Unit_2
The Telephone Network

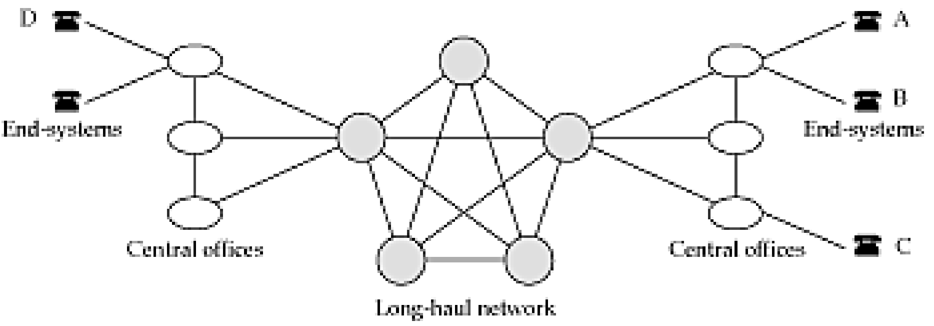
Is it a computer network?

- Specialized to carry voice
- Also carries
  - telemetry
  - video
  - fax
  - modem calls
- Internally, uses digital *samples*
- Switches and switch controllers are special purpose computers
- Principles in its design apply to more general computer networks

Concepts

- Single basic service: two-way voice
  - low end-to-end delay
  - guarantee that an accepted call will run to completion
- End points connected by a *circuit*
  - like an electrical circuit
  - signals flow both ways (*full duplex*)
  - associated with bandwidth and buffer *resources*

The big picture



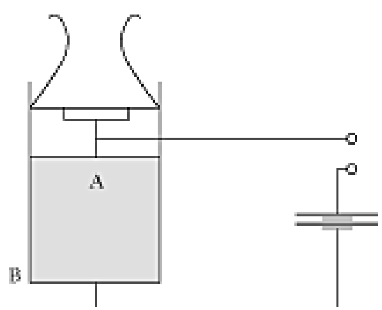
- Fully connected core
  - simple routing
  - telephone number is a hint about how to route a call
    - but not for 800/888/700/900 numbers
  - hierarchically allocated telephone number space

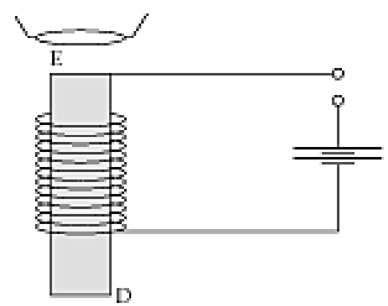
The pieces

1. End systems
2. Transmission
3. Switching
4. Signaling

1. End-systems

- Transducers
  - key to carrying voice on wires
- Dialer
- Ringer
- Switchhook





Sidetone

- Transmission circuit needs two wires
- And so does reception circuit
- => 4 wires from every central office to home
- Can we do better?
- Use *same* pair of wires for both transmission and reception
- Cancel out what is being said
- Ergonomics: leave in a little
  - *sidetone*
  - unavoidable

Echo

- Shared wires => received signal is also transmitted
- And not completely cancelled out!
- Leads to echo (why?)
- OK for short-distance calls
- For long distance calls, need to put in echo chancellors (why?)
- Expensive
- Lesson
  - keep end-to-end delays as short as possible

Dialing

- Pulse
  - sends a pulse per digit
  - collected by central office
- Tone
  - key press (feep) sends a pair of tones = digit
  - also called Dual Tone Mutifrequency (DTMF)

2. Transmission

- Link characteristics
  - information carrying capacity (bandwidth)
    - information sent as *symbols*
    - 1 symbol >= 1 bit
  - propagation delay
    - time for electromagnetic signal to reach other end
    - light travels at 0.7c in fiber ~8 microseconds/mile
    - NY to SF => 20 ms; NY to London => 27 ms
  - attenuation
    - degradation in signal quality with distance
    - long lines need regenerators
    - optical amplifiers are here

Transmission: Multiplexing

- *Trunks* between central offices carry hundreds of conversations
- Can’t run thick bundles!
- Instead, send many calls on the same wire
  - *multiplexing*
- Analog multiplexing
  - bandlimit call to 3.4 KHz and frequency shift onto higher bandwidth trunk
  - obsolete
- Digital multiplexing
  - first convert voice to *samples*
  - 1 sample = 8 bits of voice
  - 8000 samples/sec => call = 64 Kbps

Transmission: Digital multiplexing

- How to choose a sample?
  - 256 *quantization levels*
    - logarithmically spaced (why?0
    - sample value = amplitude of nearest quantization level
  - two choices of levels (mu law and A law)
- Time division multiplexing
  - trunk carries bits at a faster bit rate than inputs
  - *n* input streams, each with a 1-byte buffer
  - output interleaves samples
  - need to serve all inputs in the time it takes one sample to arrive
  - => output runs *n* times faster than input
  - *overhead* bits mark end of *frame* (why?)

Signaling Systems

Introduction to Signaling Systems

- **Signaling System :** Signaling system is defined as a set of methods or rules followed by network entities to exchange information required for communication set up.
- **Examples of Signaling Systems :**

  SS7 or CCSS7 (Common Channel Signaling System7)

  CAS (Channel associated Signaling)

  DTMF (Dual Tone – Multi frequency)

Areas of Signaling

There are mainly three areas of signaling during a telephone call :

- between subscribers and exchanges.
- within exchanges.
- between exchanges.

- Common Channel Signaling System No. 7 (SS7) is data communications network standard
- Provides call management, data base query, routing, flow and congestion control functionality for telecommunication networks
- Designed for ISDN

Characteristics of SS7

- Optimized for use in digital telecommunication networks in conjunction with digital switches
- Designed to meet present and future information transfer requirements for call control, remote control, management, and maintenance
- Provides a reliable means for the transfer of information
- Suitable for use on point-to-point terrestrial and satellite links

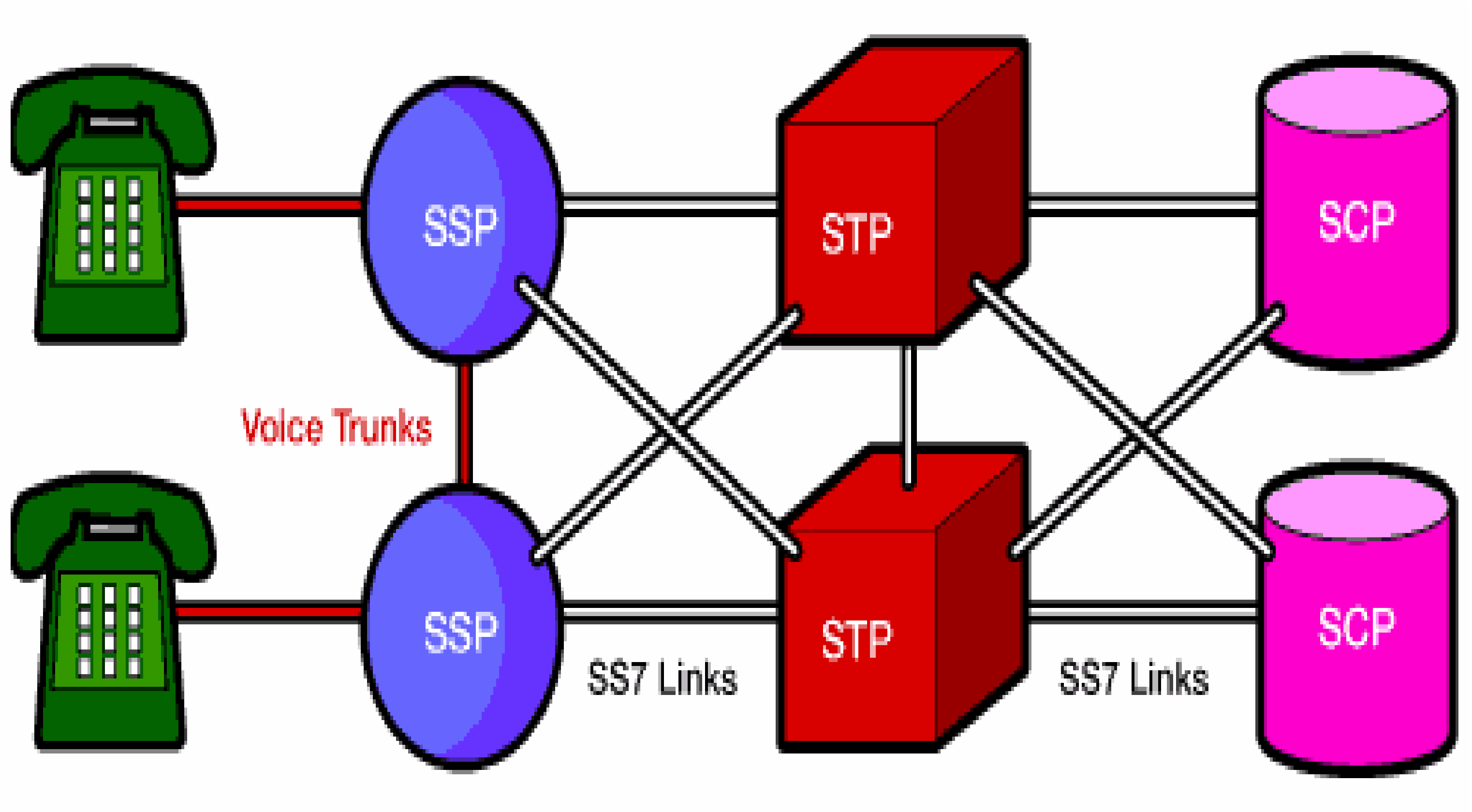
Control Signaling Functions

- The means by which the network is managed, calls are established, maintained, and terminated
- Audible communication with subscriber
- Transmission of dialed number
- Call cannot be completed indication
- Call ended indication
- Signal to ring phone
- Billing info
- Control of special equipment

Control Signal Sequence

- Both phones on hook
- Subscriber lifts receiver (off hook)
- End office switch signaled
- Switch responds with dial tone
- Caller dials number
- If target is not busy, ringer signal is sent to target subscriber
- Feedback to caller
  - Ringing tone, engaged tone, unobtainable (disconnected line, etc.)
- Target accepts call by lifting receiver
- Switch terminates ringing signal and ringing tone
- Switch establishes connection
- Connection is released when Source subscriber hangs up

SS7 Network



SS7 Network Elements

- **SSP** (Service Switching Point)
- **STP** (Signal Transfer Point)
- **SCP** (Service Control Point)

SSP

- Service Switching Points (SSP) are switches that originate and terminate calls
- An SSP sends signaling messages to other SSPs
- SSP usually originate SS7 messages

STP

- Messages travel from one SSP to another through the services of a STP
- STPs are typically adjunct computers to voice switches, rarely an STP is a stand-alone system
- STP exchange information in form of packets related to either call connections or database queries

STP

- Three levels of STPs
  - National
  - International
  - Gateway

- National STP exist in one network, no capability to convert messages into other formats
- International STP provides SS7 based interconnection between national networks
- Gateway STP provides protocol conversion between a national and international network or with other non-SS7 networks

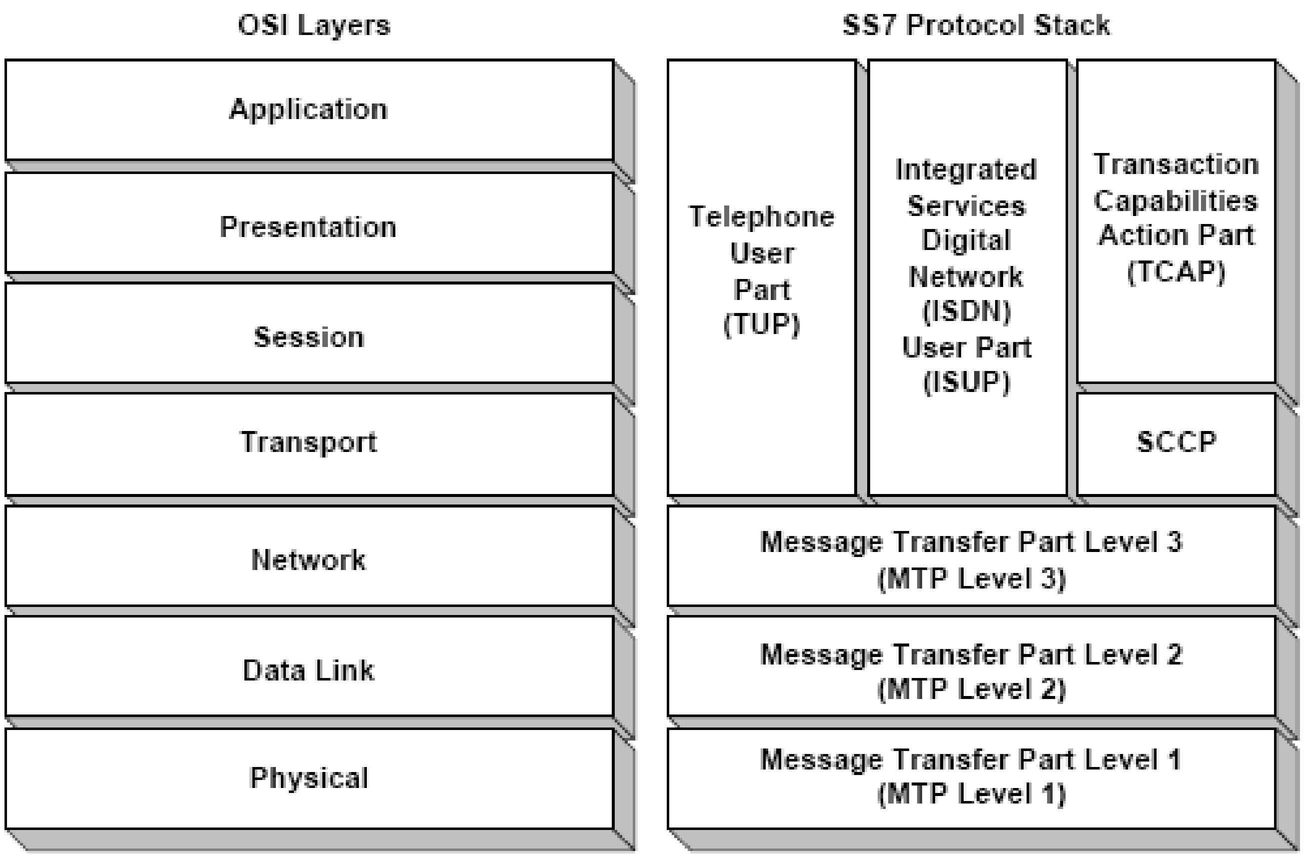
- Other tasks of the STP include
  - traffic measurements
  - usage measurements
- Traffic measurements are used for performance

  monitoring of the SS7 and telecommunication network
- Usage measurements are used for billing purposes

SCP

- SCP serves as interface to a telephone company's database
- Database store information about
  - subscriber's services
  - routing of special service numbers
  - calling card validation and fraud protection
  - advanced intelligent network features for service creation
- SCP is a computer used as a front-end to a database

SS7 Protocol Stack



Securing SS7 Telecommunications Networks

Message Transfer Part (MTP)

- Level 1: Physical layer/ **signaling data link**

➢ Similar to OSI physical layer

➢ defines the physical, electrical and functional characteristics of a signaling data link

➢ represents the bearer for a signaling link.

➢ In a digital network, 64-kbit/s channels are generally used as signaling data links.

➢ analog channels (4.8 k bit/s) can also be used via modems as a signaling data link.

- Level 2: Data link layer/ **Signaling link**
- defines the functions and procedures for a correct exchange of user messages via a signaling link.
- The following functions must be carried out in level 2:
  - – error detection using check bits.
  - – error correction by re transmitting signal units.
  - – error rate monitoring on the signaling data link.
  - – restoration of fault-free operation, for example, after disruption of the signaling data link
- Reliable transfer of signaling information between SPs

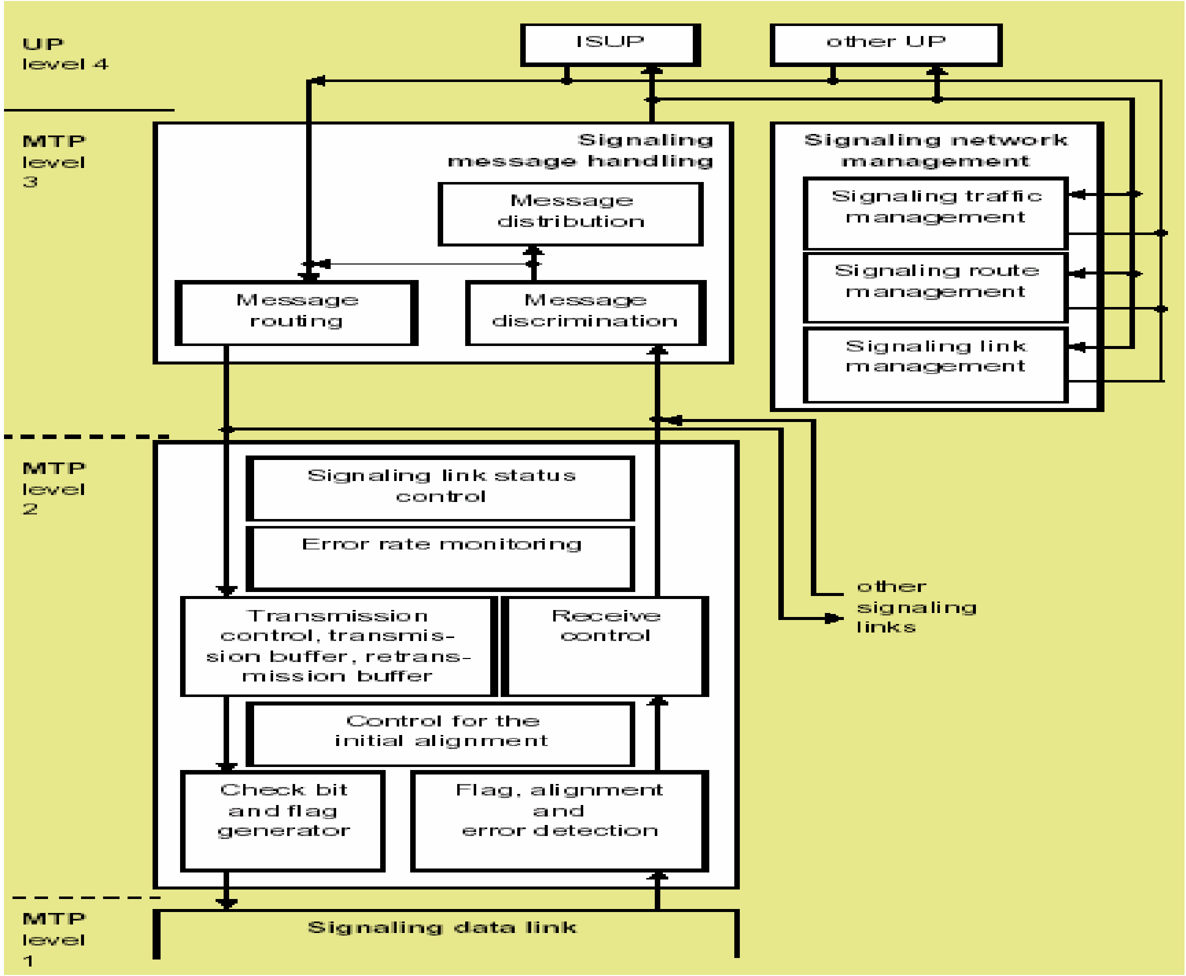
- Level 3: Network level/ **Signaling network**

  Defines the internetworking of the individual signaling links.

  A distinction is made between the two following functional areas:

  – Message handling : Directing the messages to the desired signaling link, or to the correct user part.

  – Signaling network management :control the message traffic, for example, by means of changeover of signaling links if a fault is detected and change back to normal operation after the fault is corrected.


UP
level 4
ISUP
other UP
MTP
level
3
Signaling
message handling
Message
distribution
Message
routing
Message
discrimination
Signaling network
management
Signaling traffic
management
Signaling route
management
Signaling link
management
MTP
level
2
Signaling link status
control
Error rate monitoring
Transmission
control, transmis-
sion buffer, retrans-
mission buffer
Receive
control
other
signaling
links
Control for the
initial alignment
Check bit
and flag
generator
Flag, alignment
and
error detection
MTP
level
1
Signaling data link

SCCP & TCAP

- SCCP – Signaling Connection Control Part
  - Provides additional functionality for MTP
  - Supports both connectionless and connection oriented
  - The combination of the SCCP and the message transfer part is called the network service part (NSP).
- TCAP – Transaction Capabilities Application Part
  - Deployment of Advanced Intelligent network services
  - supports connection oriented
  - Data base access

TUP

- TUP – Telephone User Part
  - International telephone control signaling functions
  - Call connection management is performed with user part,

ISUP

- ISUP – ISDN User Part
  - Compatible with TUP
  - Supports both analog and digital voice circuits
  - Supports both ISDN and non ISDN calls
  - Defines the protocol used to setup, manage, and release trunk circuits that carry voice and data between SSPs
  - The ISUP has interfaces to the MTP and the signaling SCCP for the transport of message signal units.
  - The ISUP can use SCCP functions for end-to-end signaling.

Role of SS7

- SS7 carries information of every call in the network
- SS7 provide the bridge between circuit and packet switched networks
- The private nature of SS7 networks is critical for security and reliability

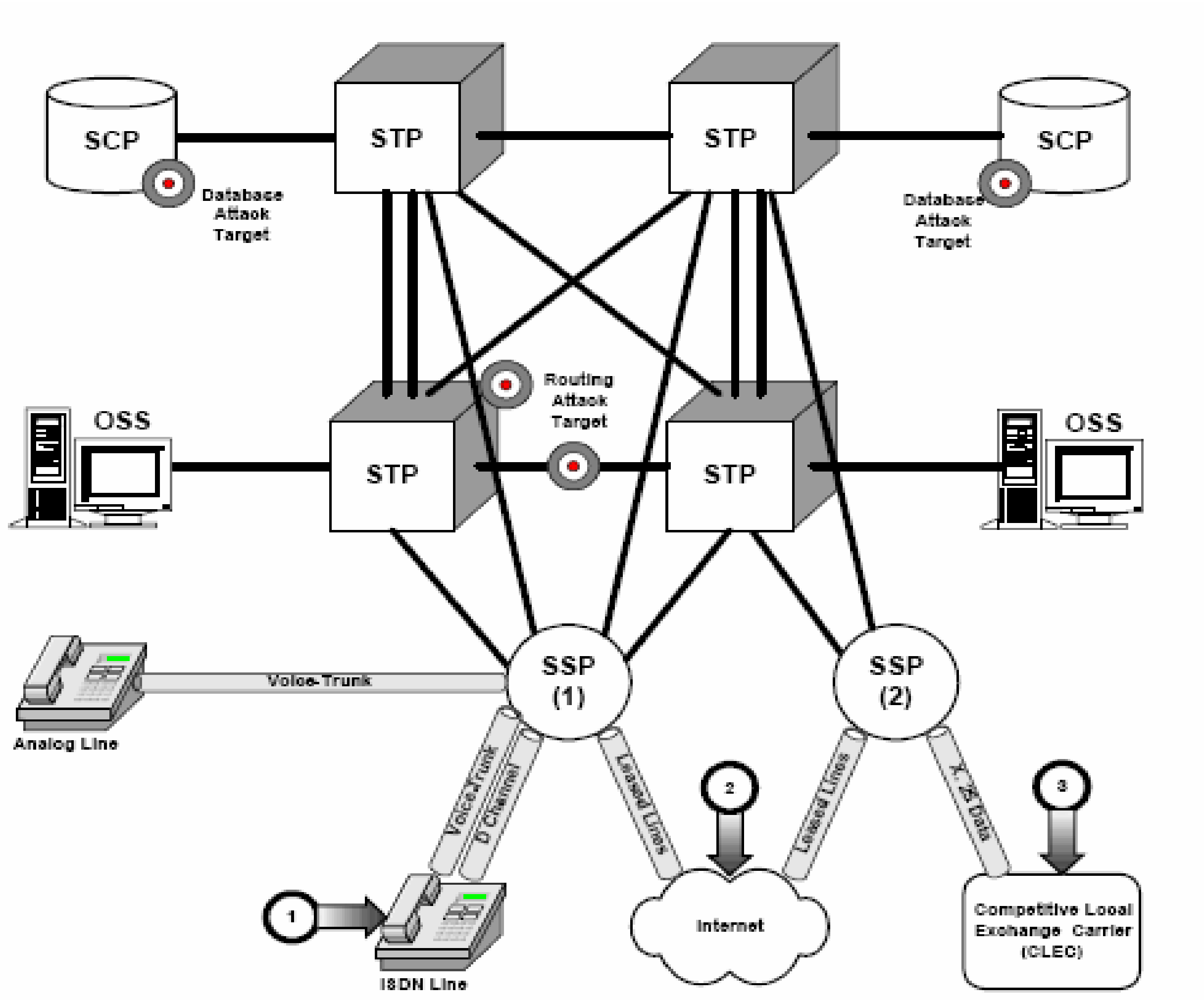
National Security

- Due to the widespread use of SS7 networks, security is major cause for concern
- Disrupting emergency services ex. Denial-of-Service attacks
- Disrupting Surveillance by the government authorities

Attack Vectors

- ISDN Lines
- CLECs – Competitive Local Exchange Carriers
- Internet and Leased Lines

Vulnerabilities of SS7



Securing SS7 Telecommunications Networks

Asynchronous Transfer Mode (ATM)

An Overview of ATM

- ATM is Asynchronous Transfer Mode.
- Also called "cell relay"
- ATM is originally the transfer mode for implementing Broadband ISDN (B-ISDN).
- ATM is used for data transfer over high speed data network.
- Developed to enable simultaneous Voice, Video and Data traffic on the same network

An Overview of ATM

- Connection-oriented packet-switched network
- Permanent VCs (PVCs)
  - long lasting connections
  - e.g., “permanent” route between two IP routers
- Switched VCs (SVC):
  - dynamically set up on per-call basis
- Used in both WAN and LAN settings
- Uses Signaling (connection setup) Protocol
- ATM guarantees that cells will not be disordered.

- International networking standard for a high speed switching architecture

  -Operates at Layer 2 of the OSI-Model
- ATM is the most popular switching technology in WAN backbone networks
- Bandwidth can be allocated as needed
- Predefined and guaranteed Quality of Service (QoS) and Class of Service (CoS)
- Superior management features
- Scalability in speed and network size
- Ease of integration with other technologies

“High-Speed Networks”

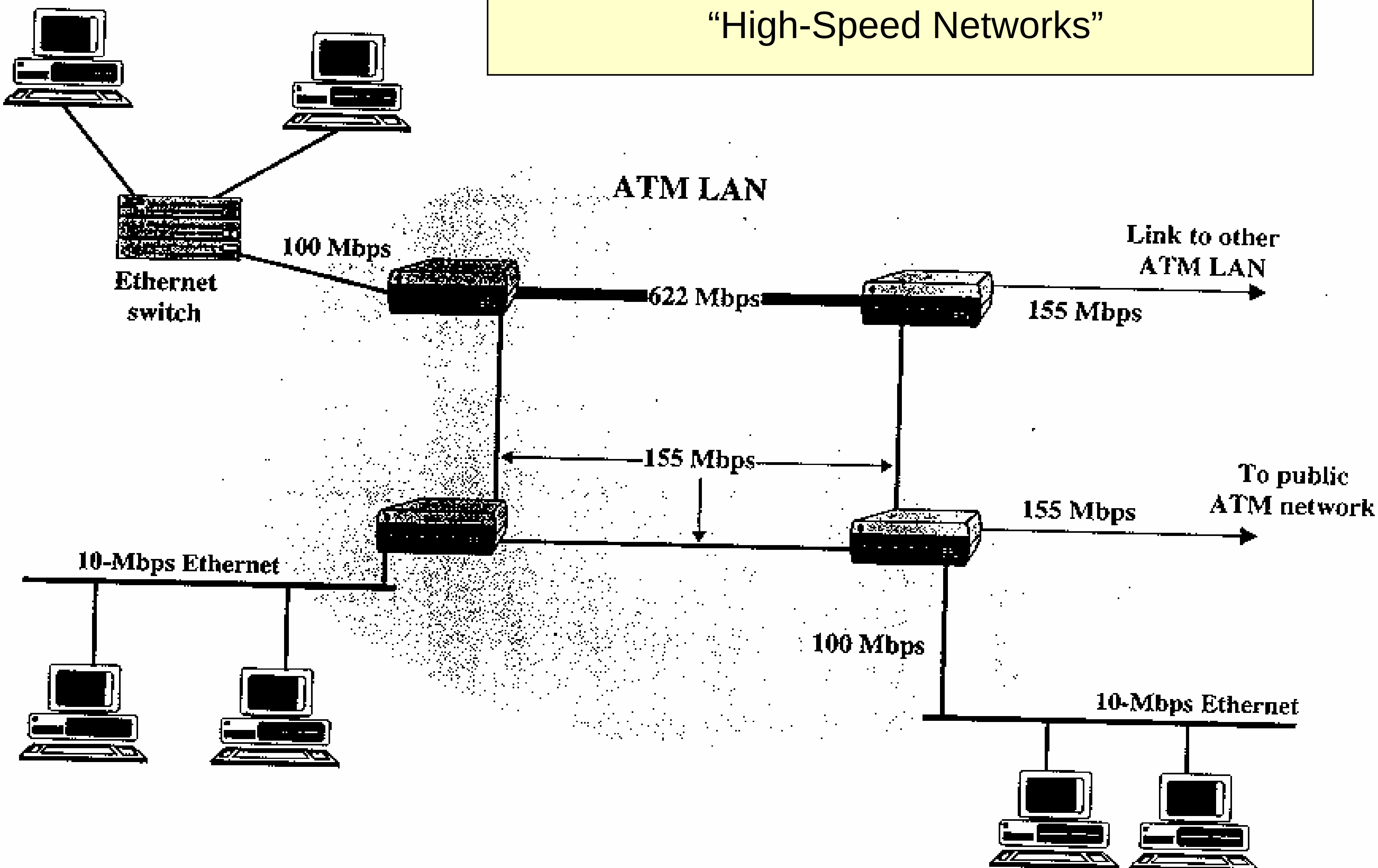


Figure 5.9 Example ATM LAN configuration.

“High-Speed Networks”

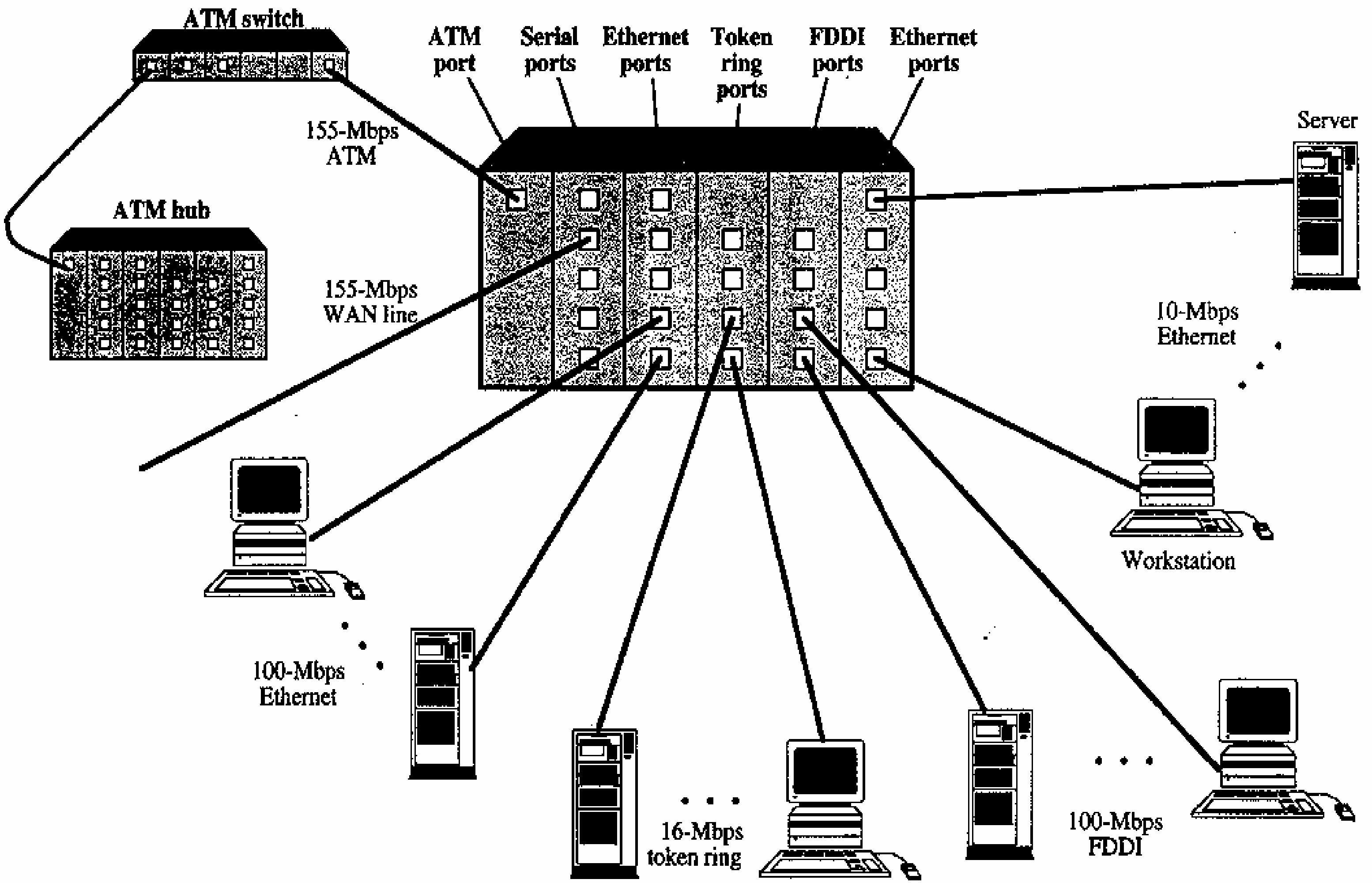
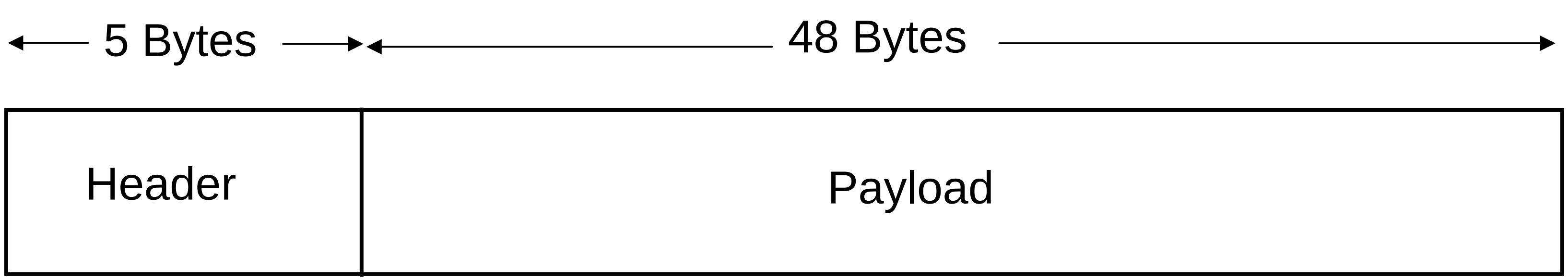


Figure 5.10 ATM LAN hub configuration.

