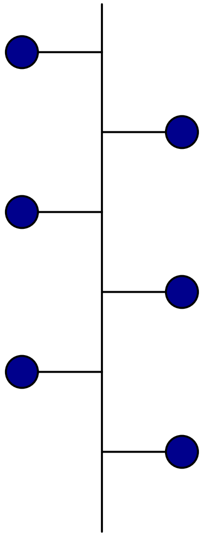
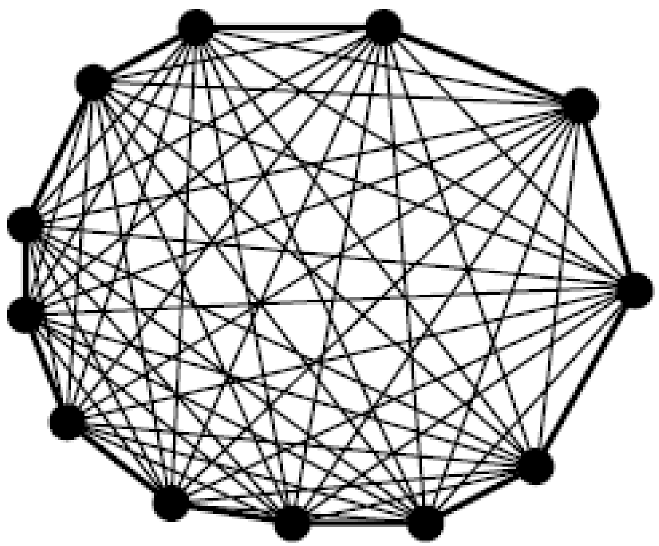
Unit 5
Switching Principles

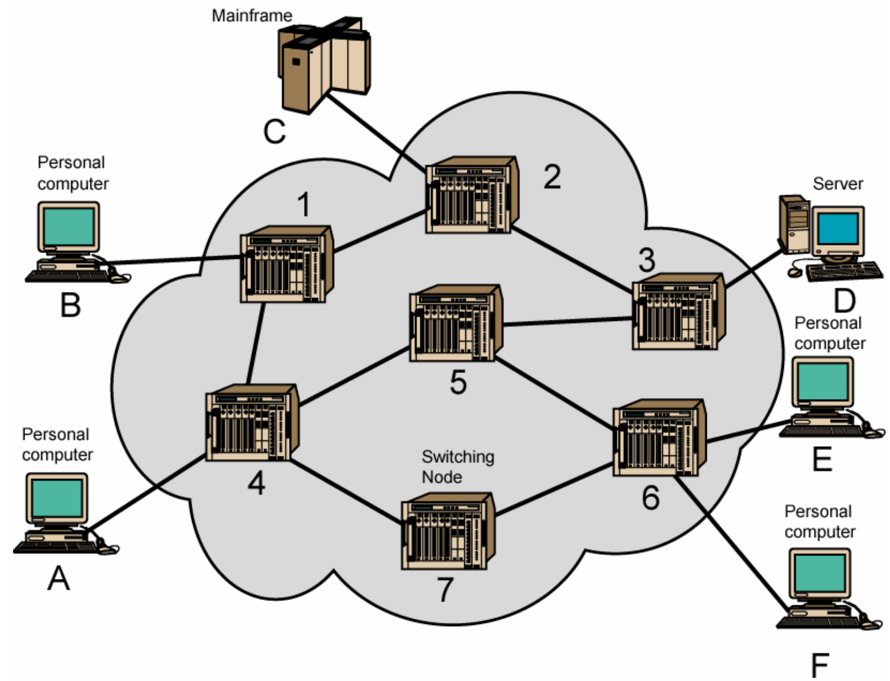


Acknowledgements – slides comming from:

- **Data and Computer Communication** by Wiliam Stallings (our supplementary textbook) – numerous slides!
- **Data Communications and Networking** by B. **Forouzan**, Mc Graw Hill, 2004
- Some figures have been used form the earlier issues of the EECS 122 tought by Prof Jean Walrand.
- **Introduction to Telephones & Telephone Systems** by A. Michael Noll, Artech House, 1986

Switching

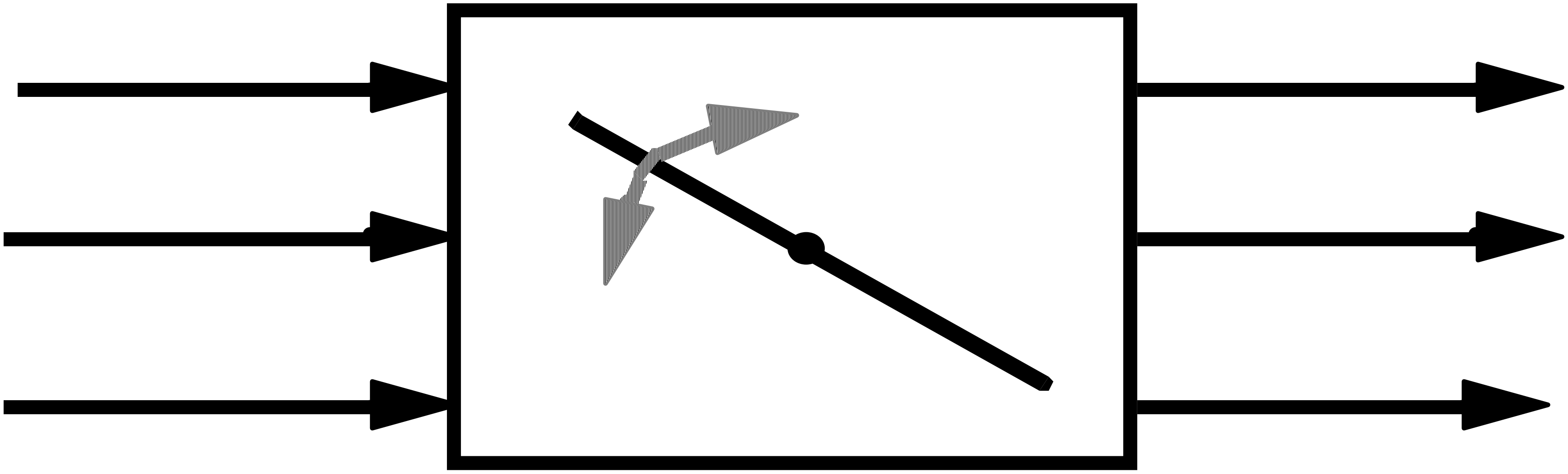




- It is NOT efficient to build a physically separate path for each pair of communicating end systems (*left picture*).
- There is a set of path sections (e.g. electrical cables) and switches (*right picture*).

Circuit Switching – Principle

A connection between the ingoing and outgoing segments of the transmission path is established on demand, for the exclusive use of a pair of end users - until explicitly released



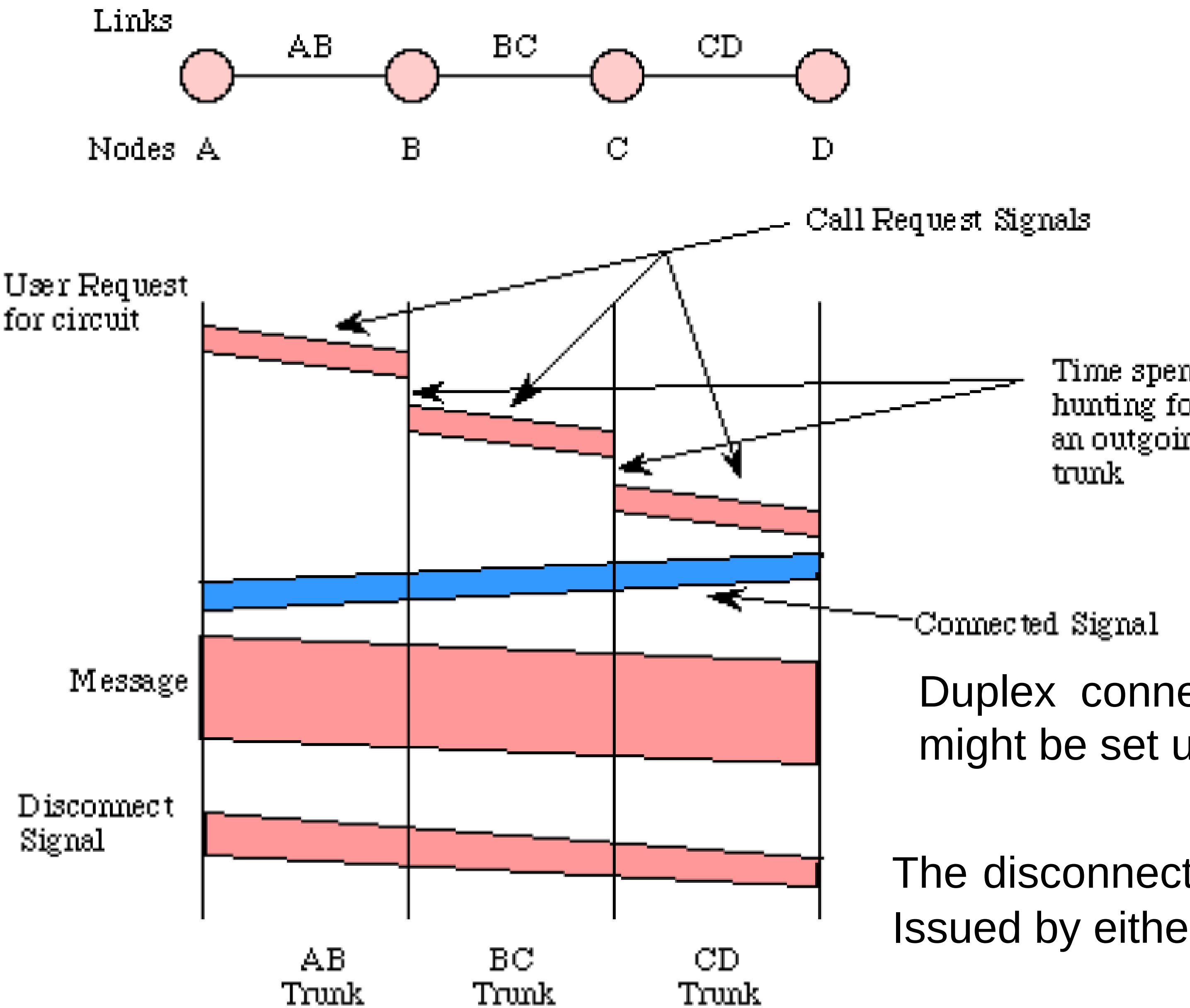
Circuit Switching – features

- The whole path is reserved for the single pair of end users - inefficient use of the path if there is bursty traffic
- The delay in transmission of user data is constant, determined *mainly* by the signal propagation
- Explicit setup and release of a switch setting is needed, the intention to setup/release a connection must be conveyed from the initiator to each switch (signaling)
  - Time is needed for both: propagation of the signaling information and operation of each switch, as well as propagation of the confirmation of path setting
- During the establishing/releasing the path segments can not be used – but later the resources are assured!!!

Perfect for LONG transmissions of flows with pretty constant bit rate!!!

Circuit Switching

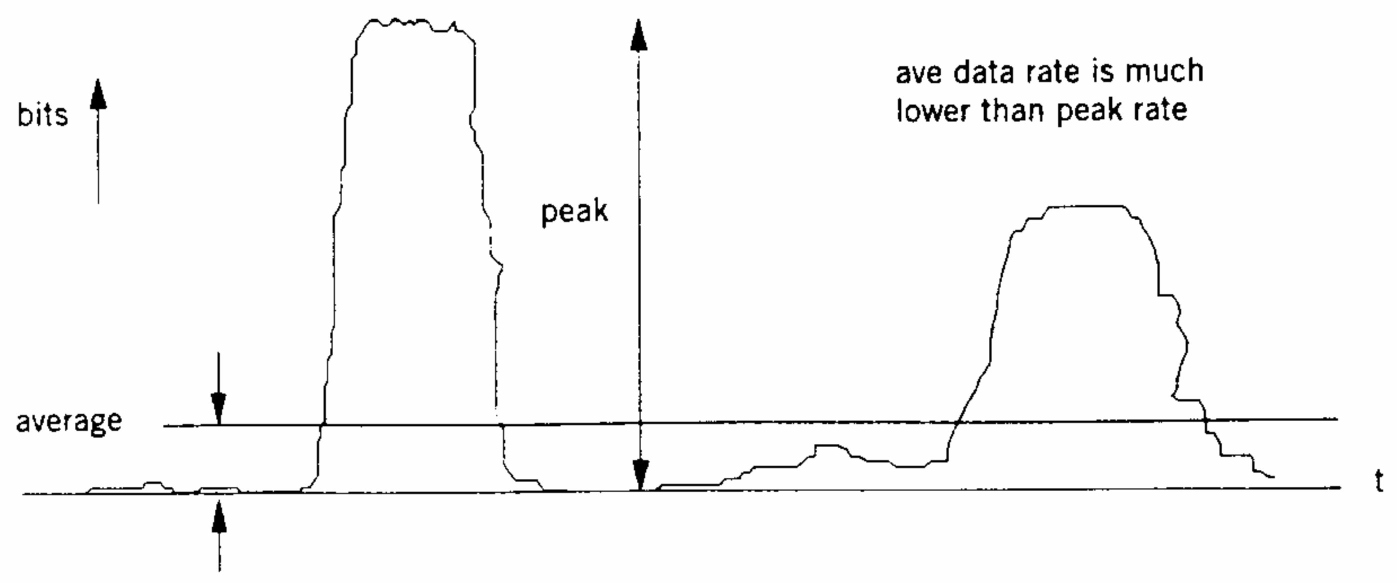
[Fairhurst]



Duplex connectivity might be set up...

The disconnect might be Issued by either side!!!

