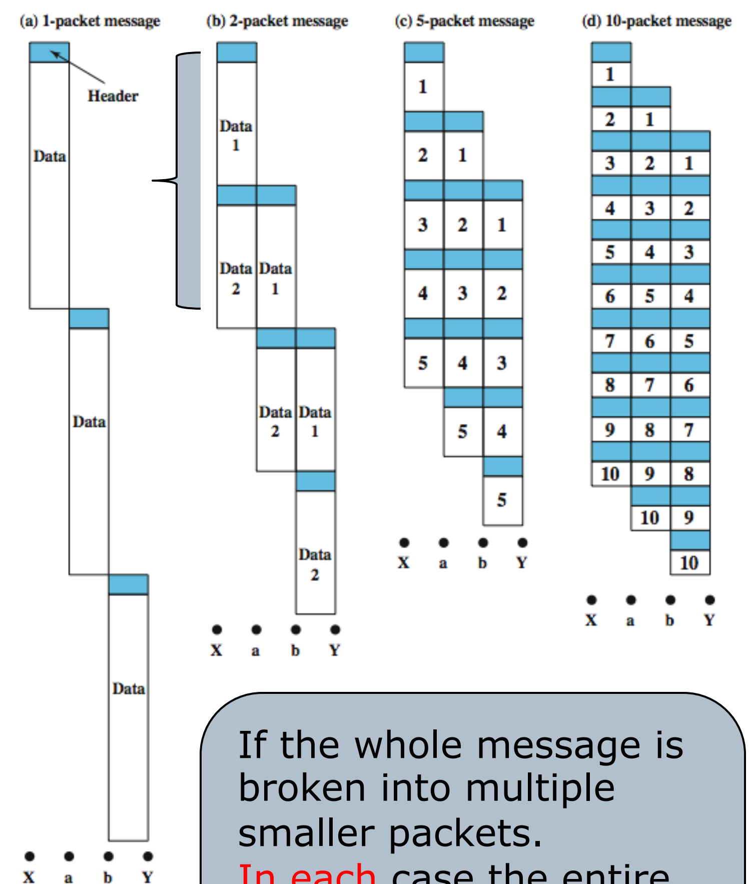
$$D_{circuit\_switch} = K / R$$

$$D_{packet\_switch} = \frac{P}{R}(N+1) + \frac{K-P}{R}$$

$$D_{message\_switch} = \frac{K}{R}(N+1)$$

Note: we are ignoring the overhead and setup delay and propagation delay

The transmission delay for the first packet



If the whole message is broken into multiple smaller packets. In each case the entire message/packet must be received before retransmission!

Example:

- Assume the message is 10^6 bits long
- Transmission rate is 50Kbps
- Four switches in the path
- Packet size is 2000bit
- Calculate the delay for packet switched network and circuit switched network
- Neglect call setup and overhead

$$K = 1000000 bit$$

$$P = 2000 bit$$

$$R = 50000 bps$$

$$N = 4$$

$$D_{circuit\_switch} = K / R$$

$$= 1000000 / 50000 = 20 \sec$$

$$D_{packet\_switch} = \frac{P}{R}(N+1) + \frac{K-P}{R} = \frac{K}{R}(1 + \frac{PN}{K})$$

$$= 2000(5)/50000 + (1000000 - 2000)/50000 = 20.16 \sec$$

Note if P<<K then delay will be the same!

Applet:

http://www.slideshare.net/Convergent_Technology/next-generation-networks-8193677

Example:

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$$= 2000(5) / 50000 + (1000000 - 2000) / 50000 = 20.16 \sec$$

The Throughput =

Total number of bits transmitted

Total Delay

Goodput =

Total number of useful bits transmitted

Total Delay

Applet:

http://www.slideshare.net/Convergent_Technology/next-generation-networks-8193677

Circuit vs. Packet Switching

- performance depends on various delays
  - propagation delay
  - transmission time
  - node delay
  - transparency
  - amount of overhead

X.25

- ITU-T standard for interface between host and packet switched network
- almost universal on packet switched networks and packet switching in ISDN
- defines three layers
  - Physical
  - Link
  - Packet

X.25 - Physical

- interface between station node link
- two ends are distinct
  - Data Terminal Equipment DTE (user equipment)
  - Data Circuit-terminating Equipment DCE (node)
- physical layer specification is X.21
- can substitute alternative such as EIA-232