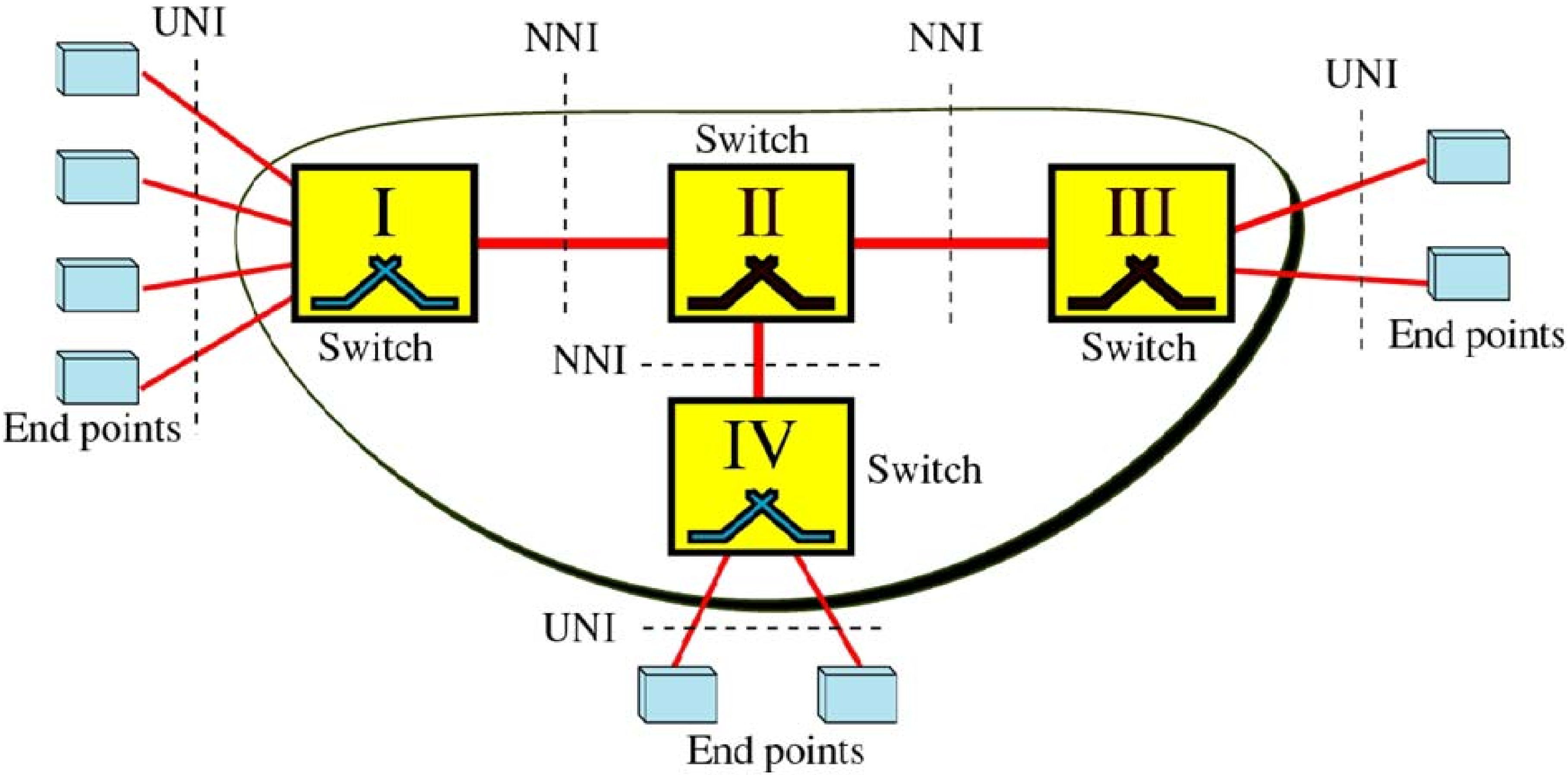
ATM

ATM is a form of cell switching using small fixed-sized packets.

Basic ATM Cell Format



ATM Architecture



1. ATM network will be organized as a hierarchy.
   - User's equipment connects to networks via a **UNI** (User-Network Interface).
   - Connections between provided networks are made through **NNI** (Network-Network Interface).
2. ATM will be connection-oriented.
   - A connection (an ATM channel) must be established before any cells are sent.

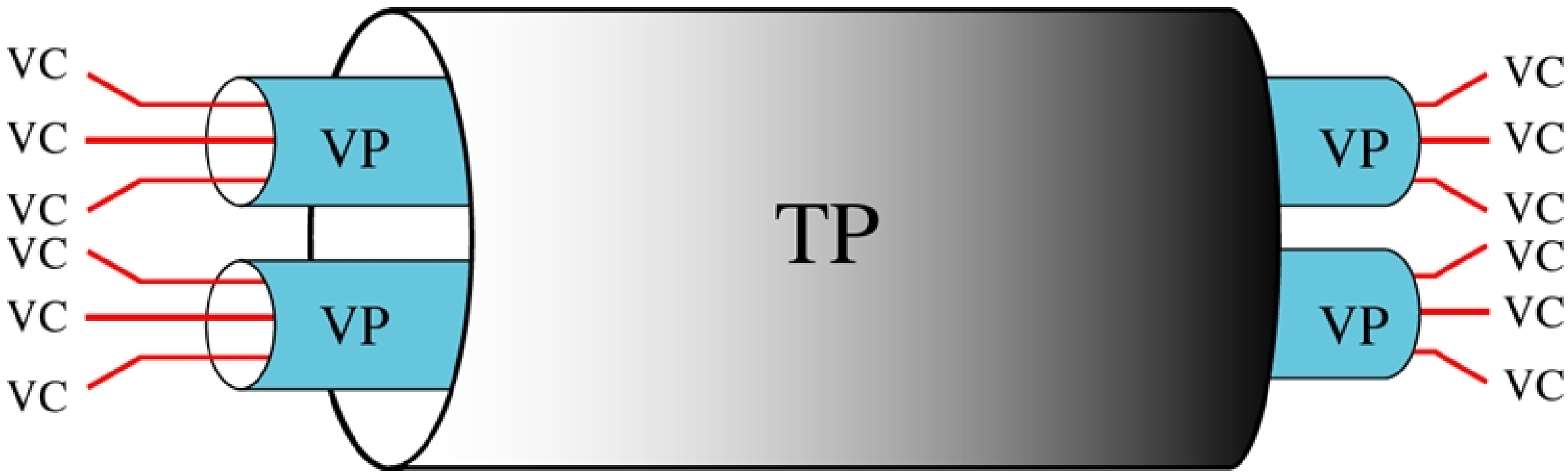
Virtual Connection

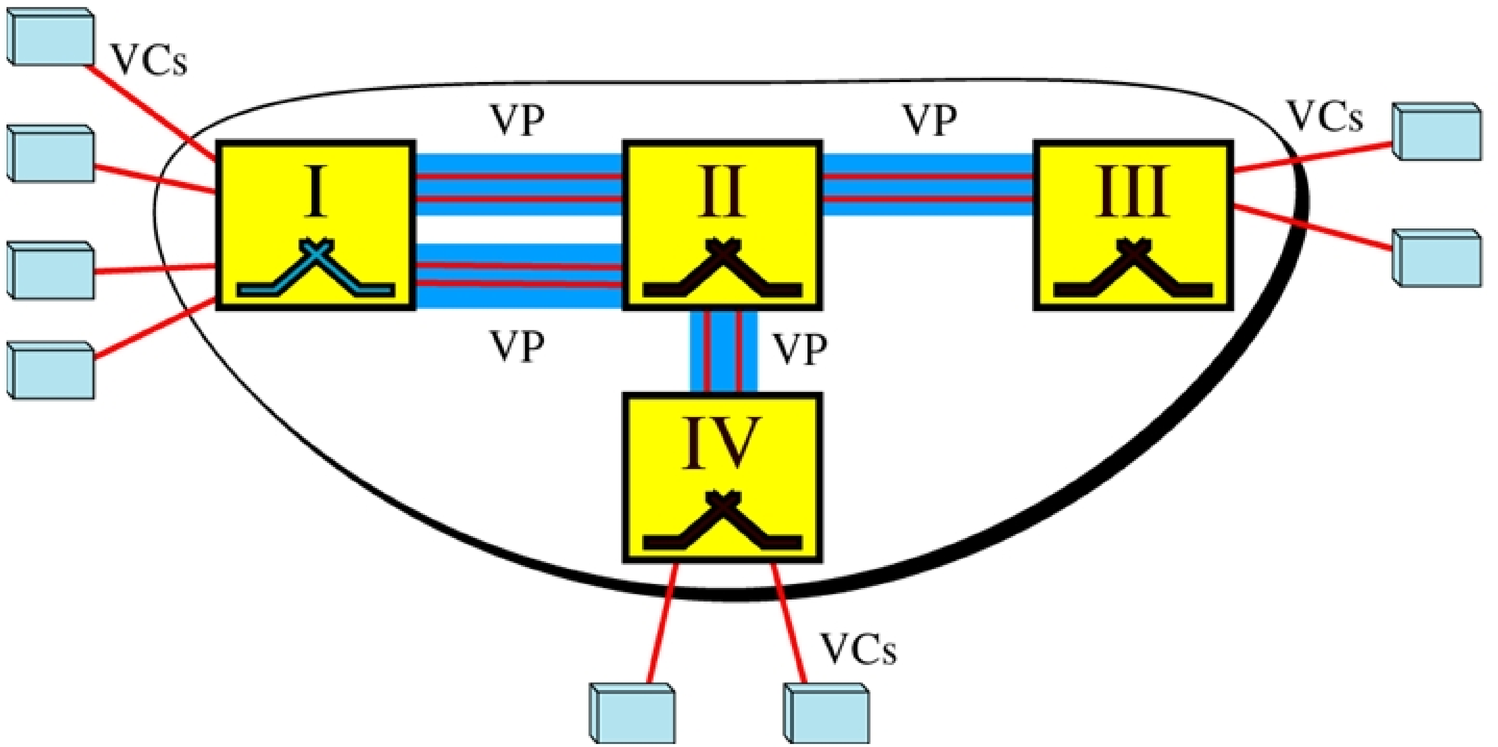
- Connection between two endpoints is accomplished through Transmission Paths (TPs), Virtual Paths (VPs), and Virtual Circuits (VCs)
- A Transmission Path (TP) is the physical connection (wire, cable, satellite) between an end point and a switch or between two switches
- A Transmission Path is divided into several Virtual Paths

- A Virtual Path (VP) provides a connection or a set of connections between two switches

- Cell networks are based on Virtual Circuits (VCs)
- All cells belonging to a single message follow the same virtual circuit and remain in their original order until they reach their destination

Virtual Connection



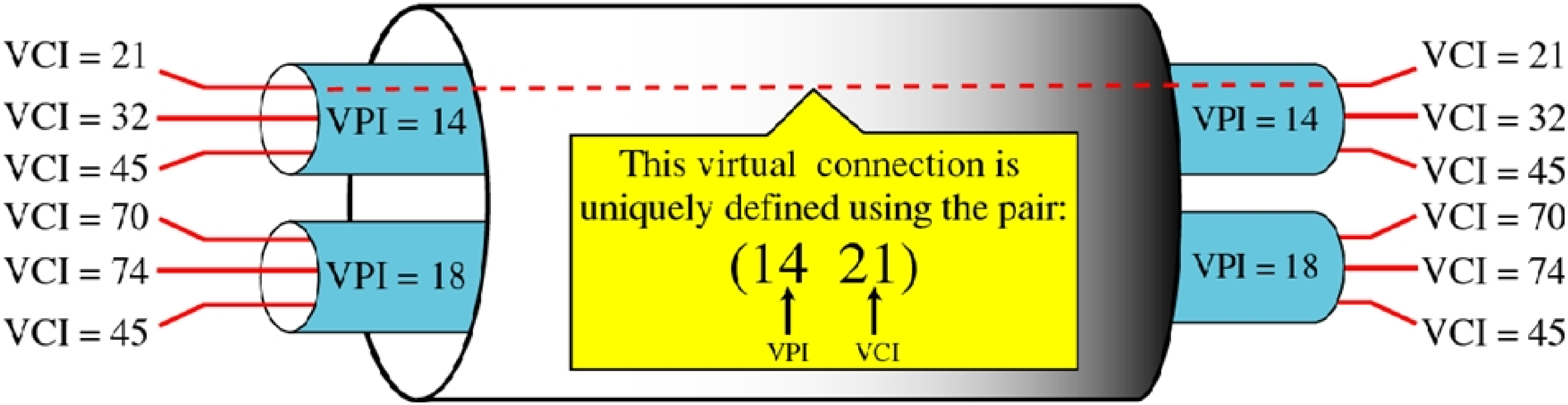


Connection Identifiers

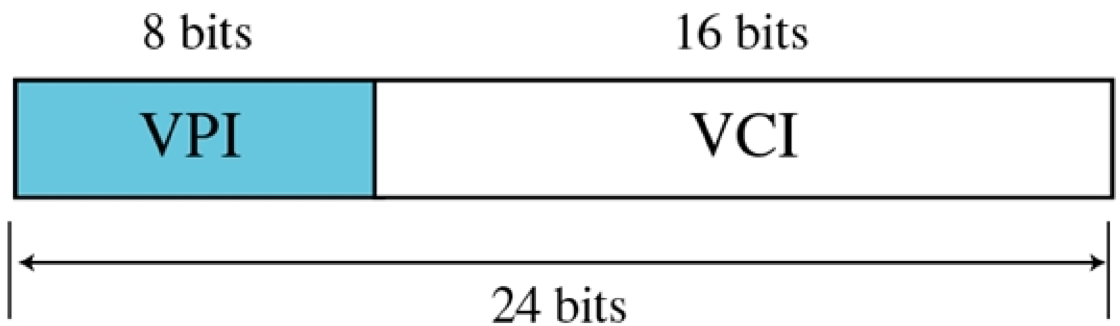
- In a virtual circuit network, to route data from one end point to another, the virtual connections need to be identified
- Hierarchical Identifier
    - Virtual Path Identifier (VPI)
    - Virtual Circuit Identifier (VCI)
- Virtual connection is defined by a pair of numbers: the VPI and the VCI
- Idea behind dividing a virtual connection identifier into two parts is to allow hierarchical routing

Connection Identifiers

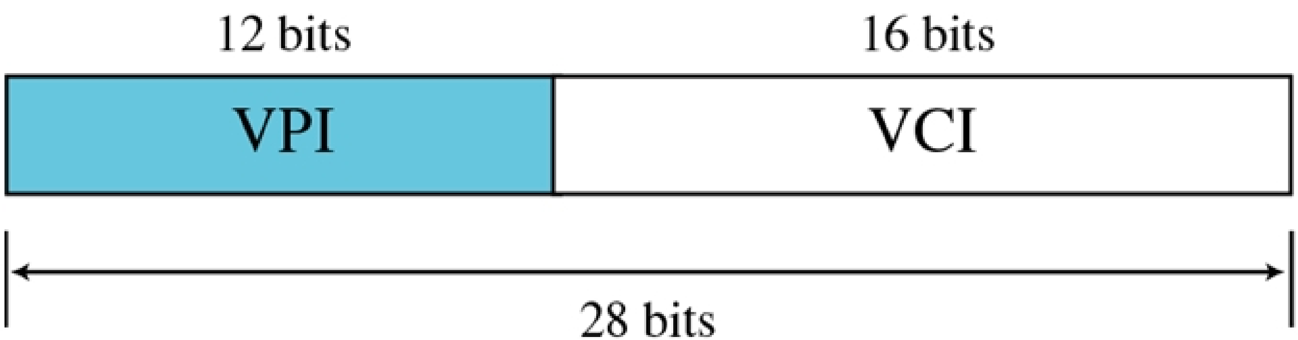
- Most of the switches in ATM network use VPI
- The switches at the boundaries of the network, those that interact directly with the endpoint devices, use both VPIs and VCIs



Connection Identifiers



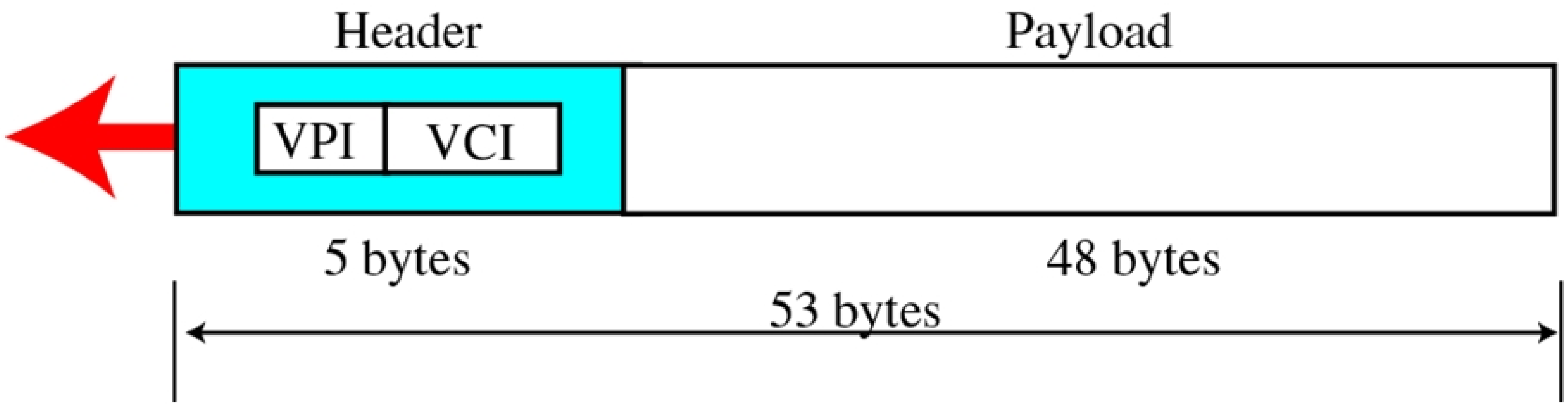
a. VPI and VCI in a UNI interface



b. VPI and VCI in an NNI interface

ATM Cells

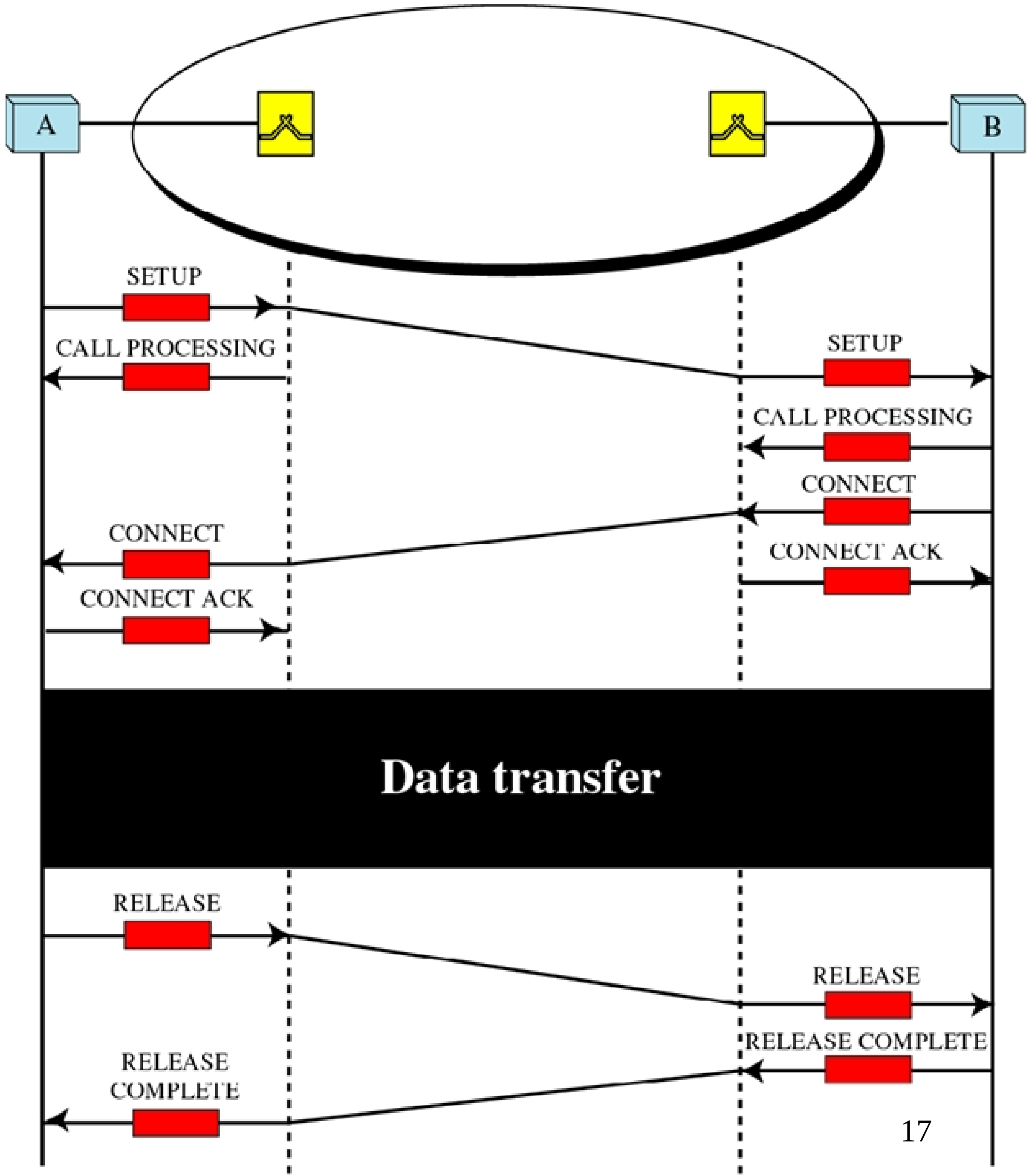
- Basic data unit in an ATM network is called a Cell



Connection Establishment and Release

- ATM uses two types of connections:
  - Permanent Virtual Circuit (PVC)
  - Switched Virtual Circuit (SVC)
- PVC
  - Connection is established between two endpoints by the network provider, and VC is up all the time
  - VPIs and VCIs are defined for the permanent connections, and the values are entered for the tables of each switch
- SVC
  - Each time an endpoint wants to make a connection with another endpoint, a new virtual circuit is established - Needs network layer addresses and the services for connection establishment and release

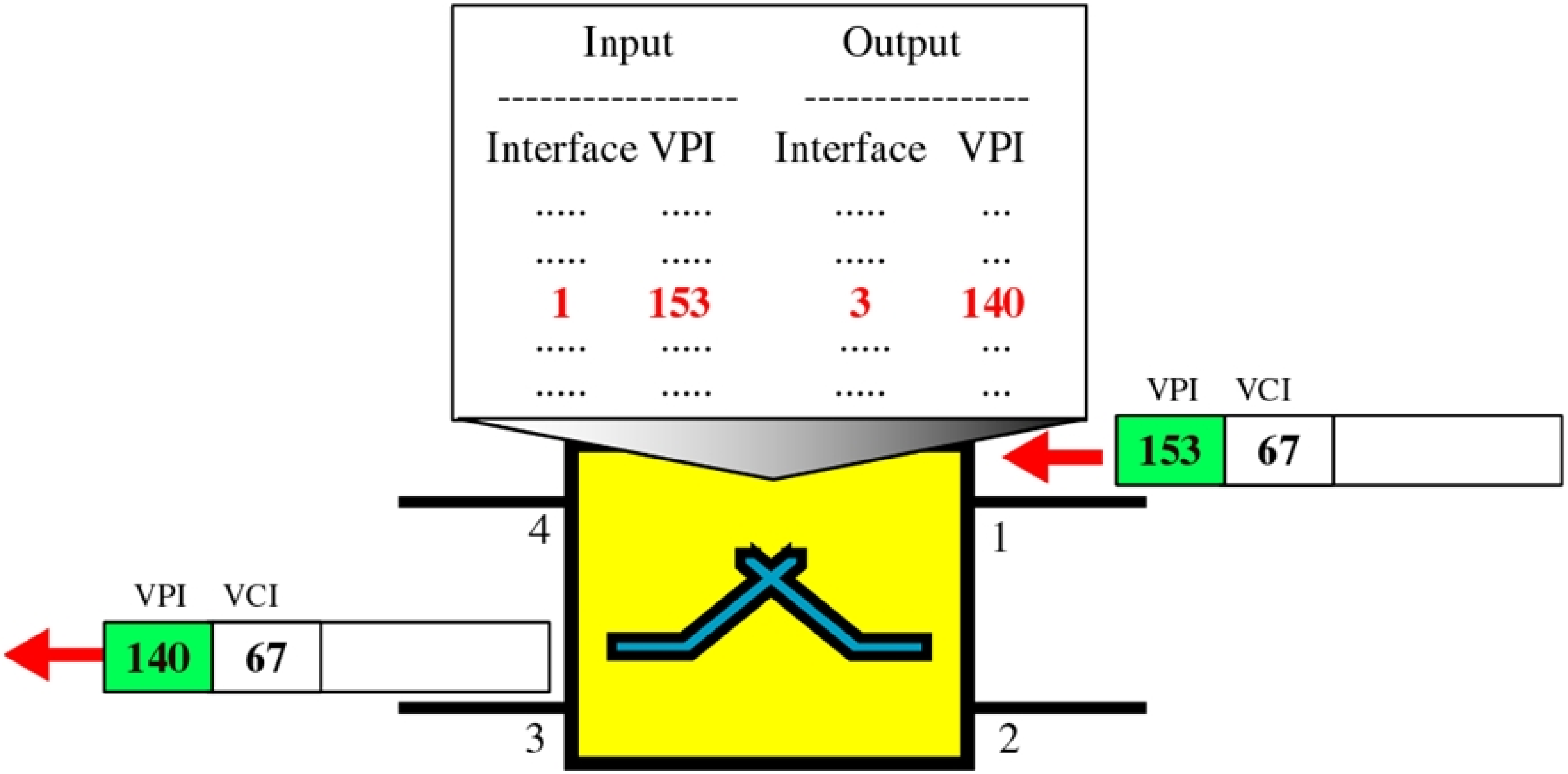
SVC Setup



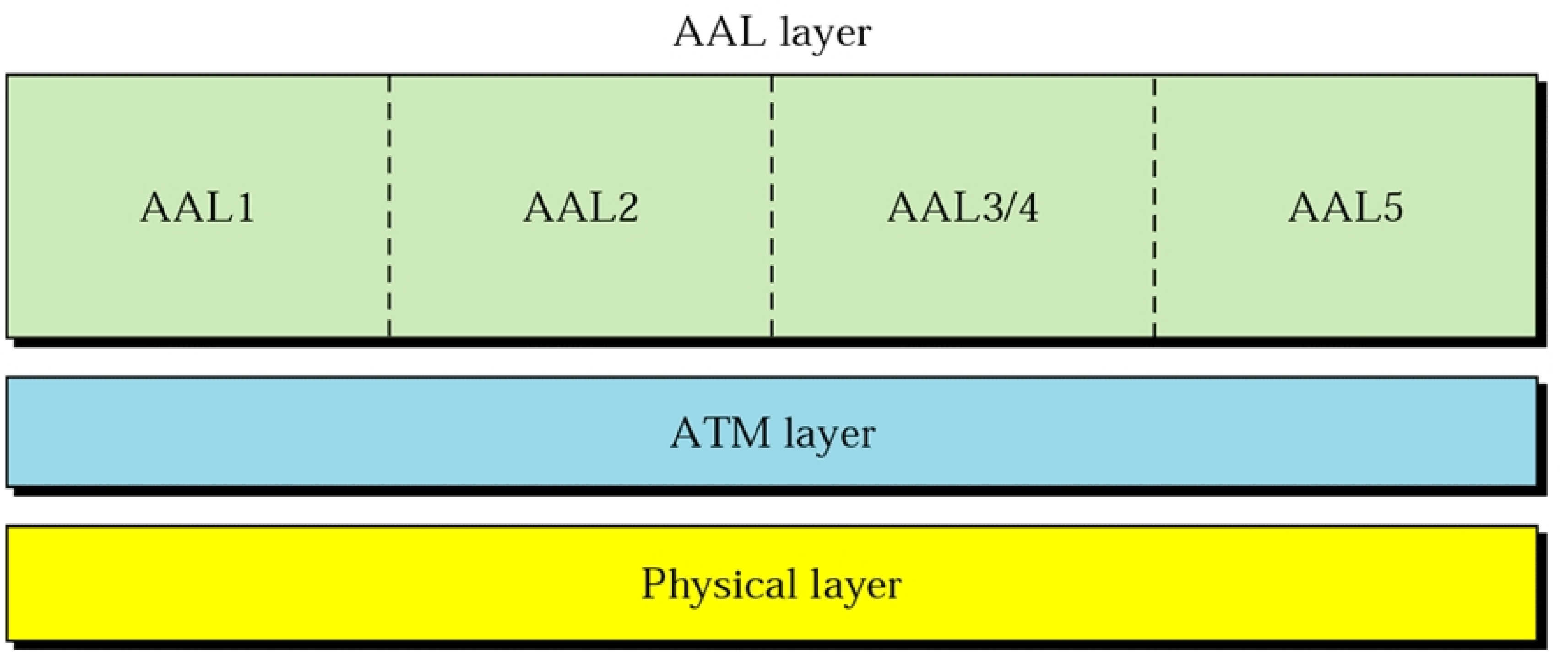
A
B
SETUP
CALL PROCESSING
SETUP
CALL PROCESSING
CONNECT
CONNECT
CONNECT ACK
CONNECT ACK
Data transfer
RELEASE
RELEASE
RELEASE COMPLETE
RELEASE COMPLETE

Switching

- A switch routes cell using both the VPIs and the VCIs

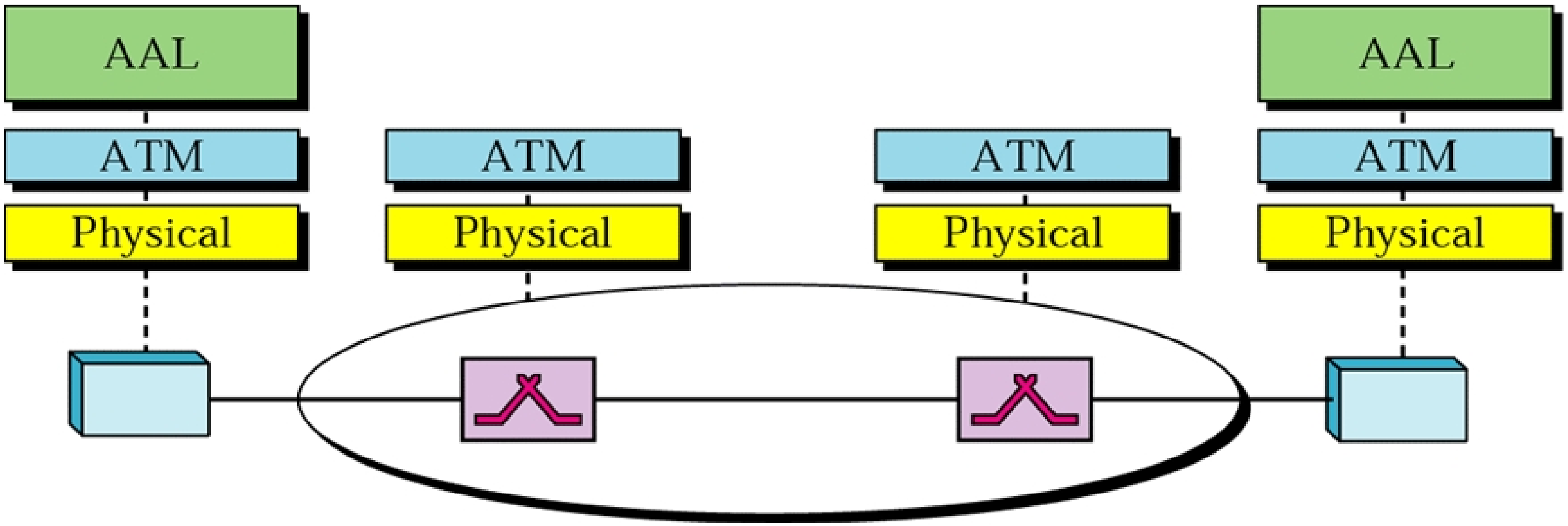


ATM Layers



ATM Layers

• Endpoints use all three layers while the switches use only two bottom layers



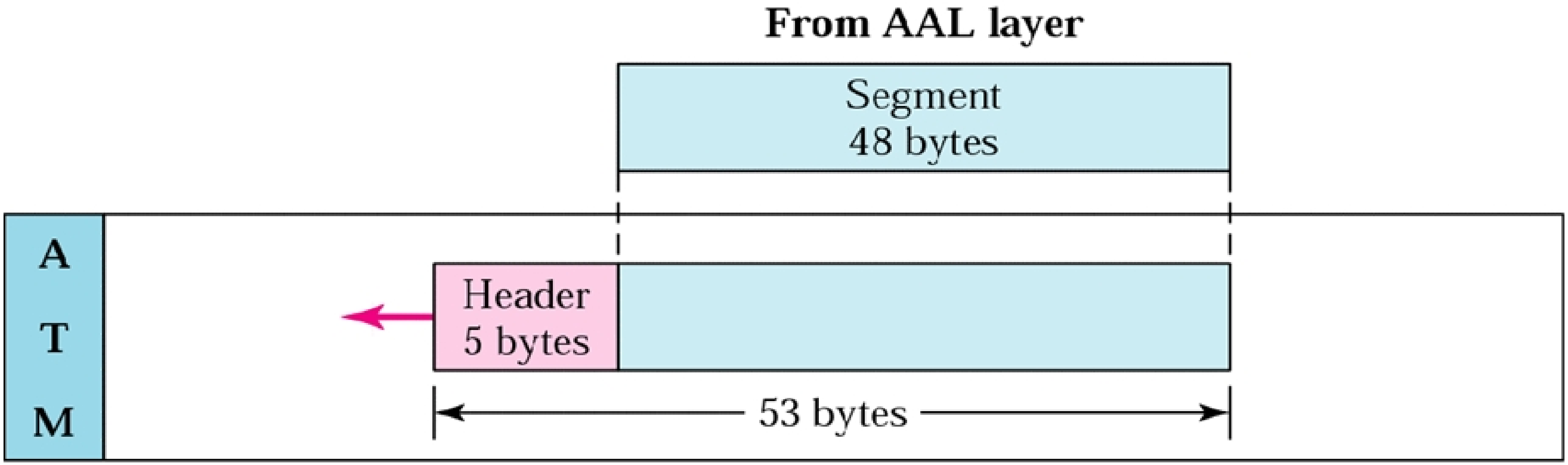
ATM layers in endpoint devices and switches