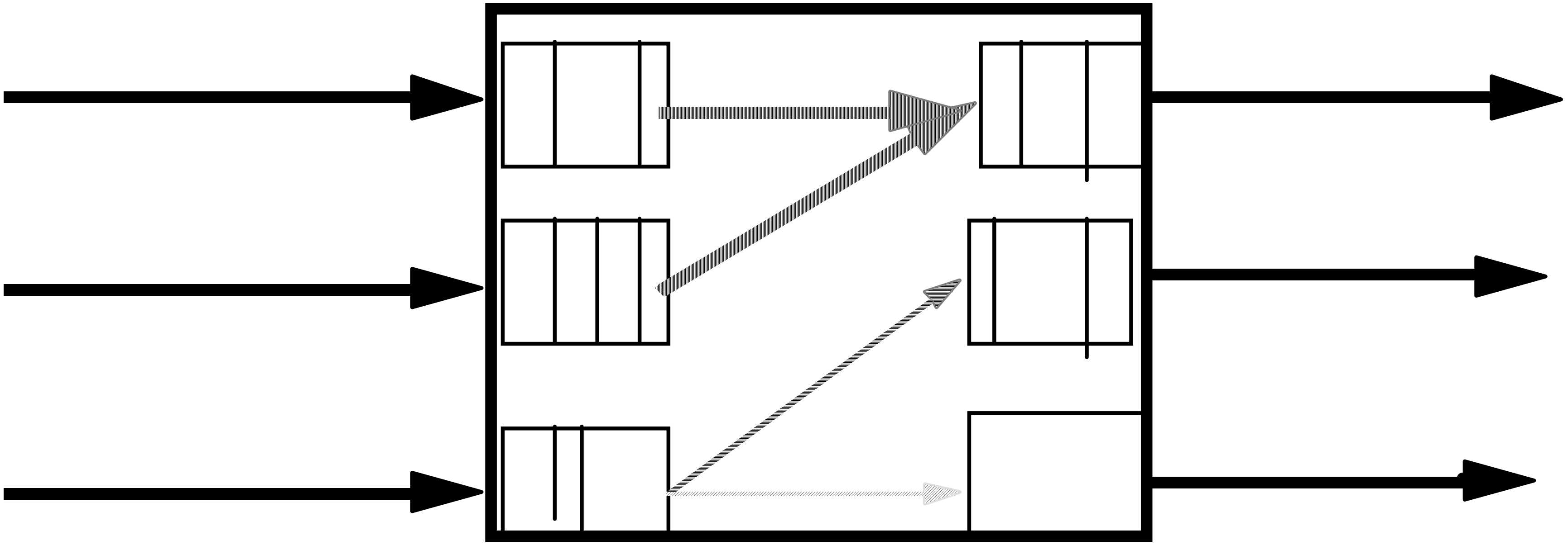
Comparison of Switching Techniques- again…



- Burstiness of data
  - In many data communication applications, data occur in bursts separated by idle periods
  - This type of intermittent data can often be transmitted more economically by assembling the data into packets (or messages) and interspersing packets from several channels on one physical communication path

Message Switching – Principle!

- There does exist a permanent connection between each input and each output of the switch (like a fully connected matrix or shared memory).
- The user generated data units (messages) have to carry information uniquely defining the route to be chosen (header)



Message Switching - features

- Path capacity is used more efficiently- multiplexing of different flows (pairs of users) on a single path segment takes place

- Each message must carry a header with routing information. This header must be processed upon arrival of the message to the switch.
  - Usually the store and forward principle is used. Cut-through principle fairly difficult to implement.

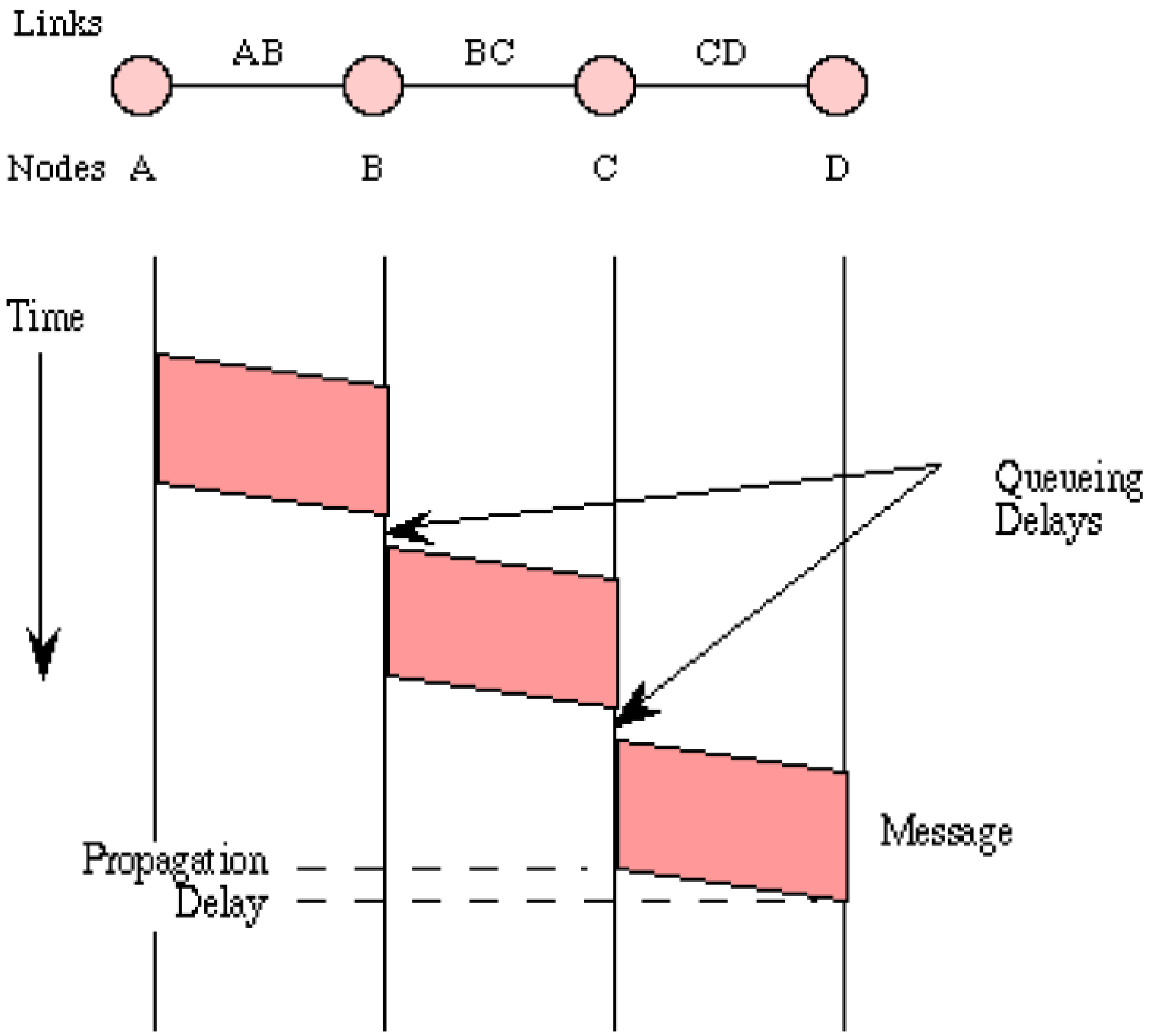
- Buffering is needed in the switches in order to avoid overloading of the output segments - thus variable queuing delay is enforced in addition to the propagation delay.

- The transmission can start immediately

- *Variable data length makes the control (e.g. memory management) difficult*

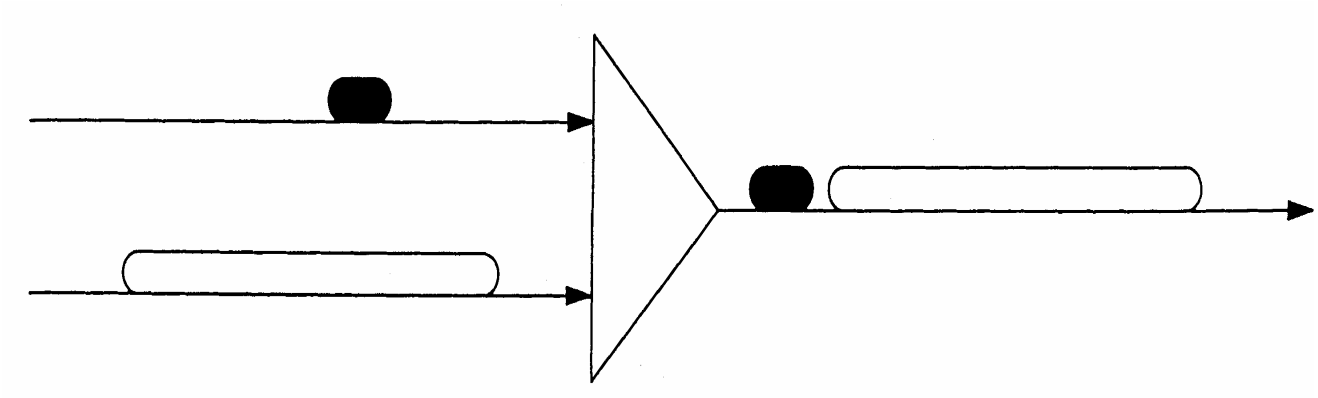
Message switching

[Fairhurst]



Serialization

- Small message caught behind big message



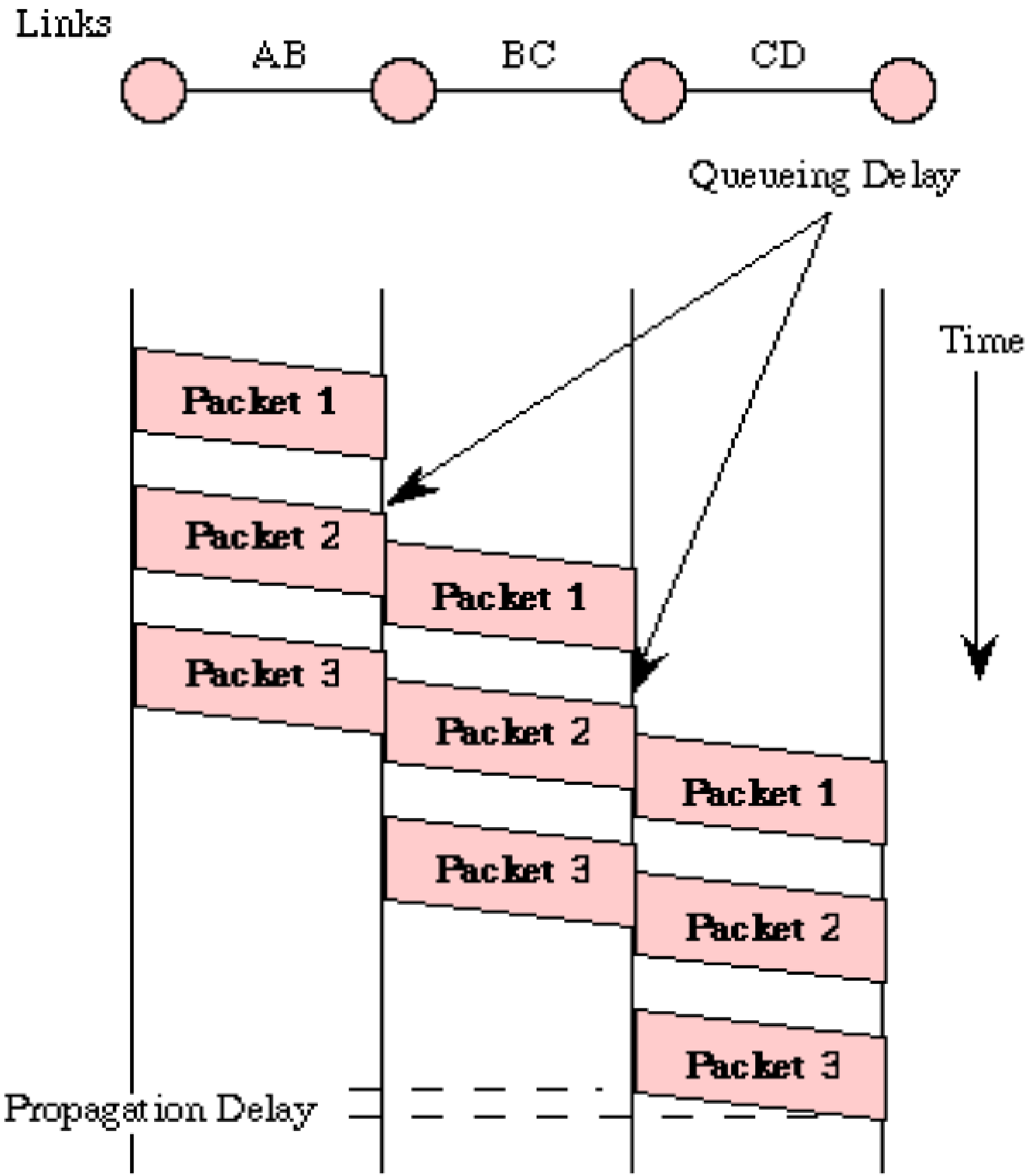
Packet Switching – Principle and features

A similar approach as above, but the length of the transmitted information is limited to a certain, user independent block- called the packet.

- The above mentioned effect is removed…
- Packets have a unique maximal size, making the control (e.g. memory management, header processing) easier.
- There is a pipelining effect, increasing the path utilization
- There is an overhead for dividing messages into packets and putting them together within the end systems
- The processing overhead within the switch (e.g. routing) is pro packet rather than pro message
- The information overhead is pro packet rather than pro message

Packet switching

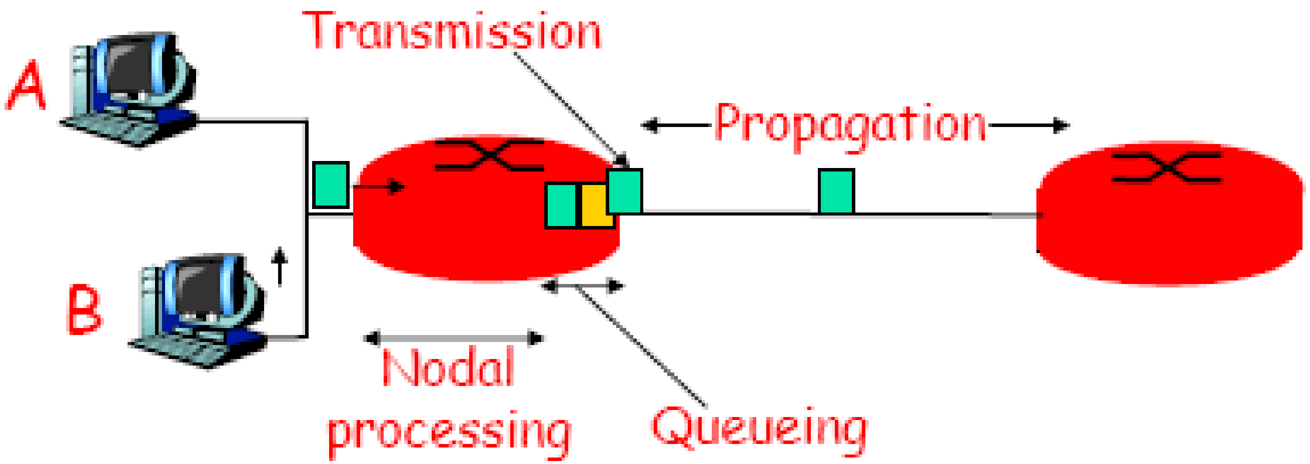
[Fairhurst]



Delay on the way – summary

[Source: Dr. Cheng Lehigh Univ.]

