LAN and WAN Standards

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Network Standards

- Standards
  - » allow different computers to communicate
  - » increase the market for products adhering to the standard, resulting in mass production and cheaper prices
- Standards fall into two categories:
  - » De facto (Latin for ñ**from the fact**ò): those standards that have just happened, without any formal plan (e.g., IBM PC, Unix)
  - » De jure (Latin for ñby lawò): formal, legal standards adopted by some authorization body

Important Standards Organizations

- ITU-T: International Telecommunication Union (a United Nations specialized agency, was created on March 1, 1993)
- ISO: International Organization for Standardization (an international voluntary, nontreaty organization, founded in 1946)
- IETF: Internet Engineering Task Force (responsible for publishing RFCs (Requests For Comments))
- IEEE: Institute of Electrical and Electronic Engineers

(ATM Forum: This organization is not a standard organization. After ITU defined the ATM concept in Nov 1990, ATM Forum was initiated in October 1991 to accelerate the deployment of ATM products and services. ATM Forum develops implementation agreements and publishes them as ñspecificationsòon its web site: www.atmforum.com)

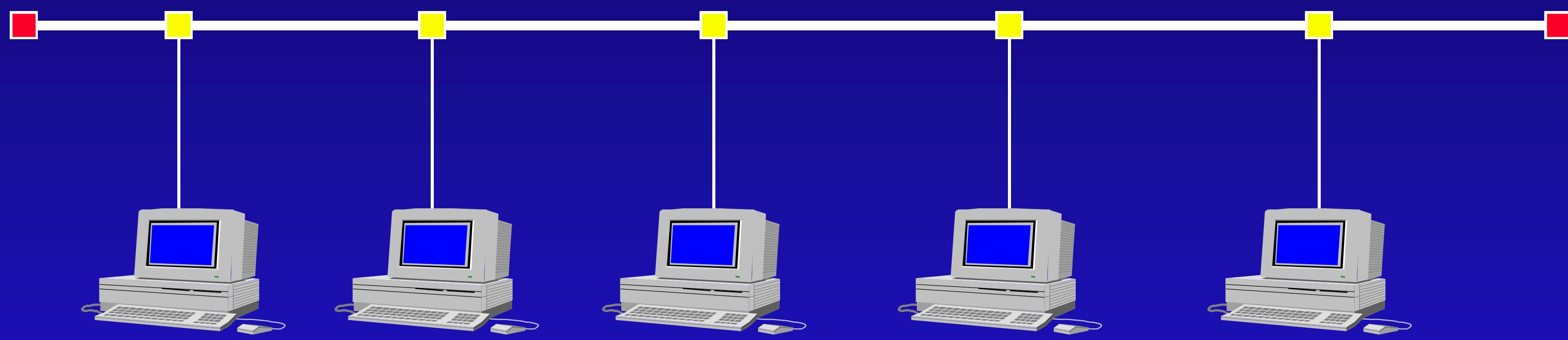
Terminology

- Networks are classified on the basis of geographic span.
  - Local Area Networks (LANs)
  - Metropolitan Area Networks (MANs)
  - Wide Area Networks (WANs)
- The difference in geographical extent between WANs and LANs account for significant differences in their respective design issues.

Terminology(cont.)

- LANs have generally three characteristic features:
  - » A diameter of no more than few kilometers.
  - » A total data rate of at least several Mega bits per second.
  - » Complete ownership by a single organization.

LANs



LANs are designed around a high speed low noise connecting link. They operate quite differently from WANs:

C (Medium Access Control) Standards

- Polling
- ALOHA Protocols
- CSMA (Carrier Sense Multiple Access) Protocols
- CSMA/CD, MAC protocols of Ethernet, Token Bus, Token Ring, FDDI, 100VG-AnyLAN
- Wavelength Division Multiple Access Protocols
- Wireless LAN Protocols

Communication Protocols

- A communication protocol is the set of rules that determines how and when stations are allowed to transmit or receive data, how the data is formatted, and how error checking is performed, etc.
- A MAC (Media Access Control) protocol is a set of rules to control access to a shared communication medium among various users.
- One station transmit at a time

Three Main Categories

- Multiple access schemes can be classified into three main categories:
  - » Fixed Assignment such as
    - ï FDMA (Frequency Division Multiple Access)
    - ï TDMA (TDMA Division Multiple Access)
  - » Random Assignment such as CSMA, CSMA/CD
  - » Demand Assignment

Poll and Select

- Primary (supervisor) station asks each secondary station in a sequence if it has data to send (this process is polling)
- A secondary station can send only if the primary station permits.
- This method may be used in a star network.
- Having backup supervisor for the supervisor malfunctions
- Polling list can be modified in case of higher priority stations; Example: 1,2,3,4,5,1,6,7,8,1,2,3,4,5,1,6,7,8,1, é .

ALOHA Protocols

- developed for packet radio networks in 1970
  - » radio encompasses all frequency bands between 30 kHz and 300 GHz
- **PURE ALOHA**
  - » Whenever a station has a frame to send, it does so. Then, station listens for a round-trip propagation time; if no ack, then retransmits.
  - » collision occurs if two frames interfere each other
  - » the number of collisions rise rapidly with increased load.

PURE ALOHA (cont)

- maximum utilization of the channel is 18 %.
- $S = G e^{-2G}$
  - » S: Throughput of network
    - ï S: (successful load) / (capacity of channel)
  - » G: The total rate of data presented to network (offered load)

    G= S+(number of retransmitted packets per unit time)
- vulnerable period = 2 X (frame time)

Slotted ALOHA

- vulnerable period = frame time
- $S = G e^{-G}$
- Maximum throughput = 37%

Carrier Sense Multiple Access) Protocol

- A station wishing to transmit first listens to the medium if another transmission is in progress (carrier sense).
  - » If the medium is in use, station waits
  - » if the medium is idle, station may transmit
- Collisions can occur only when more than one user begins transmitting within the period of propagation delay.

CSMA (cont)

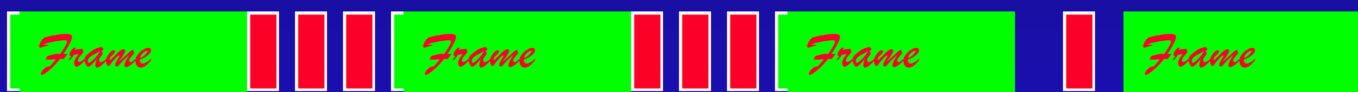
- 1-persistent CSMA
  - » if the medium is idle, transmit.
  - » if the medium is busy, continue to listen until the channel is sensed idle; then transmit immediately.
- Nonpersistent CSMA
  - » if the medium is busy, station waits a random amount of time
- p-persistent CSMA
  - » if medium is idle, station transmits with a probability p.

CSMA/CD (CSMA with Collision Detection)

- Drawback of CSMA: when two frames collide, the medium remains unusable for the duration of transmission of both damaged frames.
- CSMA/CD:
  - » 1. if the medium is idle, transmit; otherwise, go to step 2.
  - » 2. if the medium is busy, continue to listen until the channel is idle, then transmit.
  - » 3. if a collision is detected during transmission, transmit a brief jamming signal
  - » 4. after transmitting a jamming signal, wait a random amount of time, then attempt to transmit.

CSMA/CD (cont)

- Collisions occur only when more than one user begins transmitting within the period of propagation delay.



- To detect collision, the station's hardware must listen to the cable while it is transmitting. If what it reads back is different from what it is putting out, it knows a collision is occurring.

CSMA/CD (cont)

- The IEEE 802.3 standard is for a 1-persistent CSMA/CD LAN.
- Ethernet uses 1-persistent CSMA/CD
  - » when a station wants to transmit, it listens to the cable. If the cable is busy, the station waits until it goes idle; otherwise it transmits immediately.
  - » when collision occurs, all colliding stations terminate their transmission, wait a random time, and repeat the whole process again
- The binary exponential backoff algorithm is used.
- 10BASE5, 10BASE2, 10BASET, 10BASEF, 10BROAD36

  <data rate in Mbps><signaling method><maximum segment length in hundreds of meters>

FAST ETHERNET

- a low-cost, Ethernet compatible LAN operating at 100 Mbps
- 100BASE-T options use the IEEE 802.3 MAC protocol and frame format
- 100BASE-X options use the physical medium specifications originally defined for FDDI.
  - » All of the 100BASE-X schemes use two physical links between nodes: one for transmission and one for reception.
- 100BASE-TX make use of shielded twisted pair (STP) or high-quality unshielded twisted pair (UTP).

Token Bus (IEEE 802.4)

- Disadvantages of IEEE 802.3 CSMA/CD:
  - » a station may wait arbitrarily long to send a frame due to its probabilistic nature.
  - » frames do not have priorities
- Physically, the token bus is a linear cable onto which stations are attached. Logically, stations are organized into a ring.
- A special control frame called token is transmitted from one station to the next, with each station knowing the address of the station to its ``leftö and ``rightö.
- Token bus defines four priority classes: 0, 2, 4, and 6 for traffic, with 0 the lowest and 6 the highest.

TOKEN RING

- IEEE 802.5 Medium Access Protocol
- The token ring technique is based on the use of a small frame, called a token that circulates.
  - » A station wishing to transmit must wait until it detects a token passing by.
  - » It then seizes the token by changing one bit in the token which transforms it from a token into a start-of-frame sequence for a data frame.
  - » The station then appends and transmits the remainder of the fields needed to construct a data frame.

TOKEN RING (cont)

- The transmitting station will insert a new token on the ring when both of the following conditions have been met:
  - » The station has completed transmission of its frame.
  - » The leading edge of the transmitted frame has returned (after a complete circulation of the ring) to the station. (This condition ensures that only one data frame at a time may be on the ring, thereby simplifying error-recovery procedures).

TOKEN RING (cont)

- » Once the new token has been inserted on the ring, the next station downstream with data to send will be able to seize the token and transmit.
- Note that under lightly loaded conditions, there is some inefficiency with token ring because a station must wait for the token to come around before transmitting.
- The principal disadvantage of token ring is the requirement for token maintenance.
  - » Loss of token prevents further utilization of the ring.
  - » One station must be selected as a monitor.

Token Ring Priority

- The 802.5 standard includes a specification for an optional priority mechanism. Eight levels of priority are supported by providing two 3-bit fields in each data frame and token: a priority field and a reservation field.