ATM Layers

- **Physical Layer**
  - ATM Cells can be carried by any physical layer carrier
  - ATM does not prescribe a particular set of rules
  - ATM has been designed to be independent of the transmission medium
- **ATM Layer**

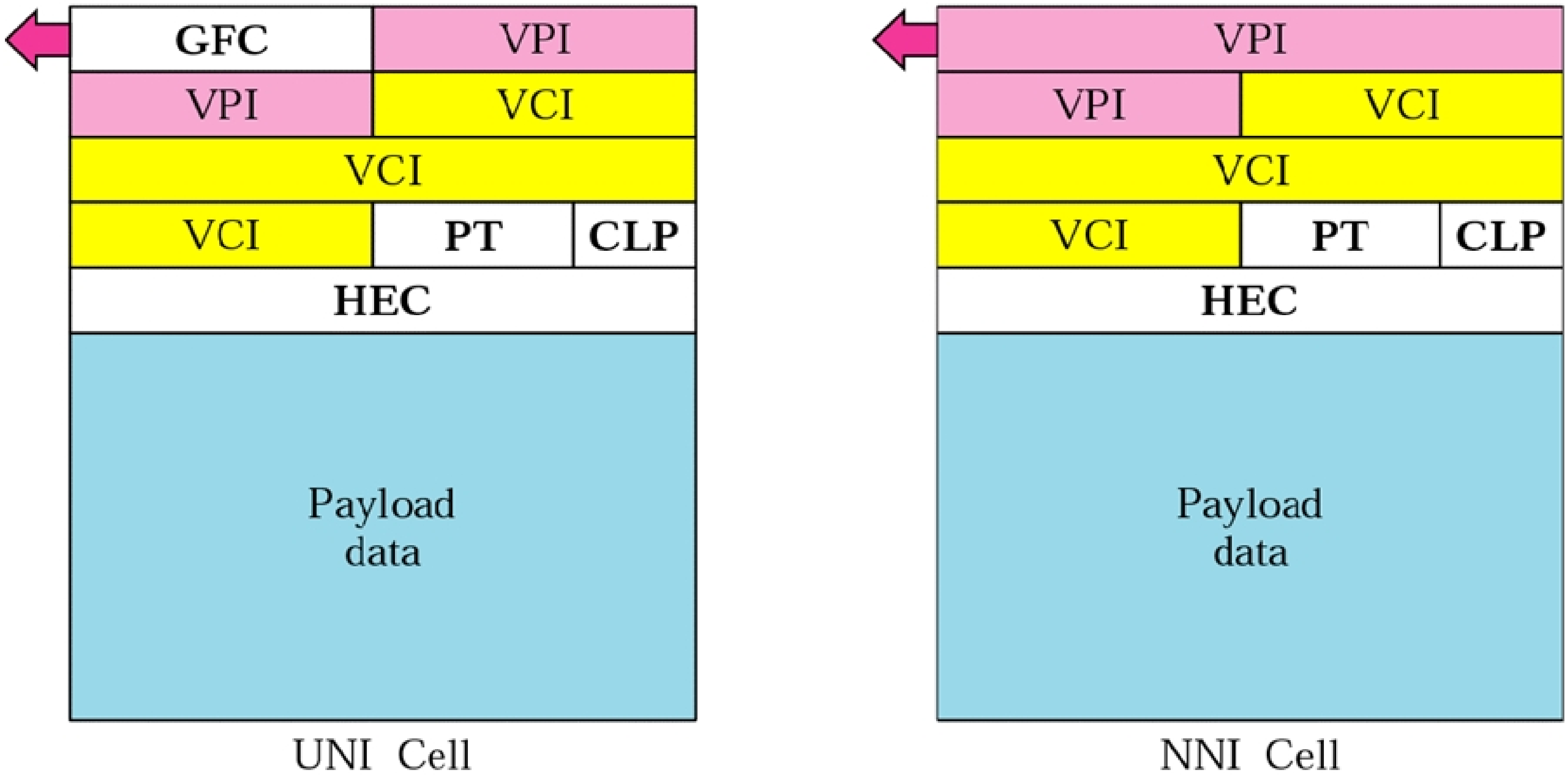
  - Deals with
    - Cells and Cell Transport
    - Establishment and Release of Virtual Circuits
    - Congestion Control
    - Routing, Traffic Management, Switching and Multiplexing

ATM Layer



ATM Layer

GFC: Generic flow control
VPI: Virtual path identifier
VCI: Virtual channel identifier
PT: Payload type
CLP: Cell loss priority
HEC: Header error control



ATM Headers

ATM Layer

- 4-bit GFC field provides flow control at the UNI level
- VPI is an 8-bit field in a UNI cell and 12-bit field in an NNI cell
- VCI is a 16-bit field
- In 3-bit PT field, first bit defines the payload as user data or managerial information. Interpretation of last 2 bits depends on the first bit
- 1-bit CLP field is provided for congestion control. A cell with its CLP bit set to 1 must be retained as long as there are cells with a CLP of 0
- HEC is a code computed for the first 4 bytes of header. It is a CRC with divisor x^8+x^2+x+1 that is used to correct single-bit errors and a large class of multiple-bit errors

Application Adaptation Layer AAL

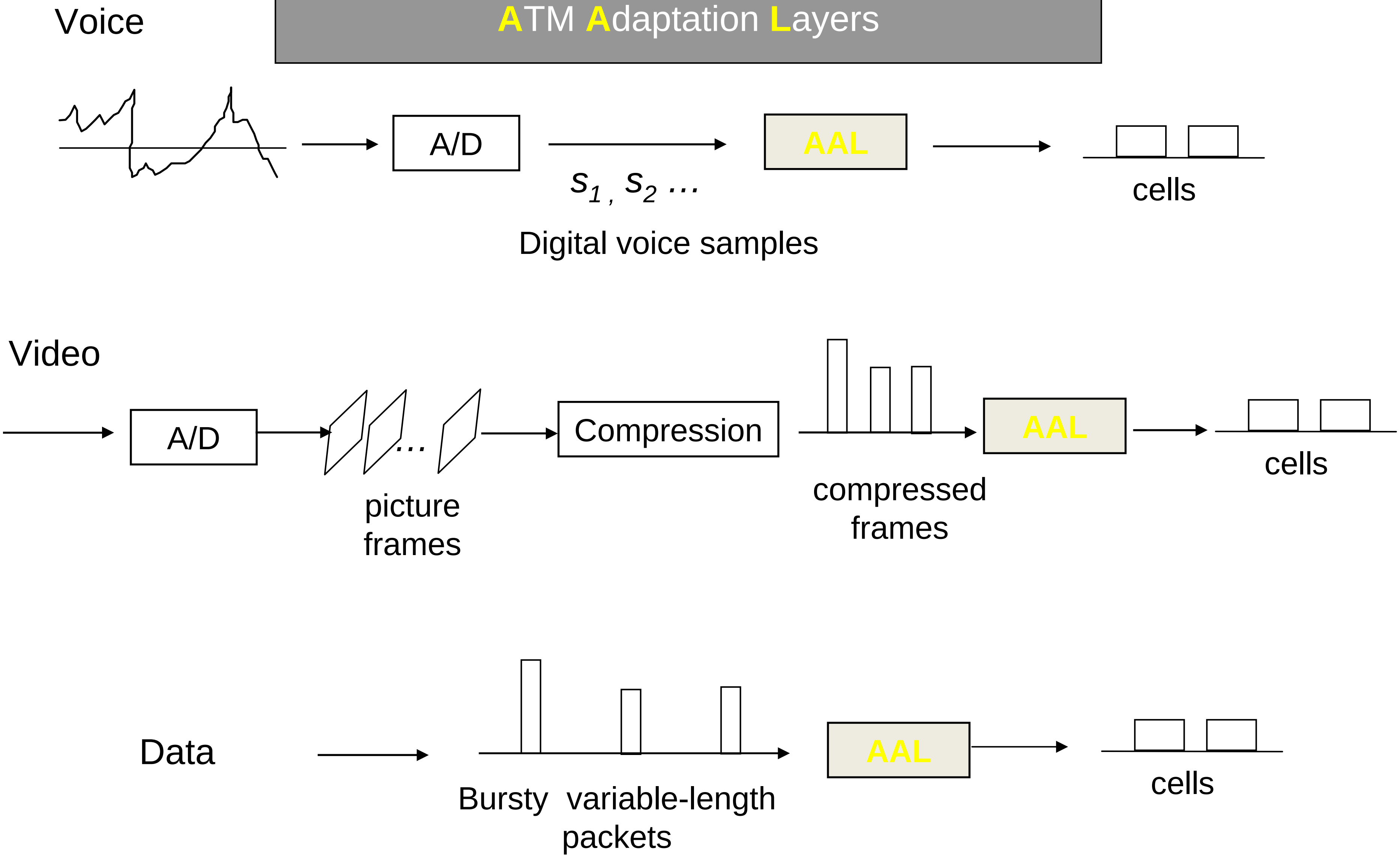
- Allows existing networks (such as packet networks) to connect to ATM
- AAL protocols accept transmissions from upper- layer services (e.g., packet data) and map them into fixed-sized ATM cells
- Such transmission can be of any type (voice, data, audio, video) and can be of variable or fixed rates

AAL layer is divide into two sub layers:

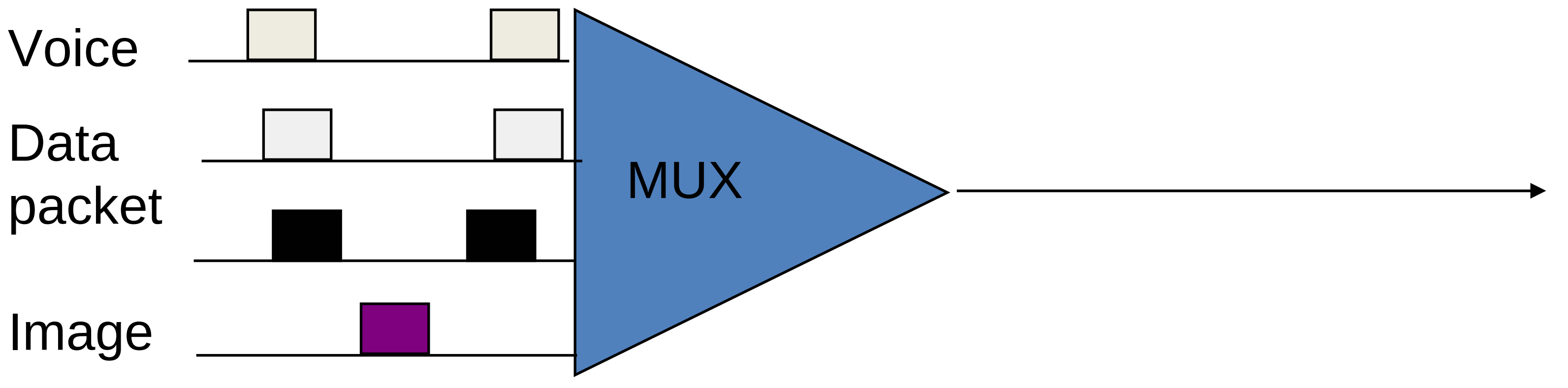
- Convergence sub layer (CS)

-Segmentation and reassembly (SAR)

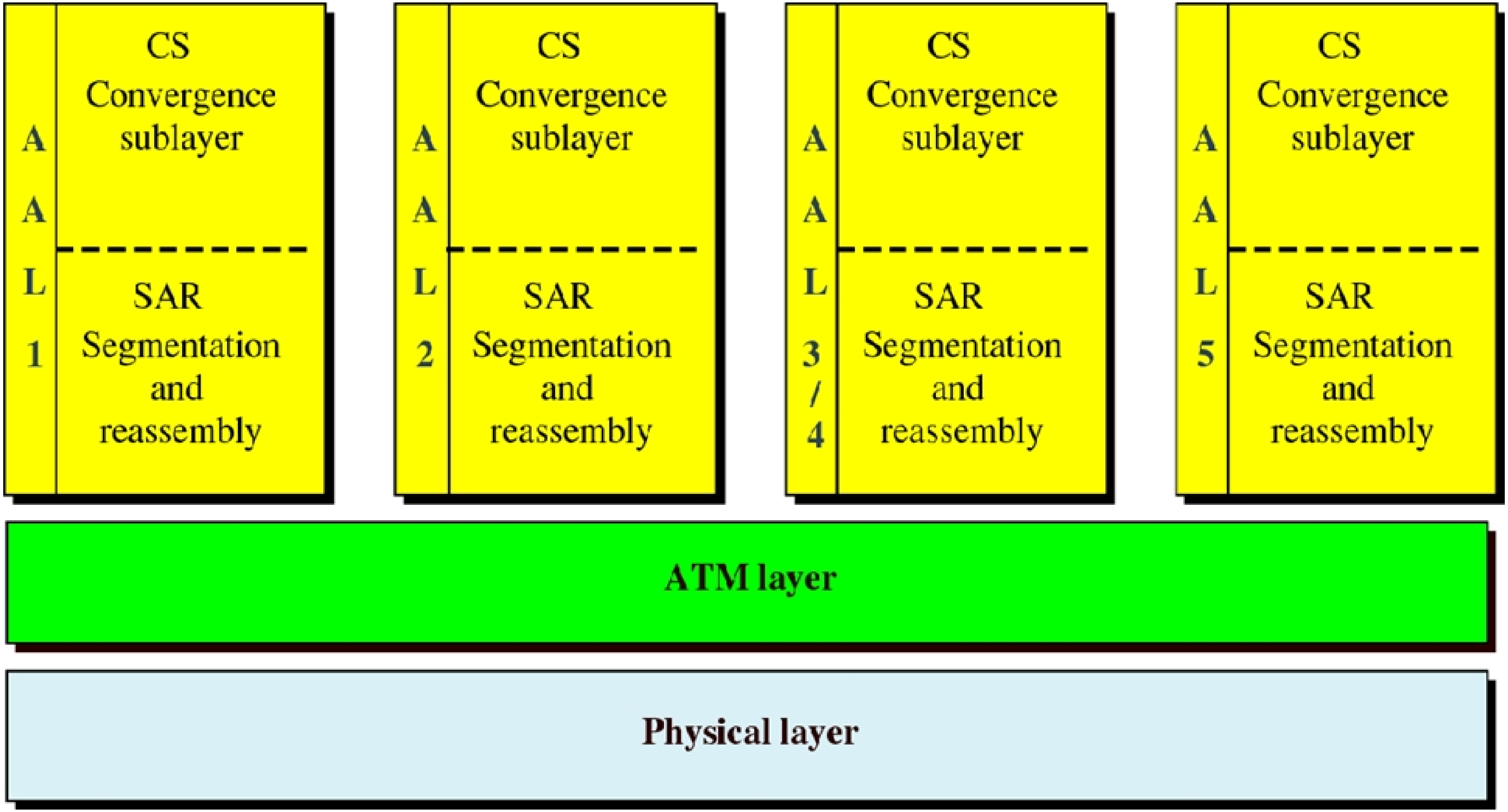
ATM Adaptation Layers



Asynchronous Transfer Mode (ATM)



AAL Types



CS
Convergence sublayer
SAR
Segmentation and reassembly
AAL 1
CS
Convergence sublayer
SAR
Segmentation and reassembly
AAL 2
CS
Convergence sublayer
SAR
Segmentation and reassembly
AAL 3/4
CS
Convergence sublayer
SAR
Segmentation and reassembly
AAL 5
ATM layer
Physical layer

Data-Stream Types

- ATM deals with four types of data streams

  - Constant-bit rate (CBR): real time application, such as real-time voice (telephone calls), real-time video (TV) transmission delay must be minimal

  - Variable-bit-rate (VBR): bit rate may vary from section to section of transmission: compressed voice and video, data

  -Connection-oriented packet data: X.25, TCP protocol

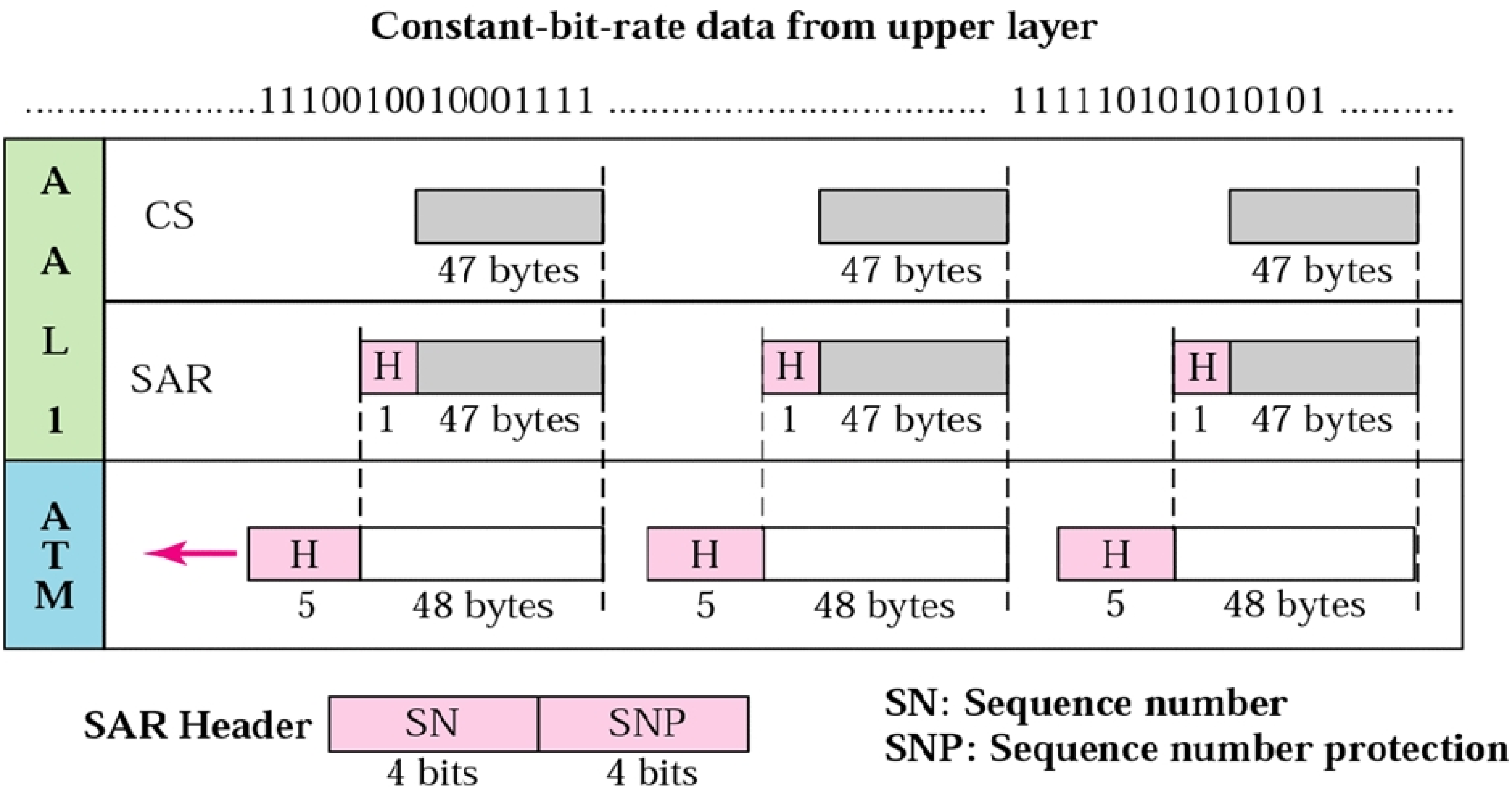
  - Connectionless packet data: datagram applications: IP protocols

Application Adaptation Layer : AAL1

- Supports applications at constant bit rate (CBR): voice, video, existing digital telephone networks

- AAL layer is divide into two sublayers:
  - Convergence sublayer (CS)
  - Segmentation and reassembly (SAR)
- Convergence sublayer (CS): divides the bit stream into 47-byte segments and pass them to the SAR below
- CS sublayer does not add a header, but SAR sublayer adds 1-byte header

Application Adaptation Layer : AAL1

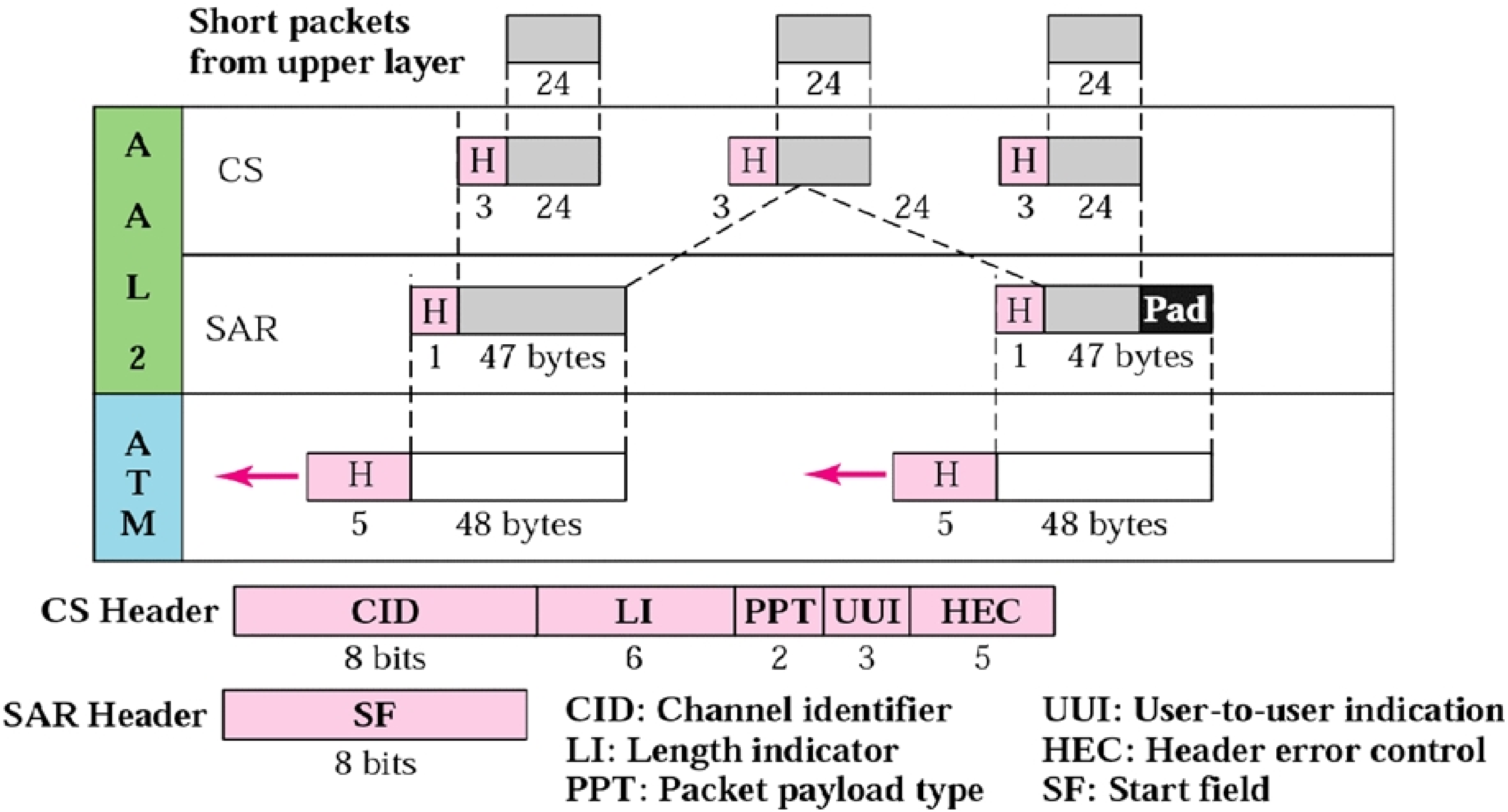


Segmentation and reassembly (SAR)

- Sequence Number (SN): The first bit is sometimes used for timing, which leaves 3 bits for sequencing

- Sequence Number Protection (SNP): First three-bit is cyclic redundancy check field calculated over the first four bits. Last bit is parity bit calculated over the first seven bits.

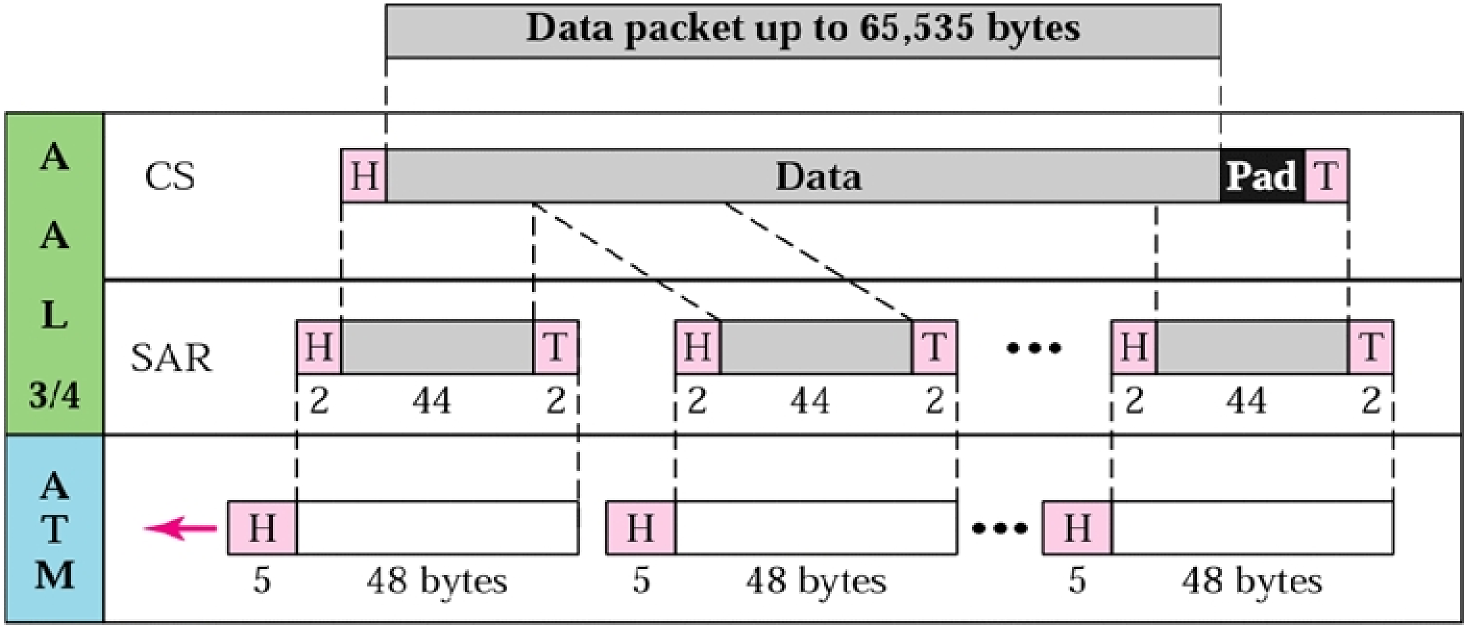
AAL2

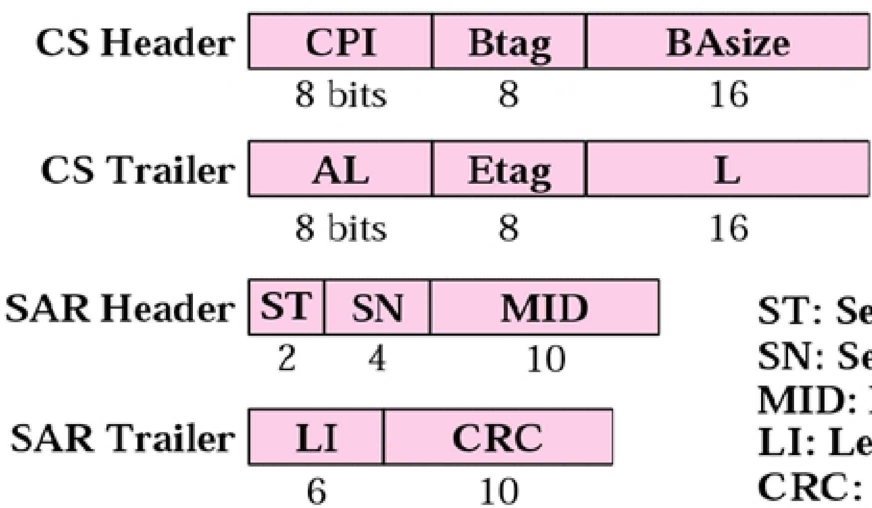

Short packets
from upper layer
24
24
24
AAL2
CS
H
H
H
3
24
3
24
3
24
SAR
H
1
47 bytes
H
Pad
1
47 bytes
ATM
H
5
48 bytes
H
5
48 bytes
CS Header
CID
LI
PPT
UUI
HEC
8 bits
6
2
3
5
SAR Header
SF
8 bits
CID: Channel identifier
LI: Length indicator
PPT: Packet payload type
UUI: User-to-user indication
HEC: Header error control
SF: Start field

AAL2

- Supports variable bit-rate (VBR) applications
- Used for low-bit-rate traffic and short-frame traffic such as audio, video or fax
- CS layer Header:
  - Channel Identifier (CID): defines the channel (user) of the short packet
  - Length Indicator (LI): indicates how much of the final packet is data
  - Packet Payload Type (PPT): defines the type of packet
  - User-to-User Indicator (UUI): used by end-to-end users
  - Header Error Control (HEC): used to correct errors in the header
- SAR layer Header:
  - Start Field (SF): defines the offset from the beginning of the packet

AAL3/4





CPI: Common part identifier
Btag: Beginning tag
BAsize: Buffer allocation size
AL: Alignment
Etag: Ending tag
L: Length

ST: Segment type
SN: Sequence number
MID: Multiplexing identifier
LI: Length identifier
CRC: Error detector

AAL3/4

- Initially, AAL3 was intended to support connection-oriented data services and AAL4 to support connectionless services
- Convergence sublayer:

  - accepts data packet of no more than 65,535 (2^{16}-1) bytes from upper layer service
  - adds a header and trailer, which indicate the beginning and end of the message and how much of the final frame is padding (Padding size is 0 - 43 bytes)
  - Message (including header/trailer/padding) is passed to the SAR layer

AAL3/4

- CS header and trailer:

-Common Part Identifier (CPI): defines how the subsequent fields are to be interpreted. The value at present 0.
-- Begin tag (Btag): value of this field is repeated in each cell to identify all the cells beginning to the same packet. The value is same as the Etag.

- Buffer-allocation Size (BAsize): tells the receiver what size buffer is needed for the coming data

-Alignment (AL): to make the rest of the trailer 4 bytes long
-- Ending tag (Etag): Serves as an ending flag. Its value is same as Btag.

- Length (L): length of the data unit

AAL3/4

- Segmentation and reassembly: accepts 44-byte pay load from CS and adds 2-byte header and 2-byte trailer. The resulting 48-byte data unit is passed to ATM for inclusion in the cell
- SAR Header and trailer:

  -Segment type (ST): 2-bit ST indicates whether the segment belongs to the beginning (00), middle (01), or the end (10) of a message, or is a single-segment message (11)

  - - Sequence Number (SN): 4-bit field defines a sequence number to order the bits. The first bit is sometimes used for timing, which leaves 3 bits for sequencing (module 8)

AAL3/4

- SAR Header and trailer cont'd
  - Multiplex identification (MID): 10-bit identifies cells coming from different data flows and multiplexed on the same virtual connection
  - Length indicator (LI): defines how much of the packet is data, not padding.
  - CRC: last 10 bits of the trailer are the CRC of the entire data unit

AAL5

- AAL3/4 provides comprehensive sequencing and error control mechanisms that are not necessary for every application
- AAL5 defined for these applications, Called “simple and efficient adaptation layer (SEAL)
- Assumes that all cells travel sequentially and rest of functions provided by CS and SAR are already included in upper layers, hence no provision for addressing, sequencing or other CS and SAR heading information
- Only padding and four-field trailer are added at CS
- Padding and trailer are added to the end of the entire message of 65,536 bytes or less

AAL5

- Segments consist of 48 bytes of data, last segment has 40 bytes of data and 8 bytes overhead (trailer)
- Trailer:

  - Pad (PAD): between 0 and 47 bytes, making the message divisible by 48

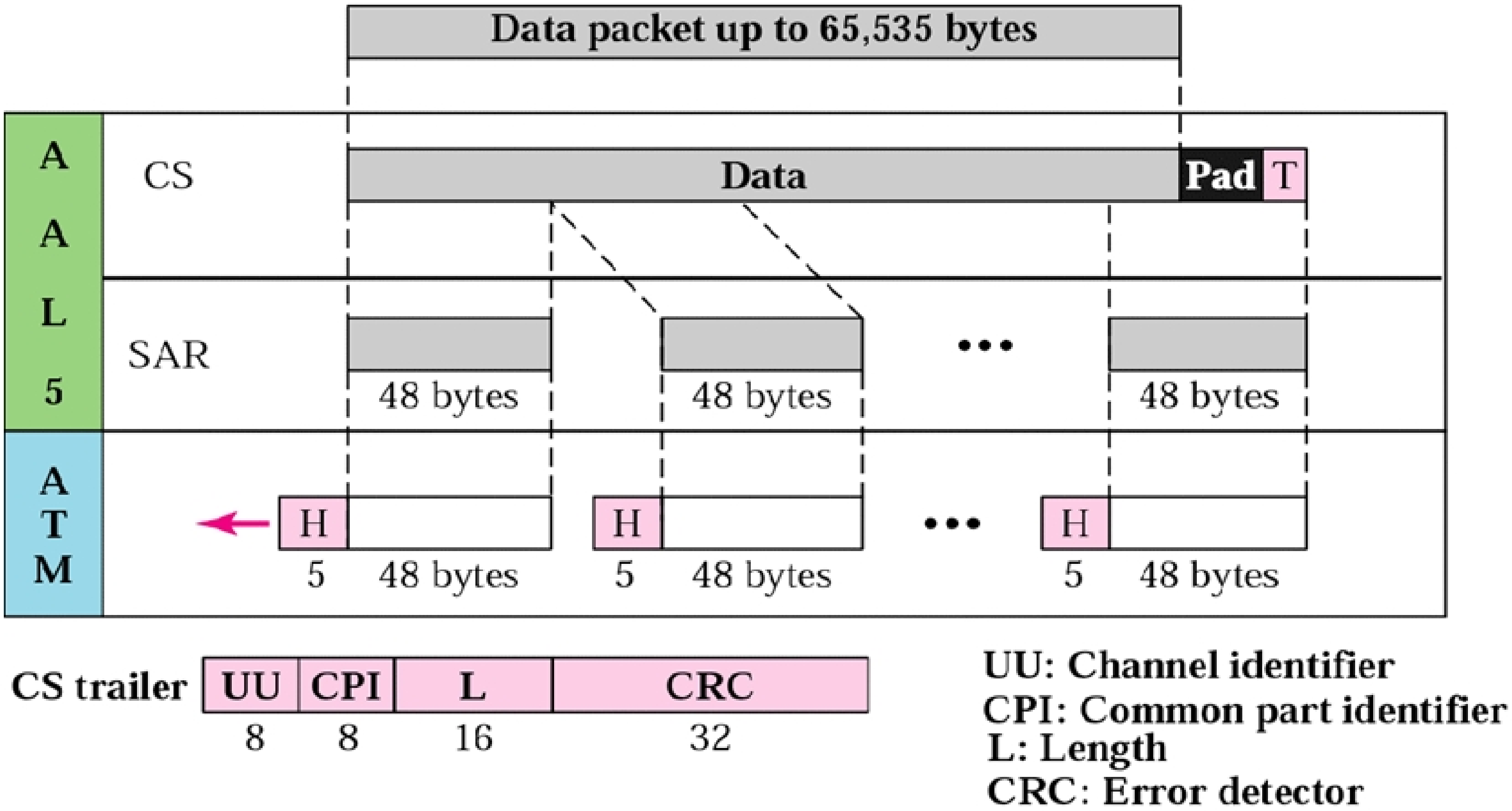
  - User-to-user ID (UU): one byte UU field (user defined)

  - Common Part Identifier (CPI): defines how the subsequent fields are to be interpreted. The value at present 0.