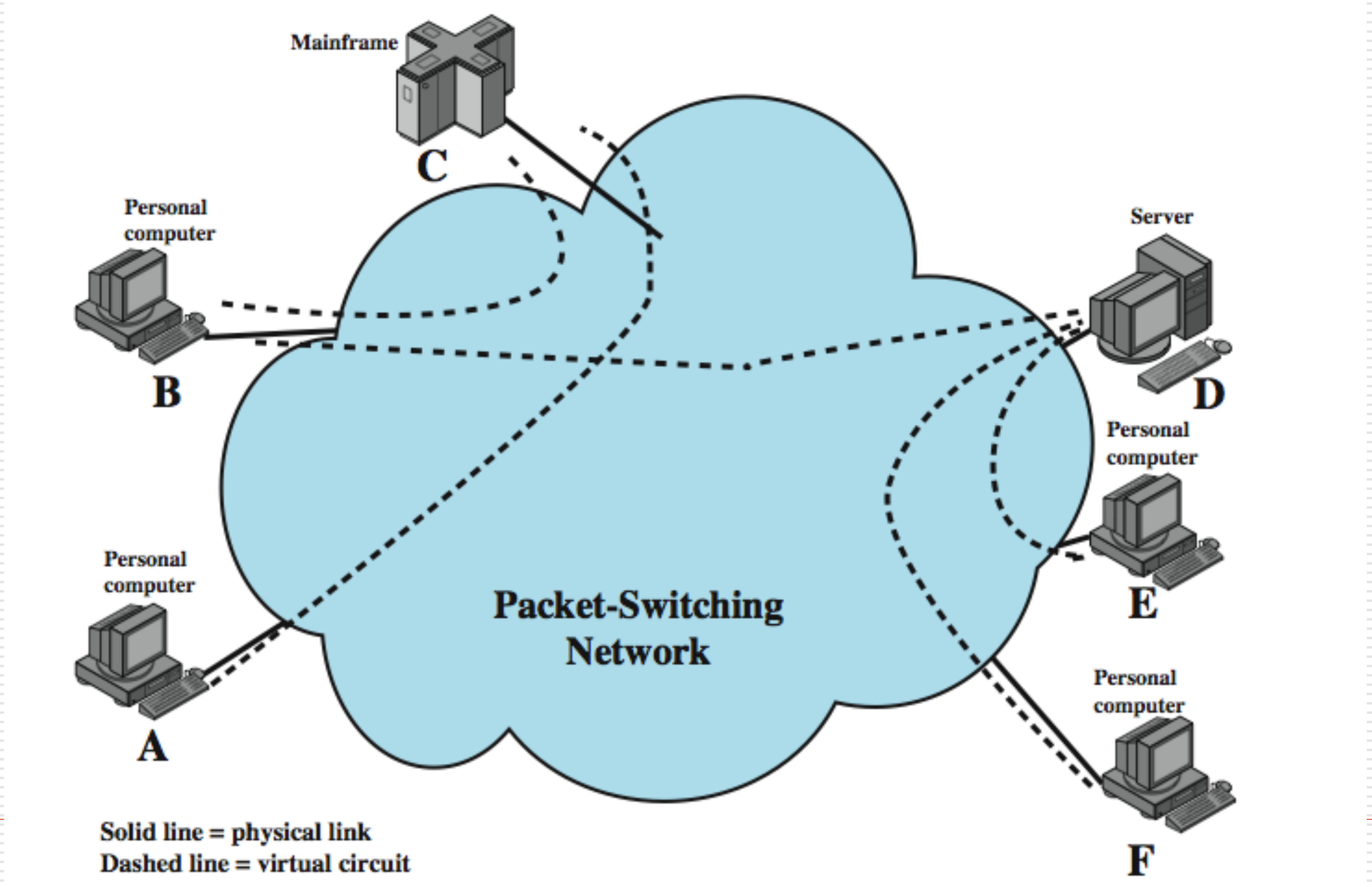
X.25 - Link

- Link Access Protocol Balanced (LAPB)
  - Subset of HDLC (described later)
- Provides reliable transfer of data over link
- Sends a sequence of frames