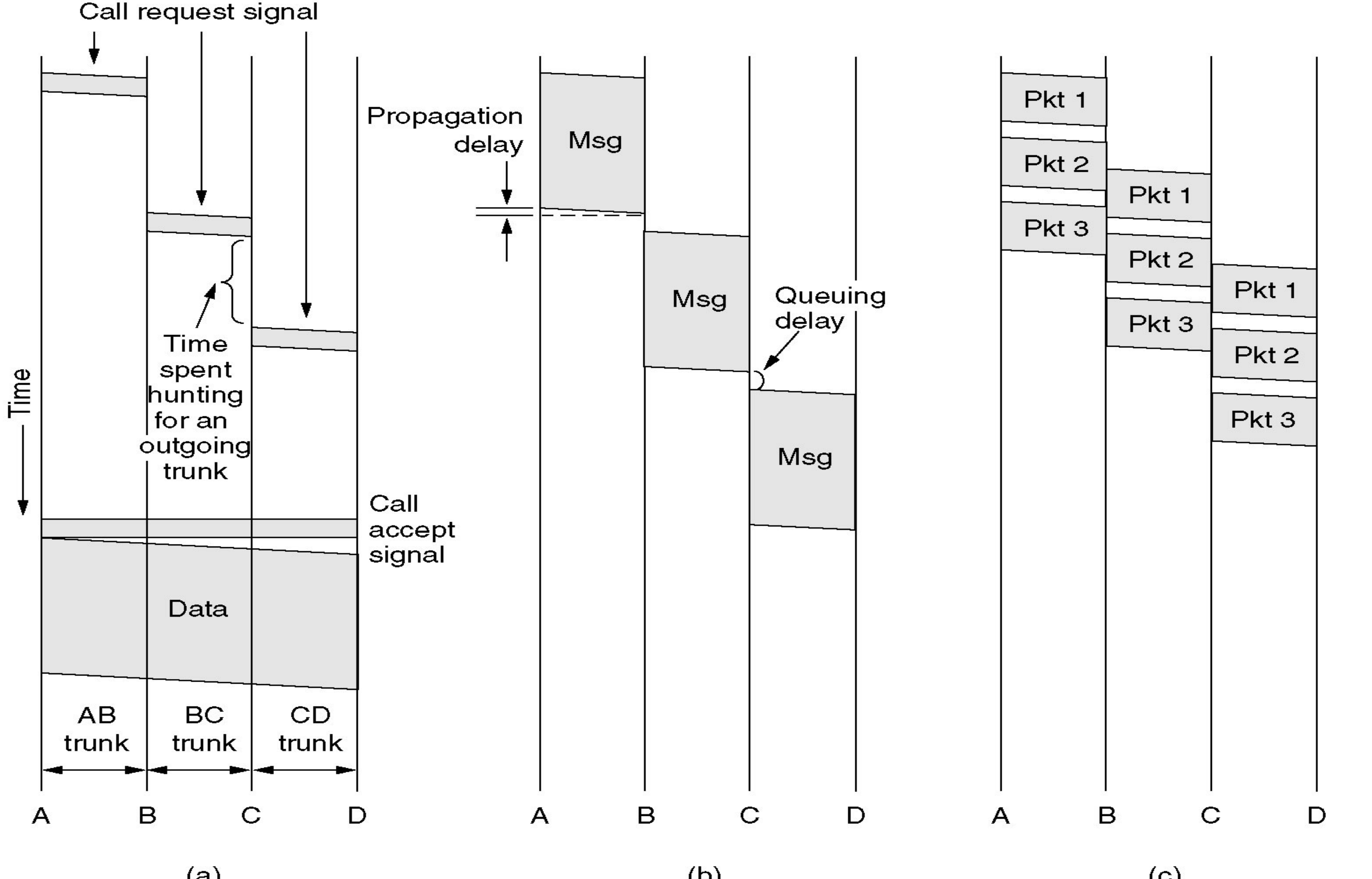
1. Nodal processing:
   - Check bit errors
   - Determine output
2. Queueing
   - Time waiting at output for trans.
   - Depends on congestion at router
3. Transmission delay:
   - R=link bandwidth (bps)
   - L=packet length (bits)
   - Time to send bits into link: L/R
4. Propagation delay:
   - d = length of physical link
   - s = propagation speed in medium
   - Propagation delay = d/s



More features:

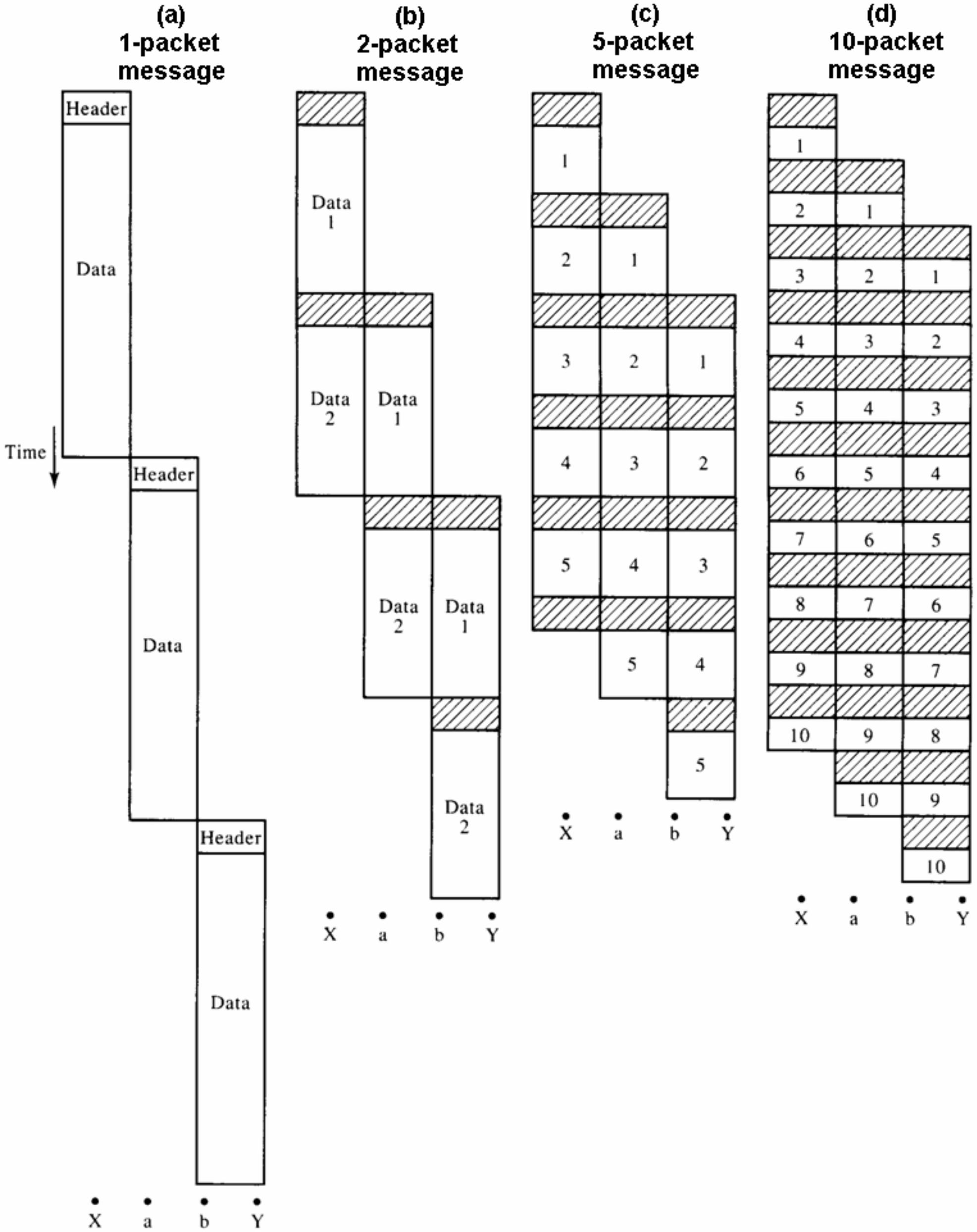
- Line efficiency (+)
  - Single node to node link can be shared by many packets over time
  - Packets queued and transmitted as fast as possible
- Data rate conversion (+)
  - Each station connects to the local node at its own speed
  - Nodes buffer data if required to equalize rates
- Packets are accepted even when network is busy (-)
  - Delivery may slow down
- Priorities can be used per packet…

Comparison of switching approaches [Tannenbaum]



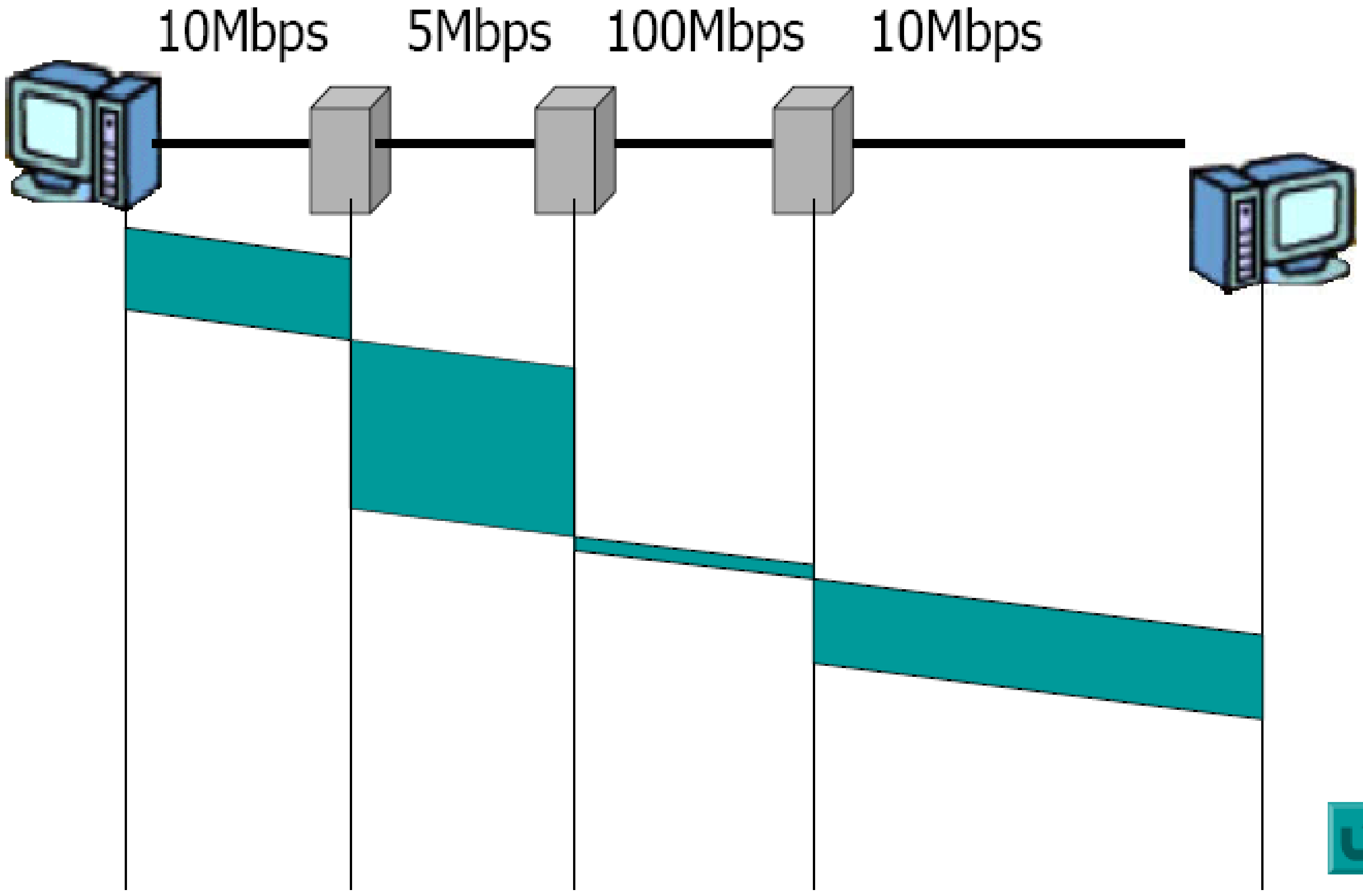
(a) Circuit switching (b) Message switching (c) Packet switching

Effect of Packet Size on Transmission Time

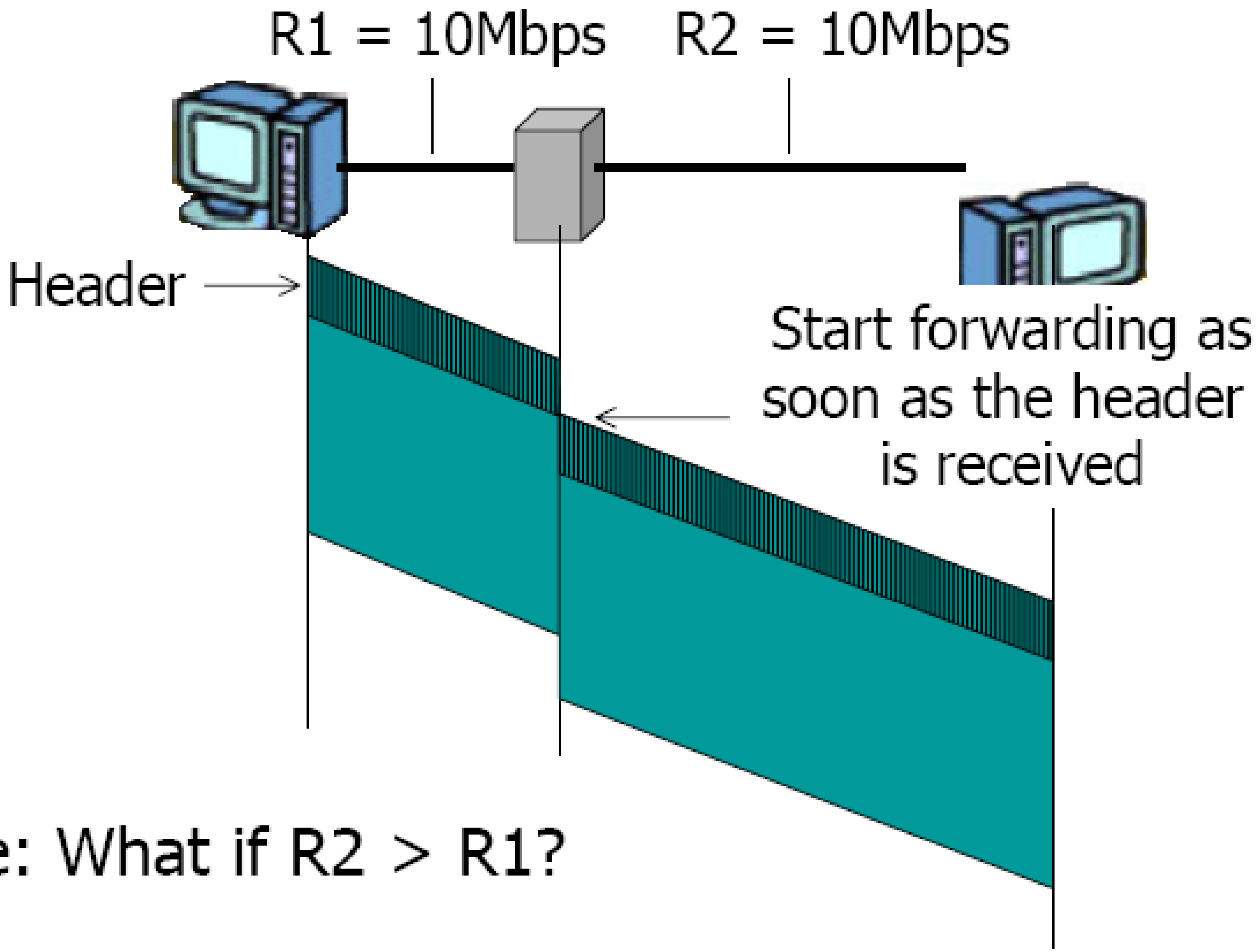


Store and forward packet switching

[eecs122, walrand]