  - Length (L): two-byte L fields indicates length of the original data

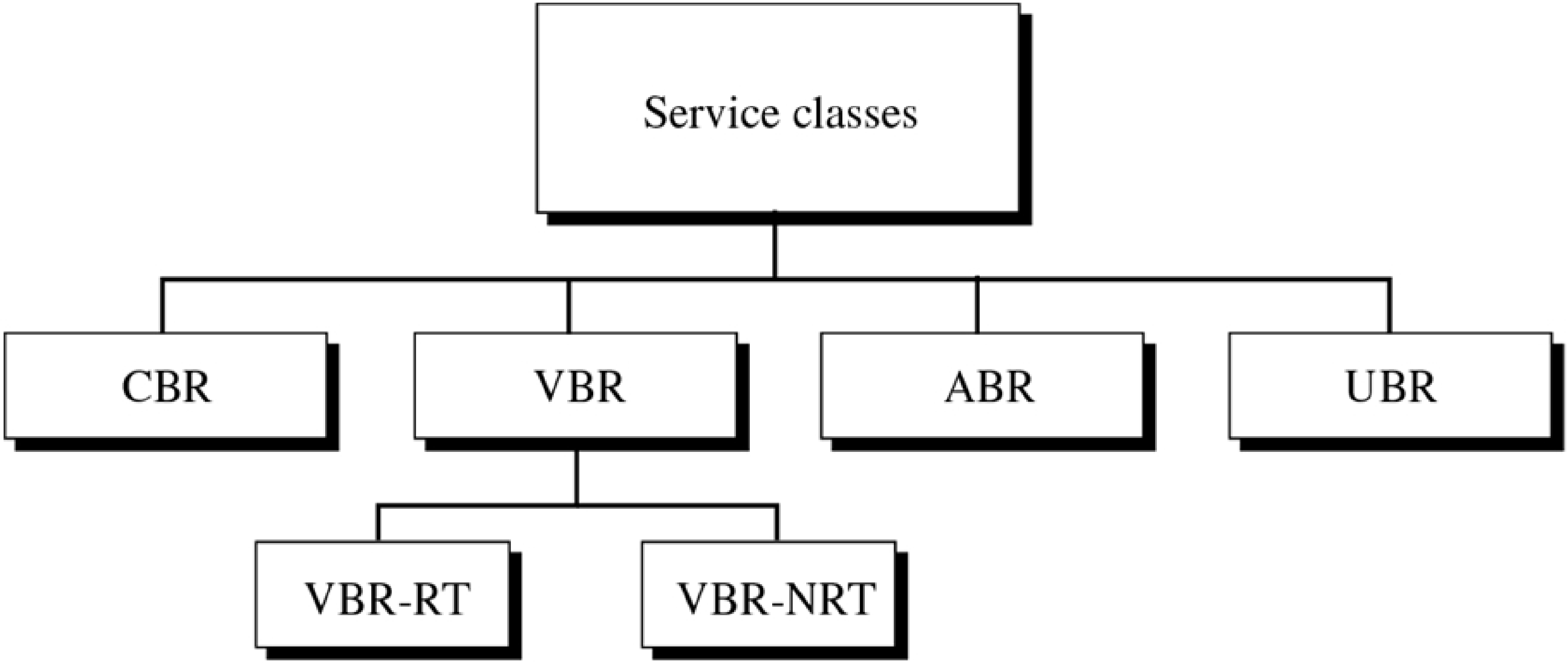
  - CRC: 4-byte error check for the entire data unit

AAL5

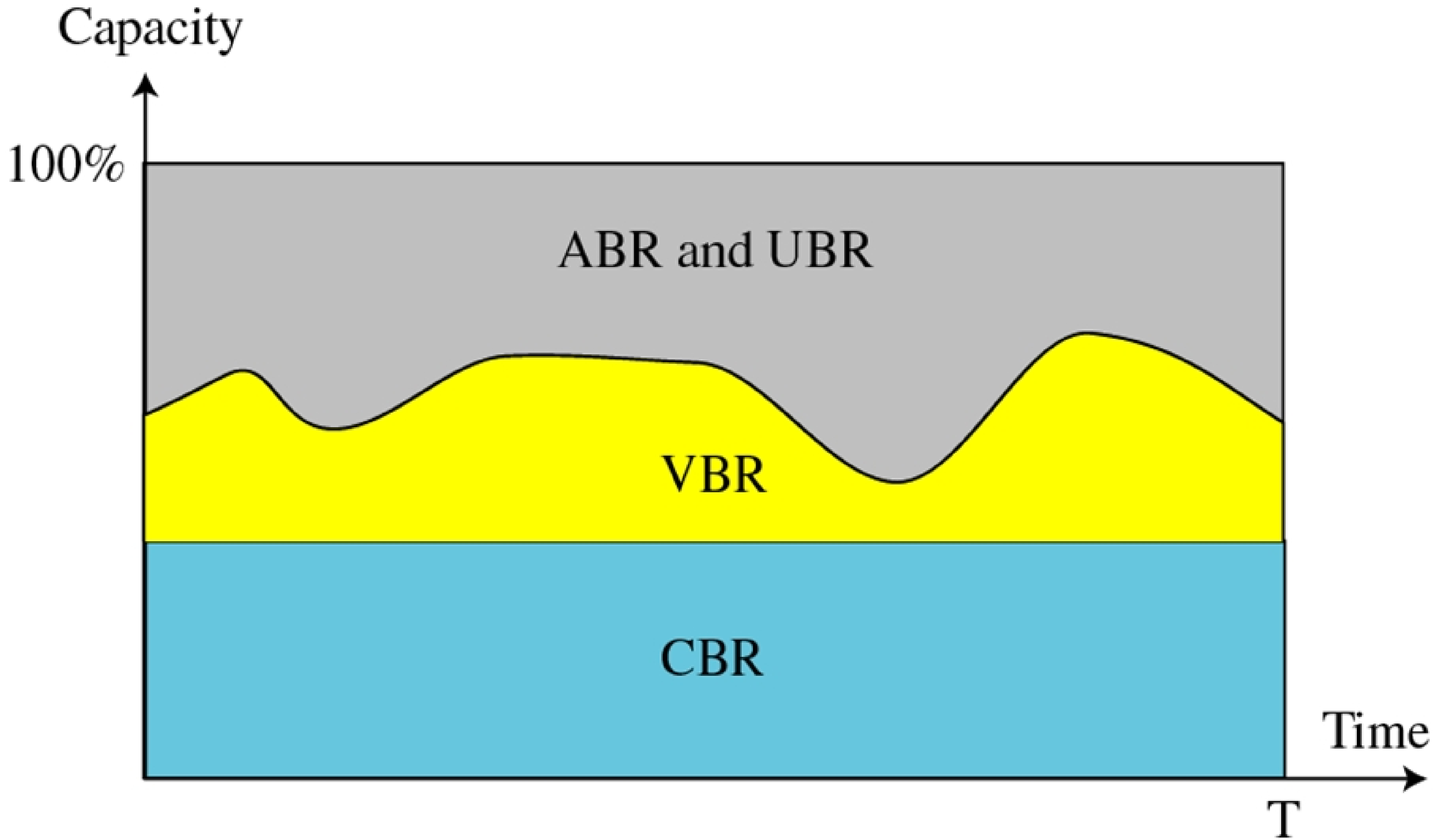


Data packet up to 65,535 bytes
A
A
L
5
CS
Data
Pad
T
SAR
48 bytes
48 bytes
48 bytes
A
T
M
H
H
H
5
48 bytes
5
48 bytes
5
48 bytes
CS trailer
UU
CPI
L
CRC
8
8
16
32
UU: Channel identifier
CPI: Common part identifier
L: Length
CRC: Error detector

Service Classes



Service Classes and Capacity of Network



Service Classes

- The ATM Forum defines four service classes: CBR, VBR, ABR, and UBR.
- CBR: The constant bit rate (CBR) class is designed for customers that need realtime audio or video services. The service is similar to that provided by a dedicated line such as a T-line.
- VBR. The variable bit rate (VBR) class is divided into two subclasses:
  - Real time (VBR-RT) is designed for those users that need real-time services(such as voice and video transmission) and use compression techniques to create a variable bit rate.
  - Nonreal time (VBR-NRT). designed for those users that do not need real-time services but use compression techniques to create a variable bit rate.

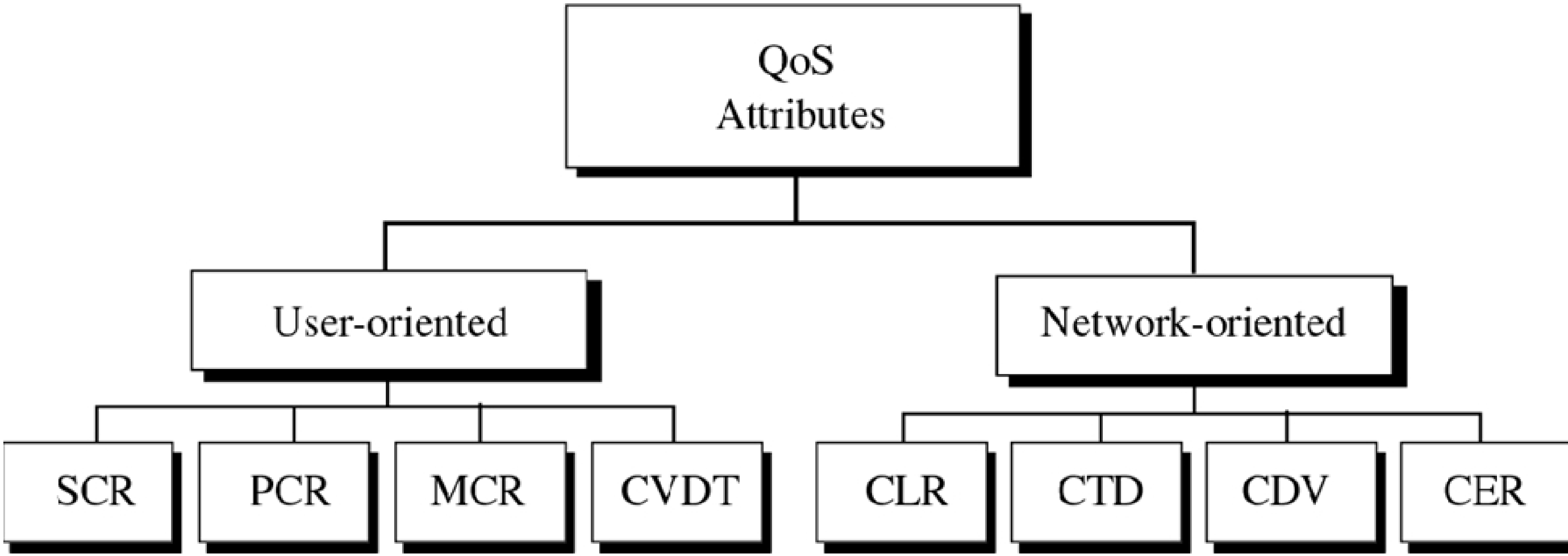
Service Classes Cont’d

- ABR. The available bit rate (ABR) class delivers cells at a minimum rate. If more network capacity is available, this minimum rate can be exceeded. ABR is particularly suitable for applications that are bursty in nature.
- UBR. The unspecified bit rate (UBR) class is a best-effort delivery service that does not Guarantee anything.

Quality of Service (QoS)

- Quality of service (QoS): set of attributes related to the performance of the connection.
- For each connection, the user can request a particular attribute.
- Attributes are categorize into those related to the *user* and those related to the *network*.

Quality of Service (QoS)



User Related Attributes

- Sustained cell rate (SCR): average cell rate over a long time interval. The actual cell rate may be lower or higher than this value, but the average should be equal to or less than the SCR.
- Peak cell rate (PCR): sender's maximum cell rate. The user's cell rate can sometimes reach this peak, as long as the SCR is maintained.

User Related Attributes Cont’d

- Minimum cell rate(MCR): minimum cell rate acceptable to the sender. Example: if the MCR is 50,000, the network must guarantee that the sender can send at least 50,000 cells per second.

- Cell variation delay tolerance(CVDT) is a measure of the variation in cell transmission times. Example: for CVDT of 5 ns, the difference between the minimum and the maximum delays in delivering the cells should not exceed 5 ns.

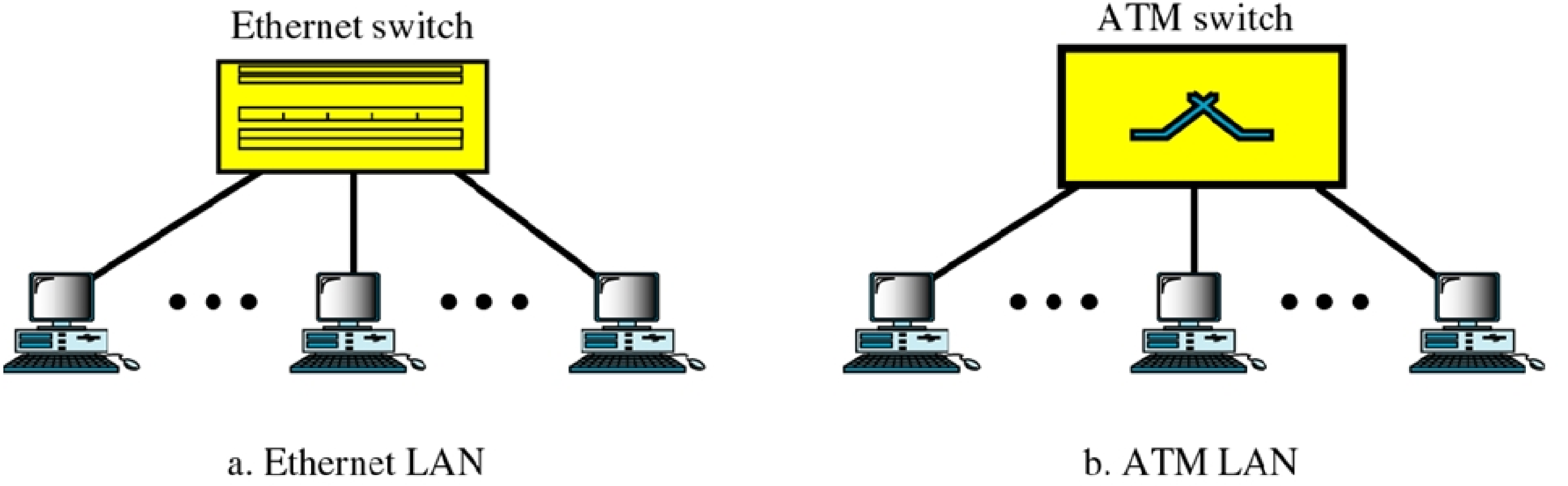
Network Related Attributes

- Cell loss ratio(CLR): fraction of cells lost(or delivered so late that they are considered lost) during transmission. Example: if in average one cell in every million is lost then , the CLR is

$$CLR= 1/1000\,000 = 10^{-6}$$

- Cell transfer delay (CTD): Average time needed for a cell to travel from source to destination.
- Cell delay variation (CDV): Difference between the CTD maximum and the CTD minimum.
- Cell error ratio (CER): fraction of the cells delivered in error.

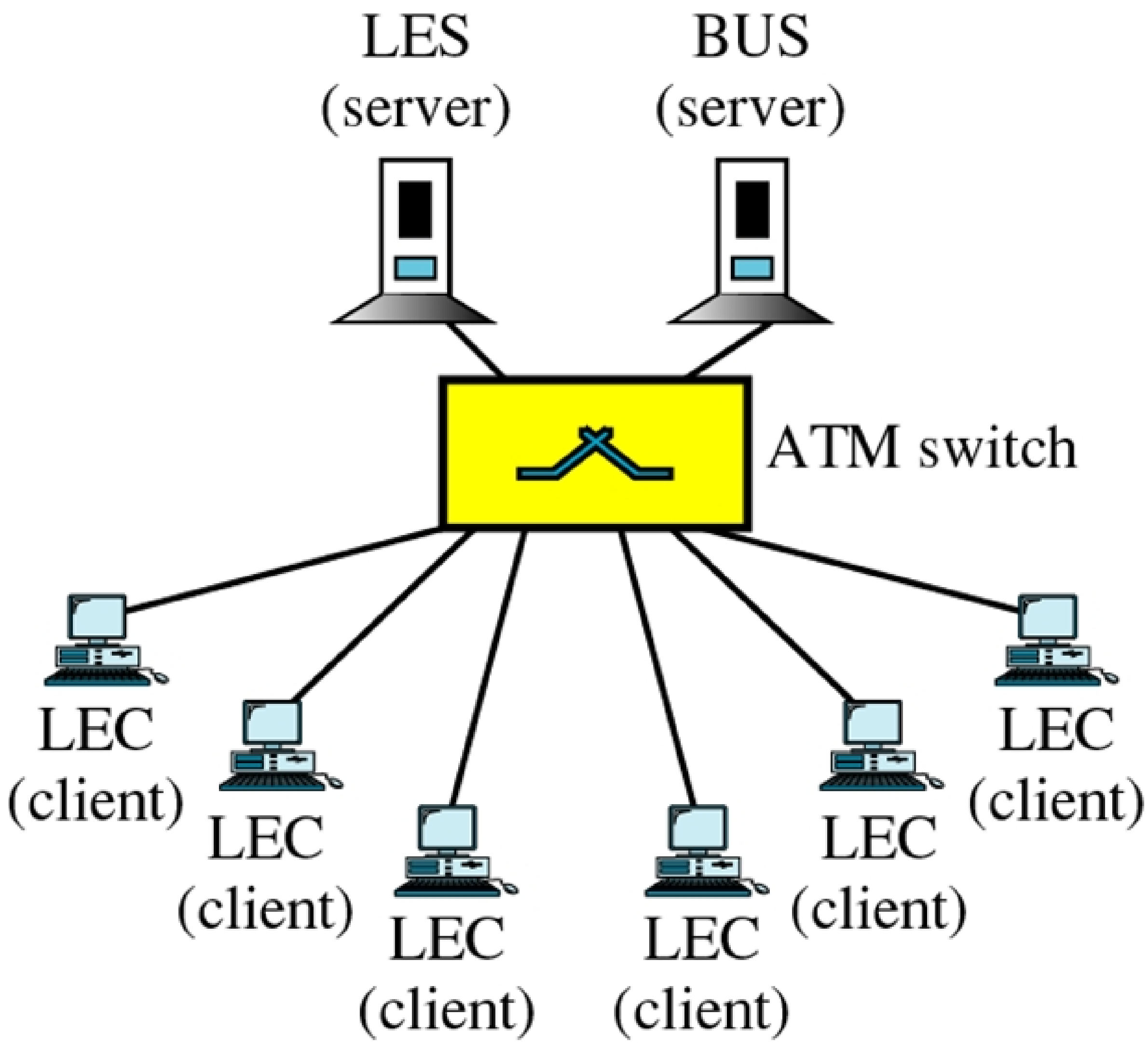
Ethernet Switch and ATM Switch



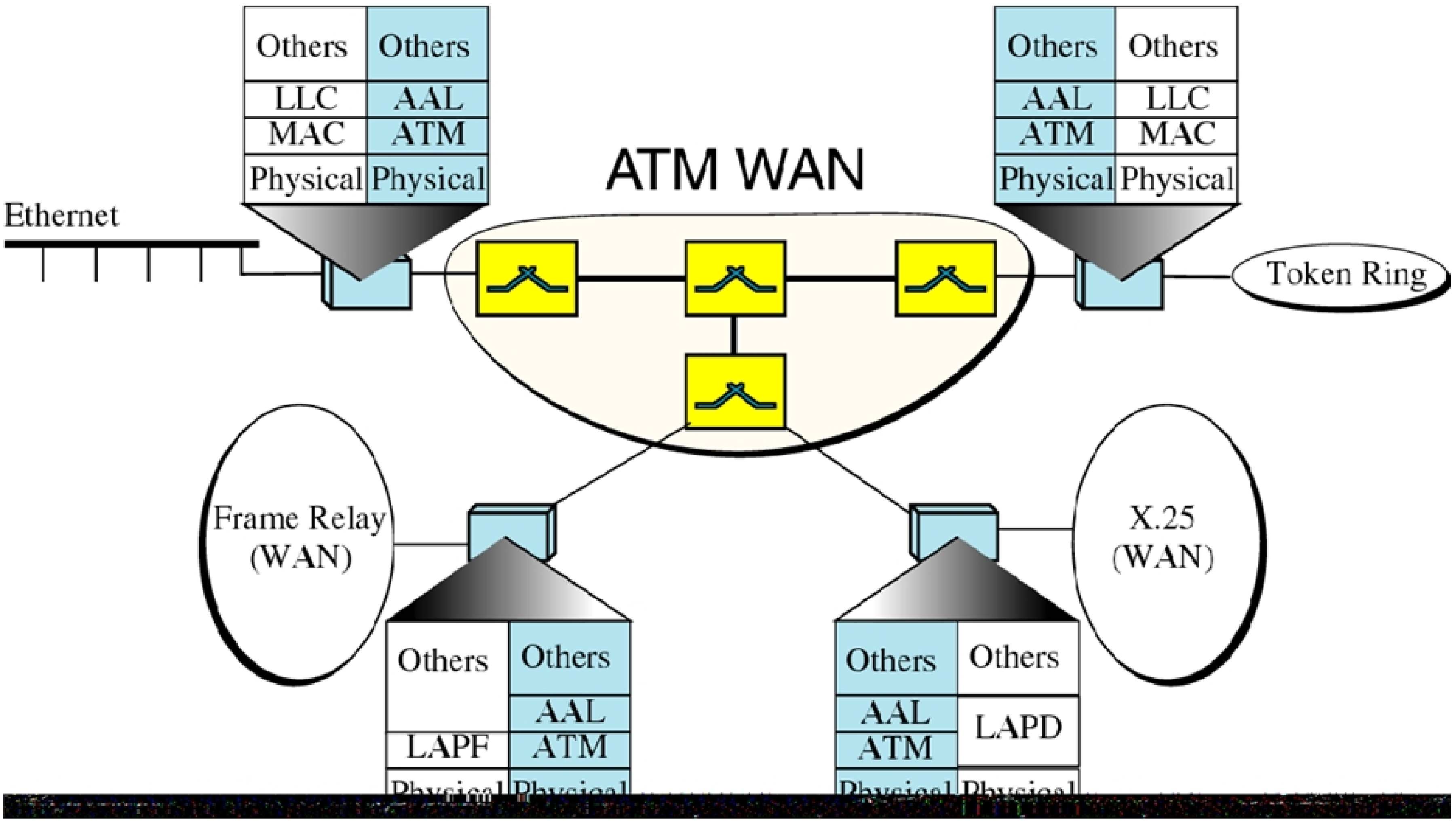
ATM LAN

- **LAN Emulation Server (LES)** is also called **ATMARP** • To lookup a network layer address, a host sends a packet (ARP request) to the LES, which then lookup corresponding ATM address and returns it to the machine requesting it
- This address then can be used to send encapsulated packets to the destination
- This solution only solves the host location problem • To support broadcasting/multicasting **Broadcast / Unknown Server (BUS)** is used
- BUS has connection to all hosts and can simulate broadcasting by sending a packet to all of them, one at a time
- Hosts can also speed up delivery of a packet to an unknown host by sending the packet to the BUS for broadcasting and then (in parallel) looking up the address using the LES

LANE Approach



ATM WAN

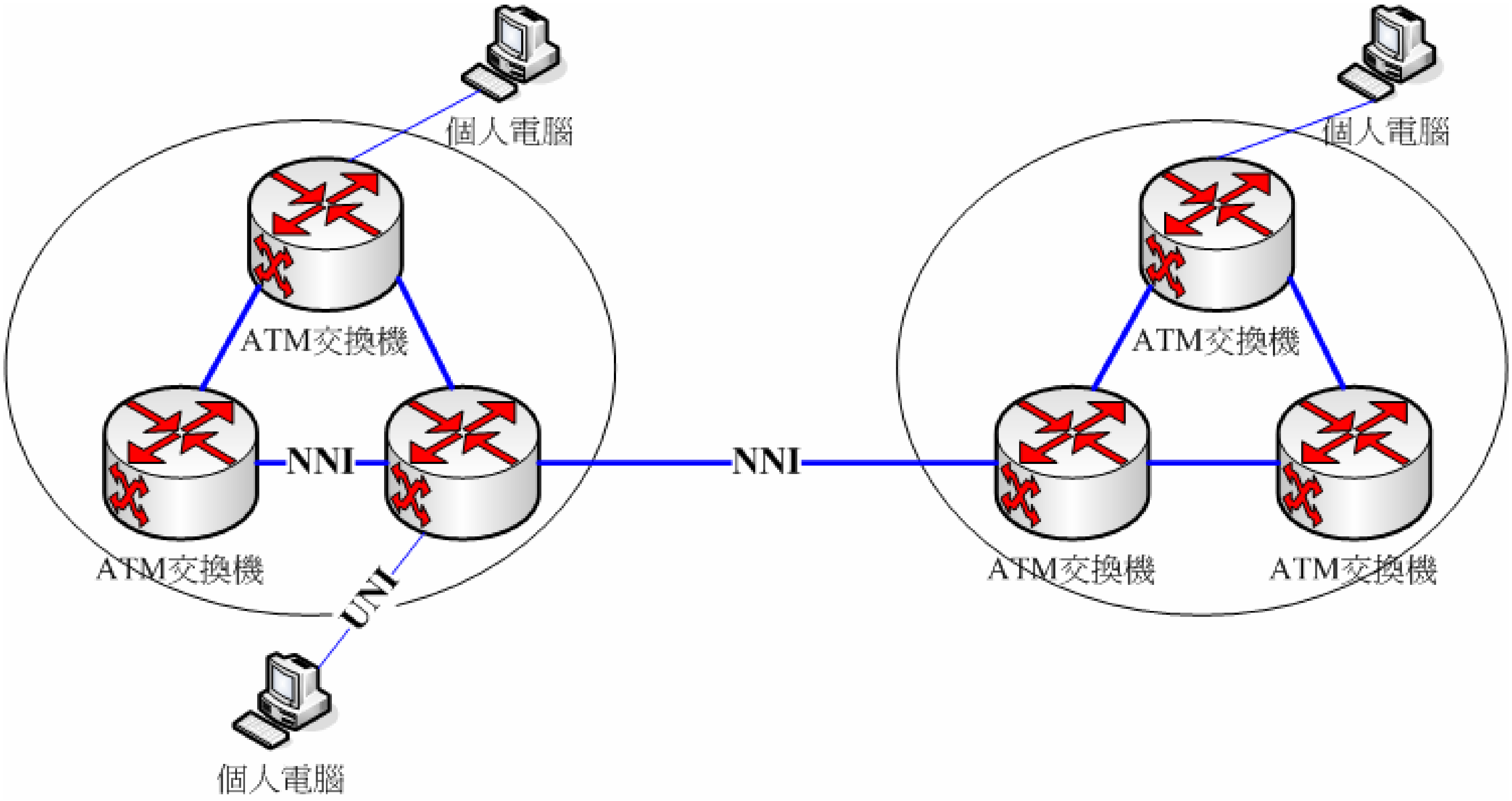

Others
Others
LLC
AAL
MAC
ATM
Physical
Physical
ATM WAN
Others
Others
AAL
LLC
ATM
MAC
Physical
Physical
Ethernet
Token Ring
Frame Relay
(WAN)
X.25
(WAN)
Others
Others
AAL
LAPF
ATM
Others
Others
AAL
LAPD
ATM

Acknowledgement

- All figures obtained from publisher-provided instructor downloads

  Data Communication and Networking by Behrouz A. Forouzan, Third Ed., Tata McGraw Hill Publishing, 2004

ATM Network Structure

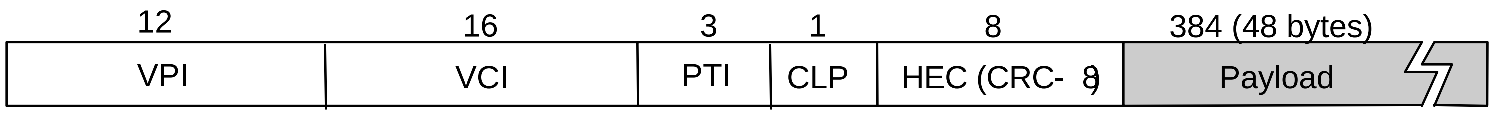


Cell Format

4	8	16	3	1	8	384 (48 bytes)
GFC	VPI	VCI	Type	CLP	HEC (CRC- 8)	Payload

- User-Network Interface (UNI)
  - host-to-switch format
  - GFC: Generic Flow Control (still being defined)
  - VCI: Virtual Circuit Identifier
  - VPI: Virtual Path Identifier
  - Type: management, congestion control, AAL5 (later)
  - CLPL Cell Loss Priority
  - HEC: Header Error Check (CRC-8)

Cell Format

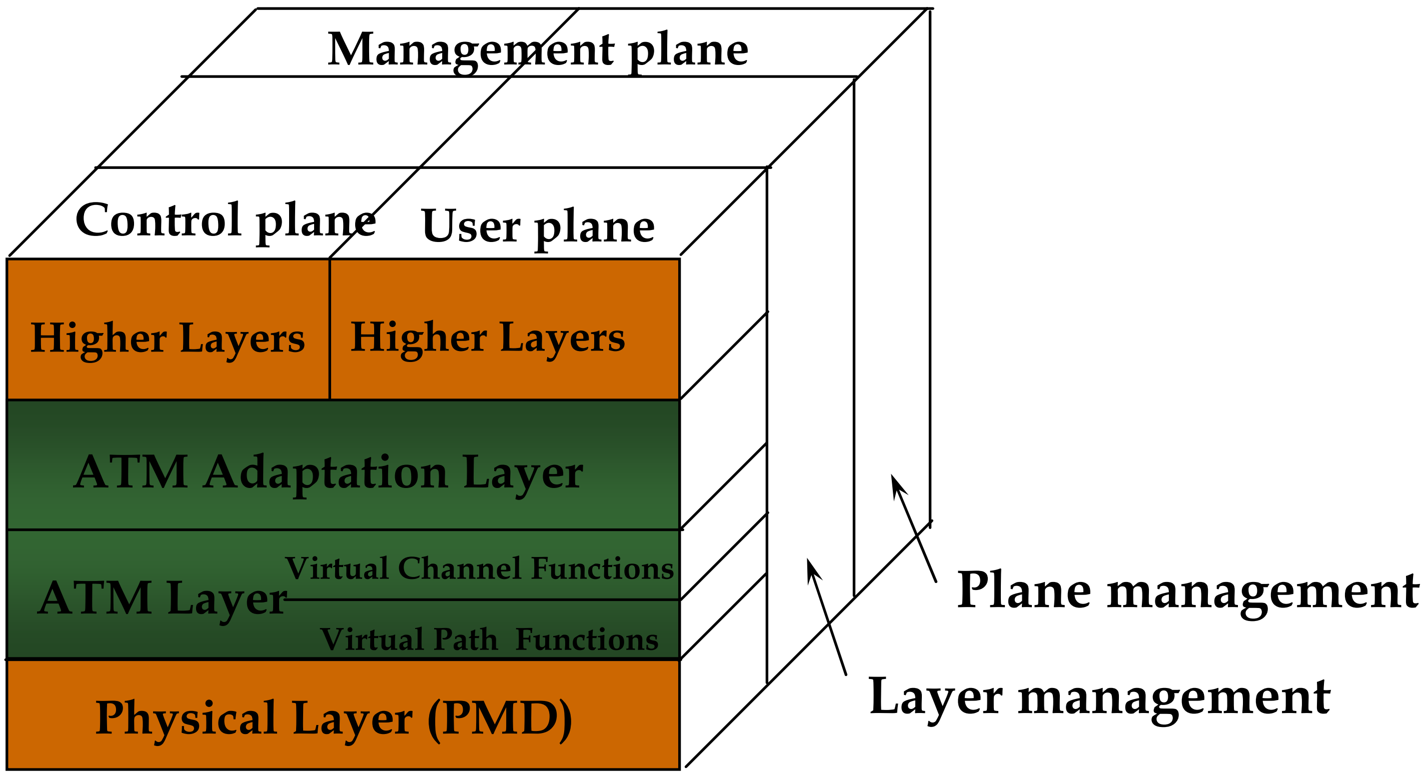


- Network-Network Interface (NNI)
  - switch-to-switch format
  - GFC becomes part of VPI field

ATM Characteristics

- No error protection or flow control on a link-by-link basis.
- ATM operates in a connection-oriented mode.
- The header functionality is reduced.
- The information field length is relatively small and fixed.

ATM Protocol Stack



Physical Layer Interface Specification

- SONET STS-3C
- SONET STS-12
- DS3
- STP for ATM LAN
- etc.