  P(f): priority of frame

  P(s): service priority; priority of current token

  R(s): reservation value in current token

  - » A station wishing to transmit must wait for a token with P(s) <= P(f).
  - » While waiting, a station may reserve a future token at its priority level P(f).
- Early token release option is added to the IEEE 802.5 for more efficient ring utilization.

FDDI

- The FDDI standard specifies a ring topology operating at 100 Mbps.
- Optical fiber or twisted pair are used for medium.
  - » Optical fiber uses 4B/5B NRZI encoding. Maximum length between repeaters is 2 km. Maximum number of repeaters is 100.
  - » Two twisted pair media are specified: 100-ohm Category 5 unshielded twisted pair and 150-ohm shielded twisted pair. Maximum length between repeaters is 100m . Maximum number of repeaters is 100.

100VG-AnyLAN

- is intended to be a 100 Mbps extension to the 10 Mbps Ethernet and to support IEEE 802.3 frame types.
- uses a MAC scheme known as demand priority;it has been standardized under IEEE 802.12.
  - » Its MAC algorithm is a round-robin scheme with two priority levels.
- Single-Hub Network
  - » When a station wishes to transmit a frame, it first issues a request to the central hub and then awaits permission from the hub to transmit.
  - » A station must designate each request as normal-priority or high-priority.

100VG-AnyLAN (contd.)

- The central hub continually scans all of its ports for a request in round-robin fashion.
- The central hub maintains two pointers: a high-priority pointer and a normal-priority pointer.
- If at any time there are no pending high-priority requests, the hub will grant any normal-priority requests that it encounters.

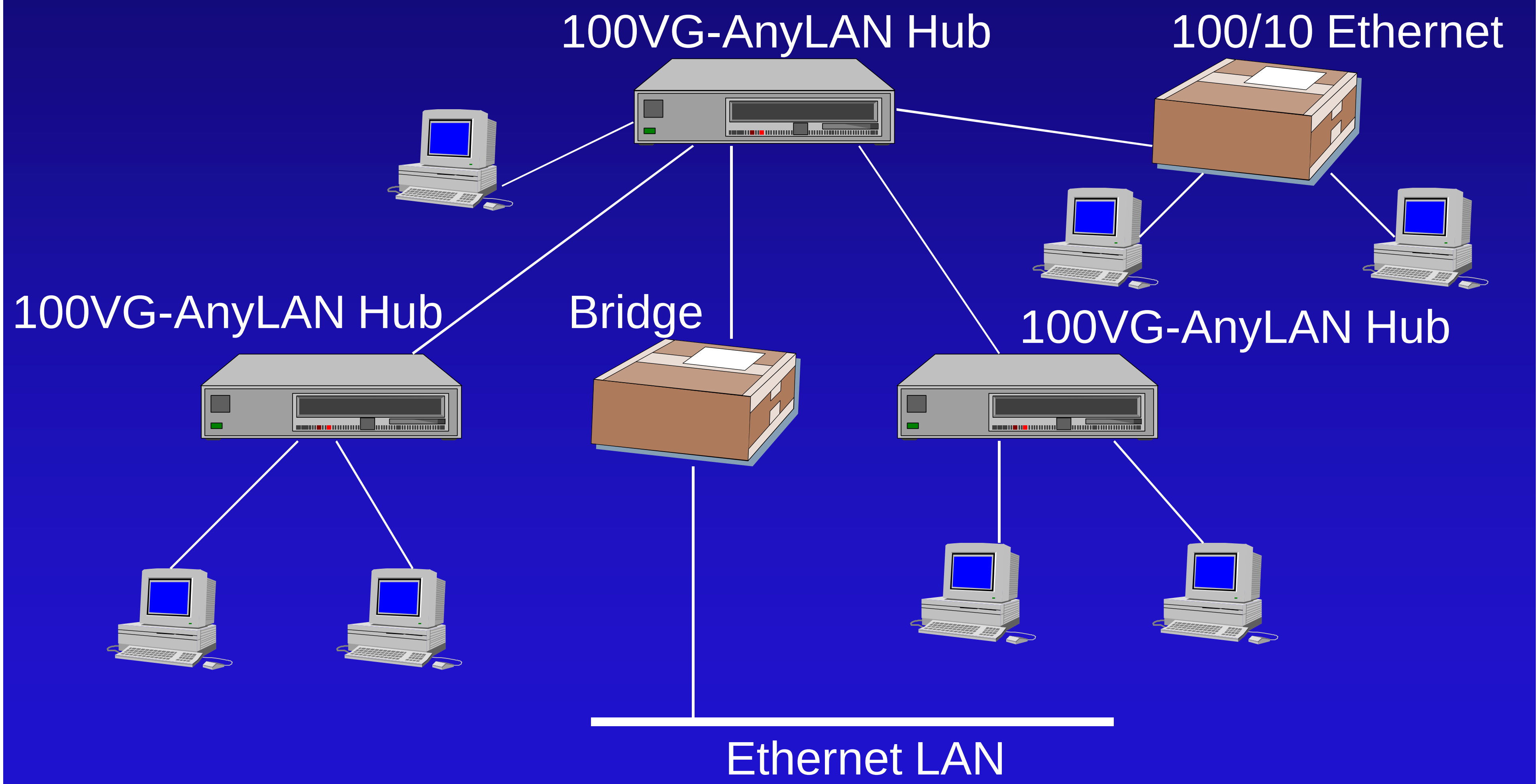
100 VG-AnyLAN (contd.)

- Hierarchical Network
  - » All of the end-system ports on all hubs are treated as a single set of ports for purposes of round-robin.
  - » Port ordering is done preorder traversal:
    - ï Visit the root
    - ï Traverse the subtrees from left to right.

100VG-AnyLAN (contd.)

- Hierarchical topology
  - » There is a single root Hub (at level 1)
  - » A level 1 Hub may have one or more subordinate level 2 hubs
  - » A level 2 hub can have one or many subordinate level 3 hubs, and so on, to an arbitrary depth
- Hub is responsible for converting between 802.3 and 802.5 frame formats if necessary

ple 100VG-AnyLAN Configuration



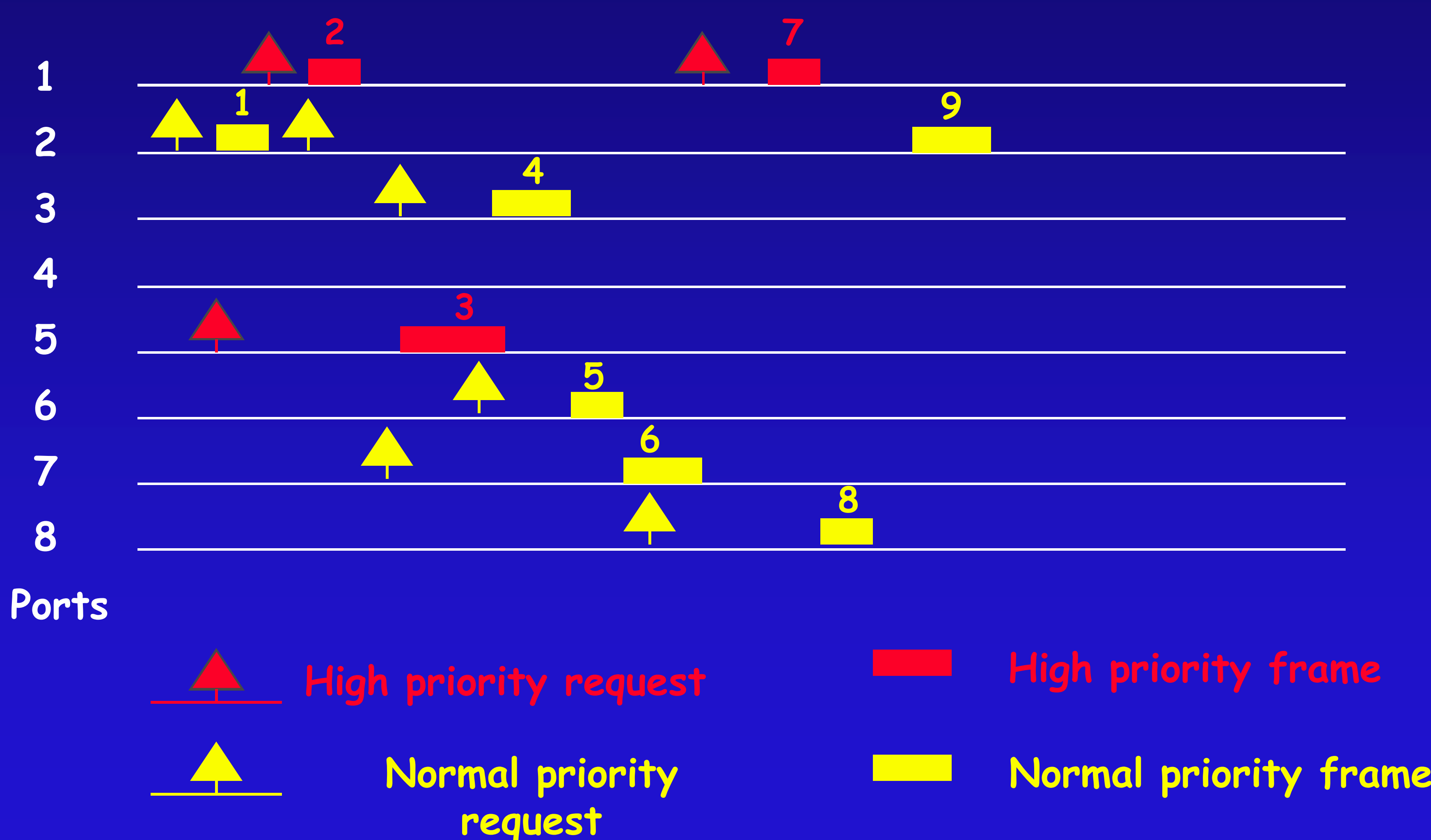
# of 100VG-AnyLAN (Single hub network)

- The MAC algorithm for 802.12 is a round-robin scheme with two priority levels
- A station wishing to transmit
  - » it first issues a request to the central hub
  - » it then awaits permission from the hub to transmit
  - » A station must designate each request as normal priority or high priority