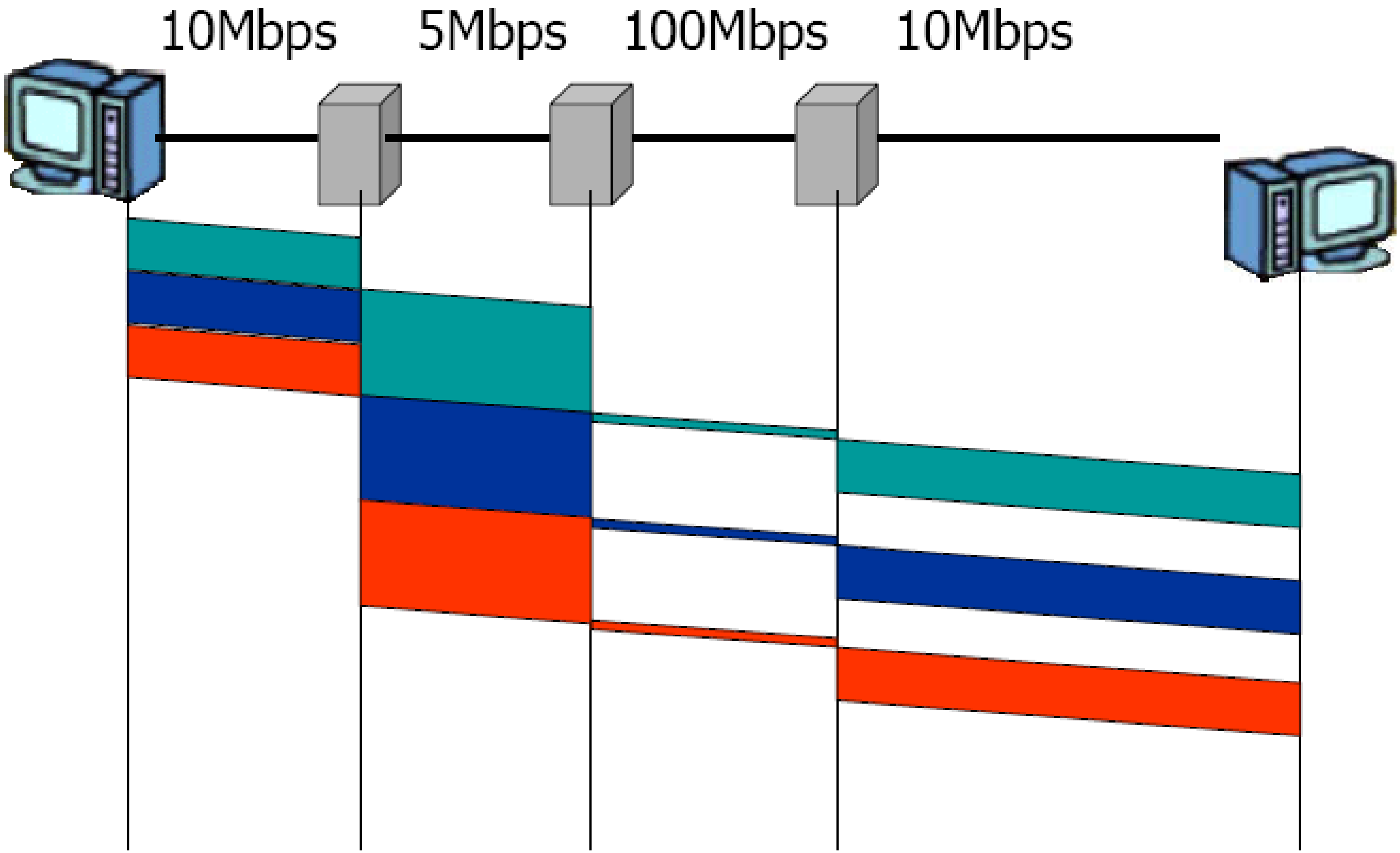


Cut-thorugh packet switching



Note: What if R2 > R1?

Bottleneck...



It is possible to estimate the bottelneck trhoughput sending „back –to-back“ packets of constant length and observing the time difference between their Arrival times...

Details of Packet Switching Techniques

- Packets can be handled in two ways
  - Datagram
  - Virtual circuit

DATAGRAMS

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets

Datagrams

- Simple idea:
  – don't set up a connection, just make sure each packet contains enough information to get it to destination
  – what is this? Complete destination address... or complete description of the route... (we will discuss this later!)
  – Different priorities per packet might be used..
- Processing of a datagram:
  – switch creates a table, mapping destinations to output port (ignores input ports)
  – when a packet with a destination address in the table arrives, it pushes it out on the appropriate output port
  – when a packet with a destination address not in the table arrives, something clever has to be done (a different problem!)
- Where does the content of this tables come from? This is again a separate issue (Routing! _ will discuss it later!)

Tables for datagram processing

Each destination has to be listed in this tables *(well – at least the „region“ in which the destination is... This is hierarchy..)*

Node 3

Destination	Next node
1	1
2	4
4	4
5	6
6	6

Node 1

Destination	Next node
2	2
3	3
4	4
5	2
6	3

Node 6

Destination	Next node
1	3
2	5
3	3
4	3
5	5

Node 4

Destination	Next node
1	1
2	2
3	3
5	5
6	3

Node 2

Destination	Next node
1	1
3	1
4	4
5	5
6	5

Node 5

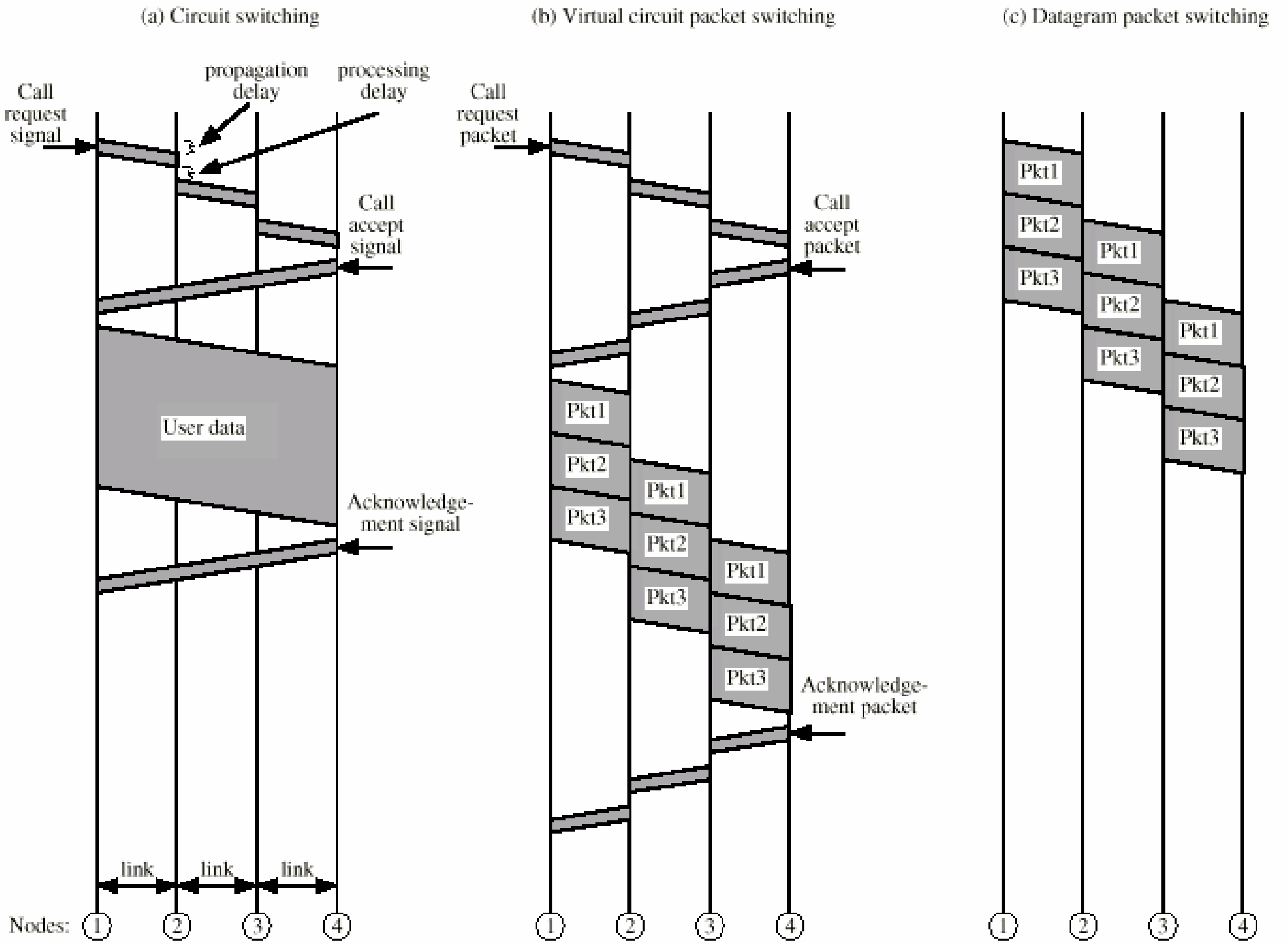
Destination	Next node
1	4
2	2
3	4
4	4
6	6

Why Virtual Circuit Packet Switching

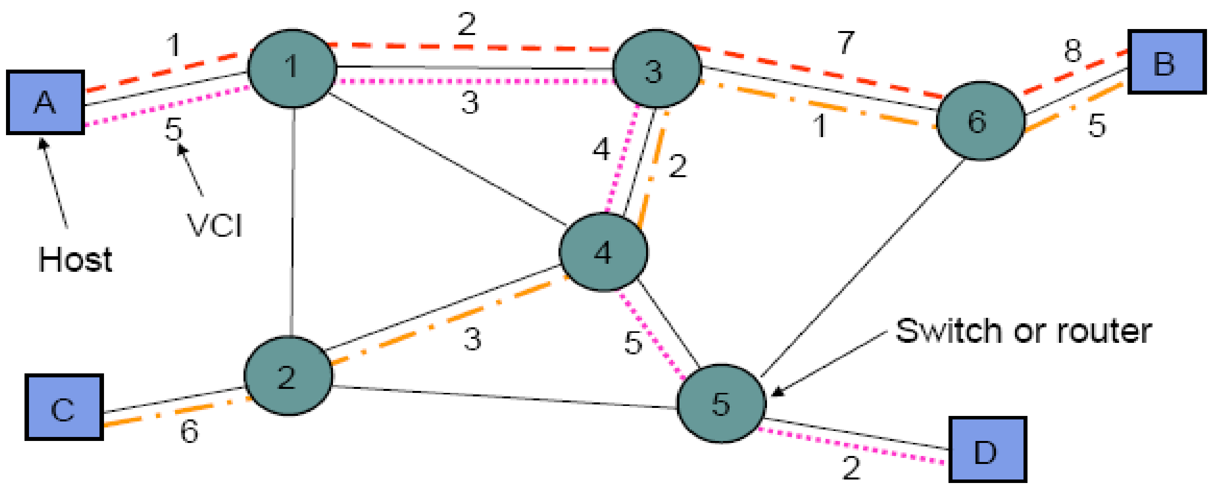
- The idea is to combine the advantages of circuit switching with the advantages of datagram switching

- Virtual circuit packet switching:
  - After a small connection setup phase only short (compared to full addresses) connection identifier are used per packet; this reduces the addressing overhead per packet
  - During the setup phase, a table is created stating how to process a packet with the corresponding connection identifier; this reduces the per packet processing! – very important for high speed links…

Event Timing



How das forwarding work in VCs?… (Garcia, Ch7)



Node 1

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
A	1	3	2
A	5	3	3
3	2	A	1
3	3	A	5

Node 3

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
1	2	6	7
1	3	4	4
4	2	6	1
6	7	1	2
6	1	4	2
4	4	1	3

Node 6

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
3	7	B	8
3	1	B	5
B	5	3	1
B	8	3	7

Node 4

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
2	3	3	2
3	4	5	5
3	2	2	3
5	5	3	4

Node 2

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
C	6	4	3
4	3	C	6

Node 5

Incoming Node	Incoming VCI	Outgoing Node	Outgoing VCI
4	5	D	2
D	2	4	5

Virtual circuit issues

- Good: easy to associate resources with flows
  - can guarantee buffering and delay, as well as care for Sequencing and Luck of errors. This makes "quality of service" guarantees (QoS) easy to provide
  - Also good: VCI small, making per-packet overhead small.
- Bad: not good in the face of crashes
  - doesn't handle host crashes well: each connection has state stored throughout network. to close connection, host must explicitly issue a "tear down."
  - In general, to survive failure, want to make stuff as "stateless" as possible, trivially eliminating any storage management problems.
  - Doesn't handle switch crashes well: have to teardown and reinitiate a new circuit