ATM Layer Service

- Transparent transfer of 48-octet data unit
- Deliver data in sequence on a connection
- Two levels of multiplexing
- Three types of connections
  - Point-to-point
  - Point-to-Multipoint
  - Multipoint-to-Multipoint
- Transport is best-effort
- Network QoS negotiation
- Traffic control and congestion control

ATM Layer Functions

- Cell multiplexing and switching
- Cell rate decoupling
- Cell discrimination based on pre-defined VPI/VCI
- Quality of Service (QoS)
- Payload type characterization
- Generic flow control
- Loss priority indication and Selective cell discarding
- Traffic shaping

Pre-assigned VPI/VCI Values

- Unassigned Cell Indication (VPI = 0, VCI = 0)
- Meta signaling (VCI=1)
  - Meta signaling is the bootstrap procedure used to establish and release a signaling VC. Not used for PVC setup.
- General broadcasting signaling (VCI=2)
- OAM F4 flow indication

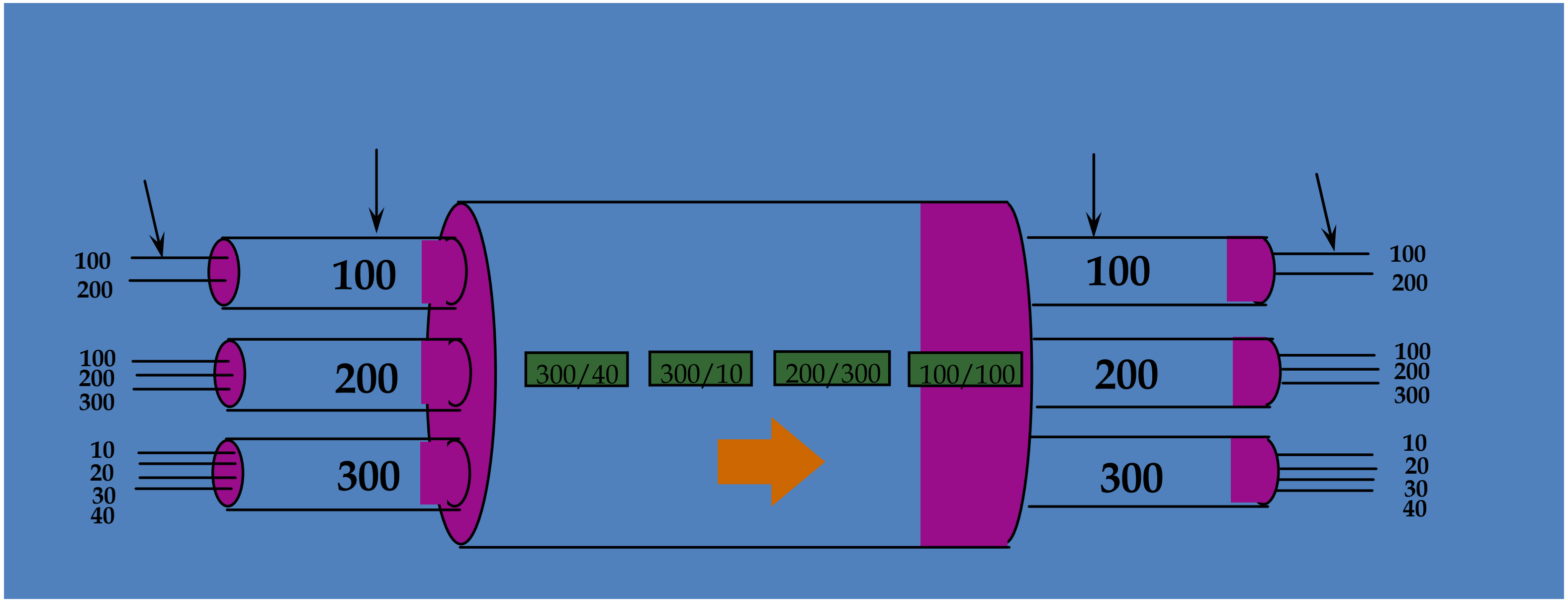
-- segment and end-to-end (VCI=3 and VCI=4)

- Point-to-Point Signaling (VCI=5)
- Carriage of Interim Local Management Interface (ILMI) messages (VPI=0, VCI=16)

Cell Rate Decoupling and Cell Discrimination

- Cell Rate Decoupling
  - ATM sending entity adds unassigned cells to the assigned cell stream in order to adjust to the cell rate acquired by the payload capacity of the physical layer (R).
- Cell Discrimination
  - Meta signaling
  - General broadcast signaling
  - Point-to-point Signaling
  - Segment OAM F4 flow cell
  - End-to-end OAM F4 flow cell
  - ILMI message
  - User data

Virtual Channels, Virtual Paths, and the Physical Channel



Virtual Channels

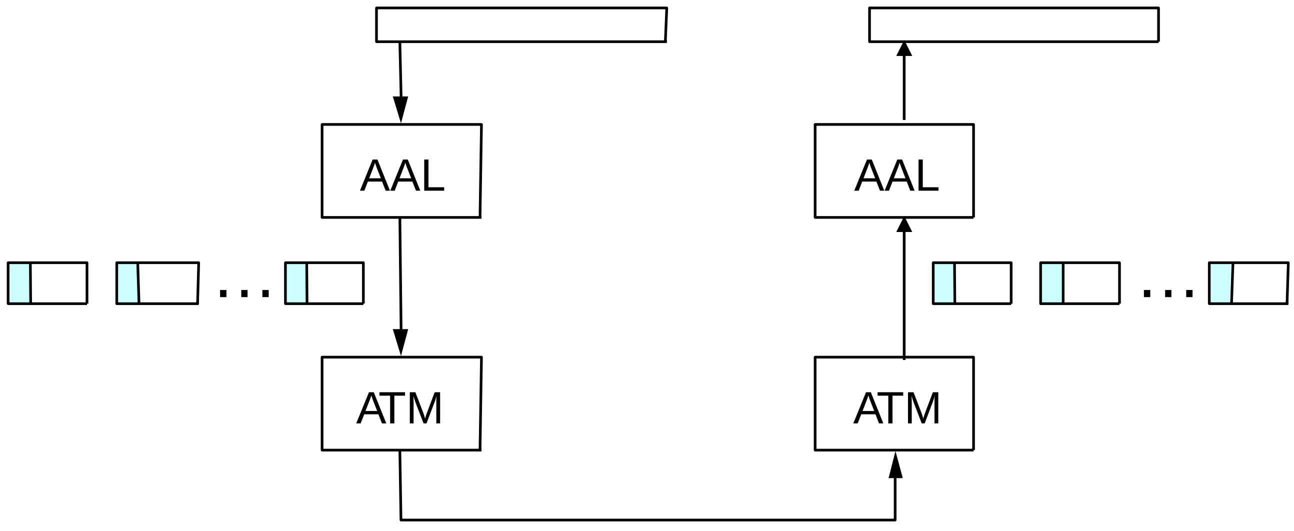
- The virtual channel (VC) is the fundamental unit of transport in a B-ISDN. Each ATM cell contains an explicit label in its header to identify the virtual channel.
  - a Virtual Channel Identifier (VCI)
  - a Virtual Path Identifier (VPI)
- A *virtual channel (VC)* is a communication channel that provides for the transport of ATM cells between two or more endpoints for information transfer.
- A Virtual Channel Identifier (VCI) identifiers a particular VC within a particular VP over a UNI or NNI.
- A specific value of VCI has no end-to-end meaning.

Virtual Paths

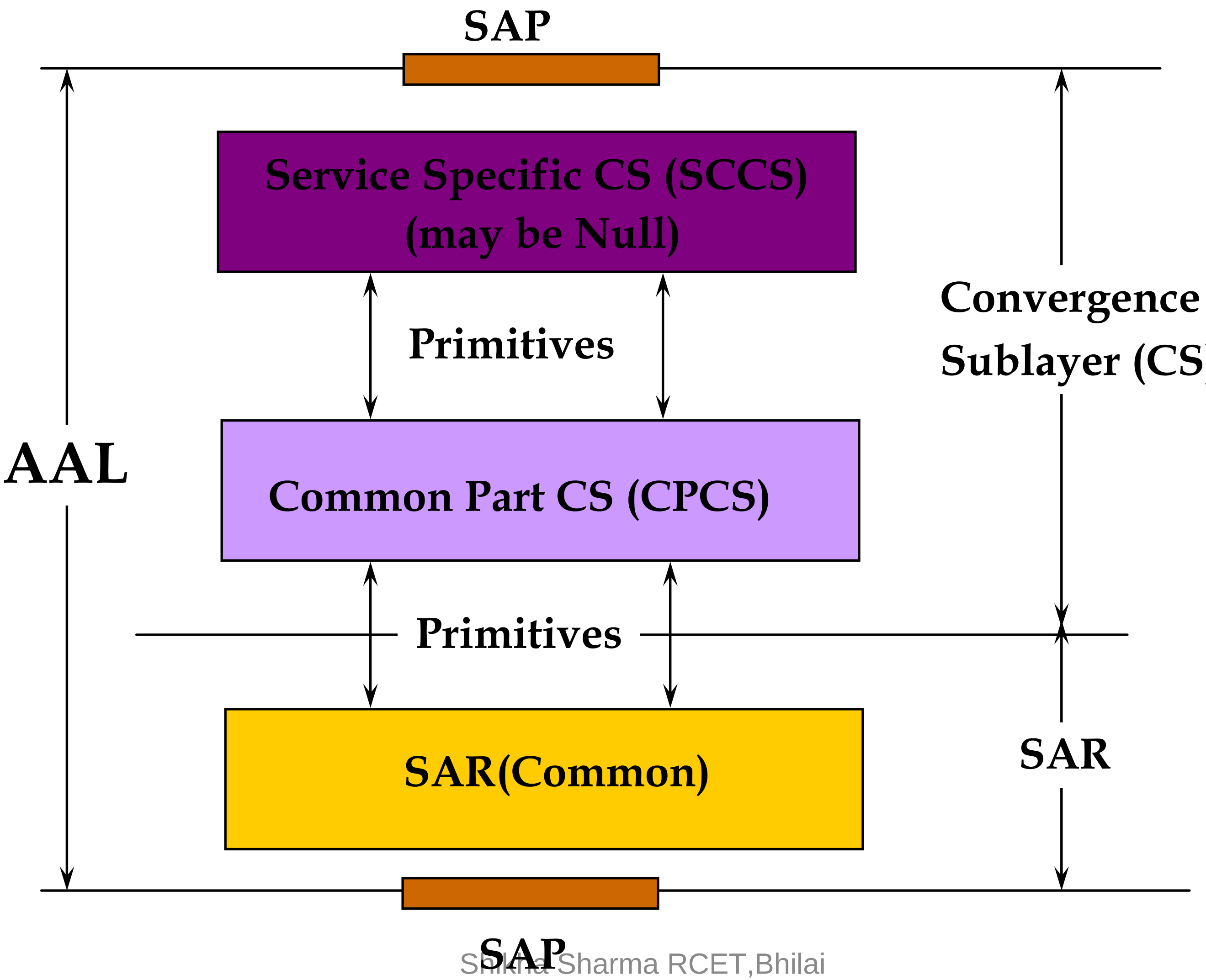
- A *Virtual Path (VP)* is a group of Virtual Channels that are carried on the same physical facility and share the same Virtual Path Identifier (VPI) value.
- The VP boundaries are delimited by Virtual Path Terminators (VPT).
- AT VPTs, both VPI and VCI are processed.
- Between VPTs associated with the same VP, only the VPI values are processed (and translated) at ATM network elements.
- The VCI values are processed only at VPTs, and are not translated at intermediate ATM network elements.

Segmentation and Reassembly

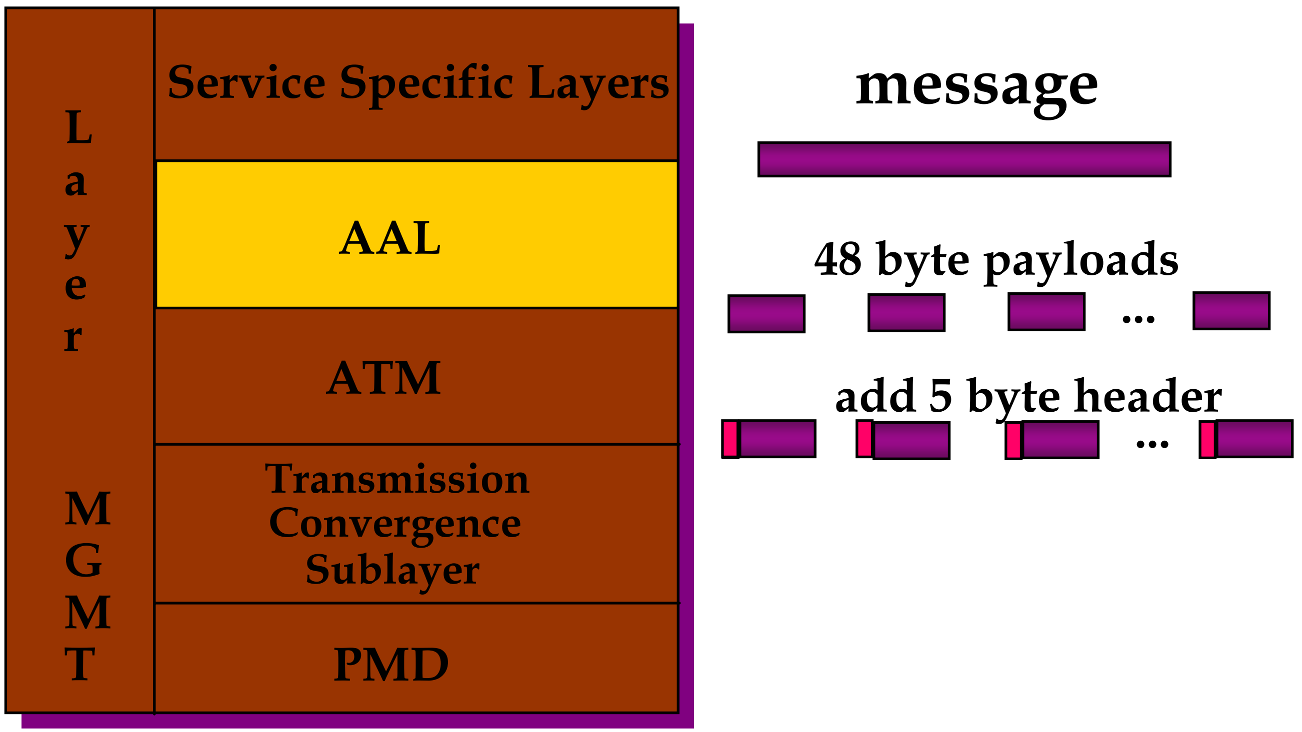
- ATM Adaptation Layer (AAL)
  - AAL 1 and 2 designed for applications that need guaranteed rate (e.g., voice, video)
  - AAL 3/4 designed for packet data
  - AAL 5 is an alternative standard for packet data



AAL Reference Structure



AAL


L
a
y
e
r
M
G
M
T
Service Specific Layers
AAL
ATM
Transmission
Convergence
Sublayer
PMD
message
48 byte payloads
...
add 5 byte header
...

ATM Adaptation Layers (AAL)

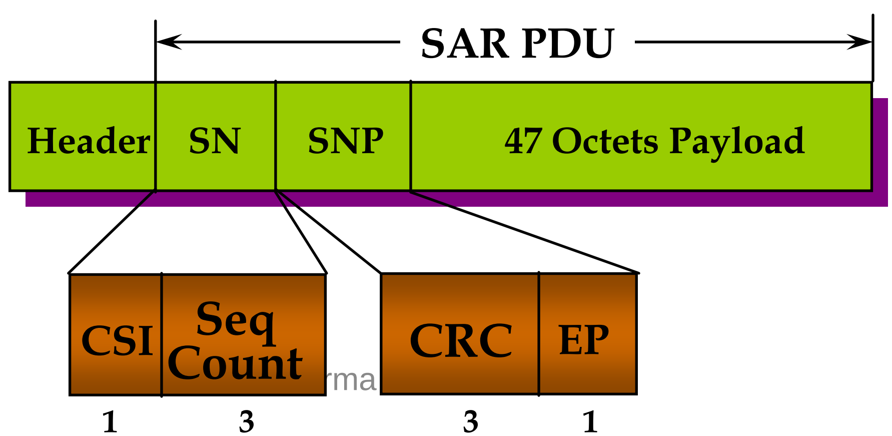
- In order to carry data units longer than 48 octets in ATM cells, an adaptation layer is needed.
- The *ATM adaptation layer* (AAL) provides for segmentation and reassembly of higher-layer data units and for detection of errors in transmission.
- Since the ATM layer simply carries cells without concern for their contents, a number of different AALs can be used across a single ATM interface.
- The AAL maps the user, control, or management protocol data units into the information field of the ATM cell and vice versa.
- To reflect the spectrum of applications, four service classes have been defined by CCITT.

AAL Service Classification

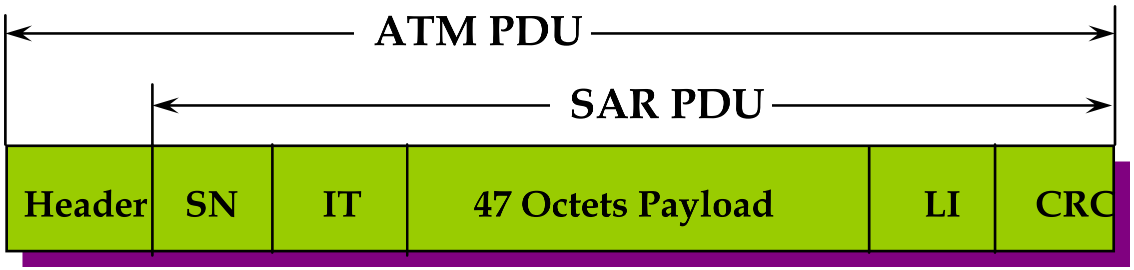
Attribute	Class A Circuit Emulation	Class B Packetized voice/video	Class C Connection Oriented Data	Class D Datagram	Signalling (Q.93B)
	AAL1	AAL2	AAL 3	AAL 4	SAAL
			AAL 5		
Timing between source and destination	Required		Not required		
Bit Rate	Constant	Variable			
Connection Mode	Connection oriented			Connectionless	

AAL 1 (Constant Bit Rate -CBR) Functions

- Emulation of DS1 and DS3 Circuits
- Distribution with forward error correction
- Handle cell delay for constant bit rate
- Transfer timing information between source and destination
- Transfer structure information (structure pointer)
- Provide indication of unrecoverable lost or errored information



AAL 2 Protocol Data Unit (PDU)



- **SN: Sequence number**
- **IT: Information Type:BOM,COM,EOM,SSM**
- **Length Indicator**

AAL 3/4

- Convergence Sublayer Protocol Data Unit (CS-PDU)

8	8	16	< 64 KB	0– 24	8	8	16
CPI	Btag	BASize	User data	Pad	0	Etag	Len

  – CPI: commerce part indicator (version field)
  – Btag/Etag:beginning and ending tag
  – BAsize: hint on amount of buffer space to allocate
  – Length: size of whole PDU

Cell Format

40	2	4	10	352 (44 bytes)	6	10
ATM header	Type	SEQ	MID	Payload	Length	CRC-10

– Type
  - BOM: beginning of message
  - COM: continuation of message
  - EOM end of message
– SEQ: sequence of number
– MID: message id
– Length: number of bytes of PDU in this cell

AAL 5 PDU Structure

- The Simple and Efficient Adaptation Layer (SEAL), attempts to reduce the complexity and overhead of AAL 3/4.
- It eliminates most of the overhead of AAL 3/4.
- AAL 5 comprises a convergence sublayer and a SAR sublayer, although the SAR is essentially null.

AAL5

- CS-PDU Format

< 64 KB	0– 47 bytes	16	16	32
Data	Pad	Reserved	Len	CRC-32

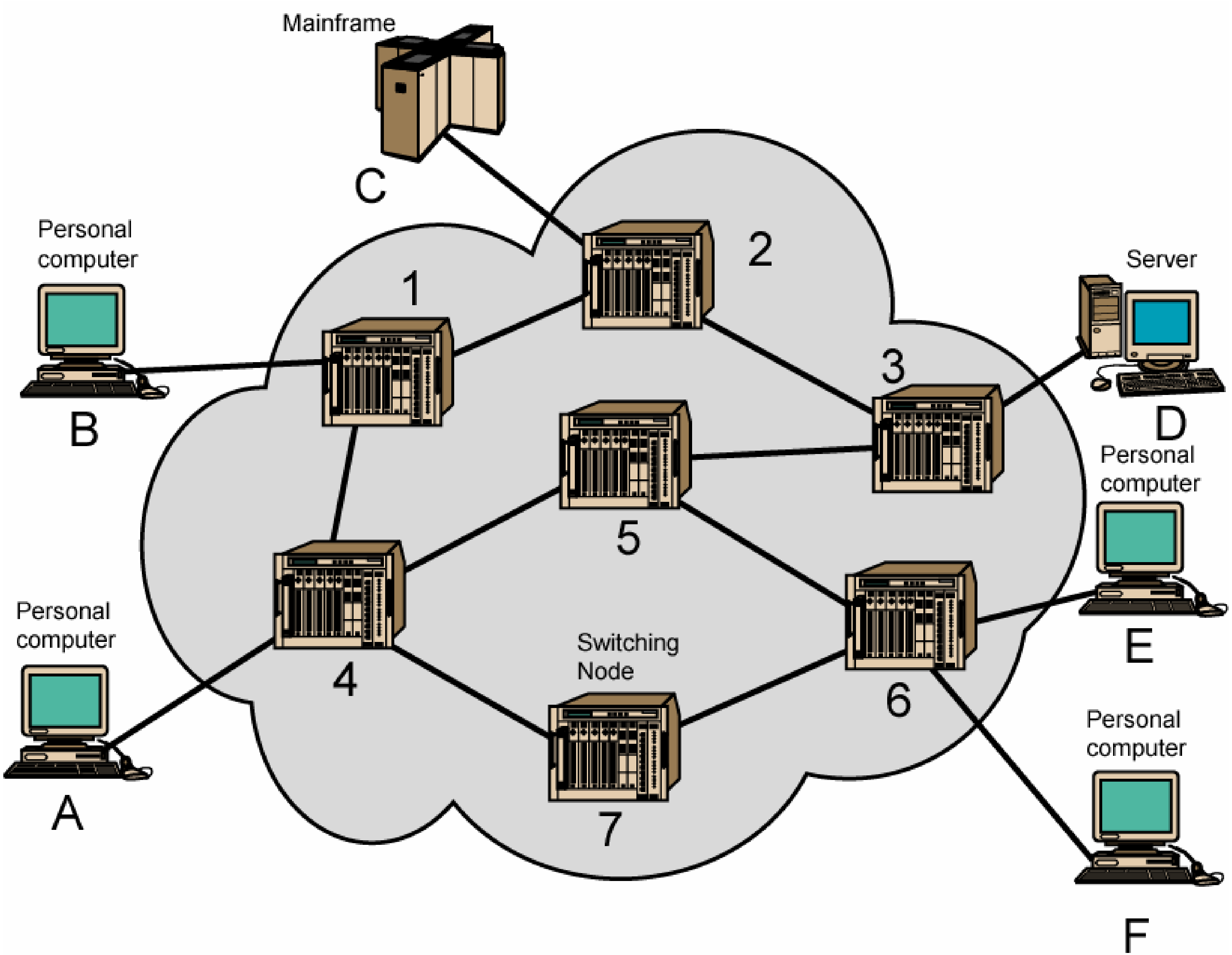
  - pad so trailer always falls at end of ATM cell
  - Length: size of PDU (data only)
  - CRC-32 (detects missing or misordered cells)
- Cell Format
  - end-of-PDU bit in Type field of ATM header

Switching

Switching Networks

- A switch determines how connections are made and how data are moves over network
- Long distance transmission is typically done over a network of switched nodes
- End devices are stations
  - Computer, terminal, phone, etc.

Simple Switched Network



- Node to node links usually multiplexed
- Network is usually partially connected
- Different switching technologies
  - Circuit switching
  - Packet switching
  - Message switching

Circuit Switching

- Dedicated communication path between two stations
- Three phases
  - Establish
  - Transfer
  - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing

Circuit-switched network

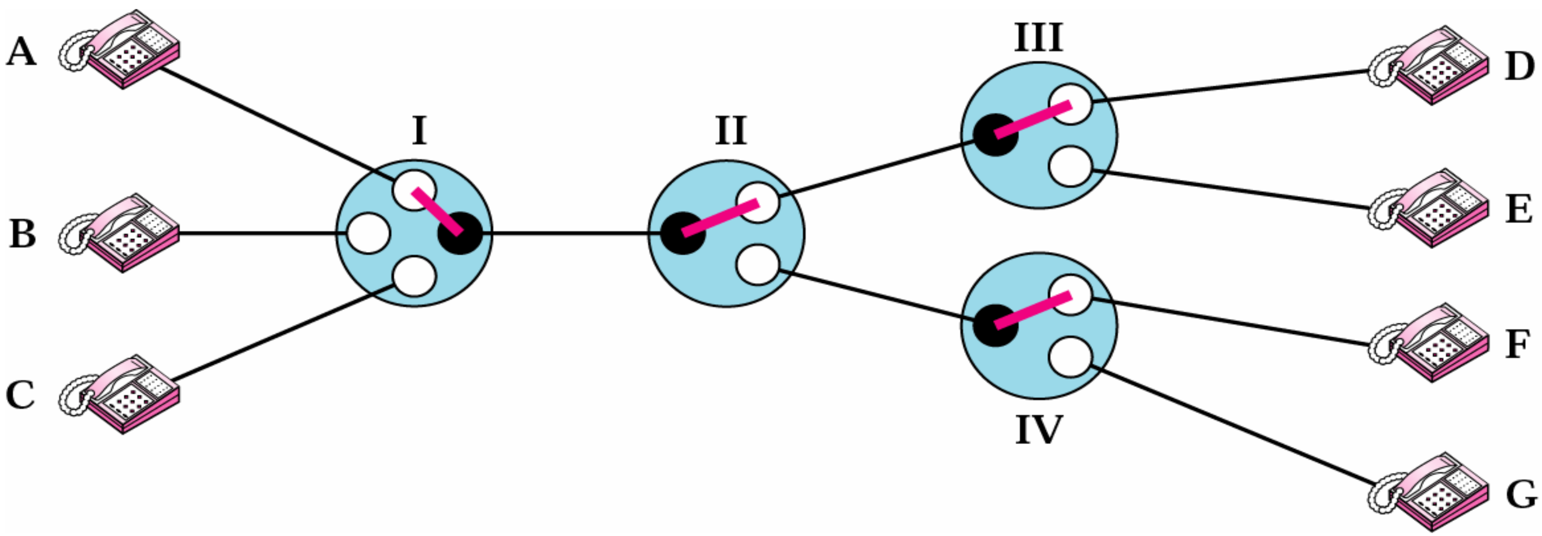
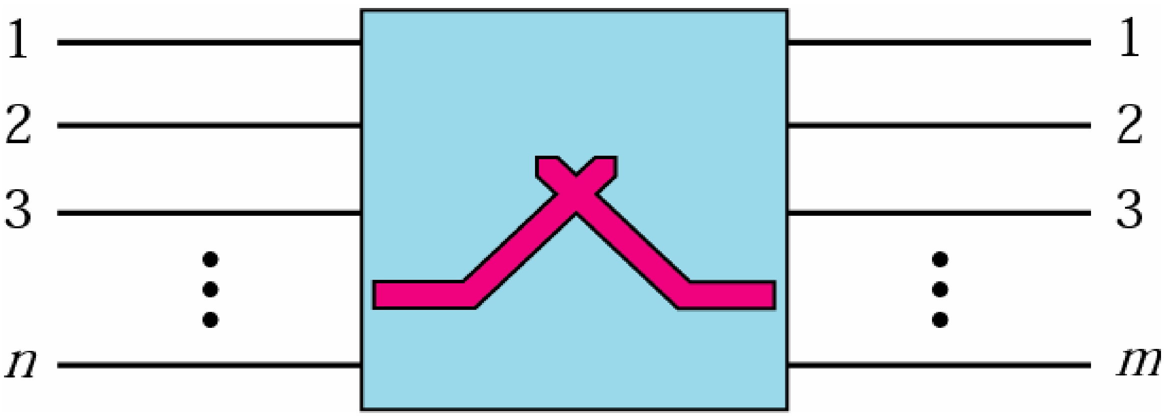
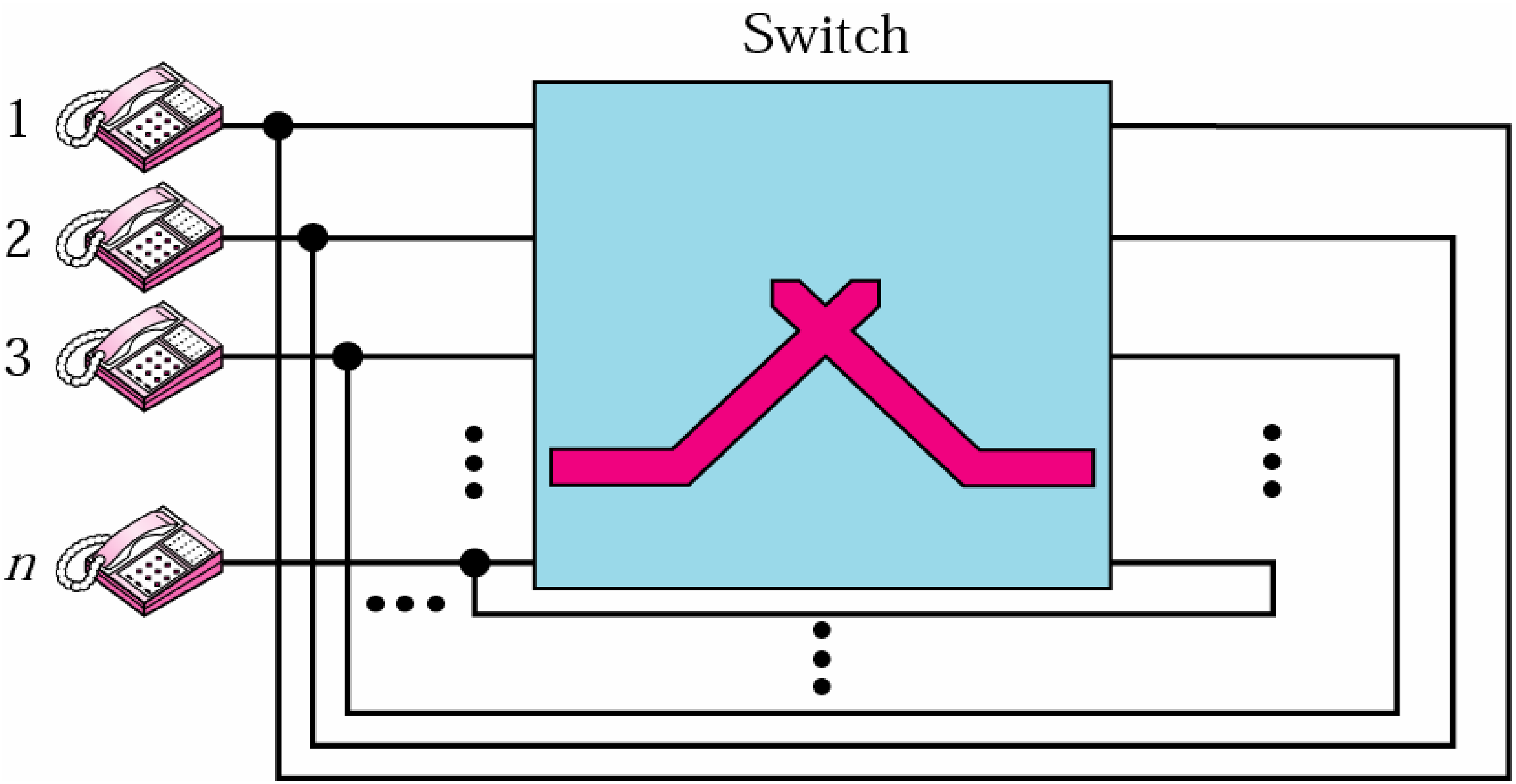


Figure 8.2 *A circuit switch*



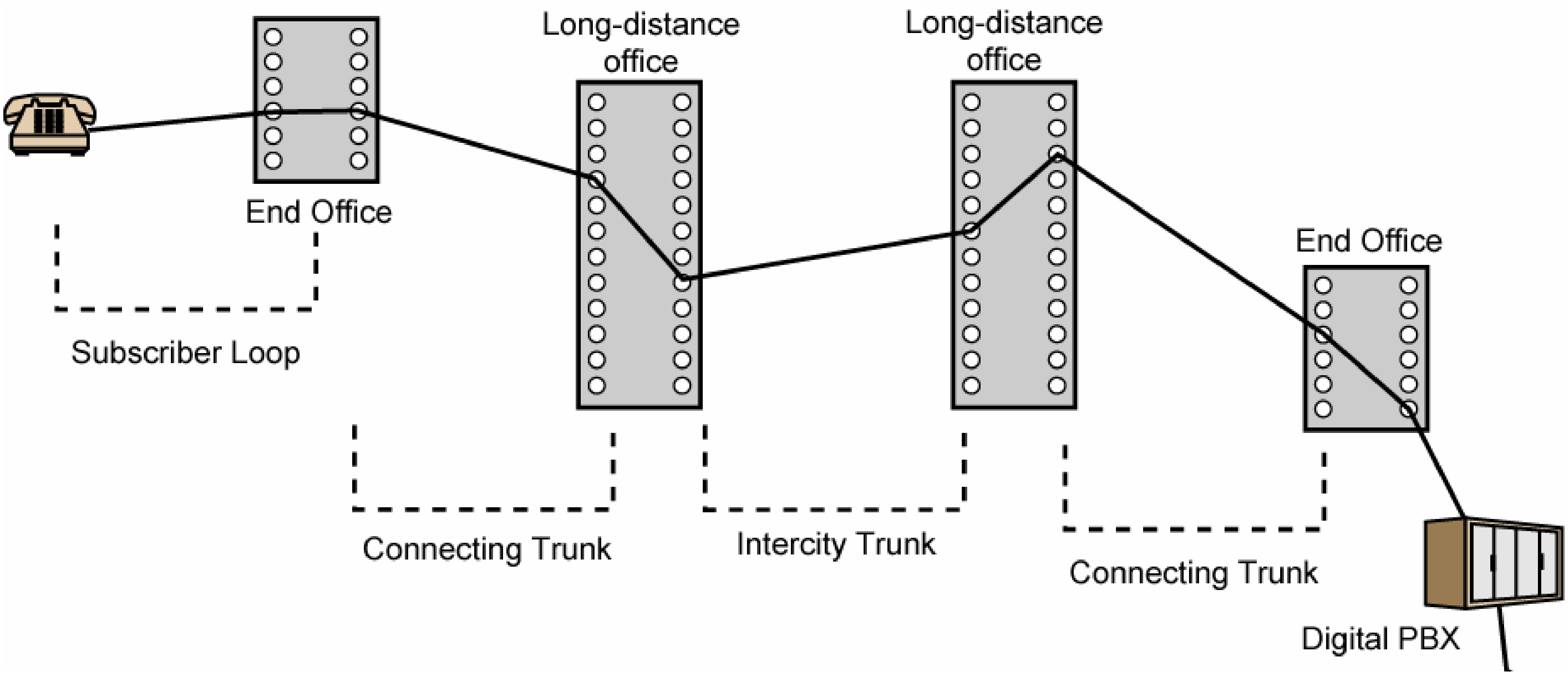
A folded switch



Circuit Switching

- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Developed for voice traffic (phone)