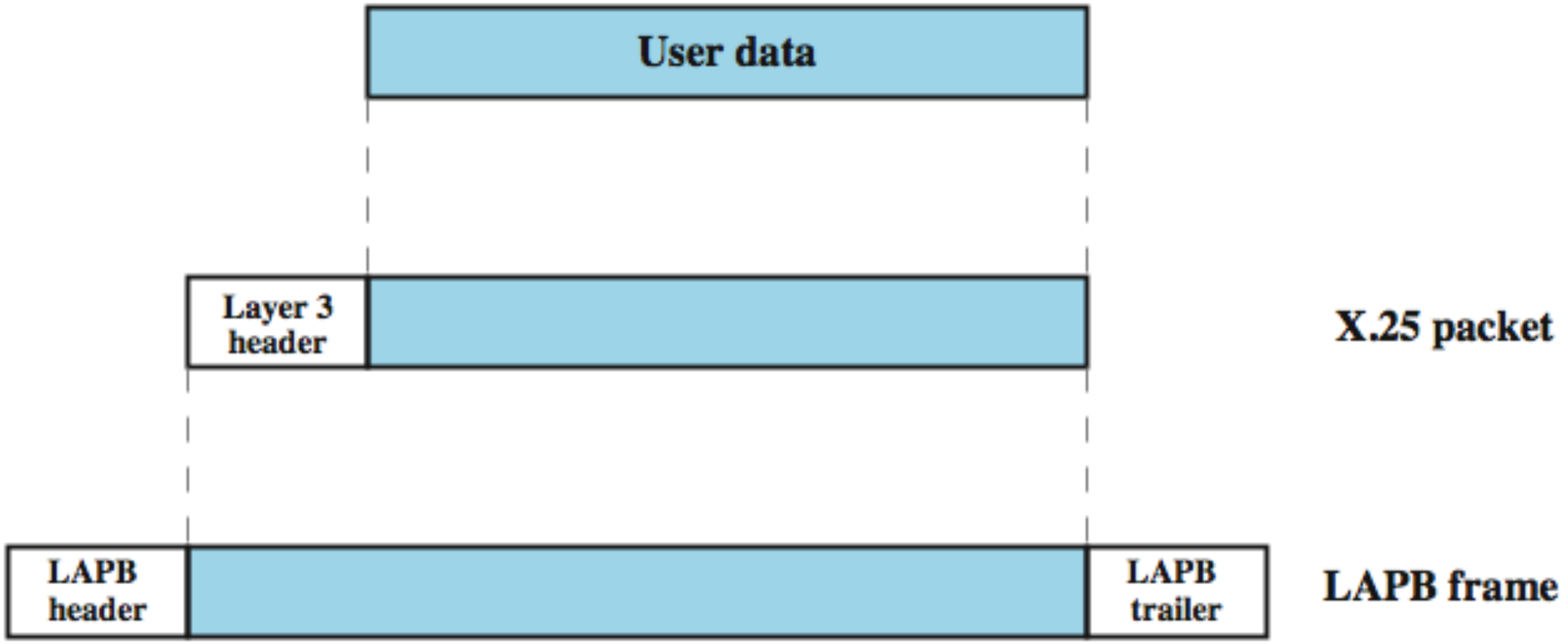
X.25 - Packet

- provides a logical connections (virtual circuit) between subscribers
- all data in this connection form a single stream between the end stations
- established on demand
- termed external virtual circuits

X.25 Use of Virtual Circuits



User Data and X.25 Protocol Control Information



Link Access Protocol Balanced

Issues with X.25

- key features include:
  - call control packets, in-band signaling
  - multiplexing of virtual circuits at layer 3
  - layers 2 and 3 include flow and error control, hence, have considerable overhead
    - no hop by hop error or flow control (rather than end-to-end) – hop-by-hop ACK
- not appropriate for modern fast digital systems requiring high reliability