ATM

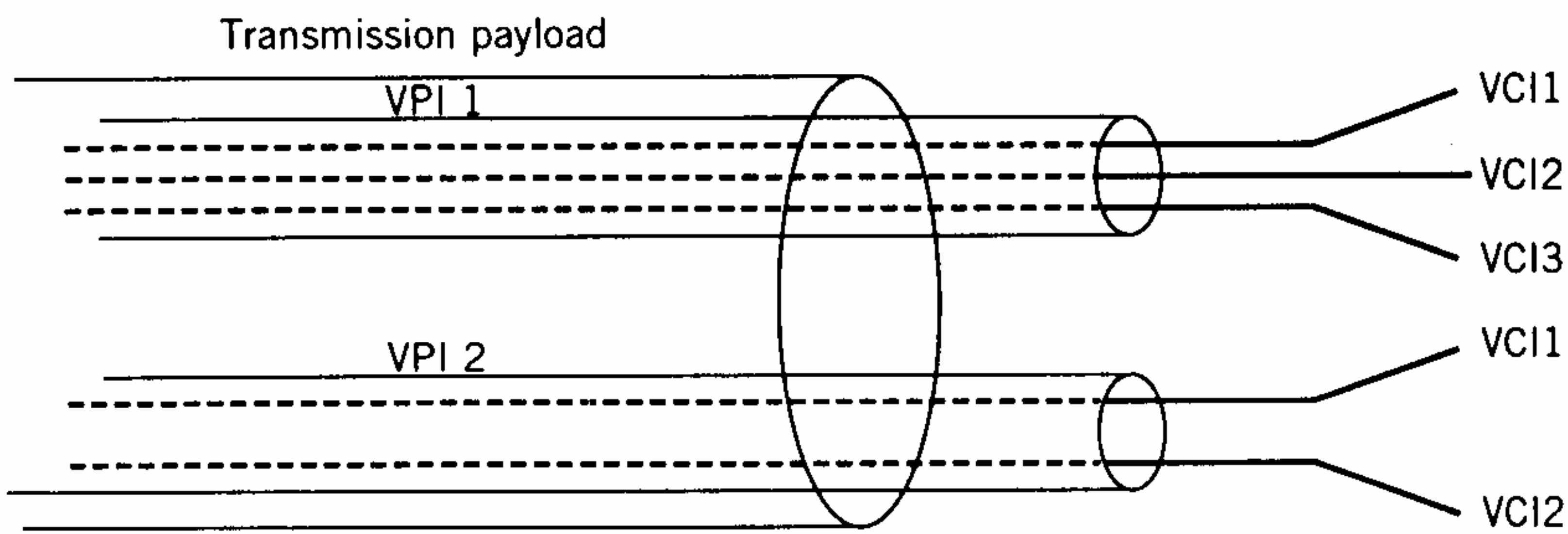
example of virtual circuit usage

Introduction to ATM

- ATM is based on some important concepts:
  - virtual circuits
  - fixed-size packets or cells
  - small cell size
  - statistical multiplexing
  - integrated services
- Usage of small and fixed sized packets simplifies the processing inside a switch and thus enables very high data rates (155,52 Mbps and 622,08 Mbps are common; higher rates are possible)
- Two protocol layer relate to ATM functions:
  - **the ATM layer** for all services that provide fixed-size packet transfer capabilities and
  - the **ATM adaptation layer** (AAL) that is service dependent (e.g. not ATM based protocols)
- These concepts build a network that can carry multiple classes of traffic with quality-of-service guarantees

Extension of the flow identifier: VCCs and VPCs

- Virtual circuits are referred to as virtual channel connections (VCC)
- A second sublayer has been introduced: the concept of virtual path connections (VPC); a VPC is a bundle of VCC that have the same endpoint; this concept is used to decrease the control costs (esp. in high speed networks like ATM) for connections that share common paths

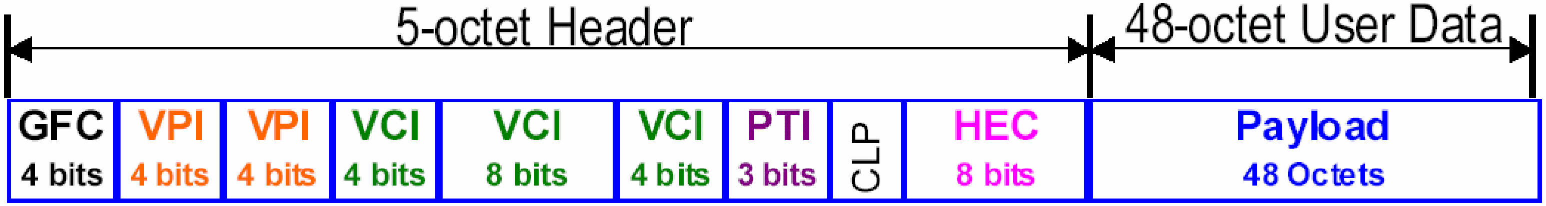


ATM connection identifier.

ATM Concepts: Small packets... (RPI)

- An ATM Layer packet has 53 bytes, including 5 Bytes header (8 bit VPI + 16 bit VCI) and 8 bit header error control...
- At 8KHz, each a byte comes every 125 microseconds
- The smaller the cell, the less an endpoint has to wait to fill it ➔*Low packetization delay, but*
- The smaller the packet, the larger the relative header overhead

ATM Cell Structure (for later discussion) [RPI]



- GFC - Generic Flow Control (4 bits)
  - Controls the flow of data across the UNI permitting multiple ATM devices to be attached to the same network interface
- VPI - Virtual Path Identifier (8 bits)
  - Contains the address of the Virtual Path for the end-to-end connection
- VCI - Virtual Channel Identifier (16 bits)
  - A pointer that identifies the virtual channel the system is using on a particular path
- PTI - Payload Type Identifier (3 bits)
  - Indicates the type of traffic contained in the cell (User Information or Control)
- CLP - Cell Loss Payload (1 bit)
  - Indicates droppability or non-droppability of a cell during congestion
  - 1 = droppable; 0 = not droppable
- HEC - Header Error Control (8 bits)
  - Provides error control for single-bit errors and error detection for multiple-bit errors in the cell error
- Payload - User Information

ATM Adaptation Layer

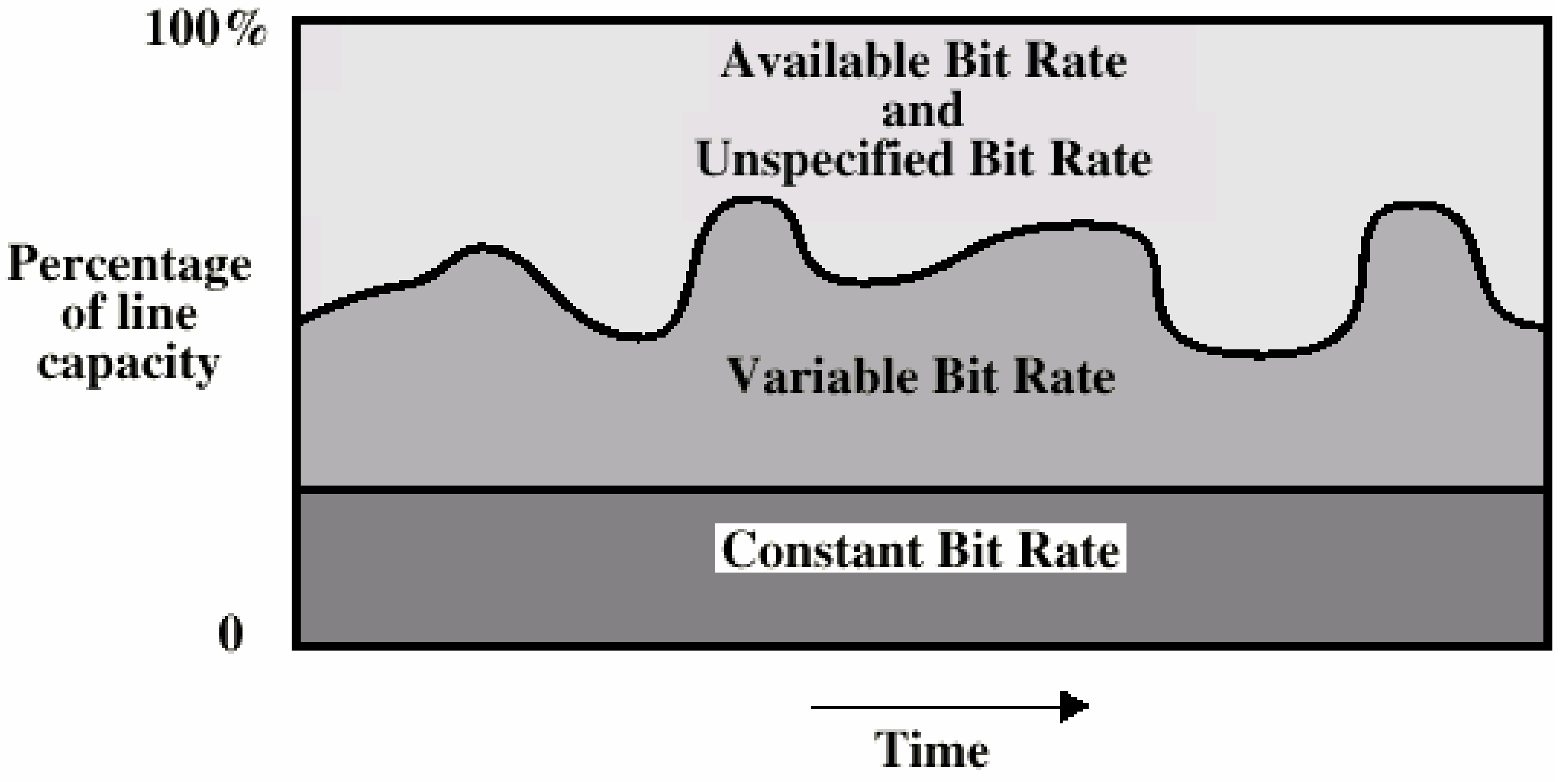
The AAL may enhance the service provided by the ATM Layer to the requirements of a specific service (user, control, management).

- Acts on ATM Layer data streams (mapping for the next higher layer)
- Different requirements of the protocols on top of the AAL

  → several AAL protocols are required

- AAL protocols are characterised by a common set of functions
  - required by several protocols to be run over an ATM network
  - specific adaptation requirements of protocols (originally designed for other network types)

ATM Service Categories (Stallings)



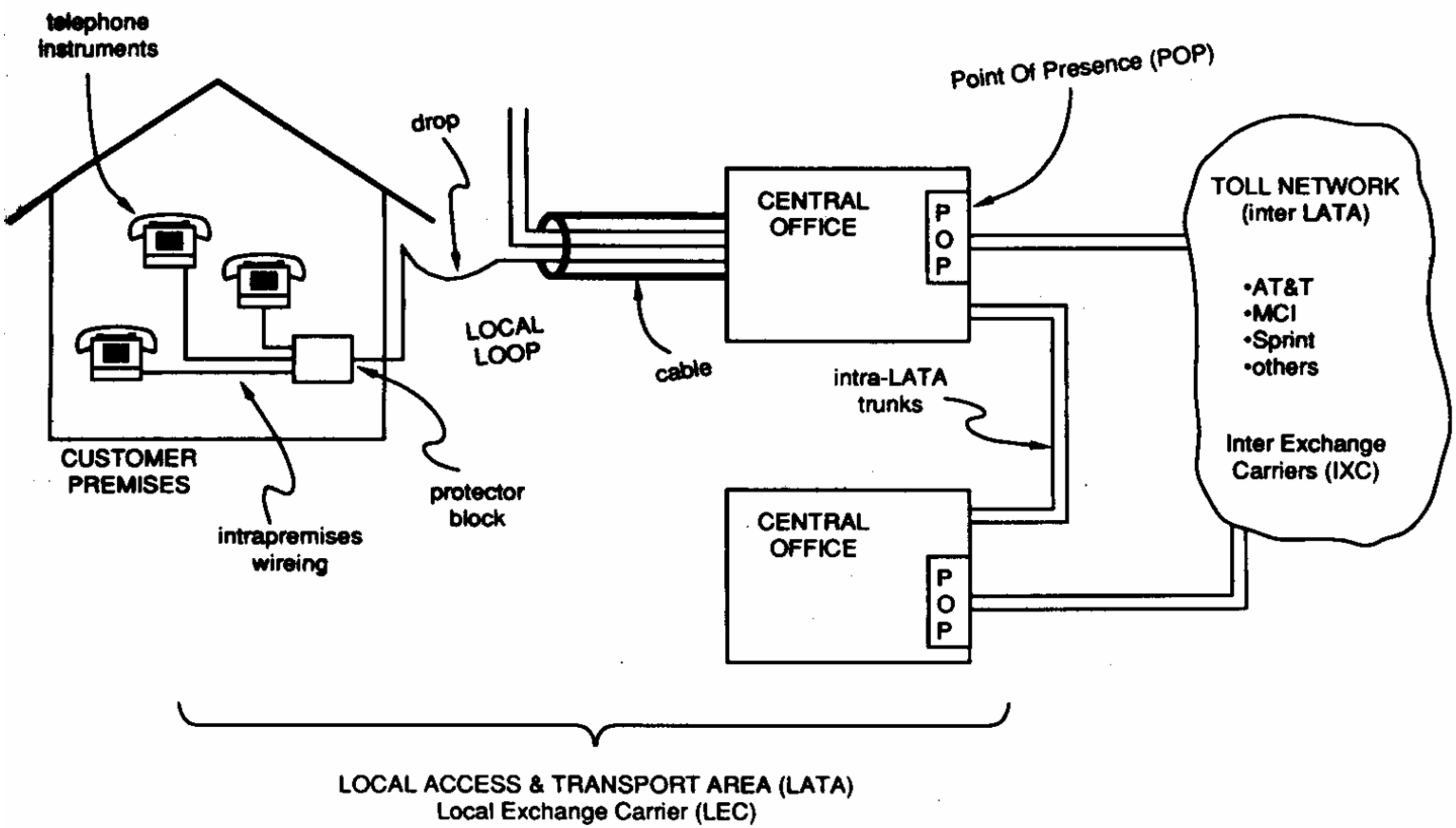
- ABR (Available bit rate): Source follows network feedback. Max throughput with minimum loss.
- UBR (Unspecified bit rate): User sends whenever it wants. No feedback. No guarantee. Cells may be dropped.