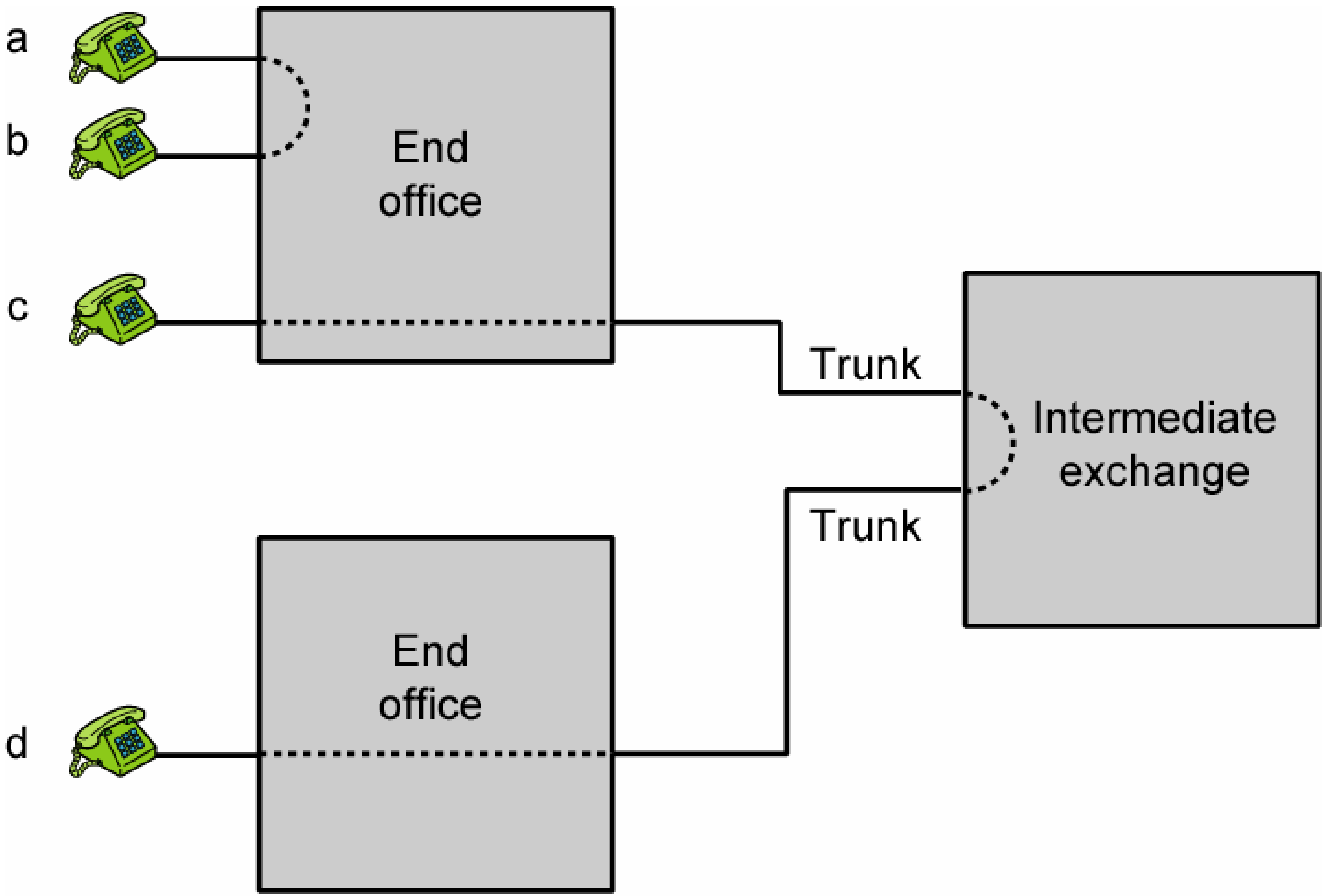
Public Circuit Switched Network



Telecomms Components

- Subscriber
  - Devices attached to network
- Subscriber line
  - Local Loop
  - Subscriber loop
  - Connection to network
  - Few km up to few tens of km
- Exchange
  - Switching centers
  - End office - supports subscribers
- Trunks
  - Branches between exchanges
  - Multiplexed

Circuit Establishment



8.1 Circuit Switching

- Space-Division Switch
- Time-Division Switch
- TDM Bus
- Combinations

Space Division Switching

- Developed for analog environment
- Separate physical paths
- Crossbar switch
  - Number of crosspoints grows as square of number of stations
  - Loss of crosspoint prevents connection
  - Inefficient use of crosspoints
    - All stations connected, only a few crosspoints in use
  - Non-blocking

Space Division Switch

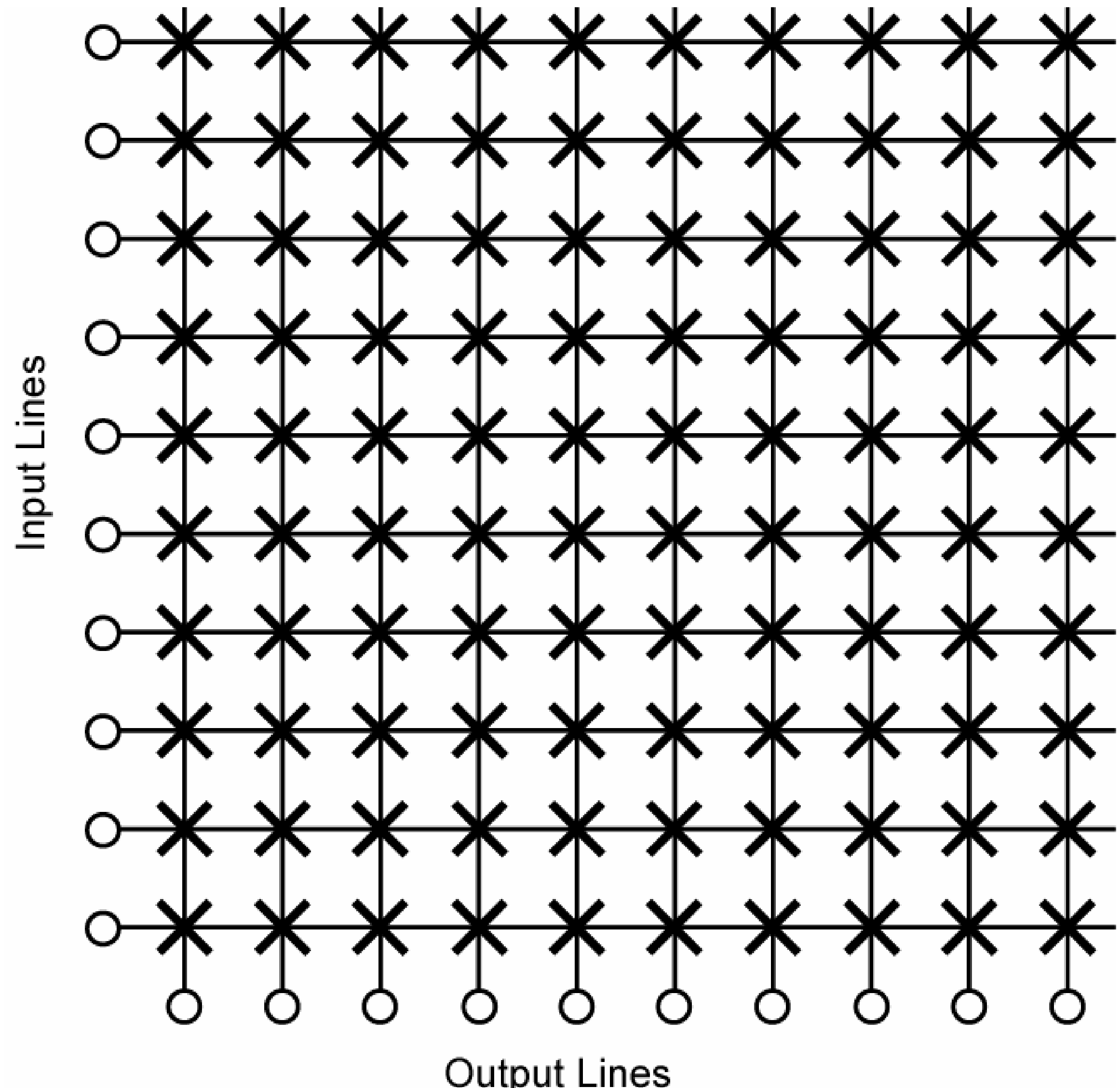
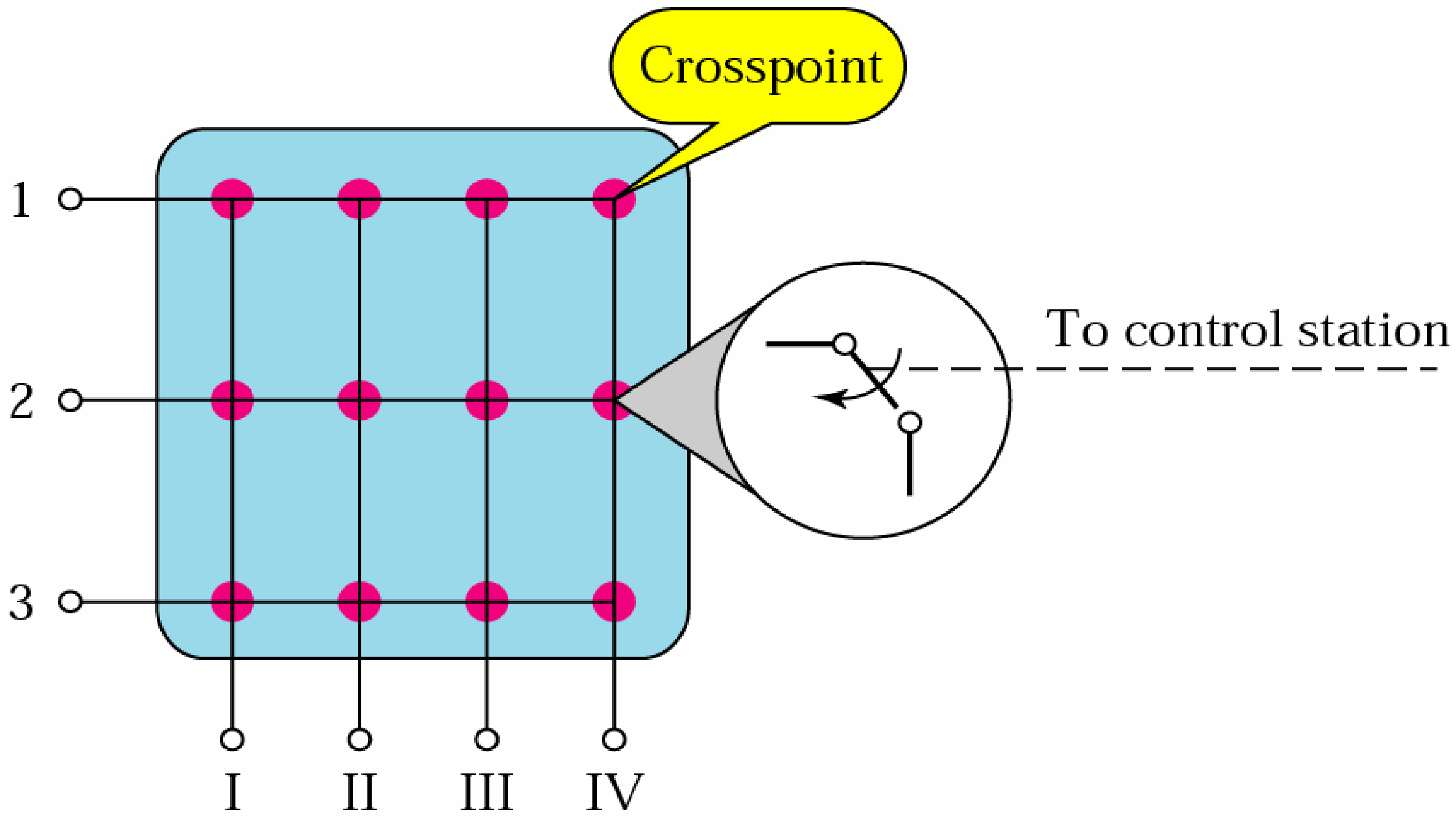


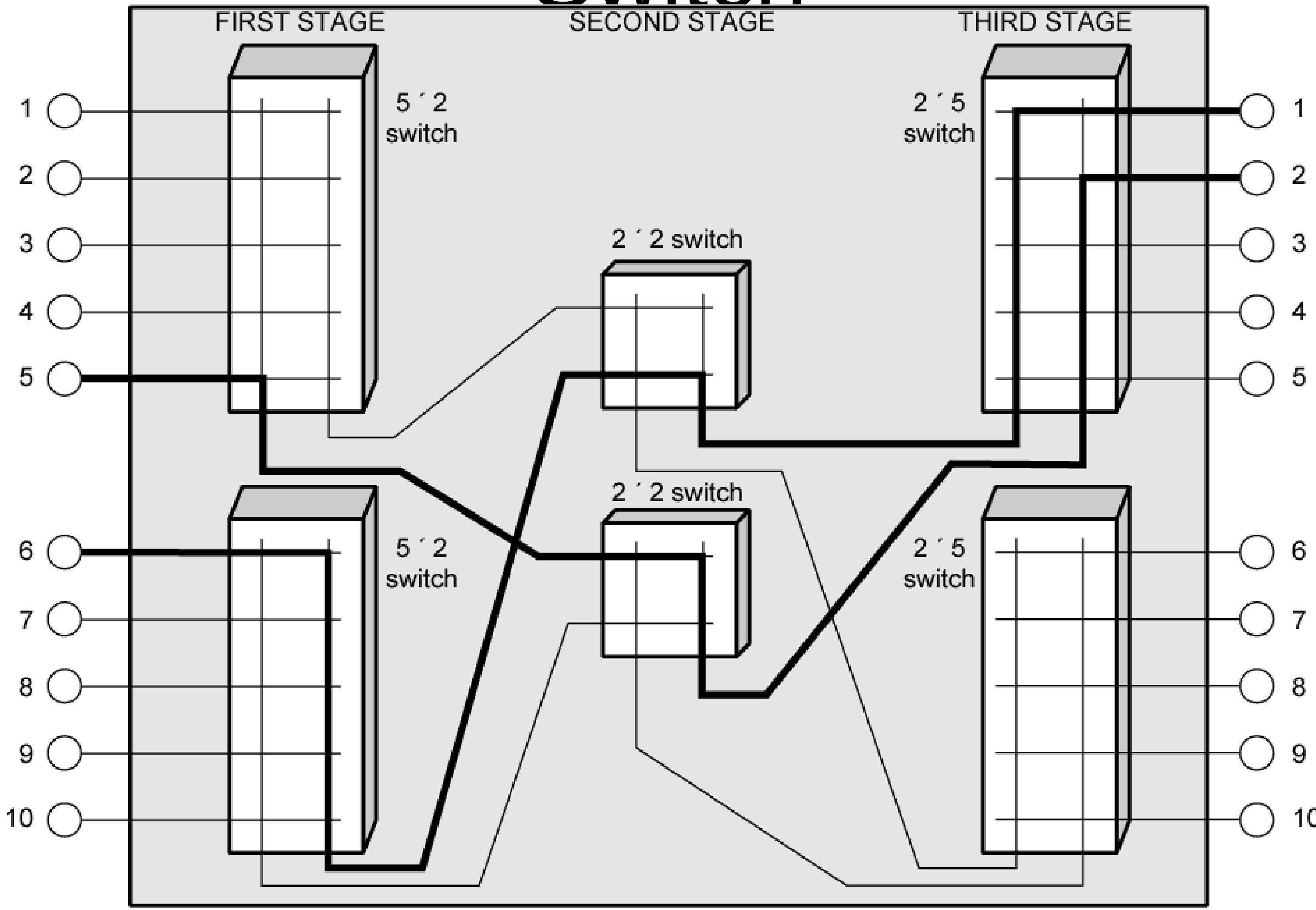
Figure 8.4 *Crossbar switch*



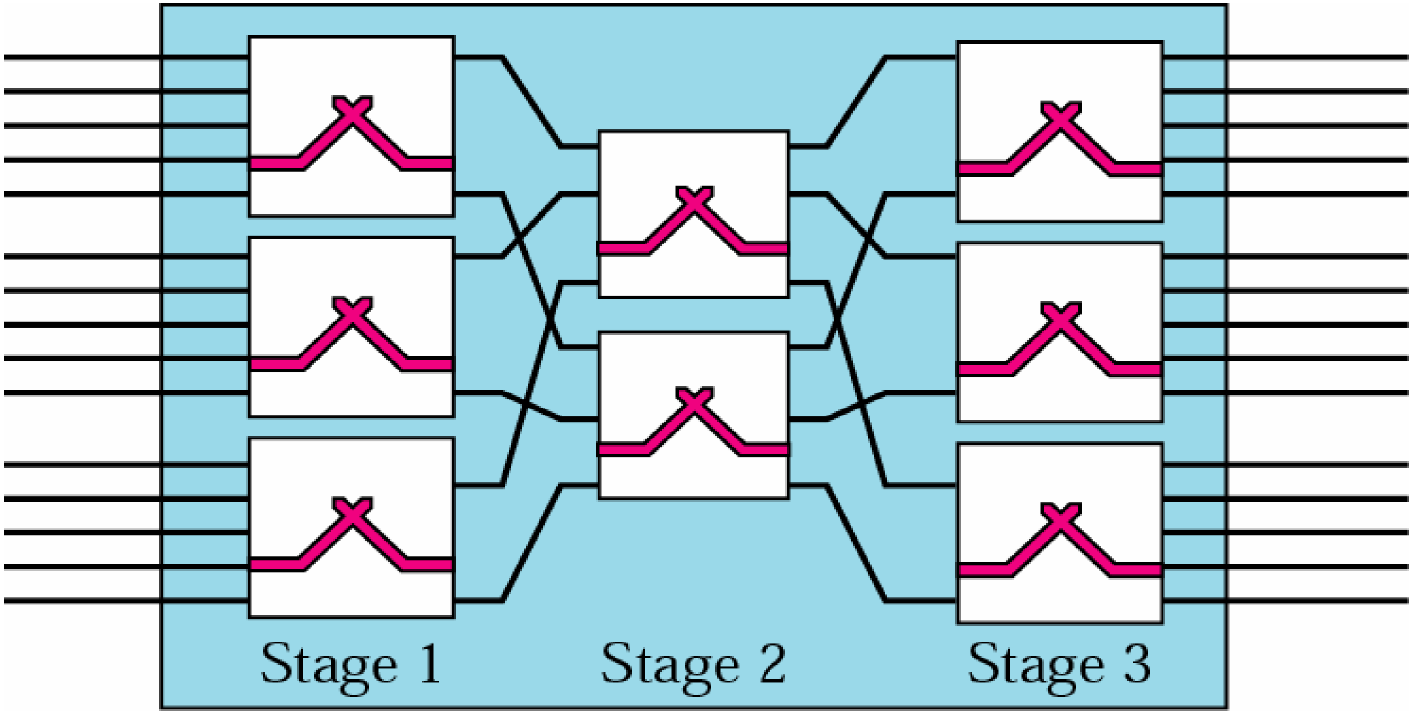
Multistage Switch

- Reduced number of crosspoints
- More than one path through network
  - Increased reliability
- More complex control
- May be blocking

Three Stage Space Division Switch



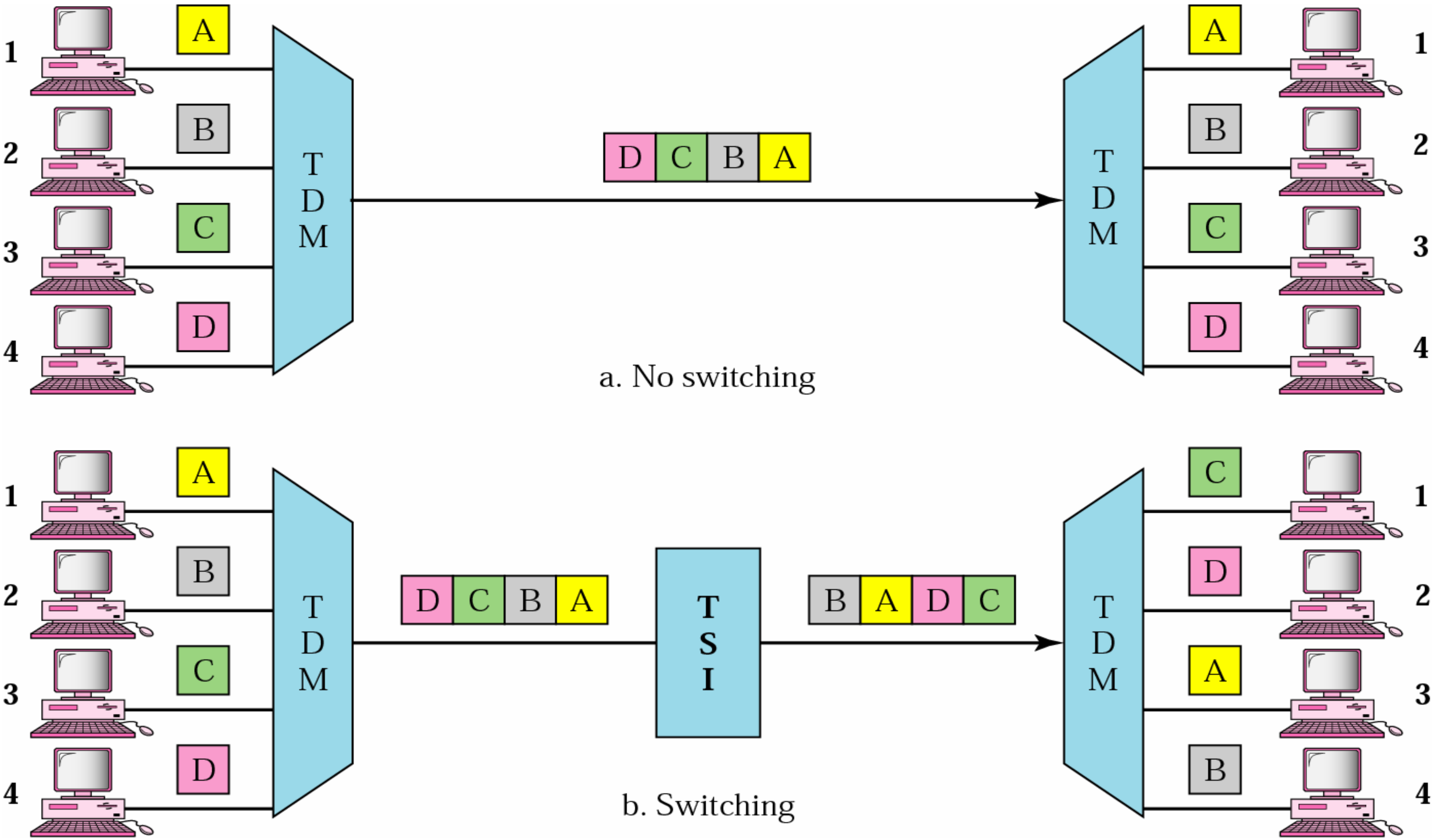
Multistage switch



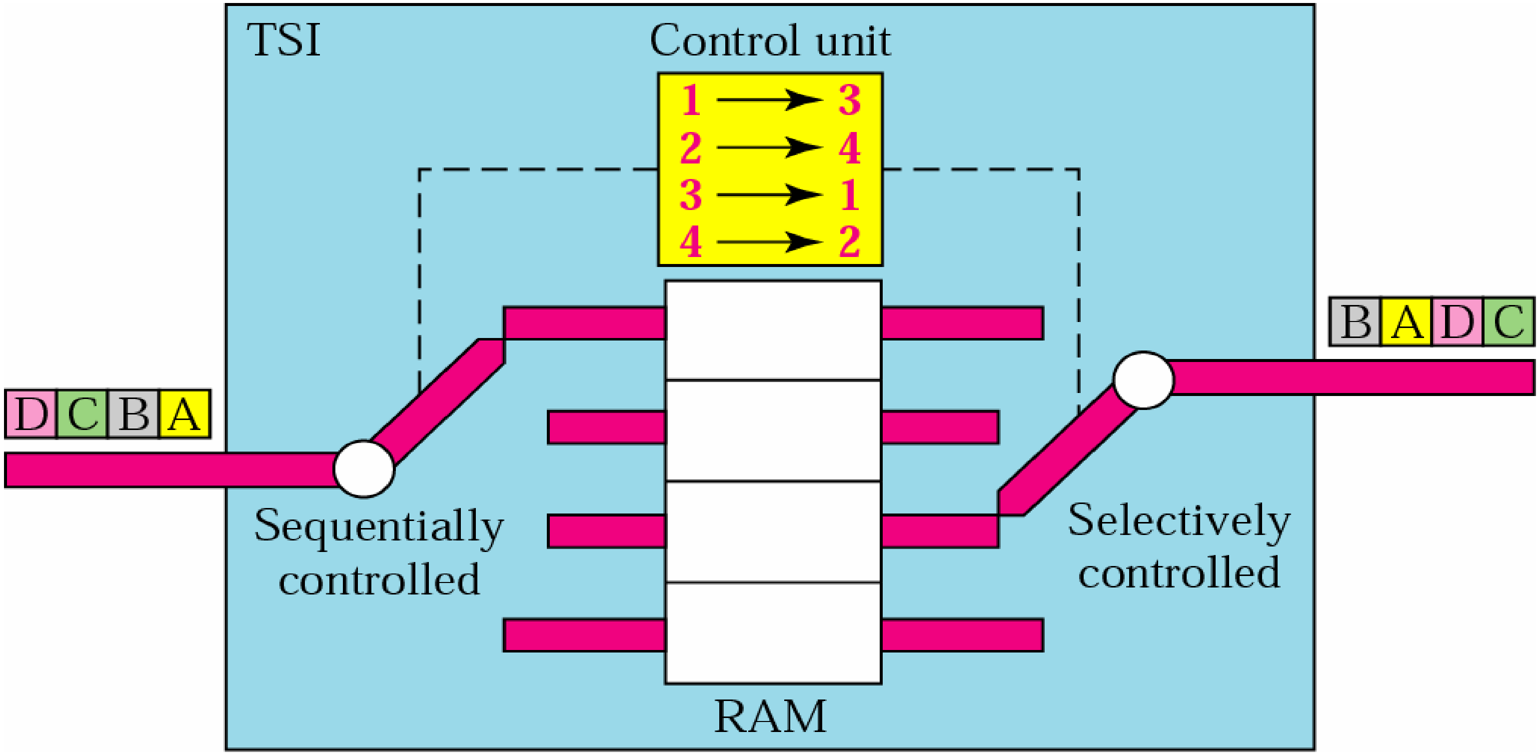
Time Division Switching

- Modern digital systems rely on intelligent control of space and time division elements
- Use digital time division techniques to set up and maintain virtual circuits
- Partition low speed bit stream into pieces that share higher speed stream
- Two methods :-

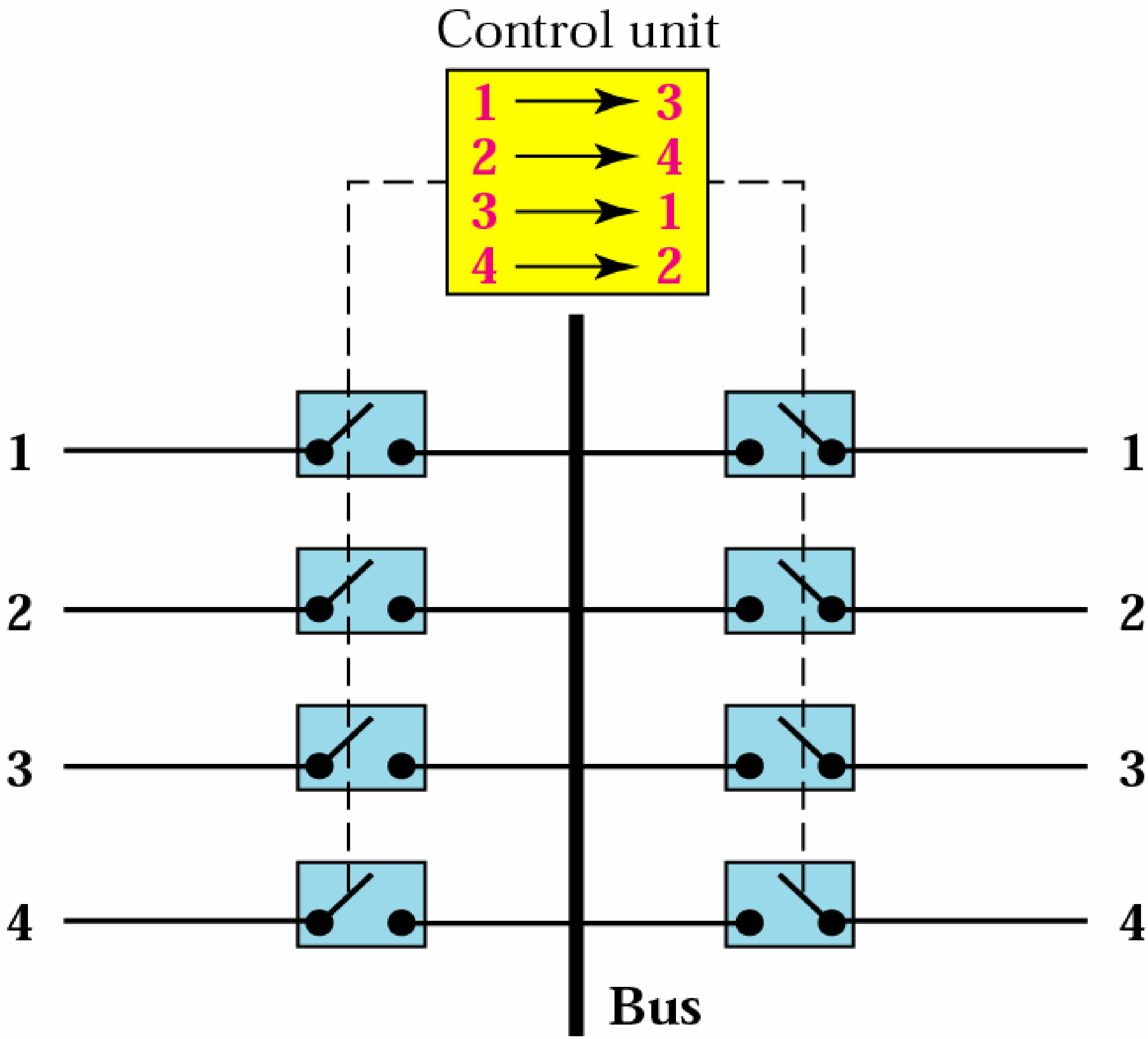
1.Time-division multiplexing, without and with a time-slot interchange



How a *Time-slot interchange works*



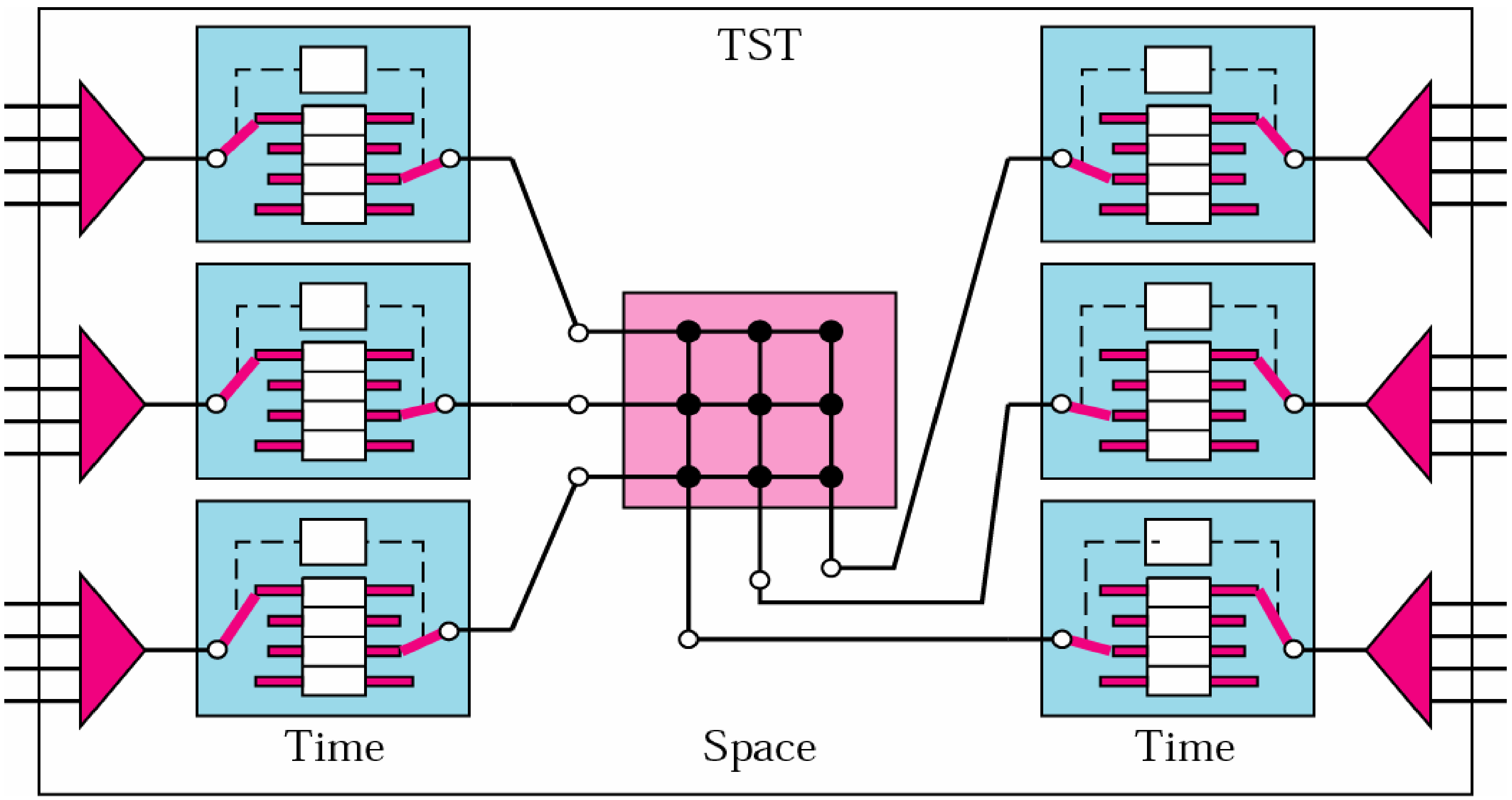
2. *TDM bus*



Blocking or Non-blocking

- Blocking
  - A network is unable to connect stations because all paths are in use
  - A blocking network allows this
  - Used on voice systems
    - Short duration calls
- Non-blocking
  - Permits all stations to connect (in pairs) at once
  - Used for some data connections