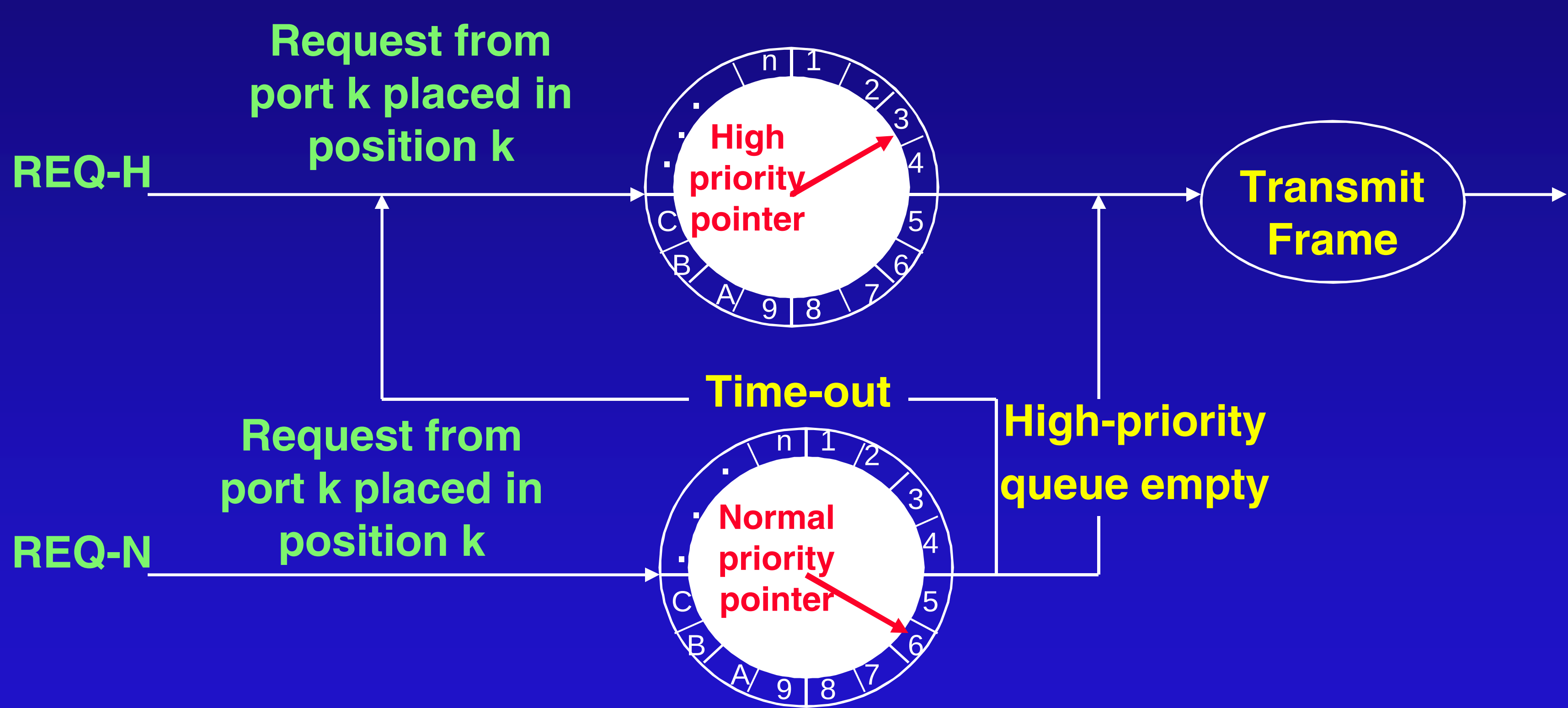
Single hub LAN (contd.)

- » The central hub continually scans all of its ports for request in round-robin fashion
- » The hub maintains two pointers
  - ï a high priority pointer and
  - ï a low priority pointer
- » During one cycle, the hub grants each high priority request in the order encountered
- » When there are no pending high priority requests, the hub grants normal priority requests in the order encountered

…le Frame Sequence in a Single-Repeater Network



100VG-AnyLAN Priority Scheme

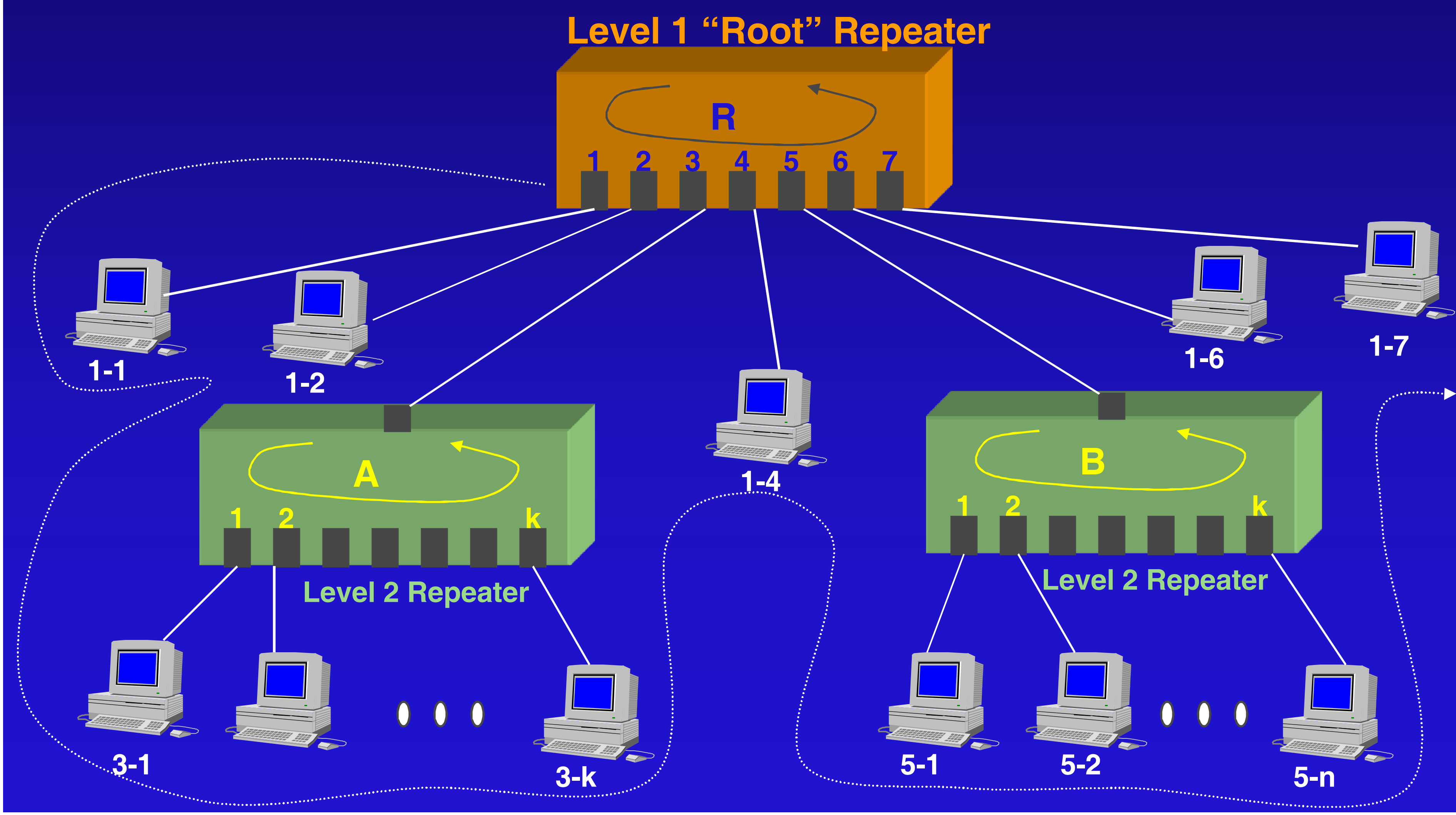


If a request remains in the normal priority buffer for too long (default=500 ms), it is moved to the corresponding position in the high-priority buffer.