Telephone Network

POTS: Plain Old Telephone Network

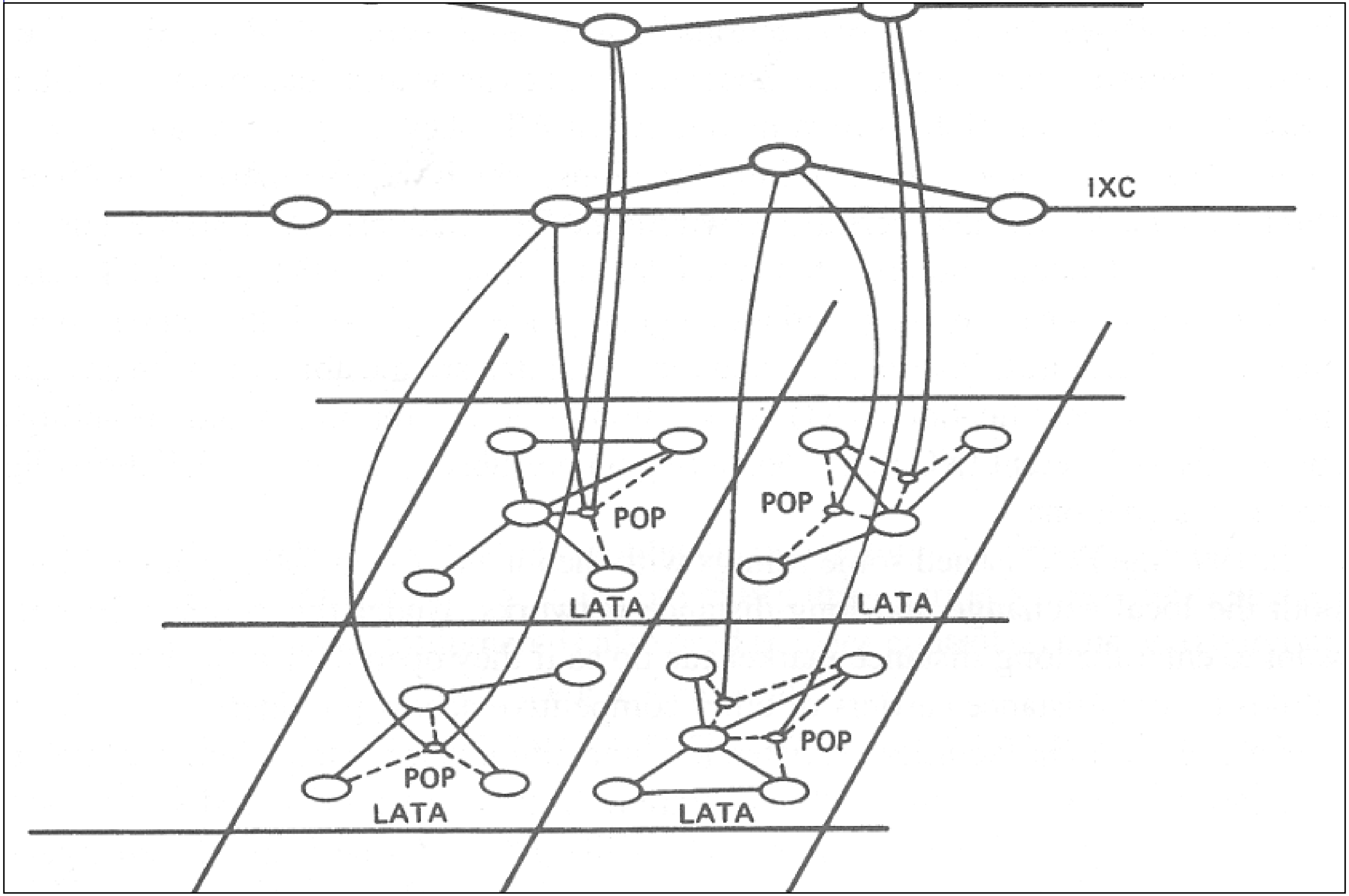
(a classical Circuit switching Network)

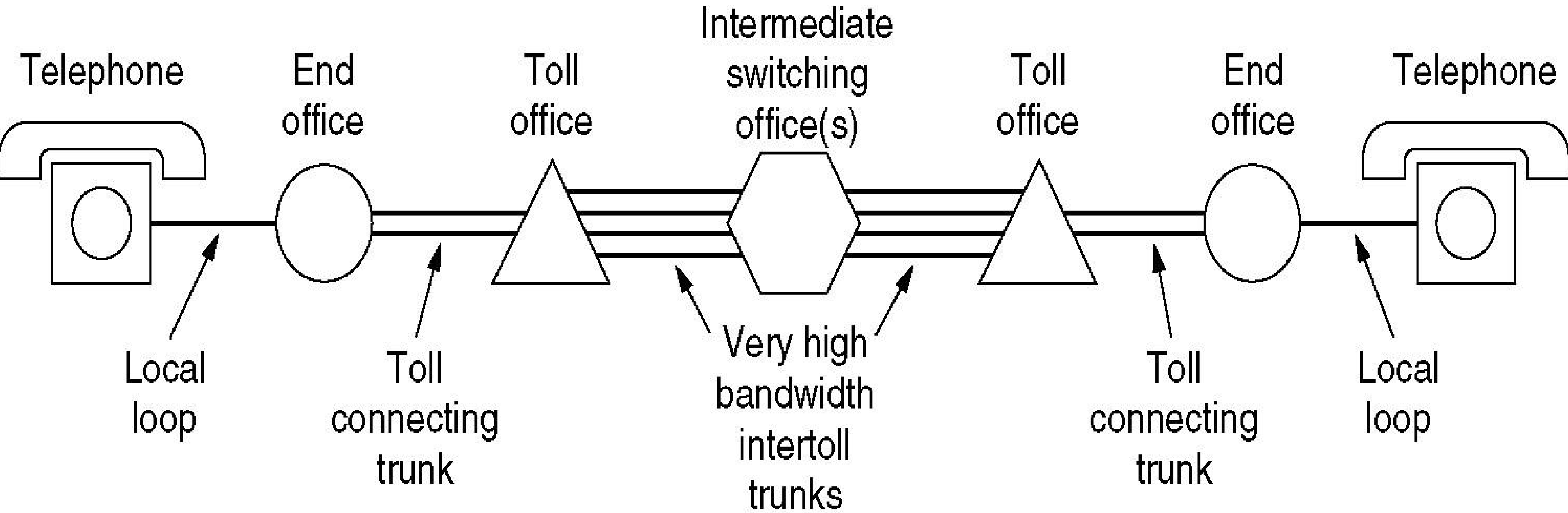
Components of the Telephone Network



A telephone call involves much switching and transmission equipment. Each telephone is connected to a central office by a pair of wires called the local loop. The first stage of switching occurs at the serving central office. Calls to another office within the local access and transport area (LATA) are carried over interoffice trunks. Calls outside the LATA are handled by interexchange carriers over their own transmission and switching facilities. The point of presence is the place where the IXC connects to the facilities of the local exchange carrier.

US structure after 1984 divestiture





- The local loop is analog.
- The toll connecting trunks are – recently – usually digital
- The chain: Analog - digital – Analog.

But: Telephony is MUCH more than VOICE Transmission!
Be aware of SIGNALLING

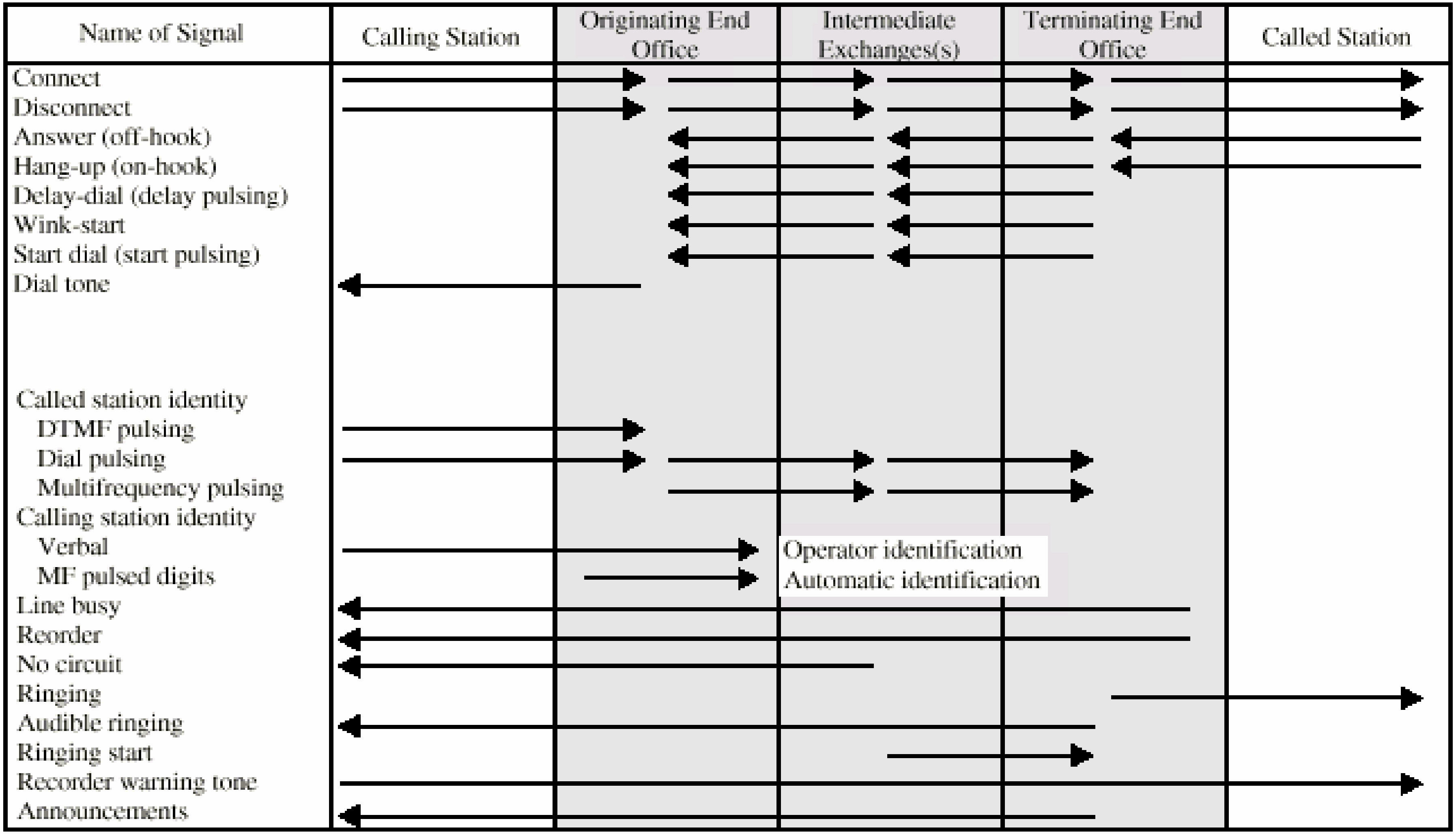
Signaling- Basics

- Signaling is needed in networks to control their operation and to indicate the status.

- Subscriber-Loop Signaling
  - Audible communication with the subscriber (dial tone, ringing tone, busy signal and so on).
  - A signal to make the telephone ring
  - Transmission of the number dialed to central office

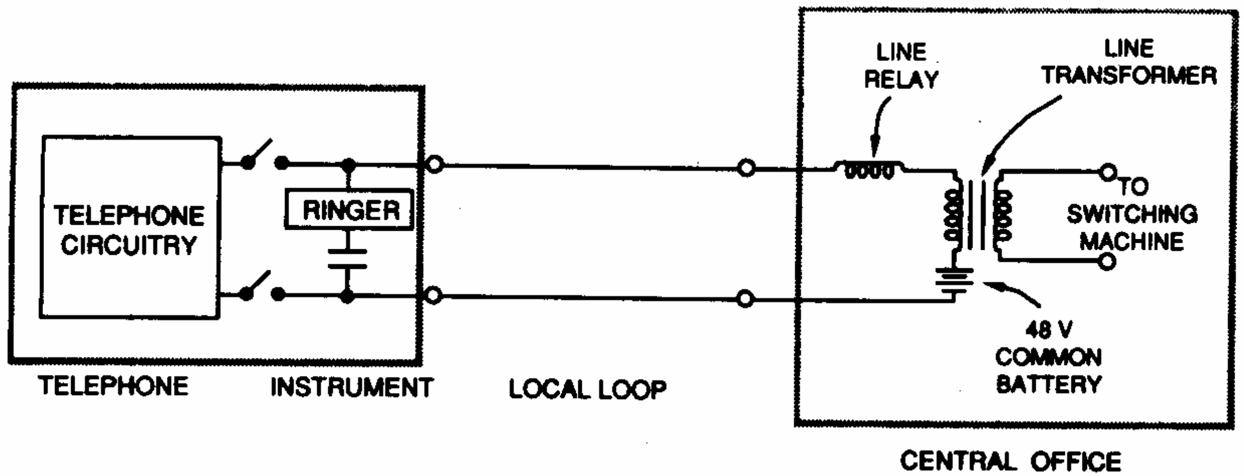
- Interoffice Signaling
  - Transmission of information between switches (e.g.: setting up a call, indicating that a call establishment is completed, can not be completed, or has ended)
  - Transmission of information for billing purposes
  - Transmission of diagnosis-relevant information

Control Signals (origin-destination)



Note: A broken line indicates repetition of a signal at each office, whereas a solid line indicates direct transmittal through intermediate offices.

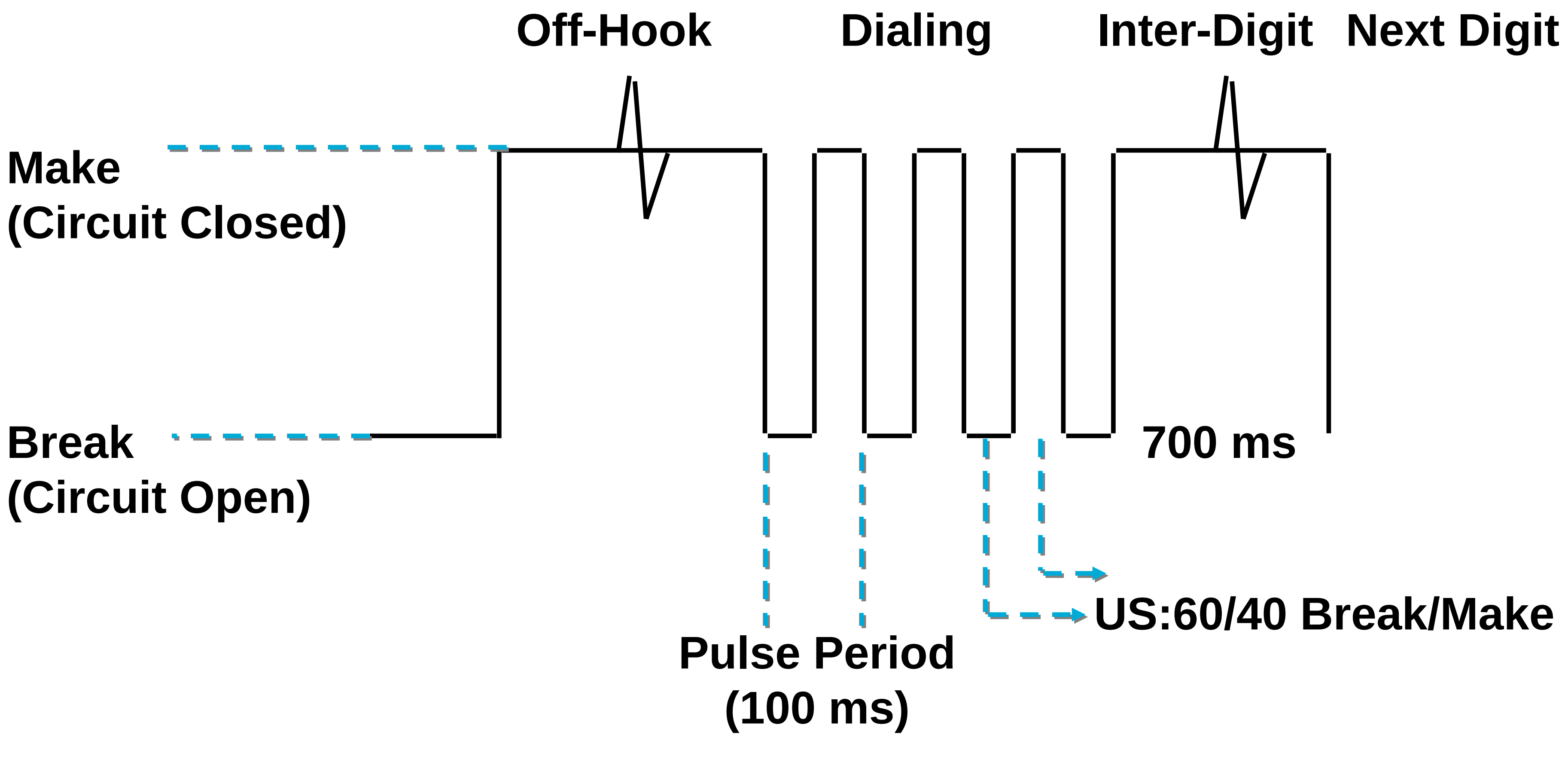
The Local Loop Signalling



The 48-volt common battery is located at the central office. The circuitry in the phone instruments draws direct current from the local loop. The flow of dc over the local loop is sensed by a line relay at the central office. A transformer connects the local loop to the switching equipment so that only the ac speech signal continues. The ringer in the telephone instrument is always connected across the line, and a capacitor prevents direct current from flowing through it.