Combination of *TST switch*



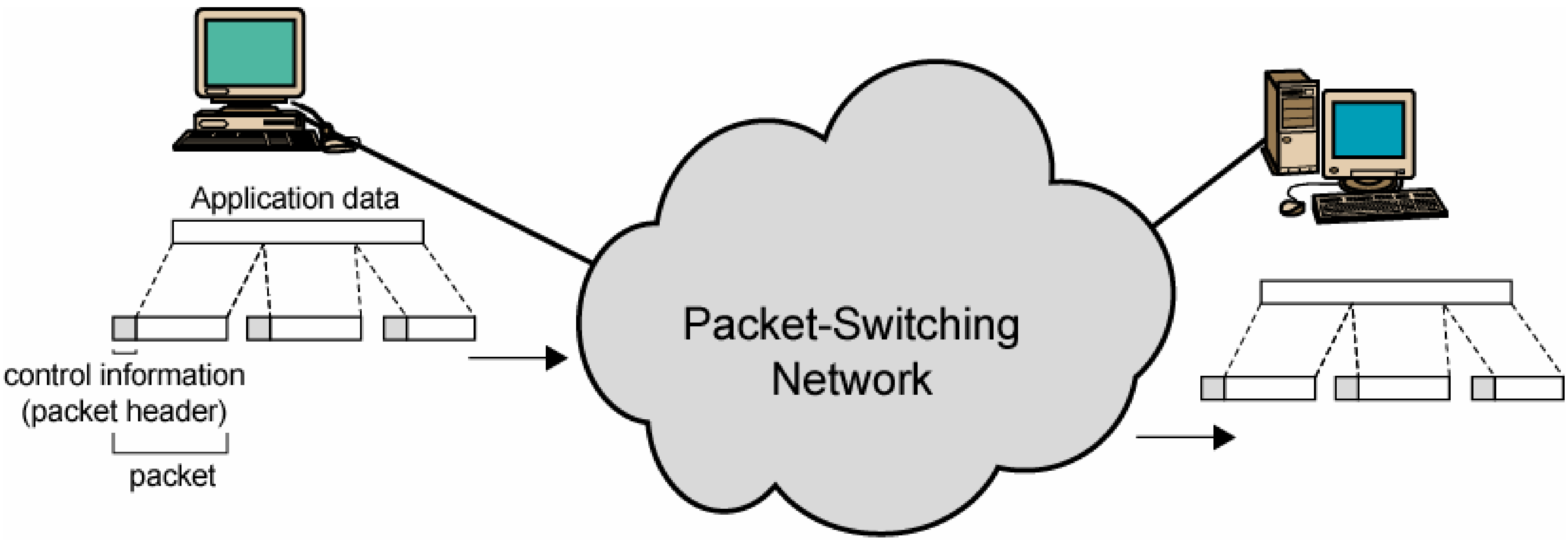
Packet Switching Principles

- Circuit switching designed for voice
  - – Resources dedicated to a particular call
  - – Much of the time a data connection is idle
  - – Data rate is fixed
    - Both ends must operate at the same rate

Basic Operation

- Data transmitted in small packets
  – Longer messages split into series of packets
  – Each packet contains a portion of user data plus some control info
- Control info
  – Routing (addressing) info
- Packets are received, stored briefly (buffered) and pass on to the next node

Use of Packets



Advantages

- 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

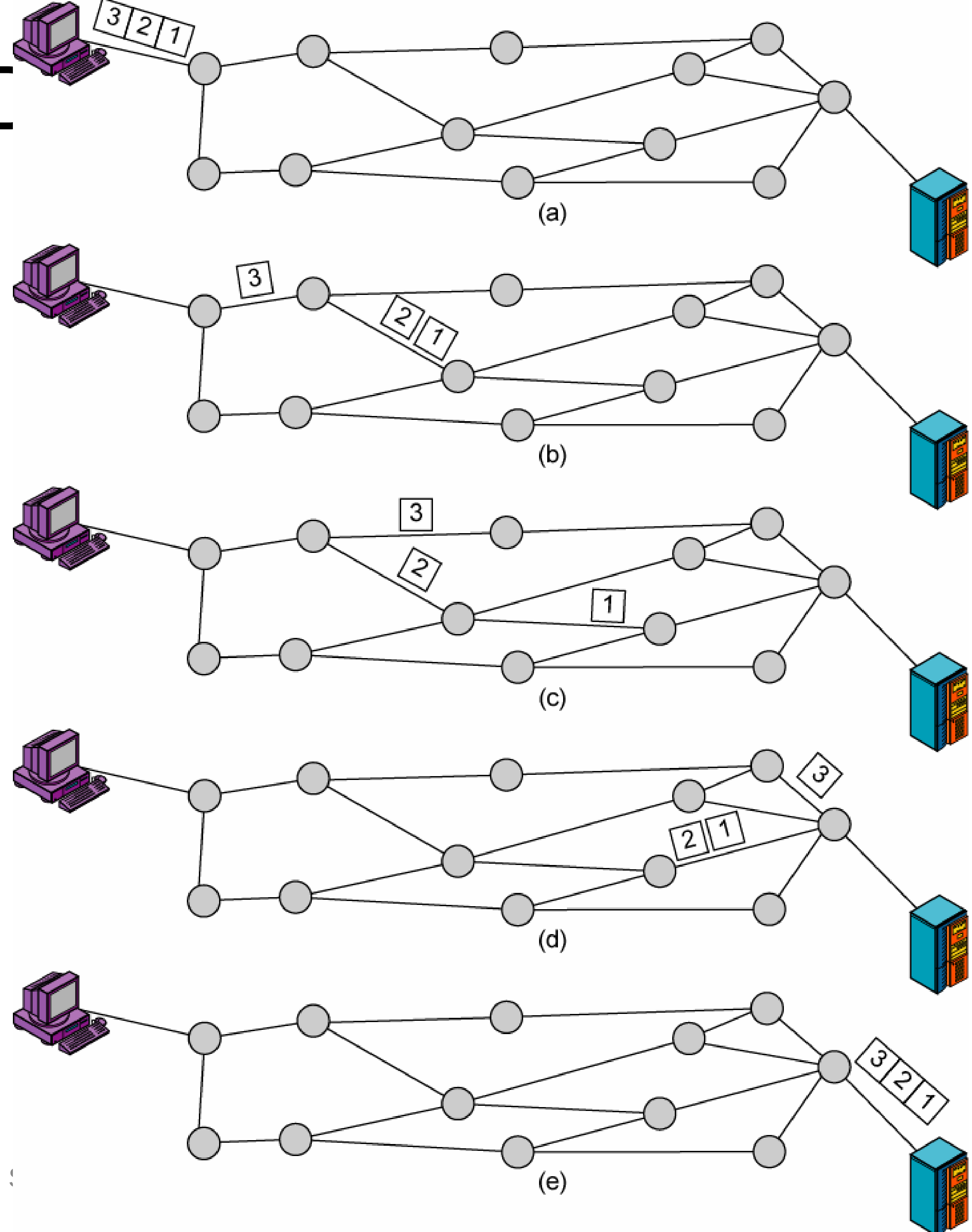
- Station breaks long message into packets
- Packets handled in two ways
  - Datagram
  - Virtual circuit

        switched virtual circuit (SVC)

        permanent virtual circuit (PVC)

Datagram

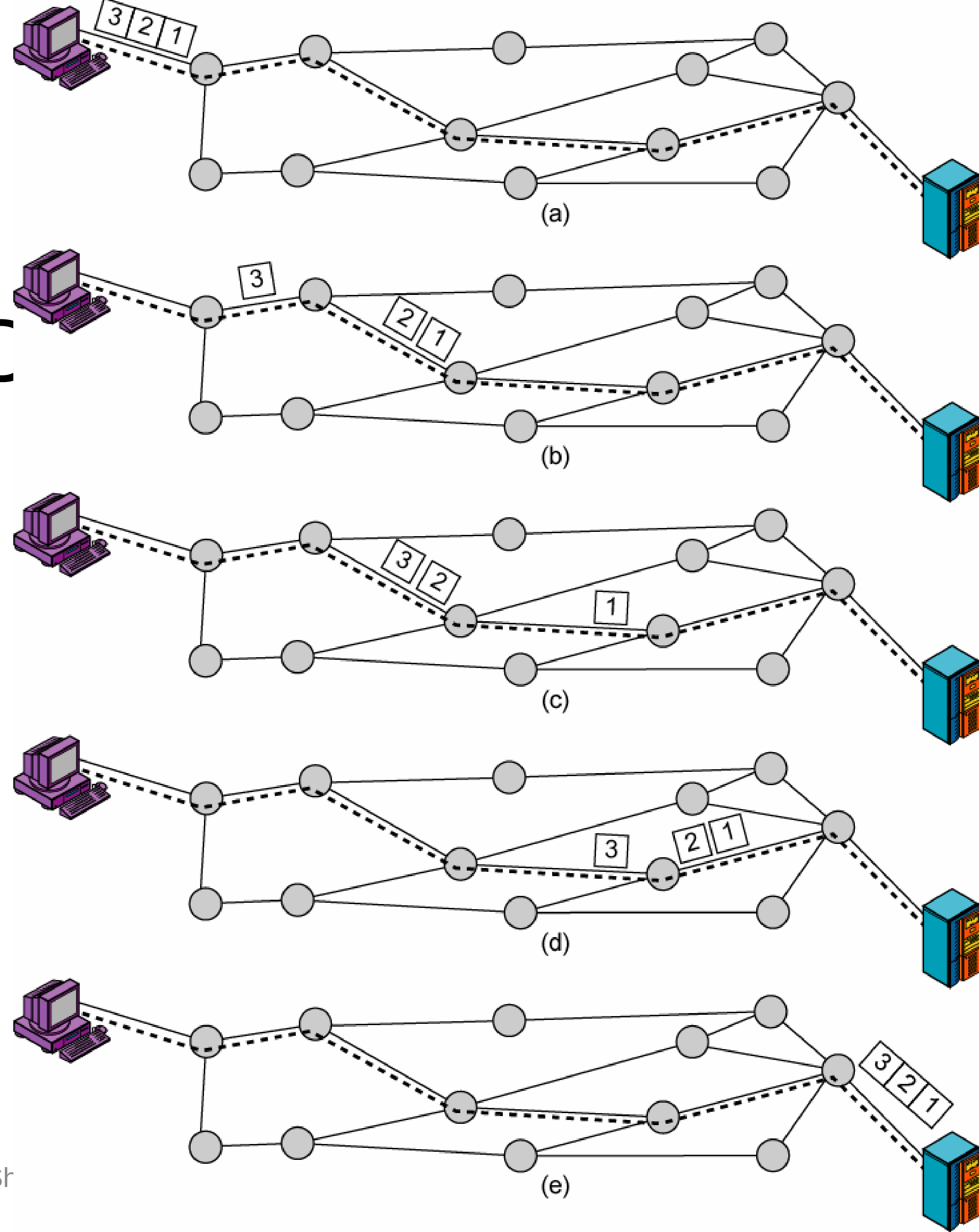
- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets



3 2 1
(a)
3
2 1
(b)
3
2
1
(c)
3
2 1
(d)
3 2 1
(e)

Virtual Circuit

- Preplanned route established before any packets sent
- Call request and call accept packets establish connection (handshake)
- Each packet contains a virtual circuit identifier instead of destination address
- No routing decisions required for each packet
- Not a dedicated path



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Virtual Circuits v Datagram

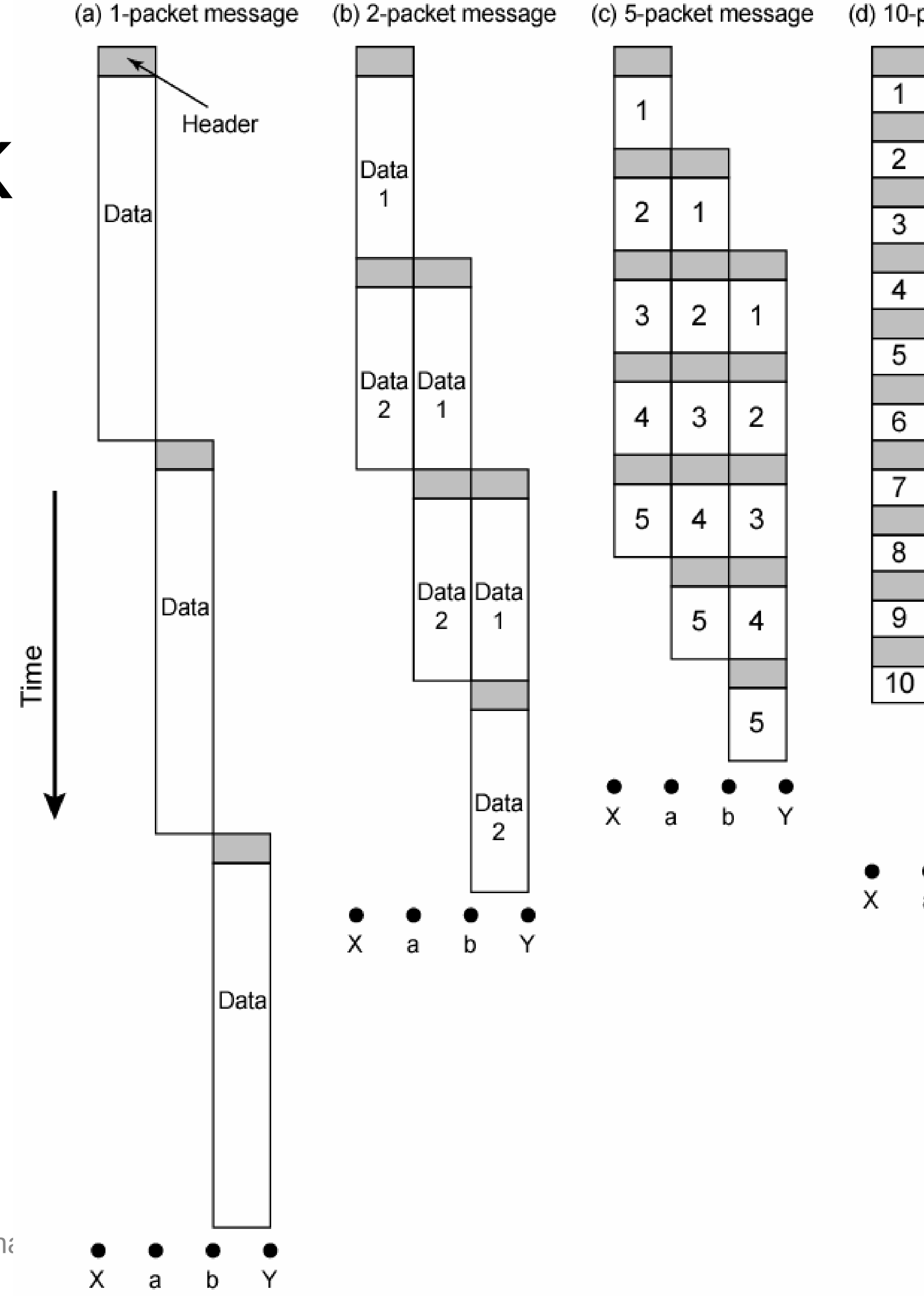
- Virtual circuits
  - Network can provide sequencing and error control
  - Packets are forwarded more quickly
    - No routing decisions to make
  - Less reliable
    - Loss of a node looses all circuits through that node
- Datagram
  - No call setup phase
    - Better if few packets
  - More flexible
    - Routing can be used to avoid congested parts of the network

Message Switching

- No path setup in advance
- Message is passes from one switching center to other
- No limit in message size
- Switching devices need more memory and disk space

- A store-and-forward network
- Since messages can be quite large, this can cause:
  - buffering problems
  - high mean delay times

Pack

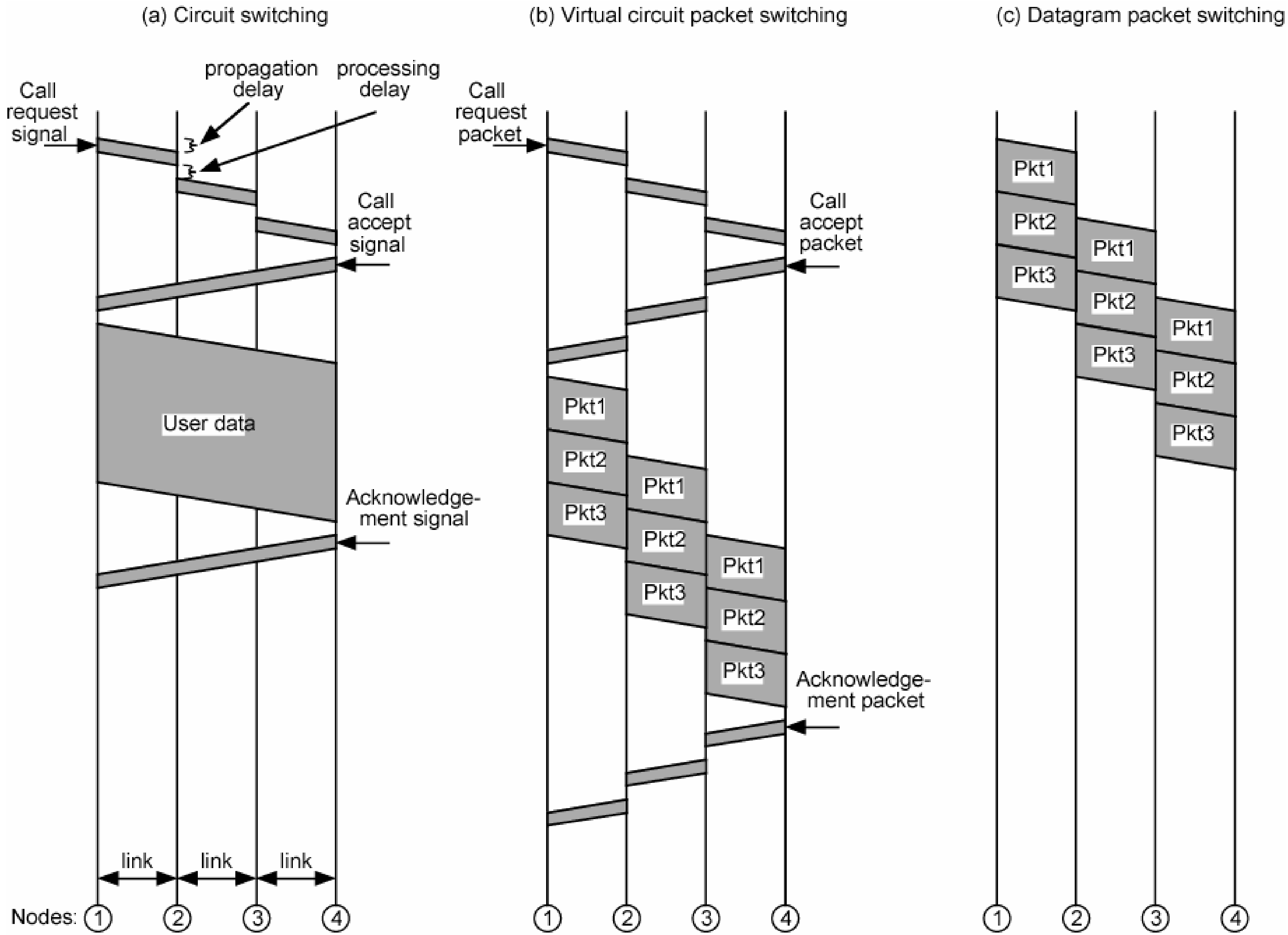


(a) 1-packet message
(b) 2-packet message
(c) 5-packet message
(d) 10-p
Header
Data
Data
Data
Data 1
Data 2
Data 1
Data 2
Data 1
Data 2
Time
X
a
b
Y

Circuit v Packet Switching

- Performance
  - Propagation delay
  - Transmission time
  - Node delay

Event Timing



ISDN Overview

There are many types of WAN technologies that can be used to solve the problems of users who need network access from remote locations.

In this chapter, you will learn about the

services, standards, components, operation, and configuration of

Integrated Services Digital Network (**ISDN**) communication.

ISDN has been specifically designed to solve the **low bandwidth** problems that small offices or dial-in users have with traditional telephone dial-in services.

Telephone companies developed ISDN with the intention of creating a totally **digital network** whilst making use of the **existing telephone wiring** system.

ISDN works very much like a telephone - When you make a data call with ISDN, the WAN link is brought up for the duration of the call and is taken down when the call is completed

What is ISDN?

ISDN allows **digital signals** to be transmitted over existing telephone wiring.

This became possible when the telephone company **switches** were upgraded to handle digital signals.

ISDN is generally viewed as an **alternative** to **leased lines**, which can be used for telecommuting and networking small and remote offices into LANs.

What Can ISDN Do?

ISDN's ability to bring digital connectivity to local sites has many benefits, including the following:

- ISDN can carry a **variety** of **user traffic** signals including:
  - digital **video, packet**-switched data, and telephone network services.
- ISDN offers much **faster call setup** than **modem** connections because it uses out-of-band (D, or delta, channel) signaling.
  - For example, some ISDN calls can be setup in less than one second.
- ISDN provides a **faster data transfer** rate than modems by using the bearer channel (B channel of 64kbps).
  - With multiple B channels, ISDN offers users more bandwidth on WANs than some leased lines.
  - For example, if you were to use two B channels, the bandwidth capability is 128Kbps because each B channel handles 64Kbps.

ISDN can provide a **clear data path** over which to negotiate **PPP links**.

ISDN Components

Component	Description
Terminal Equipment Type 1 (TE1)	Designates a device that is compatible with an ISDN network (A specialized device created for ISDN.). A TE1 connects to a network termination of either type 1 or type 2 (NT1 or NT2).
Terminal Equipment Type 2 (TE2)	Designates a device that is not compatible with an ISDN network and requires a terminal adapter (TA).
Terminal Adapter (TA)	Converts standard electrical signals into a form used by ISDN so that non-ISDN devices can connect to the ISDN network.
Network Termination Type 1 (NT1)	Connects four-wire ISDN subscriber wiring to the conventional two-wire local loop facility.
Network Termination Type 2 (NT2)	Connects four-wire ISDN subscriber wiring to the conventional two-wire local loop facility. NT2 is a more complicated device, typically found in digital Private Branch eXchanges (PBXs), that performs Layer 2 and Layer 3 protocol services.

SPID

Before you can connect a router to an ISDN service, you must be aware of the switch types used at the CO.

You specify this information during router configuration so the router can place ISDN network-level calls and send data.

In addition to learning about the switch type your service provider uses, you also need to know what Service Profile Identifiers (**SPIDs**) are assigned to your connection.

The **ISDN carrier provides** a **SPID** to identify the line configuration of the ISDN service.

SPIDs are a series of characters (that can look like phone numbers) that **identify you** to the switch at the CO.

Protocols

Protocols That Begin With This Letter	Are Used For These Purposes
E	These protocols recommend telephone **standards** for ISDN. For example, the E.164 protocol describes international addressing for ISDN.
I	These protocols deal with **concepts**, **terminology** and general methods. The I.100 series include general ISDN concepts and the structure of other I series recommendations; the I.200 series deal with service aspects of ISDN; the I.300 series describes network aspects; the I.400 series describes how the UNI is provided.
Q	These protocols cover how switching and signaling should operate. The term **signalling** in this context means call set-up.

Standards

ISDN utilizes a suite of ITU-T standards spanning the **physical**, **data-link**, and **network** layers of the OSI reference model.

When you're deploying remote access solutions, several encapsulation choices are available. The two most common encapsulations are **PPP** and **HDLC**.

ISDN defaults to **HDLC**. However, **PPP** is much more robust because it provides an excellent mechanism for authentication and negotiation of compatible link and protocol configuration.

ISDN interfaces allow only a **single encapsulation** type.

PPP is an **open standard** specified by **RFC 1661**.

- Remote access involves connecting users located at remote locations through dialup connections.
- The remote location can be a telecommuter's home, a mobile user's hotel room, or a small remote office.
- The dialup connection can be made via an analogue connection using **basic telephone service** or via ISDN.
- Connectivity is affected by **speed**, **cost**, **distance**, and **availability**.
- **Remote access links** generally represent the **lowest-speed links** in the enterprise.

With the remote nodes method, the users connect to the local LAN at the central site through the **Public Switched Telephone Network** (PSTN) for the duration of the call.

Aside from having a lower-speed connection, the user sees the **same environment** the local user sees.

The connection to the LAN is typically through an **access server**.

This device usually combines the functions of a **modem** and those of a **router**.

When the remote user is logged in, he or she can access servers at the local LAN <u>as if they were local</u>.

BRI

There are two ISDN services:

- **BRI** (**Basic** Rate Interface)
- **PRI** (**Primary** Rate Interface).

The ISDN BRI service offers **two 8-bit B** channels and **one 2-bit D** channel.

ISDN BRI delivers a total bandwidth of a **144-kbps** line into **three** separate channels.

BRI B channel service operates at **64 kbps** and is meant to carry user **data** and **voice** traffic.

The third channel, the **D channel**, is a **16 kbps signalling channel** used to carry instructions that tell the telephone network how to handle each of the B channels.

DDR

ISDN LAN routers provide routing between ISDN BRI and the LAN by using **dial-on-demand routing** (DDR).

DDR **automatically establishes** and **releases circuit-switched calls**, providing transparent connectivity to remote sites based on networking traffic.

DDR also controls establishment and release of secondary B channels based on load thresholds.

ECS5365 Lecture 1
Overview of N-ISDN

Outline

- Network evolution
- ISDN Concepts
- ISDN reference model
- ISDN services

Public Switched Telephone Network (PSTN)

- Customer Premises Equipment
- Subscriber Loop
- Local Exchange Network
- Long Distance Trunk Network

ISDN

- Culmination of digitisation of network
- Network evolution
- Signalling evolution
- Services evolution

Network Evolution

- Separate analog transmission and switching (PSTN)
  - Frequency Division Multiplexing
- Integrated Digital Transmission and Switching
  - Time Division Multiplexing
  - Integrated Digital Network (IDN)
- Digital access to the subscriber
  - Integrated Services Digital Network (ISDN)

Signalling Evolution

- In channel
  - inband
  - out of band
- Common channel signalling
- Signalling system no. 7 for inter-exchange signalling

Intelligent Network Services

- Separate the switching functions from service functions
- Use a few software based service processors with access to databases
- New services can be added quickly
- Allow users to customize network behaviour

ISDN Concepts

– Support both voice and non-voice applications
– 64 kbps channels
– Both circuit and packet switched connections
– Single integrated network access point
– Intelligence for services, maintenance and network management
– Layered protocols - OSI concepts

Standardisation

- User-network interface
- Network capabilities
- Services
- CCITT Red Book 1984
- CCITT Blue Book 1988

User-Network Interface

- Basic Rate 192 kbps
- Primary Rate 2.048 Mbps
- Separate channels for signalling and data
  - B channels for data
  - D channels for signalling (and data)

Basic Rate Interface

- 2 B channels each at 64 kbps
- 1 D channel at 16 kbps
- D channel for signalling and low priority data
- Can be supported over twisted pair
- Can be multipoint

Primary Rate Interface

- 30 B channels
- 1 D channel at 64 kbps
- Also H channels
  - H0 384 kbps
  - H11 1536 kbps
  - H12 1920 kbps
- Only ever point to point

Functional Groupings

- Network termination 1 (NT1)
- Network termination 2 (NT2)
- Terminal equipment 1 (TE1)
- Terminal equipment 2 (TE2)
- Terminal Adaptor (TA)

Network termination 1 (NT1)

- OSI layer 1 functions
- Physical and electrical termination
- Timing
- Power
- Multidrop termination
  - contention

Network termination 2 (NT2)

- OSI layer 2 and 3 functions
  - link functions
  - network functions
- NT2 devices include
  - PABX
  - LANs
  - Terminal Controllers.

Terminal equipment 1 (TE1)

- devices that support ISDN interface
- voice, data or video
- functions for call setup, teardown, maintenance

Terminal equipment 2 (TE2)

- existing non ISDN equipment
  – eg. X.25, RS232 interfaces
- Require terminal adaptors to access ISDN

Terminal adaptor (TA)

- Connects non-ISDN equipment to ISDN
- Main functions of TA
  – Rate adaptation (adaption)
  – Protocol conversion

Reference Points

- T (terminal) NT1-NT2
- S (system) NT2-TE1, NT2-TA
  - separates user's terminal equipment from network equipment
- R (rate adaption) TE2 - TA
- U (user) NT1 - public network
  - defined in USA

T Reference Point

- Terminal reference point
- Separates user's network from network provider
- Minimal ISDN network termination

S Reference Point

- Separates user's terminal equipment from network
- Individual ISDN terminal interface

R Reference Point

- Interface between user equipment that is not ISDN compatible and ISDN adaptor
- Rate and protocol adaption

U Reference Point

- NT1 - public network
- defined in USA, but not by ITU-T

D Channel Protocols

- Layer 1 (I.430 Basic, I.431 Primary)
- Layer 2 - Data Link LAP-D
- Layer 3
  - Call control - I.451
  - Packet switching X.25 level 3
- Higher layers for end to end user signalling

B Channel Protocols

- Layer 1 (I.430 Basic, I.431 Primary)
- Layer 2 - dependent on application
- Layer 3 - dependent on application
- Higher layers - dependent on application
- Packet switching services use
  - layer 2 X.25 LAP-B
  - layer 3 X.25 level 3

ISDN Services

- Bearer services
  - transport services
- Teleservices
  - combine transport function with higher processing functions
- Supplementary services
  - enhance bearer services

ISDN Bearer Services

- Means to convey information
- OSI layers 1 to 3
- Circuit mode (10 modes)
- Packet mode (3 modes)

Circuit Mode Bearer Services

- 64 kbps unrestricted, 8kHz structured
- 64 kbps, 8 kHz structured, voice
- 384 kbps unrestricted, 8kHz structured
- multiuse, higher bit rates etc.

Packet Mode Bearer Services

- Virtual circuit
- Permanent virtual circuit
- Connectionless (to be defined)

ISDN Teleservices

- Telephony
- Teletex
- Telefax - group 4 fax
- Mixed mode - text + fax image
- Videotex
- Telex

ISDN Supplementary Services

- User to user signalling
- Call forwarding unconditional
- Closed user group
- Direct Dialing in
- Call Waiting

ISDN Supplementary Services (Cont).

- Calling line identification presentation
- Calling line identification restriction
- Line hunting
- Three Party Service
- Call Transfer
- Credit Card Calling

Most Common Applications of ISDN

- Telephony and Fax
- Video-conferencing
- LAN to LAN connectivity
- Internet access

Limitations of ISDN

- Inadequate for television quality
  - Need for B-ISDN
- 64 kbps PCM voice wasteful
- Expense (at least in Australia)
- Changed technological environment
  - circuit switching / packet switching
- Changed political environment?
  - deregulation, private networks etc.

Summary

- Networks have evolved from analog to digital from the core to the edges
- ISDN is the culmination of this process
- ISDN defines a number of interfaces and functional groupings
- ISDN uses these to enable sophisticated services to be defined

Review and Preliminary Reading

- Review reading for this week
  - Chapter 4, 5 and 9 of Stallings
- Preliminary reading for next week
  - Chapter 6 and 7.1 of Stallings

Review Questions (not for assessment)

- Why don’t all TE1 devices need to connect to NT2 equipment?
- The BRI provides 2 B channels and 1 D channel, total 144 kbps. However, a BRI interface is defined at 192 kbps. Why?
- In what way might a carrier treat a 64 kbps 8kHz structured speech bearer service differently to a 64kbps, unrestricted, 8kHz structured bearer service?
- Which bearer services might be used for G4 fax?

Physical Layer Issues and Methods

Outline

802.3 Physical Layer

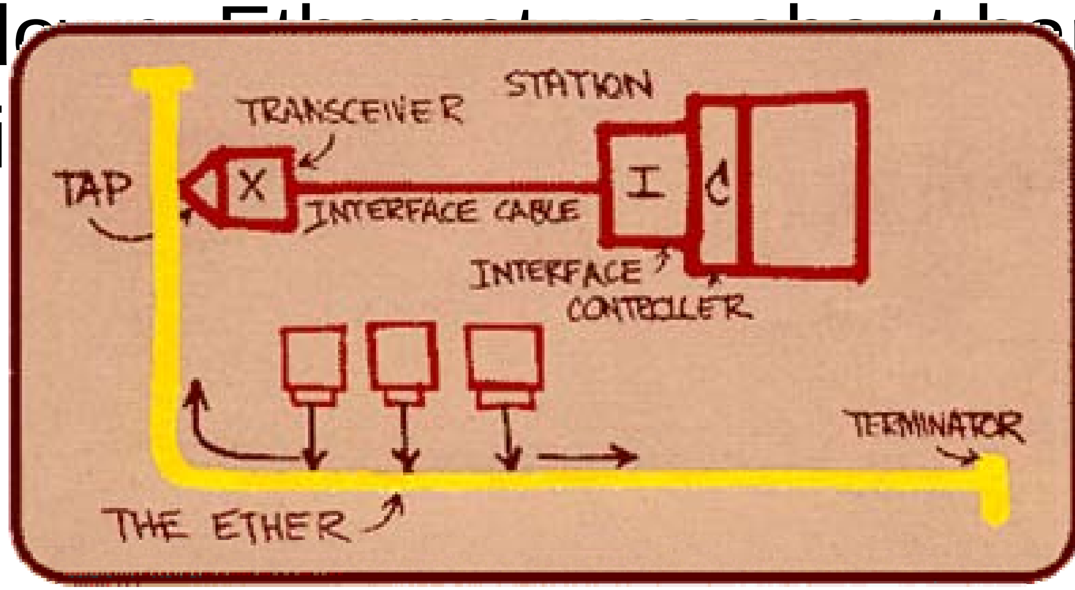
Ethernet Technology

Physical Layer Encoding

Final Exam Review - ??