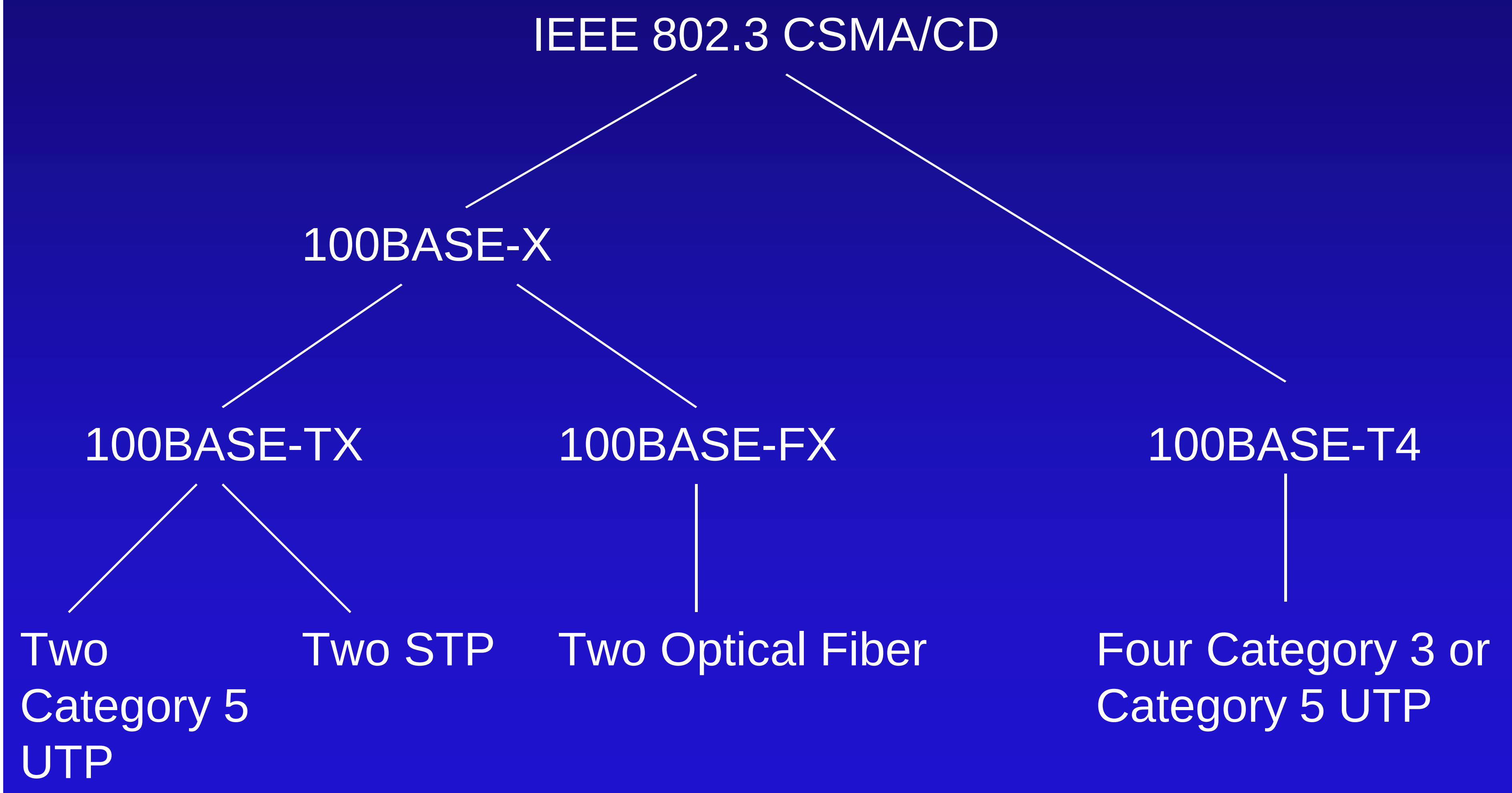
Hierarchical LAN

- The set of all hubs are treated logically as one single hub
  - » The port order is generated by performing a pre-order traversal of the tree (depth-first)
    - ï Visit the root
    - ï traverse the subtrees from left to right
  - » Each hub is running its own round-robin algorithm to service end-systems directly attached to it.

ring in a Two-Level IEEE 802.12 Network



E 802.3 CSMA/CD Labeling Terminology



100 BASE-T

- Provides a low cost Ethernet compatible LAN operating at 100 Mbps.
- All of the 100 BASE-T options use the IEEE 802.3 MAC protocol and frame format
- All of the 100 BASE-X schemes use two physical links between nodes, one for transmission and one for reception
- Provides a low cost Ethernet compatible LAN operating at 100 Mbps.

100 BASE-T

- All of the 100 BASE-T options use the IEEE 802.3 MAC protocol and frame format
- All of the 100 BASE-X schemes use two physical links between nodes, one for transmission and one for reception

100 BASE-T (contd.)

- 100 BASE T4 can use
  - » low cost option of CAT 3 voice-grade UTP
  - » higher quality CAT 5 UTP
- 100 BASE T4 uses 4 TP lines between nodes, with data transmission making use of 3 pairs in one direction at a time.
- Typically, any of the 100BASE-X options require the installation of new cable.

2.3 100BASE-T Physical Layer Medium Alternatives

	100BASE-TX		100BASE-FX	100BASE-T4
Transmission medium	Two pair STP	Two pair cat 5 UTP	Two optical fibers	Four pair, cat 3,4 or 5 UTP
Signaling technique	4B5B,NRZI	4B5B, NRZI	4B5B, NRZI	8B6T, NRZ
Data rate	100 Mbps	100 Mbps	100 Mbps	100 Mbps
Max. Segment length	100 m	100 m	100 m	100 m
Network Span	200 m	200 m	400 m	200 m

100 BASE-X

- For all transmission media specified under 100BASE-X, a unidirectional data rate of 100 Mbps is achieved transmitting over a single link
- An efficient and effective encoding scheme is used: 4B/5B-NRZ-I, originally defined for FDDI.

4B/5B-NRZI

- Encoding is done 4 bits at a time
- Each 4 bits of data are encoded into a symbol of 5 code bits
- A set of 5 code bits is a code group
- Efficiency: 80%
- Each code group is treated as a binary value and encoded using nonreturn to zero inverted (NRZI)

4B/5B-NRZI (contd.)

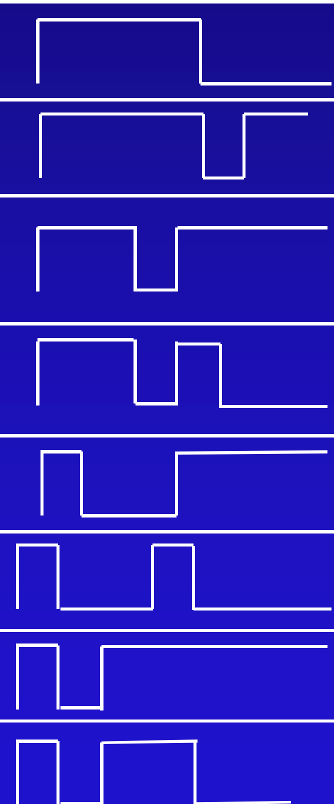
  - » 1 -> transition at beginning of bit interval
  - » 0 -> no transition
  - » There are no other transitions
- For adequate synchronization: no more than 3 zeros in a row are allowed across one or more code groups
- Code groups not used for data are either invalid or used as control symbols

4B/5B Code Groups

Data input	Code Group	NRZI Pattern	Interpretation
0000	11110		Data 0
0001	01001		Data 1
0010	10100		Data 2
0011	10101		Data 3
0100	01010		Data 4
0101	01011		Data 5
0110	01110		Data 6
0111	01111		Data 7

4B/5B Code Groups (Contd.)

Data input	Code Group	NRZI Pattern	Interpretation
1000	10010		Data 8
1001	10011		Data 9
1010	10110		Data A
1011	10111		Data B
1100	11010		Data C
1101	11011		Data D
1110	11100		Data E
1111	11101		Data F



4B/5B Code Groups (Contd.)

Data input	Code Group	NRZI Pattern	Interpretation
	11111		Idle
	11000		Start of Stream part 1
	10001		Start of Stream part 2
	01101		End of Stream part 1
	00111		End of Stream part 2
	00100		Transmit Error
	Other		Invalid codes

4B/5B code groups (contd.)

- Idle code group
  - » transmitted between data transmission sequences
  - » consists of constant flow of binary 1ôs
  - » this fill pattern establishes and maintains synchronization
  - » also indicates that the medium is idle

4B/5B Code groups (contd.)

- Start-of-stream delimiter
  - » used to delineate the starting boundary of a data transmission sequence
  - » consists of two different code groups (part 1 and part 2)
- End-of-stream delimiter
  - » used to terminate normal data transmission sequences (2 different code groups)

100 BASE-TX

- The 4B/5B signal is subject to further encoding as follows
  - » NRZI-to-NRZ conversion
  - » Scrambling: the bit stream is scrambled to produce a more uniform spectrum distribution for the next stage
  - » Encoder: the scrambled bit stream is encoded using MLT-3
  - » Driver: the resulting signal is transmitted

MLT-3 encoding

- Effect of MLT-3 is to concentrate most of the energy in the transmitted signal below 30 MHz, which reduces radiated emission
- MLT-3 encoding
  - ï produces a transition for every each ó1ô
  - ï uses three levels (+V, 0, -V)

Example of MLT-3 Encoding

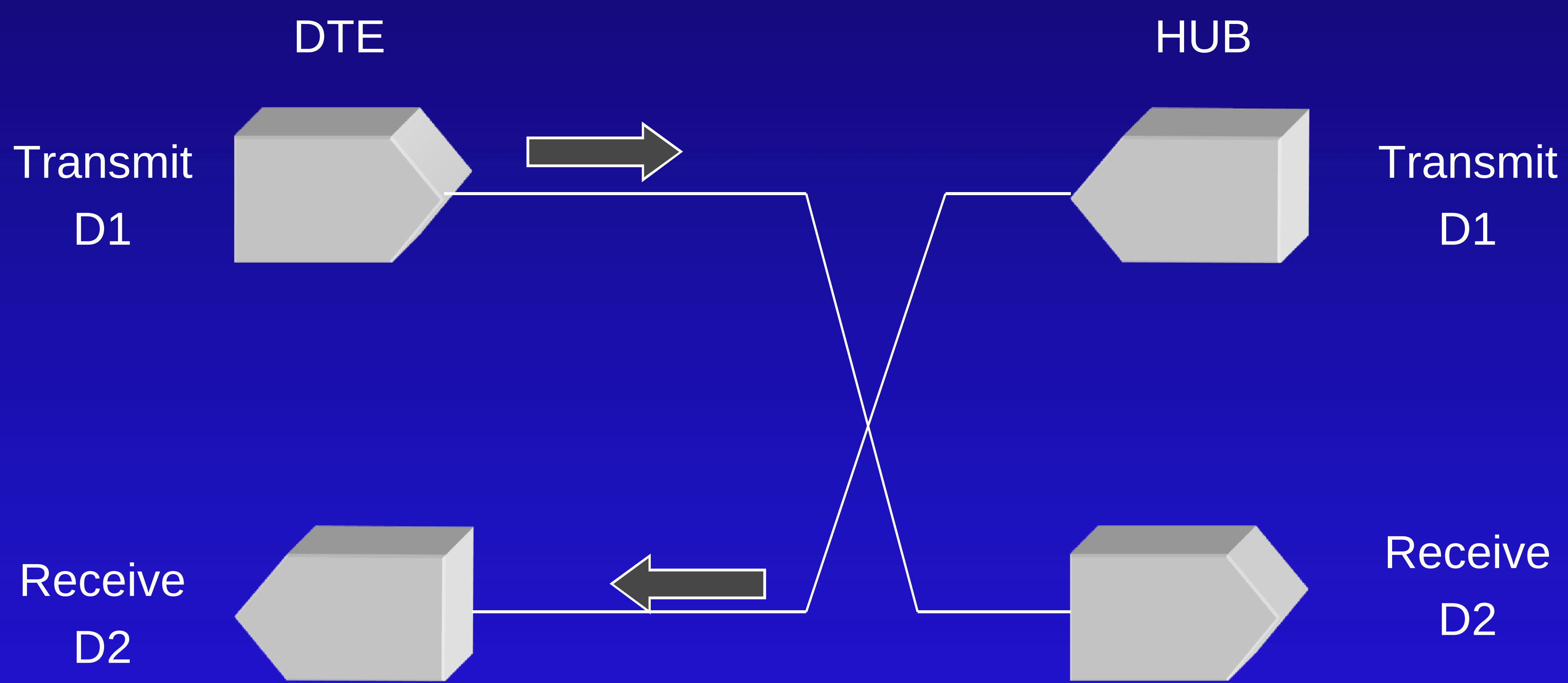
1. If the next bit is 0, then the next output is the same as the preceding output

2. If the next bit is 1, then the next output involves a transition:

   a. If the preceding output was either +V or -V, then the next output is 0

   b. If the preceding output was 0, then the next output is nonzero, and is of opposite sign to the last non zero output.