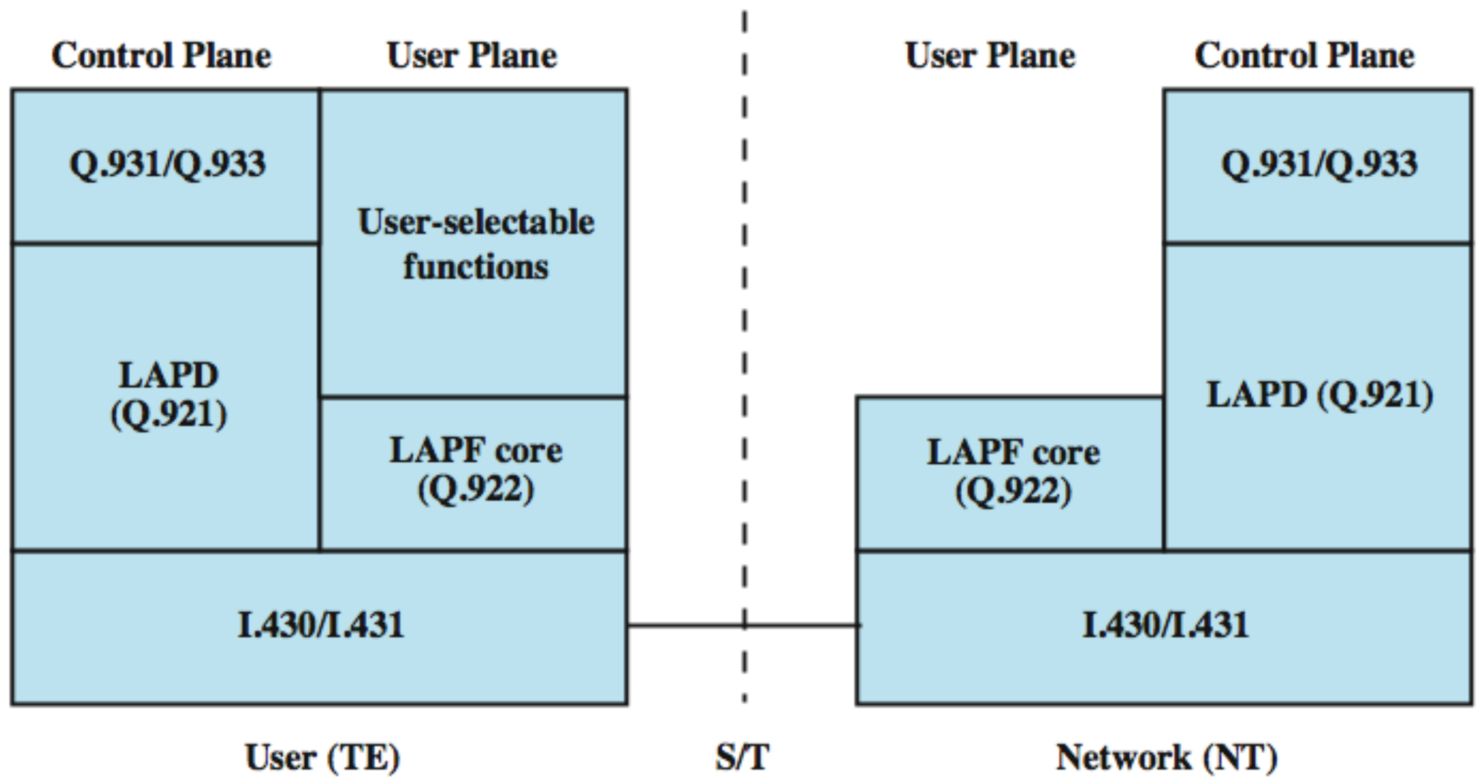
Frame Relay

- designed to eliminate most X.25 overhead
- has large installed base
- key differences:
  - call control carried in separate logical connection
  - multiplexing and switching at layer 2
  - no hop by hop error or flow control
  - Hence, end to end flow and error control (if used) are done by higher layer
- a single user data frame is sent from source to destination and higher layer ACK sent back

Advantages and Disadvantages

- lost link by link error and flow control
- increased reliability means less an issue
- streamlined communications process
  - lower delay
  - higher throughput
- frame relay can be used for access speeds up to and over 2Mbps

Protocol Architecture



LAPF Functionality

- LAPF (Link Access Procedure for Frame Mode Bearer Services) defined in Q.922
- only core functionality used:
  - frame delimiting, alignment and transparency
  - frame mux and demux using addressing field
  - ensure frame is integral number of octets
  - ensure frame is neither too long nor short
  - detection of transmission errors
  - congestion control functions
- form sub-layer of data link layer
  - data transfer between subscribers only

Frame Relay Data Link Connections

- logical connection between subscribers
- data transferred over them
- not protected by flow or error control
- uses separate connection for call control
- overall results in significantly less work in network

User Data Transfer

- only have one frame type which
  - carries user data
- no control frames means
  - no inband signaling
  - no sequence numbers
- flag and FCS function as in HDLC
- address field carries DLCI
- DLCI (Data Link Connection Identifier) has local significance only

Summary

- circuit verses packet switching network approaches
- X.25
- frame relay

References

- http://people.seas.harvard.edu/~jones/cscie129/nu_lectures/lecture11/switching/clos_network/clos_network.html
- Switch design http://www2.cs.uh.edu/~johnsson/cosc6365_08/Lecture09_S.pdf
- Circuit-Switched Coherence *www.eecg.toronto.edu/~enright/**circuit-switched**-coherence.ppt*