The ringing voltage consists of bursts of a pure tone, or sine wave, at a frequency of 20 Hz and with a rms electromotive force of 75 volts. The bursts are on for 2 seconds and off for 4 seconds.

Pulse Dialing



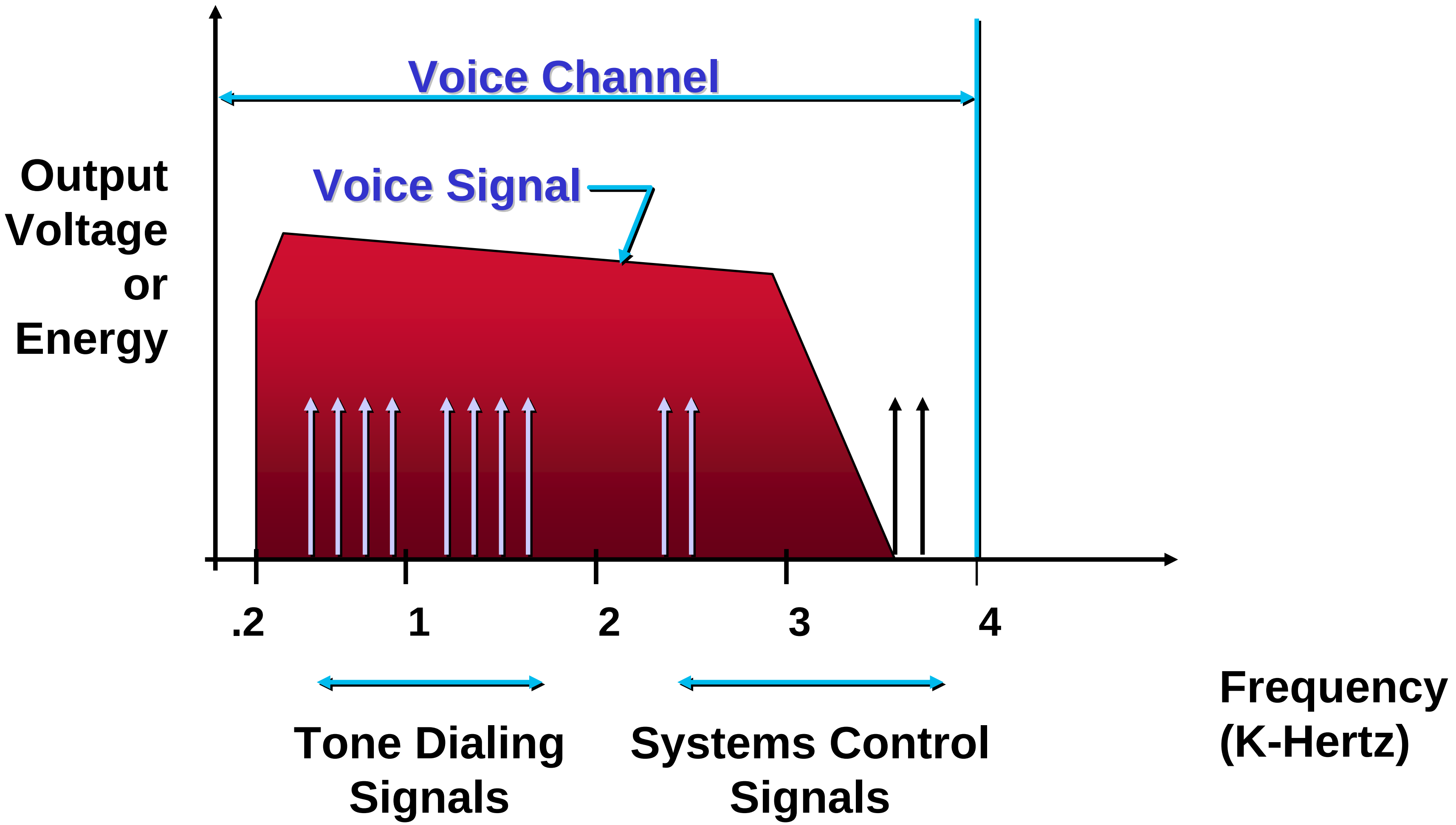
Tone Dialing

Dual Tone Multifrequency (DTMF)

	1209	1336	1477	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

Timing:
60 ms Break
40 ms Make

Voice Channel Bandwidth



Signalling on digital trunks is much more complex....

Signaling Variants

Signaling Techniques for Circuit-Switched Networks

Technique	Description	Comment
Inchannel		
Inband	Transmit control signals in the same band of frequencies used by the voice signals.	The simplest technique. It is necessary for call information signals, and may be used for other control signals. Inband can be used over any type of line plant.
Out-of-band	Transmit control signals using the same facilities as the voice signal but a different part of the frequency band.	In contrast to inband, provides continuous supervision during the life of a connection.
Common Channel	Transmit control signals over signaling links that are dedicated to control signals and are common to a number of voice channels.	Reduces call setup time compared to inchannel methods. It is also more adaptable to evolving functional needs.

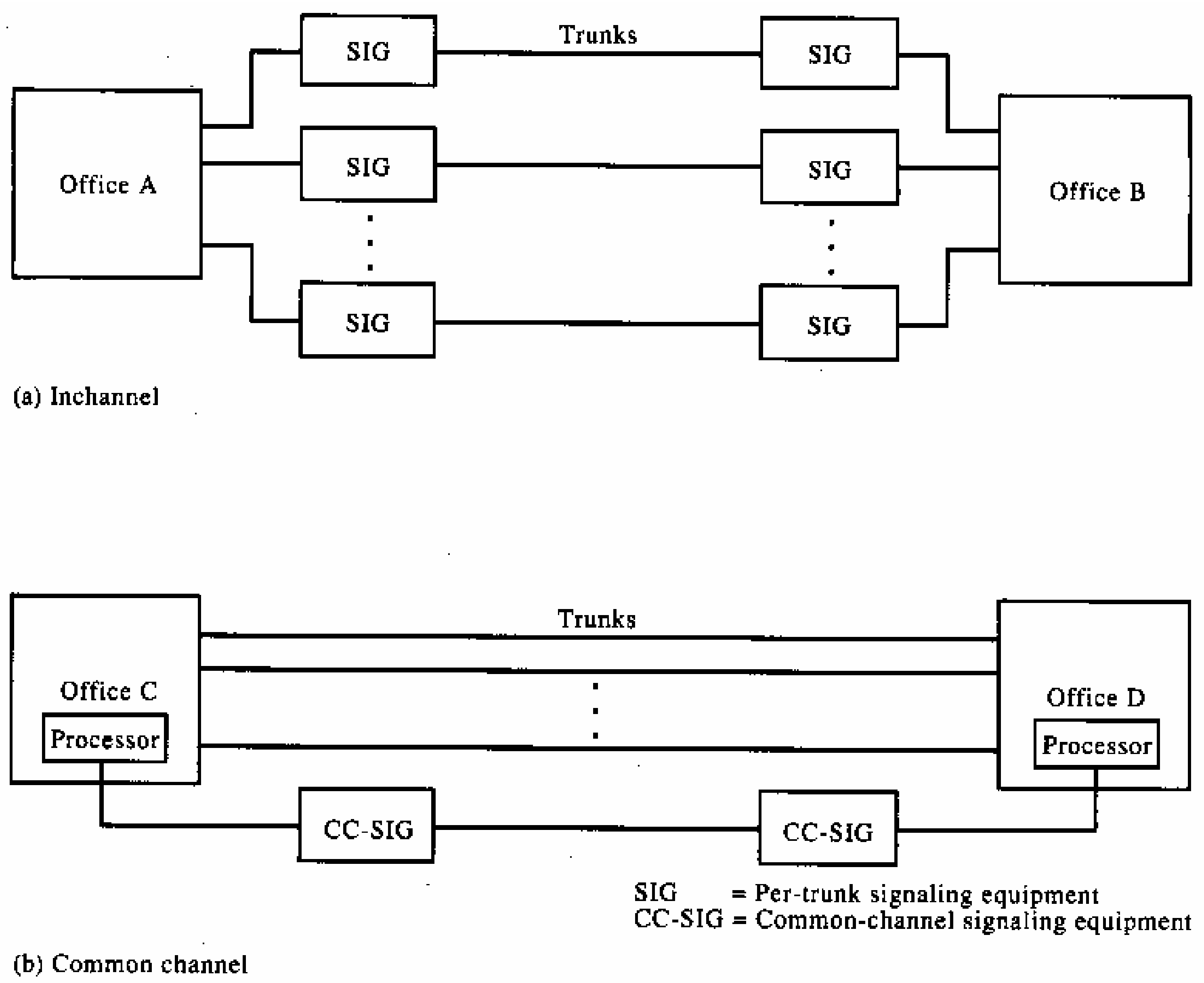
In Channel Signaling

- Use same channel for signaling and call
  - Requires no additional transmission facilities
- Inband
  - Uses same frequencies as voice signal (SF,MF,DTMF)
  - Can go anywhere a voice signal can
  - Impossible to set up a call on a faulty speech path
- Out of band
  - Voice signals do not use full 4kHz bandwidth
  - Narrow signal band within 4kHz used for control
  - Can be sent whether or not voice signals are present
  - Need extra electronics
  - Slower signal rate (narrow bandwidth)

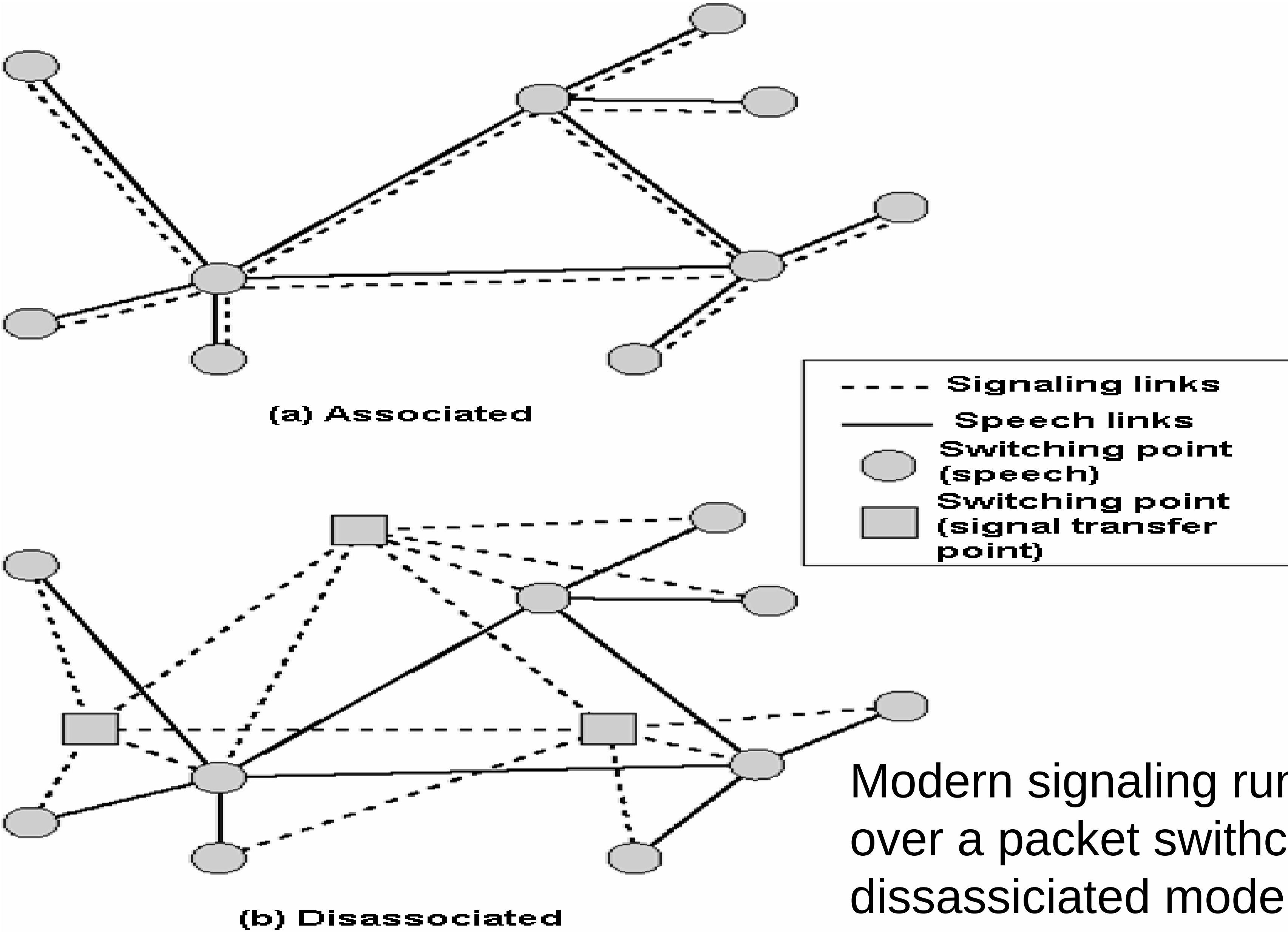
Common Channel Signaling

- Control signals carried over paths independent of voice channel
- One control signal channel can carry signals for a number of subscriber channels
- Common control channel for these subscriber lines
- Associated Mode
  - Common channel closely tracks inter-switch trunks
- Disassociated Mode
  - Additional nodes (signal transfer points)
  - Effectively two separate networks