100BASE-X Use of Wire Pairs

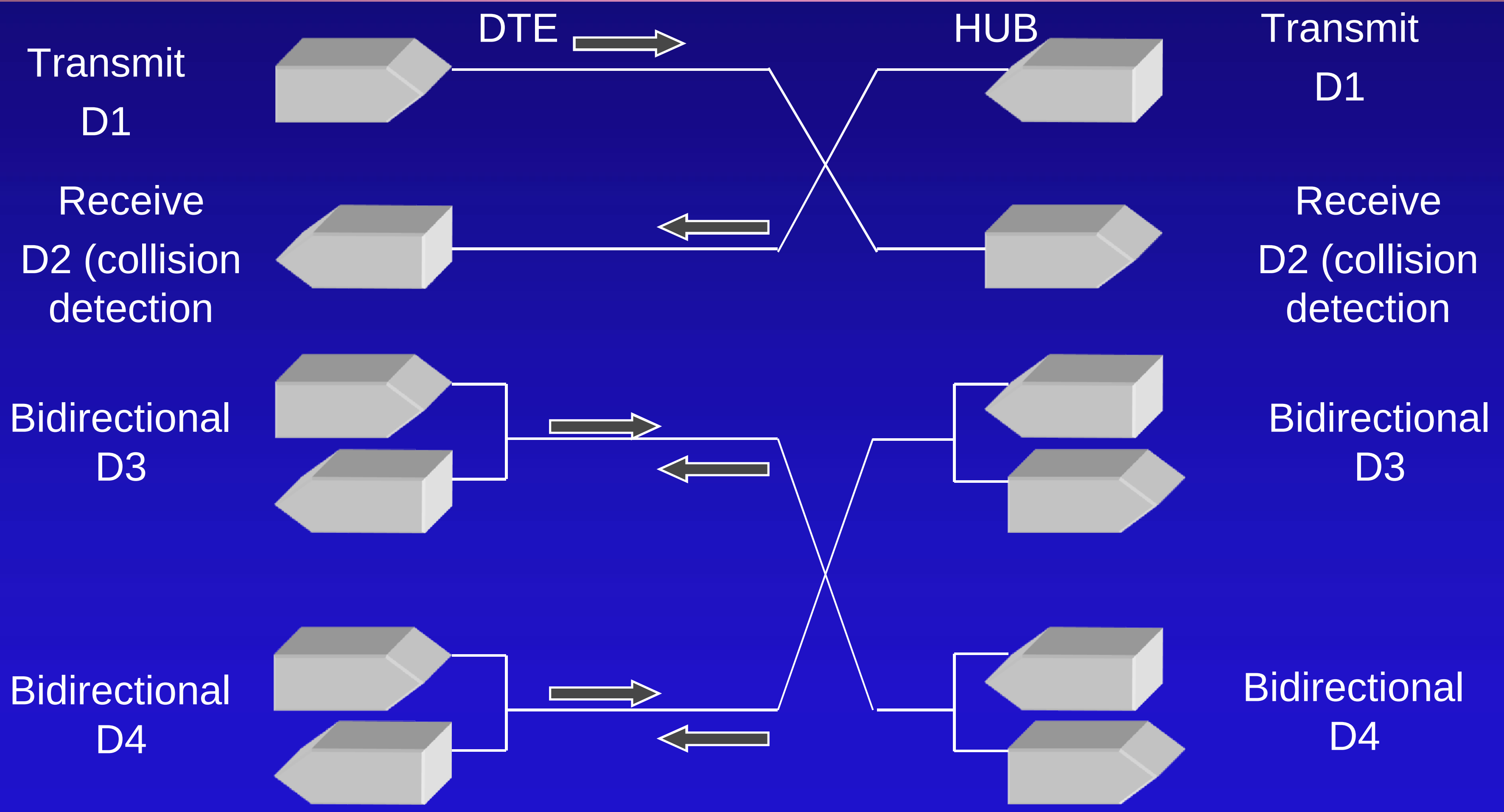


100BASE-X Configuration

100BASE-T4

- Uses voice-grade CAT-3 cable
  - » data stream is split into three separate data streams each with effective data rate of 33.333 Mbps
    - ï data transmitted using pairs labeled D1, D3, and D4
    - ï data received on pairs D2, D3, and D4.
    - ï D3 and D4 are bi-directional and D2 is used for reception as well as for collision detection

ASE-T4 Use of Wire Pairs



100BASE-T4 Configuration

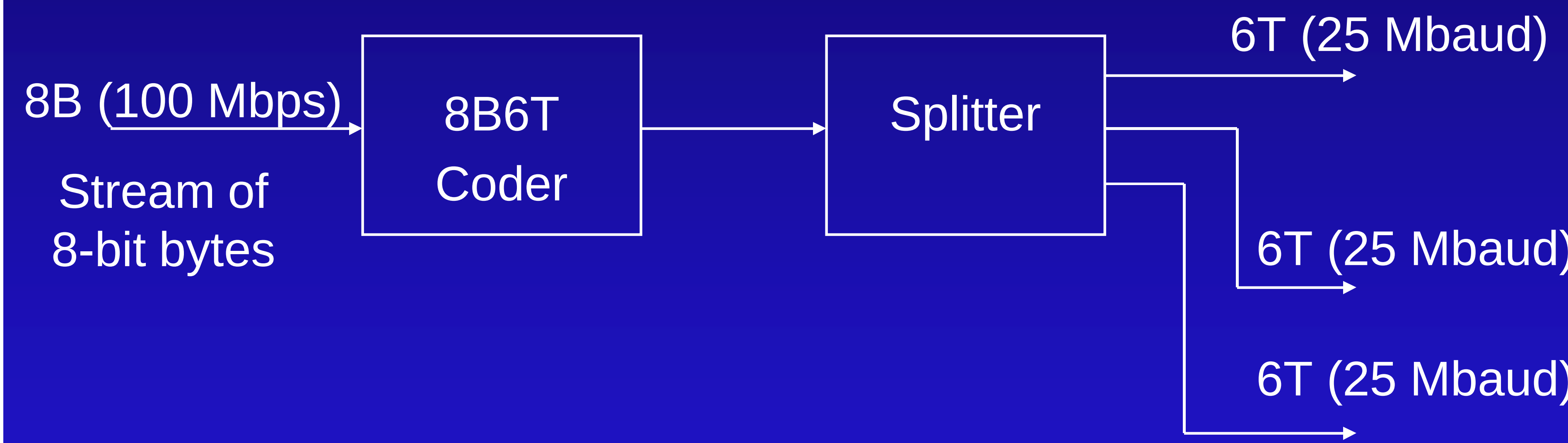
100Base-T4 (contd.)

- A simple NRZ encoding scheme would require a signaling rate of 33 Mbps. Instead, for 100BASE-T4, a ternary signaling scheme is used, where each signal element can take one of three possible values (-,0,+)
- A new block coding scheme 8B6T is used.

8B6T coding scheme

- The data to be transmitted is are handled in 8-bit blocks
- Each block of 8 bits is mapped into a code group of 6 ternary symbols
- The stream of code groups is then transmitted in round-robin fashion across the three output channels
- Thus, the ternary transmission rate on each output channel is (6/8)x33.333 = 25 Mbaud

ransmission Scheme used for 100BASE-T4



Portion of 8B6T Code Table

Data Octet	6T Code Group	Data Octet	6T Code Group	Data Octet	6T Code Group	Data Octet	6T Code Group
00	+-00+-	10	+0+--0	20	00-++-	30	+-00-+
01	0+-+-0	11	++0-0-	21	--+00+	31	0+--+0
02	+-0+-0	12	+00-0-	22	++-0+-	32	+-0-+0
03	-0++-0	13	0++-0-	23	++-0-+	33	-0+-+0
04	-0+0+-	14	0++--0	24	00+0-+	34	-0+0-+
05	0+--0+	15	++00--	25	00+0+-	35	0+-+0-
06	+-0-0+	16	+0+0--	26	00-00+	36	+-0+0-
07	-0+-0+	17	0++0--	27	--+++-	37	-0++0-
08	-+00+-	18	0+-0+-	28	-0-++0	38	-+00-+
09	0-++-0	19	0+-0-+	29	--0+0+	39	0-+-+0
0A	-+0+-0	1A	0+-++-	2A	-0-+0+	3A	-+0-+0
0B	+0-+-0	1B	0+-00+	2B	0--+0+	3B	+0--+0
0C	+0-0+-	1C	0-+00+	2C	0--++0	3C	+0-0-+
0D	0-+-0+	1D	0-+++-	2D	--00++	3D	0-++0-
0E	-+0-0+	1E	0-+0-+	2E	-0-0++	3E	-+0+0-
0F	+0--0+	1F	0-+0+-	2F	0--0++	3F	+0-+0-

...ration and Operation of 100BASE-T LAN

- Simplest configuration:
  - » Star-wire topology
  - » All stations connected to a central point called a multiport repeater
  - » The repeater has the responsibility of detecting collisions rather than the attached stations

100BASE-T Repeater

- The repeater functions as follows:
  - » A valid signal appearing on any single input port is repeated on all output ports
  - » If two or more inputs occur at the same time, a jam signal is transmitted on all links