Ethernet Standard Defines Physical Layer

- 802.3 standard defines both MAC *and* physical layer details
- Even though we have worked from top d rdware fi



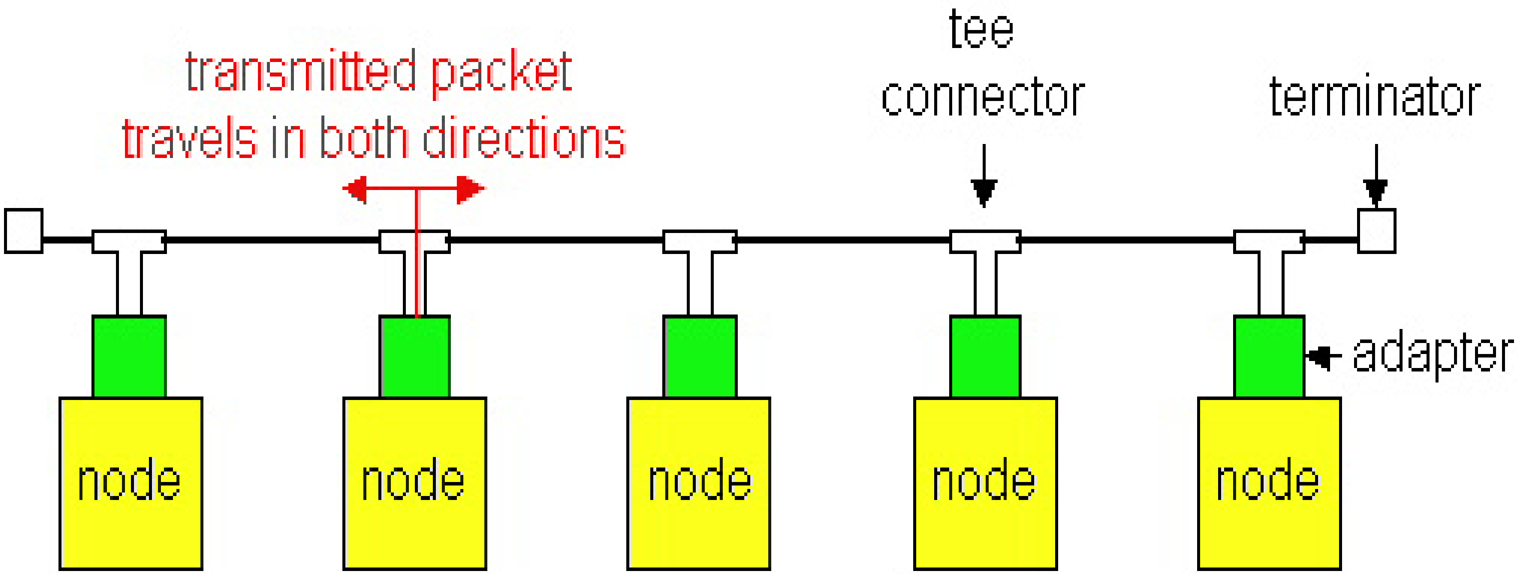
Metcalfe's original Ethernet Sketch

Physical Layer Configurations for 802.3

- Physical layer configurations are specified in three parts
- Data rate (10, 100, 1,000)
  - 10, 100, 1,000Mbps
- Signaling method (base, broad)
  - Baseband
    - Digital signaling
  - Broadband
    - Analog signaling
- Cabling (2, 5, T, F, S, L)
  - 5 - Thick coax (original Ethernet cabling)

Ethernet Technologies: 10Base2

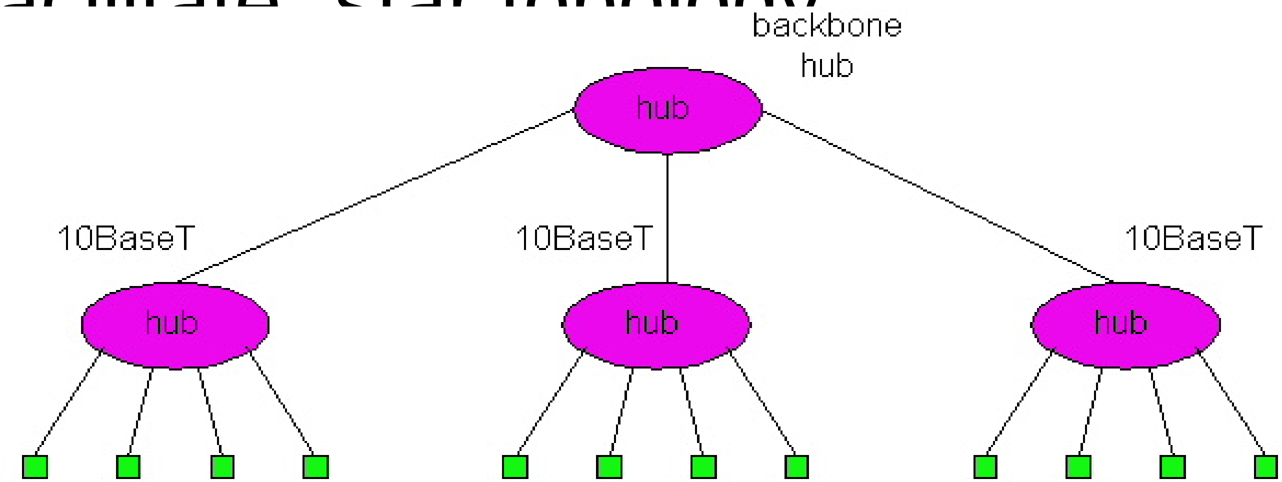
- 10: 10Mbps; 2: under 185 (~200) meters cable length
- Thin coaxial cable in a bus topology



- Repeaters used to connect multiple segments
  - Repeater repeats bits it hears on one interface to its other interfaces: physical layer device only!

10BaseT and 100BaseT

- 10/100 Mbps rate
- T stands for Twisted Pair
- Hub(s) connected by twisted pair facilitate “star topology”



Switched Ethernet

- Switches forward and filter frames based on LAN addresses
  - It's not a bus or a router (although simple forwarding tables are maintained)
- Very scalable
  - Options for many interfaces
  - Full duplex operation (send/receive frames simultaneously)
- Connect two or more "segments" by copying data frames between them
  - Switches only copy data when needed
    - key difference from repeaters

Physical Layer Data Transfer

- Signals are placed on wire via transceivers
- Problem is how to do transmit 0’s and 1’s (signal encoding) in a robust fashion
  - Binary voltage encoding
    - Map 1 to high voltage
    - Map 0 to low voltage
  - How are consecutive 0’s or 1’s detected at node?
    - Clock synchronization problem
- Transmitted signals have a variety of problems
  - Attenuation

Encoding Taxonomy

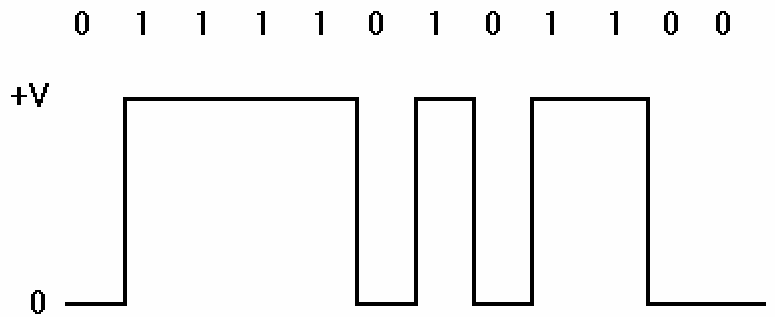
- Digital data, digital signal
  - Codes which represent bits
  - Our focus
  - Many options!
- Analog data, digital signal
  - Sampling to represent voltages
- Digital data, analog signal
  - Modulation to represent bits
- Analog data, analog signal
  - Modulation to represent voltages

Encoding Requirements

- Small bandwidth
  - Enables more efficient use of signaling capability
- Low DC level
  - Increases transmission distance
- Frequent changes in the voltage
  - Enables synchronization between the transmitter and the receiver without the addition of extra signal
- Non-polarized signal
  - Enables use of 2-wire cable to not be affected by the physical connection of the wires

Non-Return to Zero (NRZ)

- High voltage = 1 and low voltage = 0
- Voltage does not return to 0 between bits
- Receiver keeps average of signal seen to distinguish 0 from 1

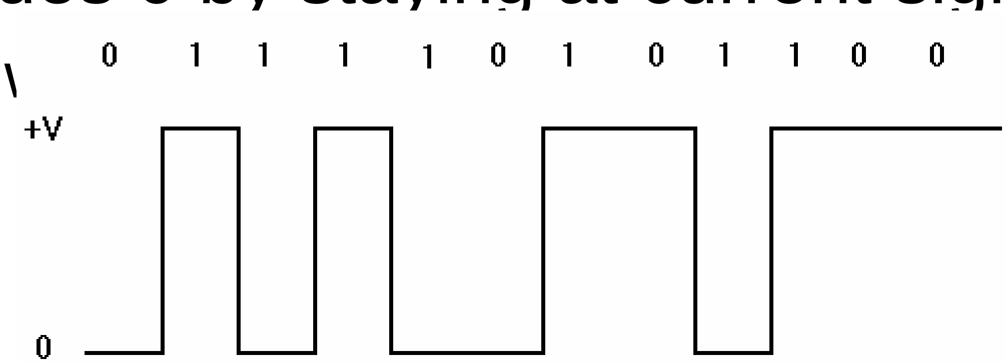


NRZ

- Benefits
  - Easy to engineer – most basic encoding
  - Efficient use of bandwidth – not many transitions
- Drawbacks
  - Long strings of 0’s can be confused with no signal
  - Long strings of 1’s can cause signal average to wander
  - Clock synchronization can be poor

NRZ-Inverted (NRZI)

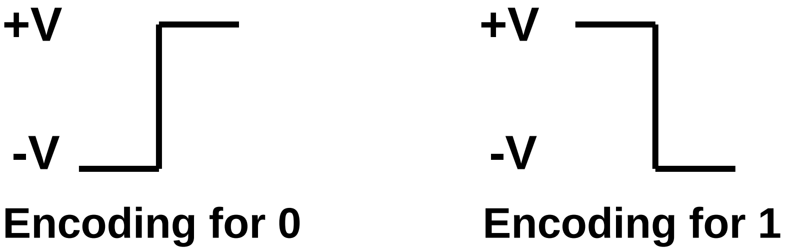
- NRZI addresses clock synchronization problem
  - Encodes 1 by transitioning from current signal
  - Encodes 0 by staying at current signal
    - So … strings of 0’s

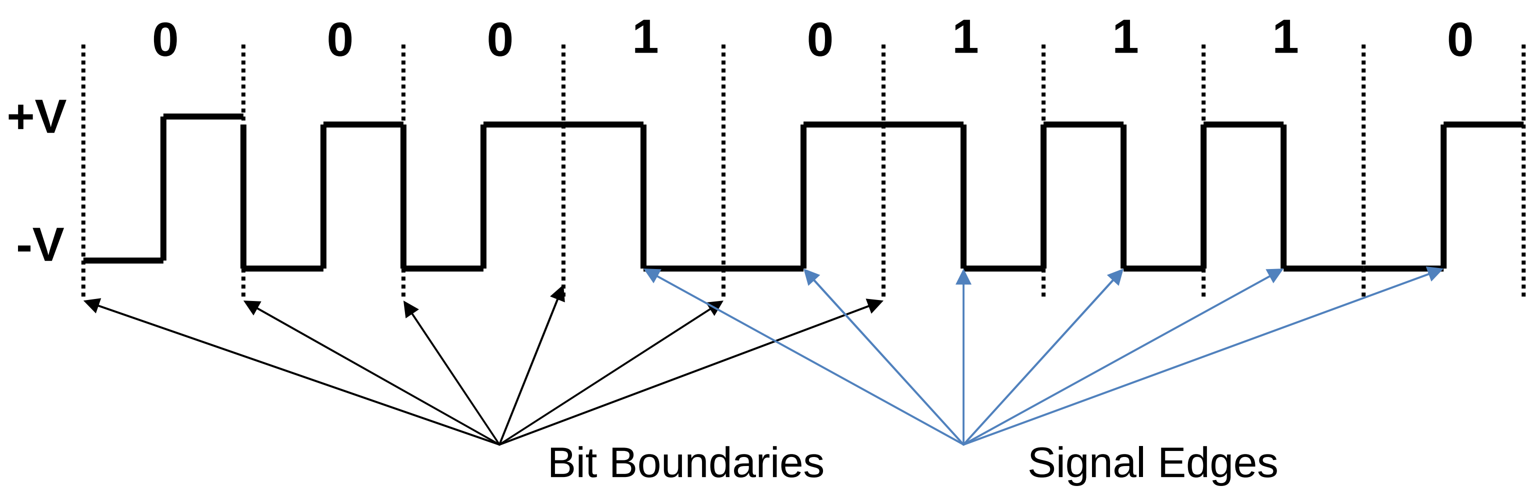


Manchester Data Encoding

- Explicit merging of clock and bit stream
  - Each bit contains a transition
    - High-low = 1
    - Low-high = 0
  - Enables effective clock signal recovery at receiver
    - Clocks are still needed to differentiate between bit boundaries
- Poor bandwidth utilization
  - Effective sending rate is cut in half

Manchester Encoding contd.





4B/5B Encoding

- Tries to address inefficiencies in Manchester
- Idea is to insert extra bits in bit stream to break up long sequences of 0’s or 1’s
- Every 4 bits of data are *encoded* in a 5 bit code
  - Encodings selections
    - At most one leading 0
    - At most two trailing 0’s
    - Never more than three consecutive 0’s
- Uses NRZI to put bits on the wire
- This is why code is focused on zeros

Control Signaling Functions

- Audible communication with subscriber
- Transmission of dialed number
- Call can not be completed indication
- Call ended indication
- Signal to ring phone
- Billing info
- Equipment and trunk status info
- Diagnostic info
- Control of specialist equipment

Control Signal Sequence

- Both phones on hook
- Subscriber lifts receiver (off hook)
- End office switch signaled
- Switch responds with dial tone
- Caller dials number
- If target not busy, send ringer signal to target subscriber
- Feedback to caller
  - Ringing tone, engaged tone, unobtainable
- Target accepts call by lifting receiver
- Switch terminates ringing signal and ringing tone
- Switch establishes connection
- Connection release when Source subscriber hangs up

Switch to Switch Signaling

- Subscribers connected to different switches
- Originating switch seizes interswitch trunk
- Send off hook signal on trunk, requesting digit register at target switch (for address)
- Terminating switch sends off hook followed by on hook (wink) to show register ready
- Originating switch sends address

Location of Signaling

- Subscriber to network
  - Depends on subscriber device and switch
- Within network
  - Management of subscriber calls and network
  - ore complex

In Channel Signaling

- Use same channel for signaling and call
  - Requires no additional transmission facilities
- Inband
  - Uses same frequencies as voice signal
  - 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)

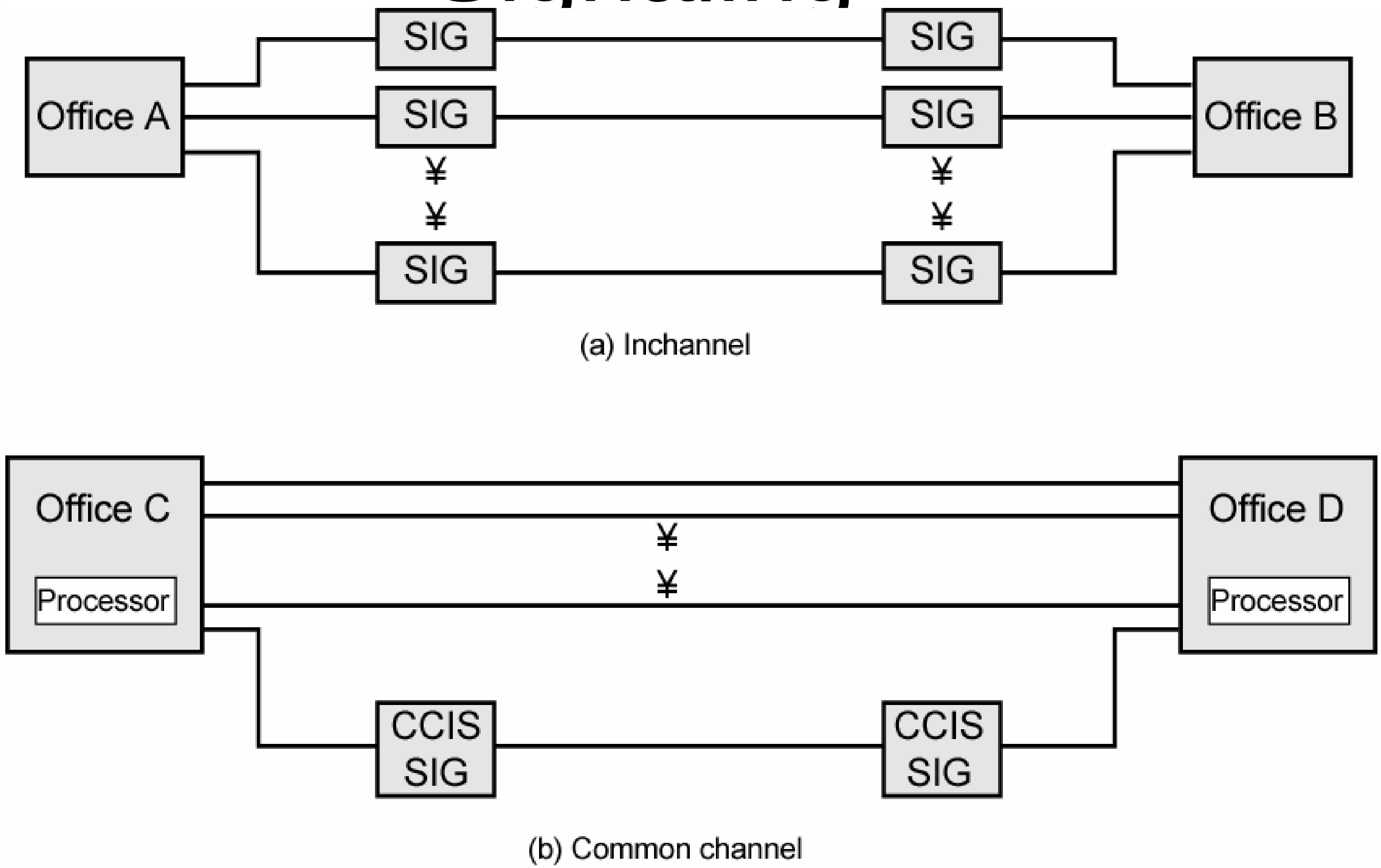
Drawbacks of In Channel Signaling

- Limited transfer rate
- Delay between entering address (dialing) and connection
- Overcome by use of common channel signaling

Common Channel Signaling

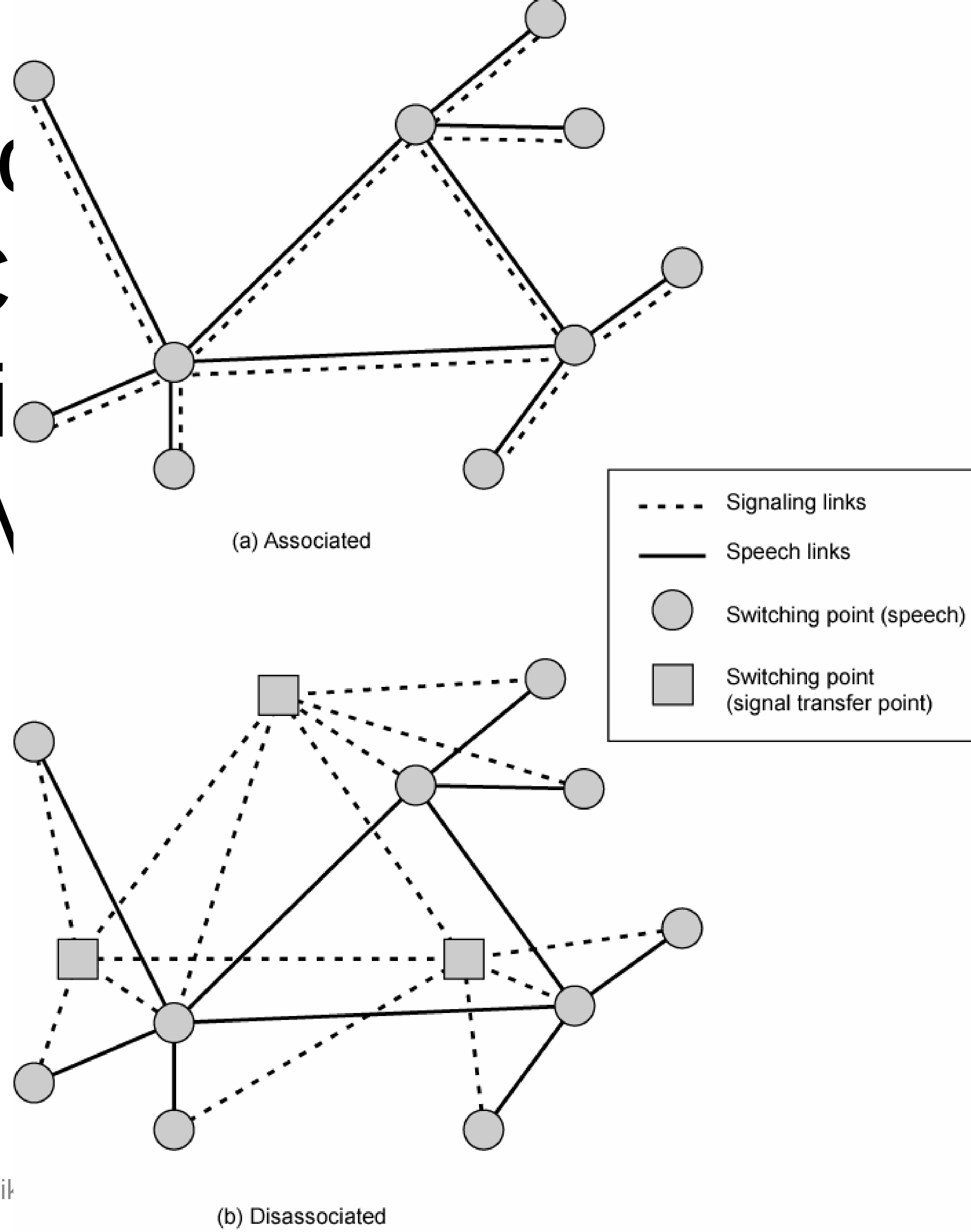
- Control signals carried over paths independent of voice channel
- One control signal channel can carry signals for a number of subscriber channels
- Common control channel for these subscriber lines
- Associated Mode
  - Common channel closely tracks interswitch trunks
- Disassociated Mode
  - Additional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

Common v. In Channel Signaling



CCIS SIG: Common-channel interoffice signaling equipment
SIG: Per-trunk signaling equipment

Co
C
Si
M


Signaling links
Speech links
Switching point (speech)
Switching point
(signal transfer point)
(a) Associated
(b) Disassociated

Shi

Signaling System Number 7

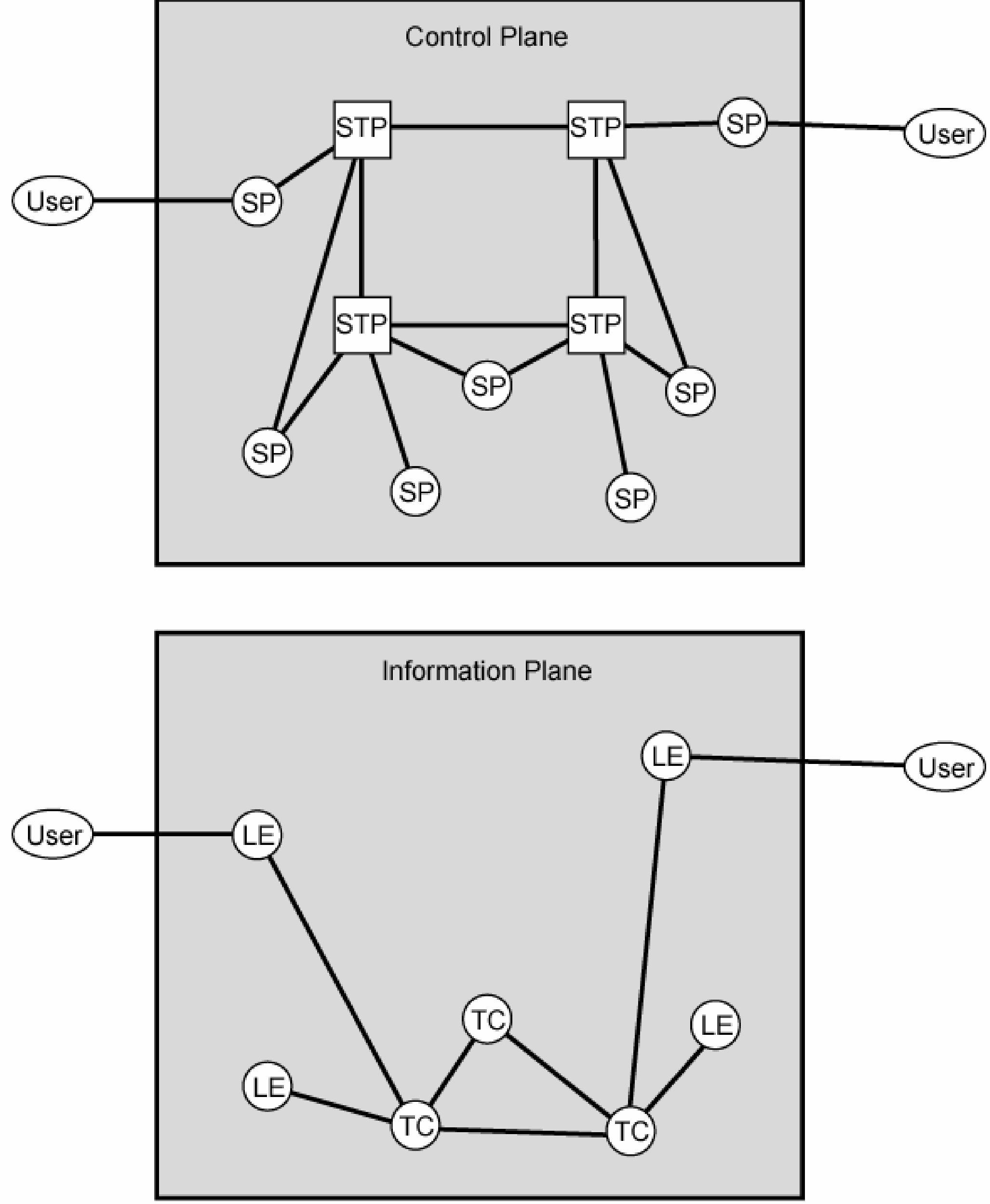
- SS7
- Common channel signaling scheme
- ISDN
- Optimized for 64k digital channel network
- Call control, remote control, management and maintenance
- Reliable means of transfer of info in sequence
- Will operate over analog and below 64k

SS7
Signaling Network Elements

- Signaling point (SP)
  - Any point in the network capable of handling SS7 control message
- Signal transfer point (STP)
  - A signaling point capable of routing control messages
- Control plane
  - Responsible for establishing and managing connections
- Information plane
  - Once a connection is set up, info is

T

I



STP = Signaling transfer point
SP = Signaling point
TC = Transit center
LE = Local Exchange

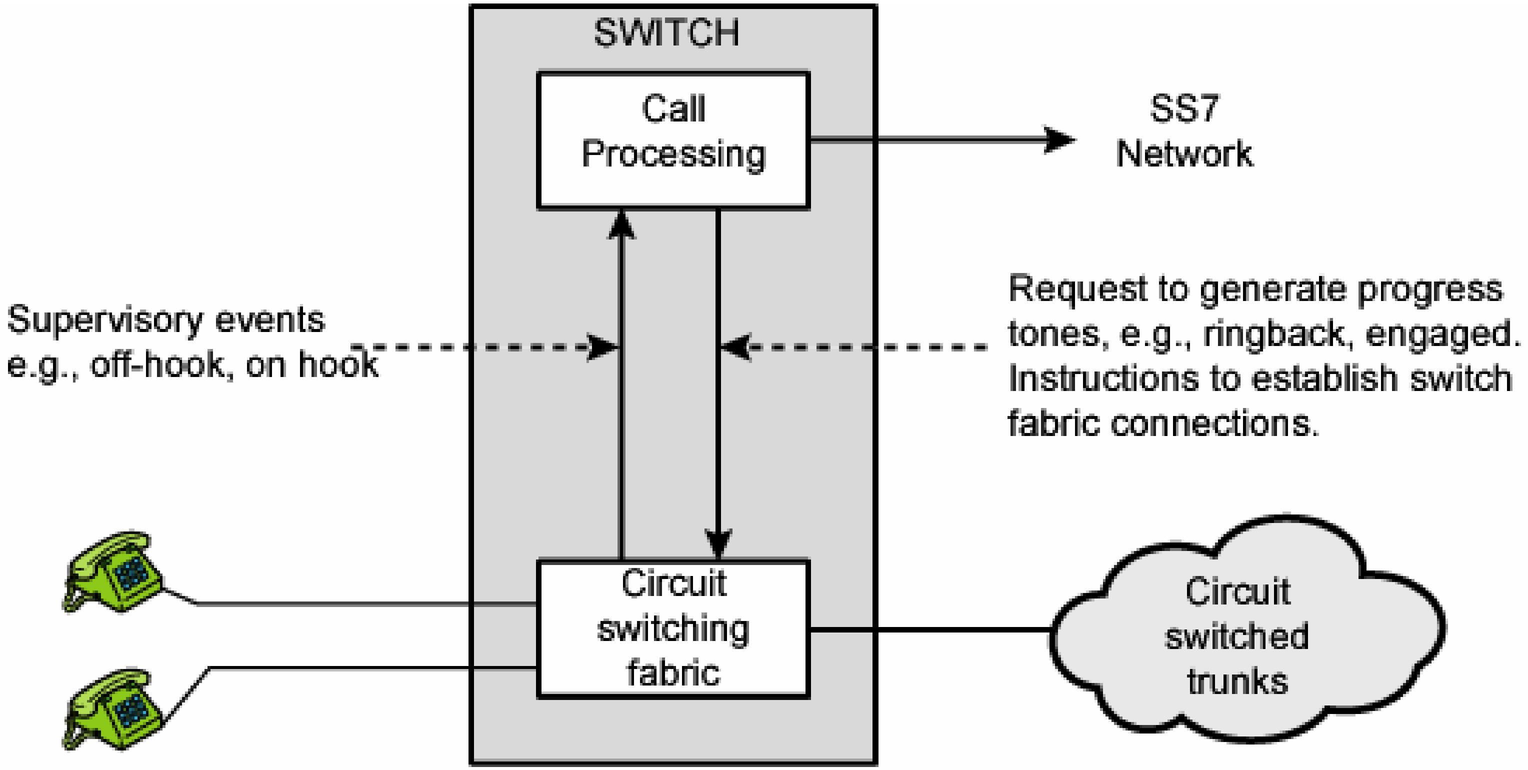
Signaling Network Structures

- STP capacities
  - Number of signaling links that can be handled
  - Message transfer time
  - Throughput capacity
- Network performance
  - Number of SPs
  - Signaling delays
- Availability and reliability
  - Ability of network to provide services in the face of STP failures

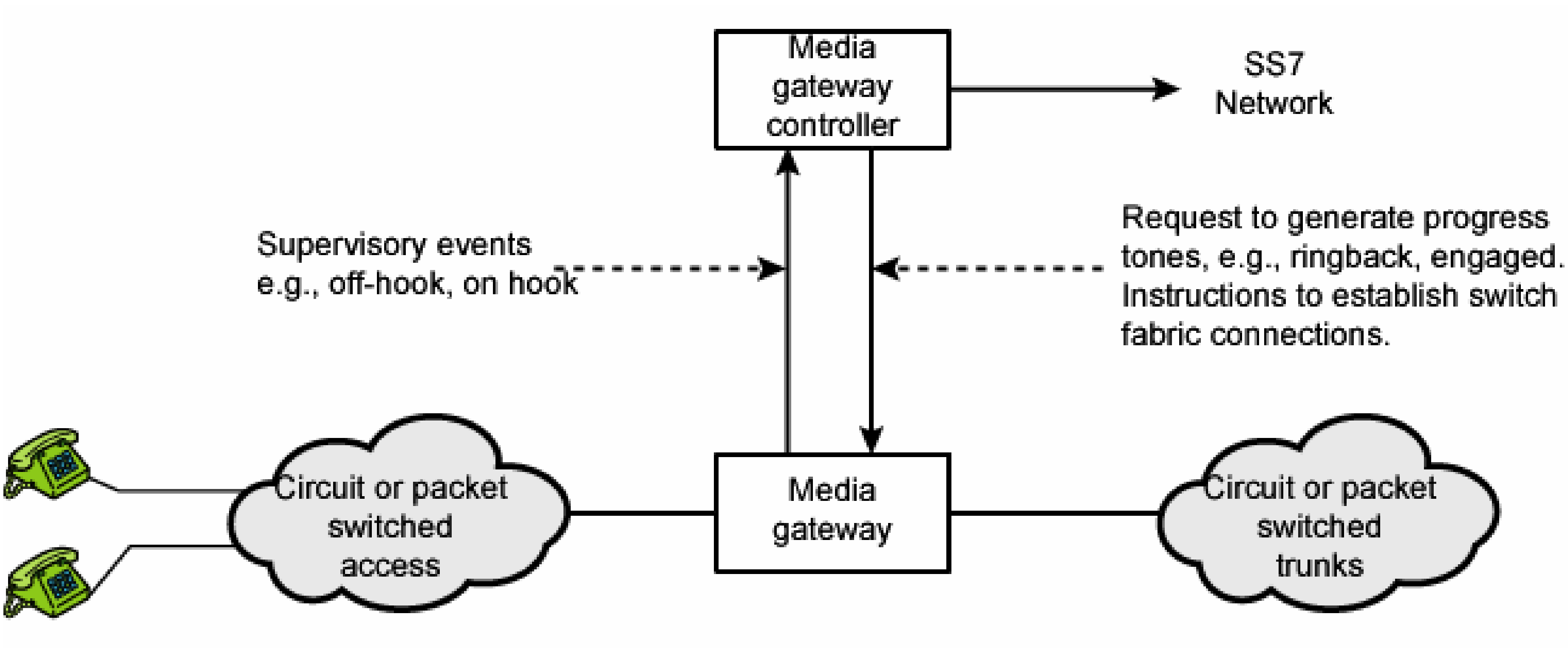
Soft switch Architecture

- General purpose computer running software to make it a smart phone switch
- Lower costs
- Greater functionality
  - Packetizing of digitized voice data
  - Allowing voice over IP
- Most complex part of telephone network switch is software controlling call process
  - Call routing
  - Call processing logic
  - Typically running on proprietary processor
- Separate call processing from hardware function of switch
- Physical switching done by media gateway
- Call processing done by media gateway controller

Traditional Circuit Switching



Soft switch


Media gateway controller
SS7 Network
Supervisory events e.g., off-hook, on hook
Request to generate progress tones, e.g., ringback, engaged. Instructions to establish switch fabric connections.
Circuit or packet switched access
Media gateway
Circuit or packet switched trunks