Signaling: In Channel vs. Common Channel



Signaling Modes



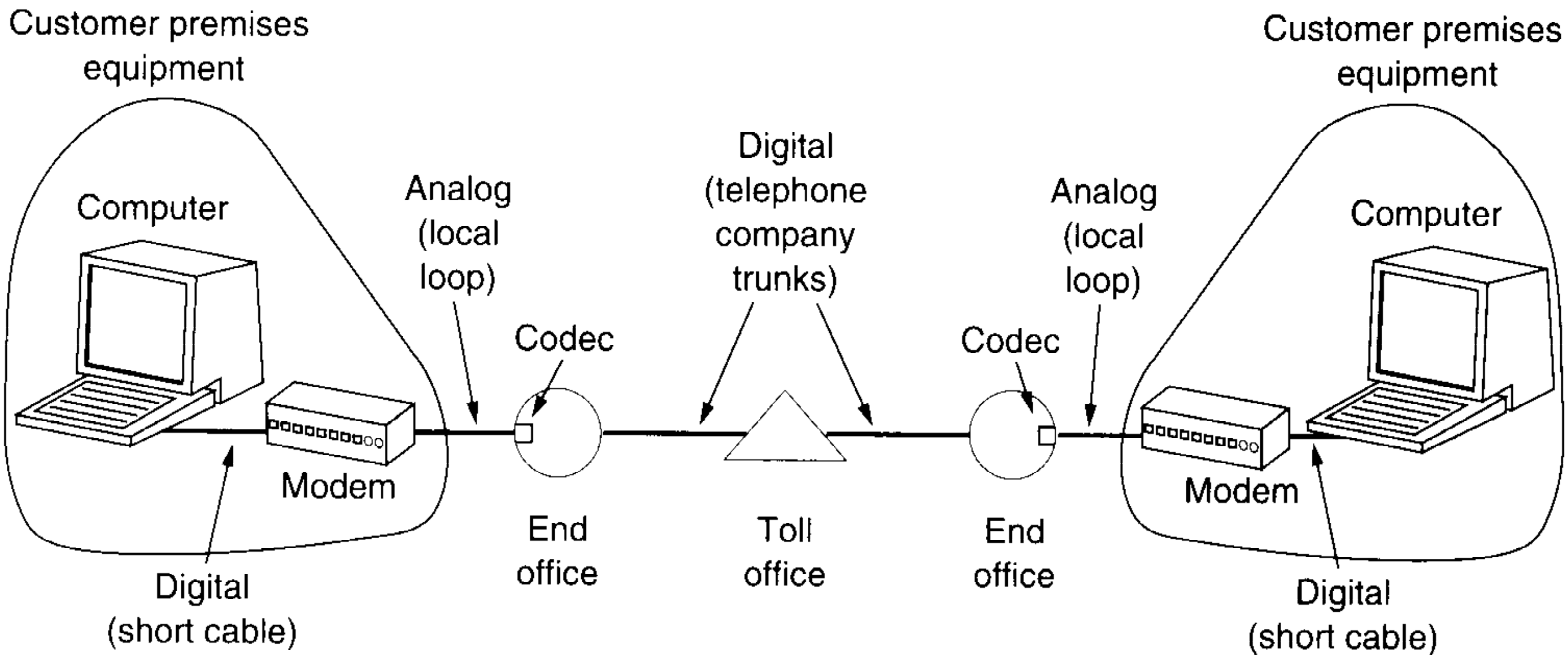
Modern signaling runs over a packet swithced dissassiciated mode...

Data communication over local loop…

- The telephone local loop is the mostly deployed communication channel: home, office…. etc…
- It has always been tempting to use it for data transmission.
- Features: Engineered to support transmisison in the spectrum 300Hz – 3400 Hz. Strongly Nonlinear Atenuation characteristics in frequencies beyond that…
- Options:
  - modem: modulate digital data onto analog voice channel
  - turn local loop completly into digital (ISDN)
    TDM access supporting 2B + D channels = (2 *64+ 16) kbits/s duplex
  - DSL – introduce in frequency division a new channel parallel to the voice channel… Dealing with the „Unpleasant attenuation“

Modem

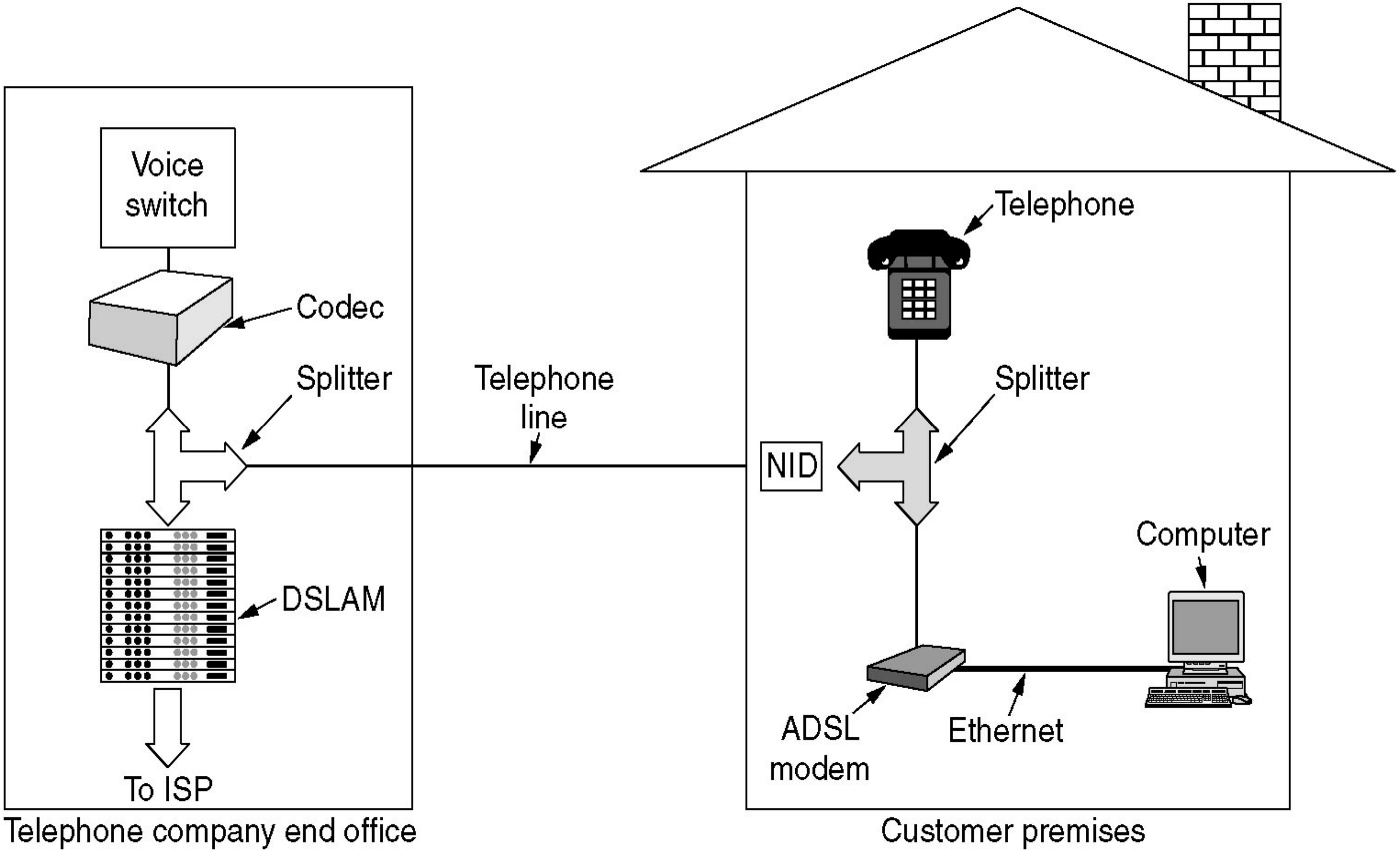
[Noll]



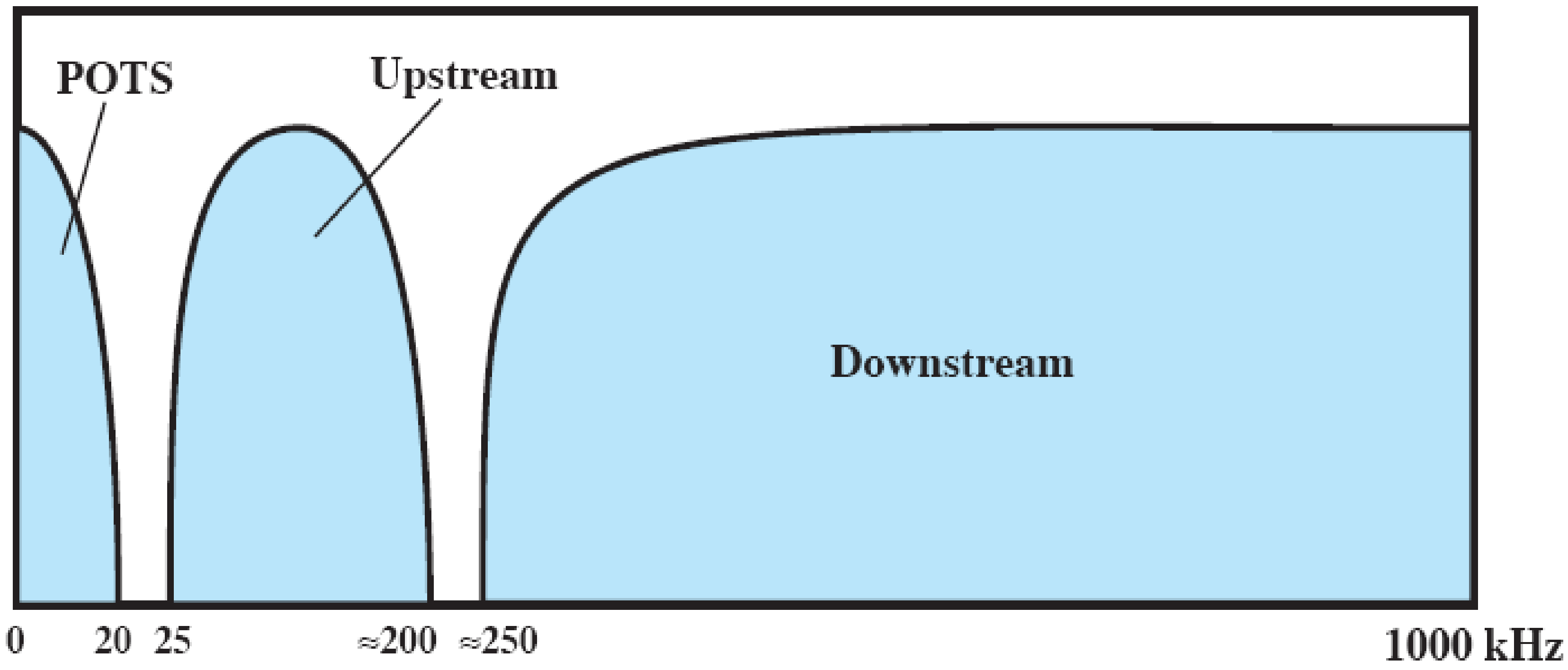
- Transmission – complex multilevel modulation, and more..
- Interface between computer and modem ...(RS232,,,)
- Control commands – Hayes Command Set...

DSL

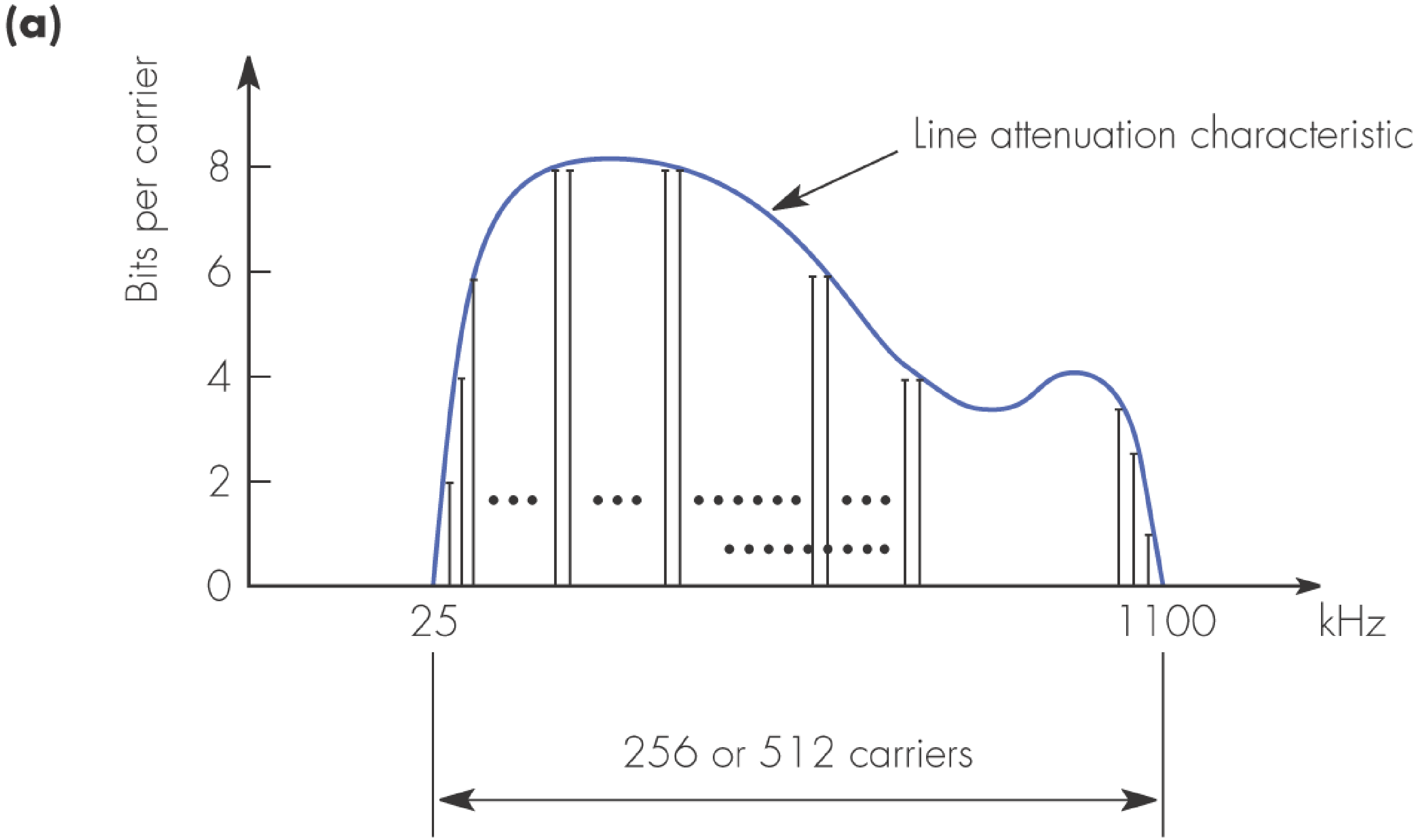
[Tannenebaum]



DSL – general usage of frequencies [Tannenbaum]



DSL: Modulation adjusted to sub-carrier quality [Halsall]



(b)

Upstream: frequency band = 25–200 kHz, bit rate = 32–384/1000 kbps
Downstream: frequency band = 240–1100 kHz, bit rate = 640–1500/8000 kbps