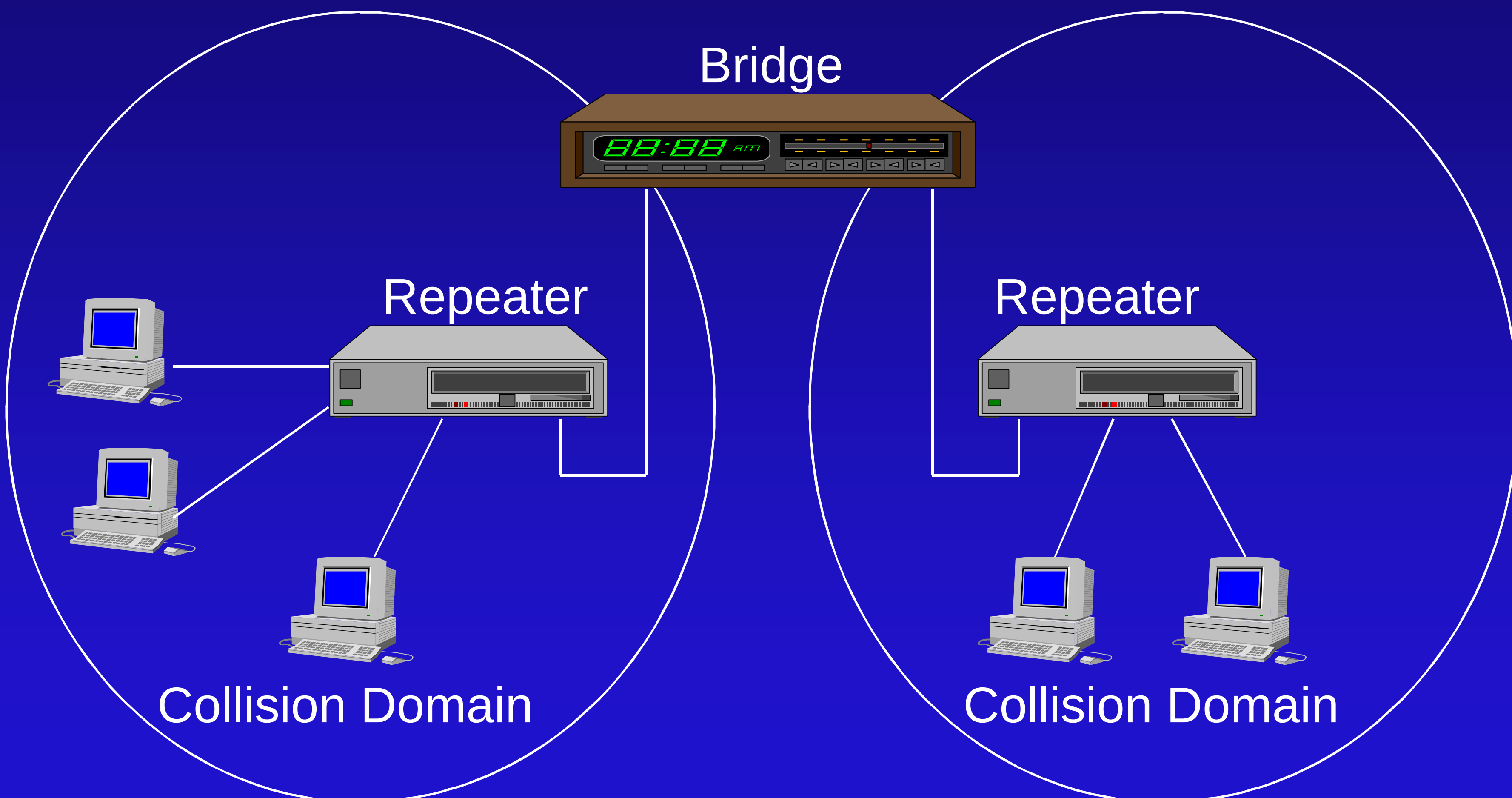
100BASE-T Repeater (contd.)

- The 100BASE-T standard defines two types of repeaters
  - » Class I repeater:
    - ï can support unlike physical media segments, e.g. 100BASE-T4 and 100BASE-TX
    - ï increased delay because of signal conversion
    - ï Only a single Class I repeater is allowed per collision domain

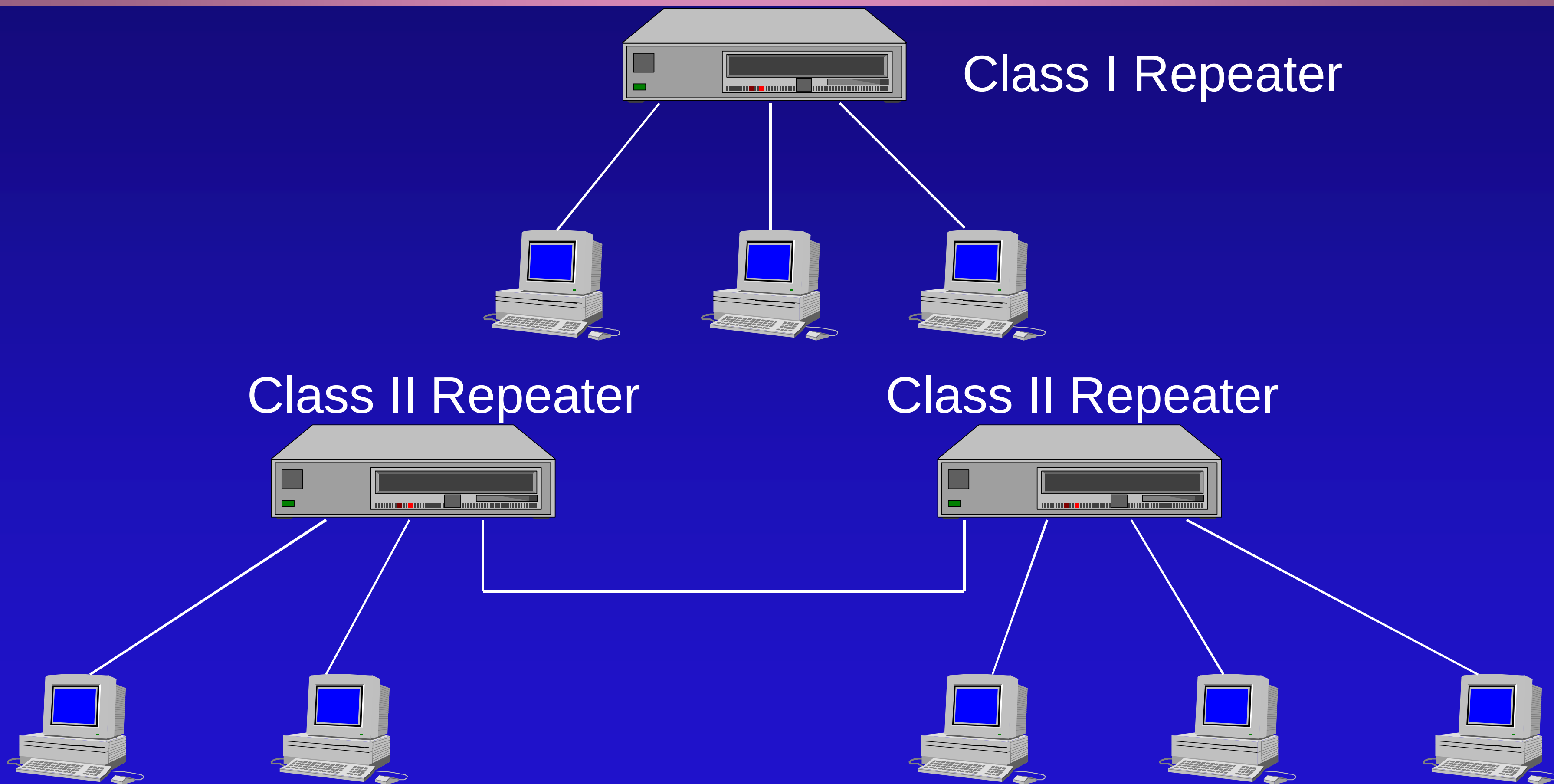
100BASE-T Repeater (contd.)

» Class II Repeater:
- ï Limited to a single type of physical media
- ï Two Class II repeaters may be used in a single collision domain

Collision Domains



100BASE-T Repeater Types



...um Collision Domain (meters)

Repeater Type	Copper	Copper and Fiber	Fiber
DTE-DTE	100	NA	400
One Class I Repeater	200	230	240
One Class II Repeater	200	285	318
Two Class II Repeaters	205 (200 Cat 3)	212	226

gth Division Multiple Access Protocols

- Are used on fiber optic LANs in order to permit different conversations to use different wavelengths (frequencies) at the same time. (wavelength X frequency = speed of light)
- A simple way to build an all optical-LAN is to use a passive star.
- To allow multiple transmissions at the same time, the spectrum is divided up into channels (wavelength bands)
- Each station is assigned two channels: one as a control channel to signal the station, and the other for the station to output data frames.

Wireless LANs

- IEEE 802.11 has developed a set of wireless LAN standards.
- A system of portable computers that communicate by radio (or infrared) signals is regarded as a wireless LAN.
- Three physical media are defined in 802.11:
  - » Infrared at 1 Mbps and 2 Mbps operating at a wavelength between 850 and 950 nm.
  - » Direct-sequence spread spectrum operating in the 2.4-GHz. Up to 7 channels, each with a data rate of 1 Mbps or 2 Mbps.
  - » Frequency-hopping spread spectrum operating in the 2.4 GHz.

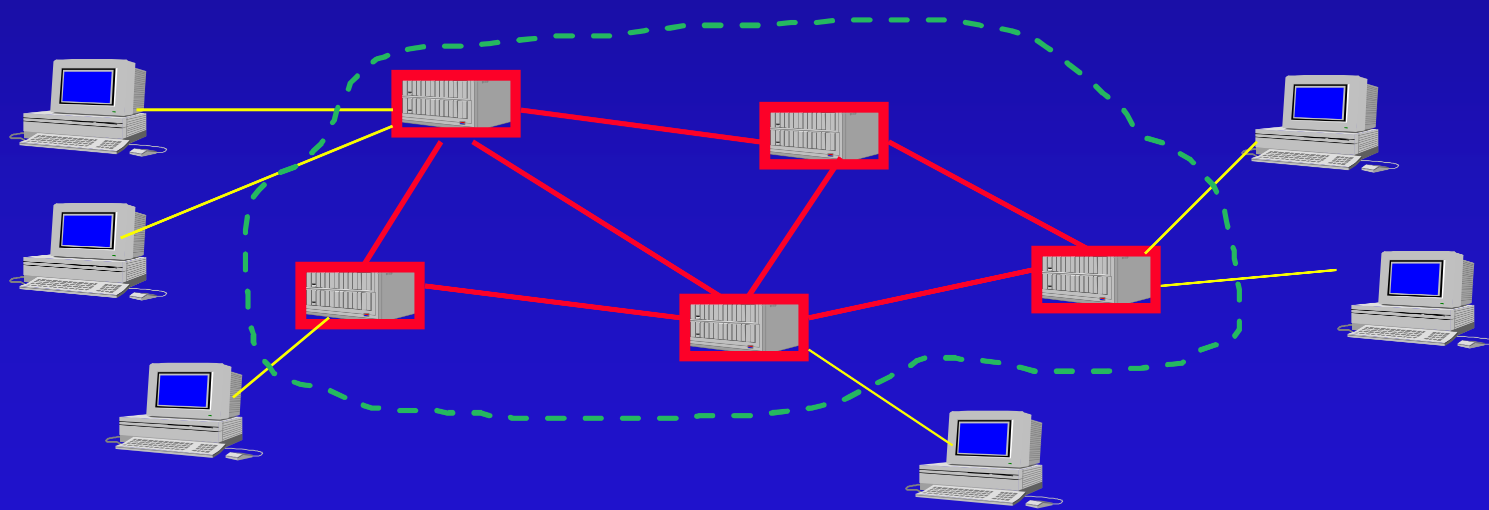
Wireless LANs (cont)

- The 802.11 is about to standardize CSMA/CA (CSMA with collision avoidance).
  - » The basic idea is for the sender to stimulate the receiver into outputting a short frame, so stations nearby can detect this transmission and avoid transmitting themselves for the upcoming large data frame. Sender sends an RTS (Request To Send) frame. Receiver replies with a CTS (Clear To Send) frame.
  - » An ACK frame is sent after each successful data frame.
  - » Binary exponential backoff algorithm is used if a transmitter does not hear anything from receiver.

Enough!

W A

WANs are structured with irregular placement of the nodes.



WANs (cont)

- WANs cover a large geographical area.
- WAN consists of a number of interconnected switching nodes. Communication is achieved by transmitting data from source to destination through these intermediate switching nodes to the specified destination device.
- Traditionally, WANs have been implemented using one of two technologies: circuit switching and packet switching. Recently, frame relay and ATM networks have assumed major roles.

WANs (cont)

- Circuit switching: a dedicated communication path is established between two stations through the nodes of the network. Example: the telephone network.
- Packet switching: At each node, a packet is received, stored briefly, and then transmitted to the next node. Example: X.25 network
  - » To compensate errors, there is a considerable amount of overhead built into the packet-switched schemes.
- Frame relay was developed to take advantage of high data rates and low error rates that are available in modern high-speed communication systems. It operates efficiently at user data rates up to 2 Mbps. It uses variable-length packets, called frames.

WANs (cont)

- ATM (Asynchronous Transfer Mode) :
  - » is a culmination of all of the developments in circuit switching and packet switching.
  - » Can be viewed as an evolution from frame relay. ATM uses fixed-length packets, called cells.
- The ISDN is intended to be a worldwide public telecommunications network to replace existing public telecommunications networks and deliver a wide variety of services.
  - » Narrowband ISDN
  - » Broadband ISDN (B-ISDN)

X.25 Networks

- was developed during 1970s by CCITT to provide an interface between public packet-switched networks and their customers. X.25 calls for three layers of functionality: physical layer, data link layer, and packet (or network) layer.
- The physical layer protocol, called X.21, specifies the physical, electrical, and procedural interface between the host and the network.
- Very few public networks actually support this standard. It requires digital, rather than analog signaling on the telephone lines.

X.25 Networks (contd)

- The data link layer protocol deals with transmission errors on the telephone line between the userꞌs equipment (host or terminal) and the public network (router).
- The network layer protocol deals with addressing, flow control, delivery confirmation, interrupts, and related issues.
  - » Establishes virtual circuits and sends packets of up to 128 bytes on them. These packets are delivered reliably in order.
  - » Most X.25 networks work at speeds up to 64 kbps
- Both data link layer and network layer include flow control and error control mechanisms.

X.25 Networks (contd)

- X.25 is connection-oriented. At network layer, X.25 provides multiplexing: a DTE is allowed to establish up to 4095 simultaneous virtual circuits with other DTEs over a single physical DTE-DCE link.
- X.25 supports both switched virtual circuits and permanent ones.
- A switched virtual circuit is created when one computer sends a packet to the network asking to make a call to a remote computer.
  - Once established, packets are sent over the connection, always arriving in order.
  - X.25 provides flow control, to make sure a fast sender cannot swamp a slow or busy receiver.

X.25 Networks (contd)

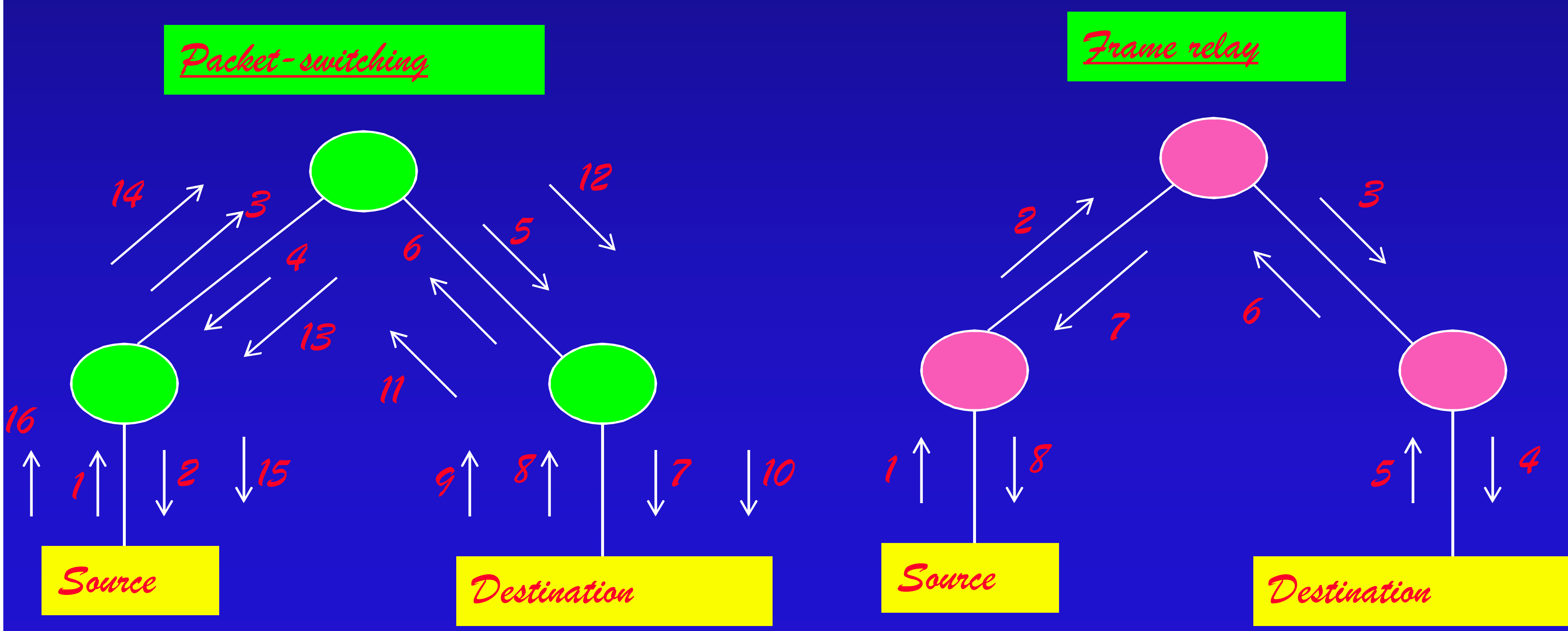
- A permanent virtual circuit
  - » is used the same way as a switched one, but it is set up in advance by agreement between the customer and the carrier.
  - » It is always present, and no call setup is required to use it. It is analogous to a leased line.
- If the user terminal does not speak X.25, then the terminal is connected to a ŕblack boxò called a PAD (Packet Assembler Disassembler) whose function is defined in the document X.3.
  - » The protocol X.28 is defined between terminal and PAD.
  - » The protocol X.29 is defined between PAD and the network.

Frame Relay

- Frame relay is designed to eliminate much of the overhead that X.25 imposes on end-user systems and on the packet-switching network.
- Frame relay can best be thought of as a virtual leased line on which data bursts may be sent at full speed, but the long-term average usage must be below a predetermined level. Therefore, the carrier charges much less for a virtual line than a physical one.
- Frame relay competes with leased lines and X.25 permanent virtual circuits, except that frame relay operates at higher speeds, usually 1.5 Mbps.

Frame Relay (contd)

- The principal disadvantage of frame relay, compared to X.25, is that we lost the ability to do link-by-link flow and error control.



Frame Relay (contd)

- Frame relay protocol architecture consists of two separate planes of operation:
  - » a control (C) plane, which deals with the establishment and termination of logical connections. C-plane protocols are between a subscriber and the network.
  - » a user (U) plane, which is responsible for the transfer of user data between subscribers. U-plane protocols provide end-to-end functionality.
- By streamlining functions, Frame Relay adjusts its bandwidth to handle bursty traffic.

ISDN, B-ISDN, and ATM

- Telephone companies are faced with a fundamental problem: maintaining multiple networks. Also, want to control cable television network
- The solution was to invent a single new network that will replace the entire telephone system and all the specialized networks.
- The new wide area service is first called ISDN (Integrated Services Digital Network) that has as its primary goal the integration of voice and nonvoice services.

ISDN, B-ISDN and ATM (contd)

- The ISDN bit pipe supports multiple channels interleaved by time division multiplexing. Several channel types have been standardized:
  - A: 4-kHz analog telephone channel
  - B: 64-kbps digital PCM channel for voice or data
  - C: 8-kbps or 16-kbps digital channel
  - D: 16-kbps digital channel for out-of-band signaling
  - E: 64-kbps digital channel for internal ISDN signaling
  - H: 384-kbps, 1536-kbps, or 1920-kbps digital channel
- Three combinations of channels:
  - Basic rate: 2B+1D
  - Primary rate: (1) 23B+1D (U.S. and Japan), (2) 30B+1D (Europe)
  - Hybrid: 1A+1C

ISDN, B-ISDN and ATM (contd)

- B-ISDN offers video on demand, live television from many sources, full motion multimedia electronic mail, CD-quality music, LAN interconnection, high-speed data transfer.
- The underlying technology that makes B-ISDN possible is called ATM (Asynchronous Transfer Mode) because it is not synchronous (i.e, not tied to a master clock).
- ATM is the standard technology for switching and multiplexing in B-ISDN. (Multiplexing determines how sources of data streams share a single communication channel (e.g., TDM, FDM, asynchronous TDM). Switching determines how message will be sent on the medium from source to destination (e.g., circuit switching, virtual circuit packet switching, packet switching, etc)).

ISDN, B-ISDN and ATM (contd)

- The basic idea behind ATM is to transmit all information in small, fixed-size packets called cells.
  - » Cells are 53 bytes long, of which 5 bytes are header and 48 bytes are payload.
- ATM networks are connection-oriented (I.e., a path is established before communication takes place).
  - » The actual service offered is connection oriented, but it is implemented internally with packet switching, not circuit switching.
  - » Two kinds of connections are offered: (i) permanent virtual circuits that remain in place for months and years, (ii) switched virtual circuits that are like telephone calls: they are set up dynamically as needed.

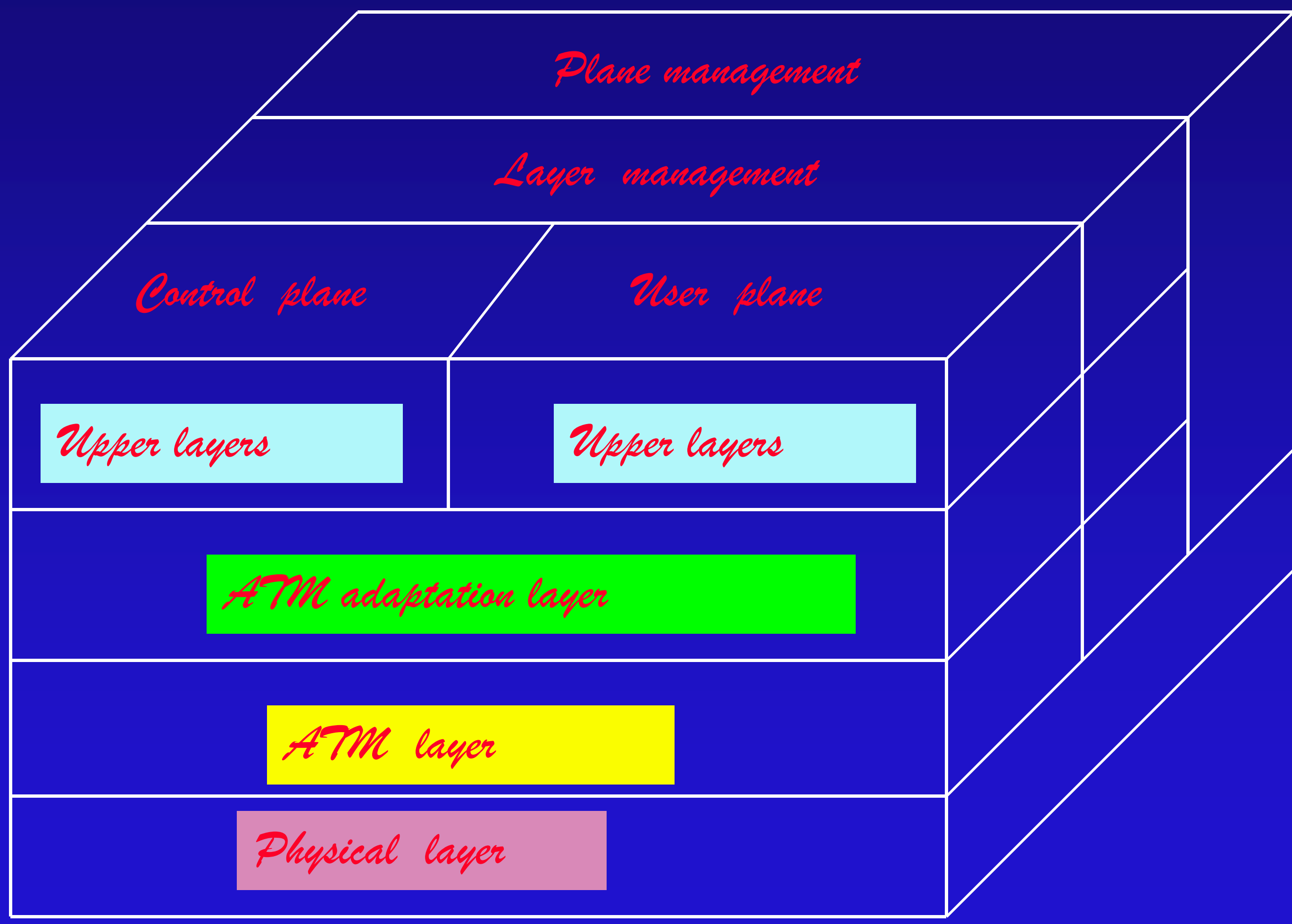
ISDN, B-ISDN and ATM (contd)

- ATM networks are organized like traditional WANs, with lines and switches (routers).
- The intended speeds for ATM networks are 155.52 Mbps and 622.08 Mbps to make them compatible with SONET that is the standard used on fiber optic links.
- ATM uses cell switching because
  - it is highly flexible can handle both constant rate traffic (audio, video) and variable rate traffic (data) easily,
  - at the very high speeds, digital switching of cells is easier than using traditional multiplexing techniques, especially using fiber optics
  - cell switching can provide broadcasting, circuit switching cannot.

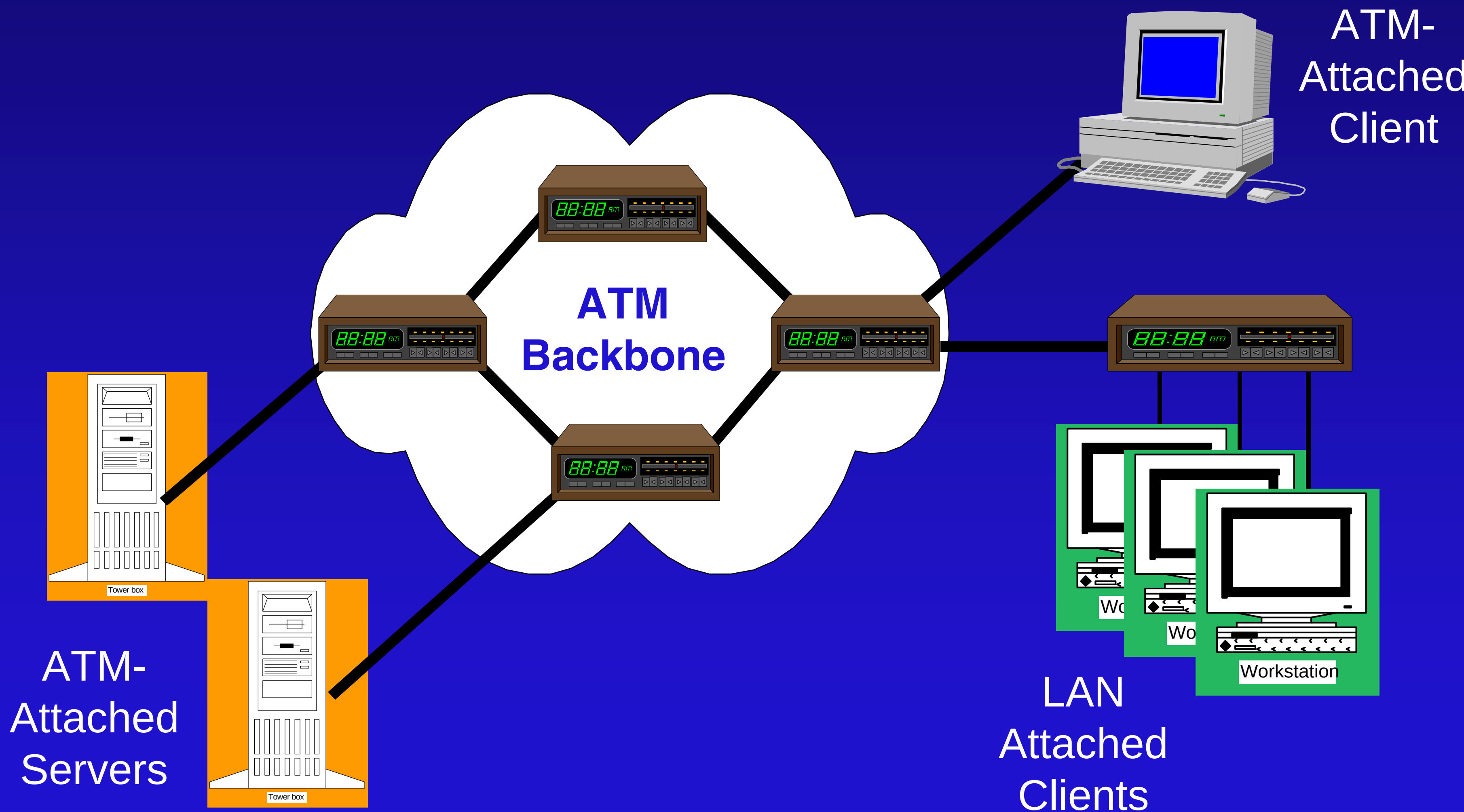
ISDN, B-ISDN and ATM (contd)

- B-ISDN using ATM has its own reference model, different from the OSI model and also different from the TCP/IP model. The model
  - » consists of three layers, the physical, ATM layer, ATM adaptation layers, plus whatever the users want to put on top of that.
  - » The physical layer deals with the physical medium: voltages, bit timing, etc.
  - » The ATM layer deals with cells and cell transport: defines the layout of cells, deals with establishment and release of virtual circuits, and congestion control.
  - » The AAL (ATM Adaptation Layer segments incoming packets from the upper layers, transmits the cells individually and reassembles them at the other end.
- ATM model is three-dimensional. The user plane deals with data transport, flow control, error correction, and other user functions. The control plane is concerned with connection management. The layer management and plane management functions relate to resource management and interlayer coordination.

...he B-ISDN ATM Reference Model



ATM Backbone



Internet

- Is a large collection of interconnected networks, all of which use TCP/IP protocol suite
- began with the development of ARPANET in 1969

  (ARPA: Advanced Research Project Agency)
- ARPANET protocols were not suitable for running over multiple networks. This led to the invention of the TCP/IP model and protocols by Cerf and Kahn in 1974.
- TCP/IP became the only official protocol on Jan. 1, 1983. The glue that holds the Internet together is the TCP/IP protocol stack.

Internet (contd)

- A machine is on the Internet if it runs the TCP/IP protocol stack, has an IP address, and can send IP packets to any machine on the Internet.
- Until the early 1990s, Internet users were academic, industrial, and government researchers. But, WWW (World Wide Web) brought millions of nonacademic users.
- WWW made the underlying facilities of the Internet easier to use.

Enough!