

LAN 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 %from the fact→): those standards that have just happened, without any formal plan (e.g., IBM PC, Unix)
 - » **De jure** (Latin for %by law→): 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 specifications on its web site: www.atmforum.com)

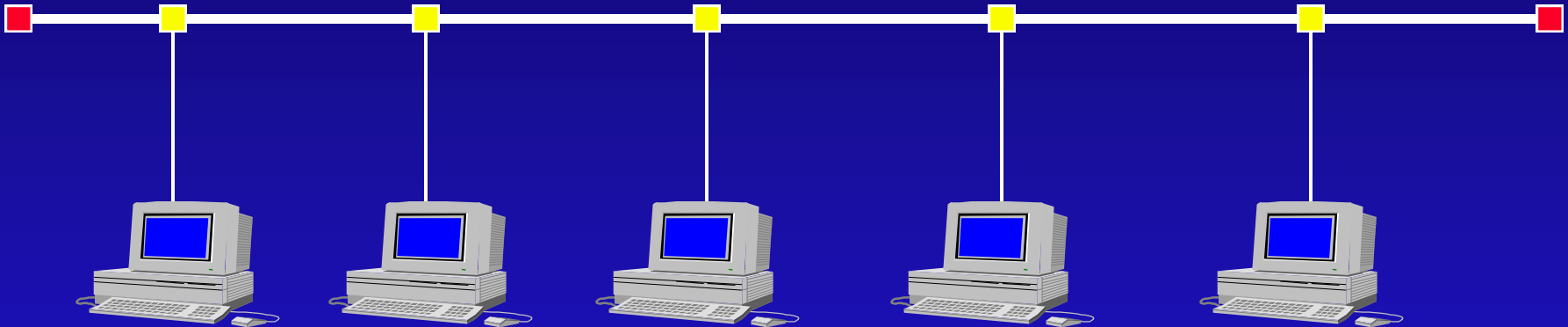
Terminology

- 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:

MAC (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
 - . FDMA (Frequency Division Multiple Access)
 - . 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, ð .

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
 - . S: (successful load) / (capacity of channel)
 - » G: The total rate of data presented to network (offered load)
 - $G = S + (\text{number of retransmitted packets per unit time})$
- 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).

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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 ``left`` and ``right``.
- 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 $P(s) \leq P(f)$.
 - » 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.

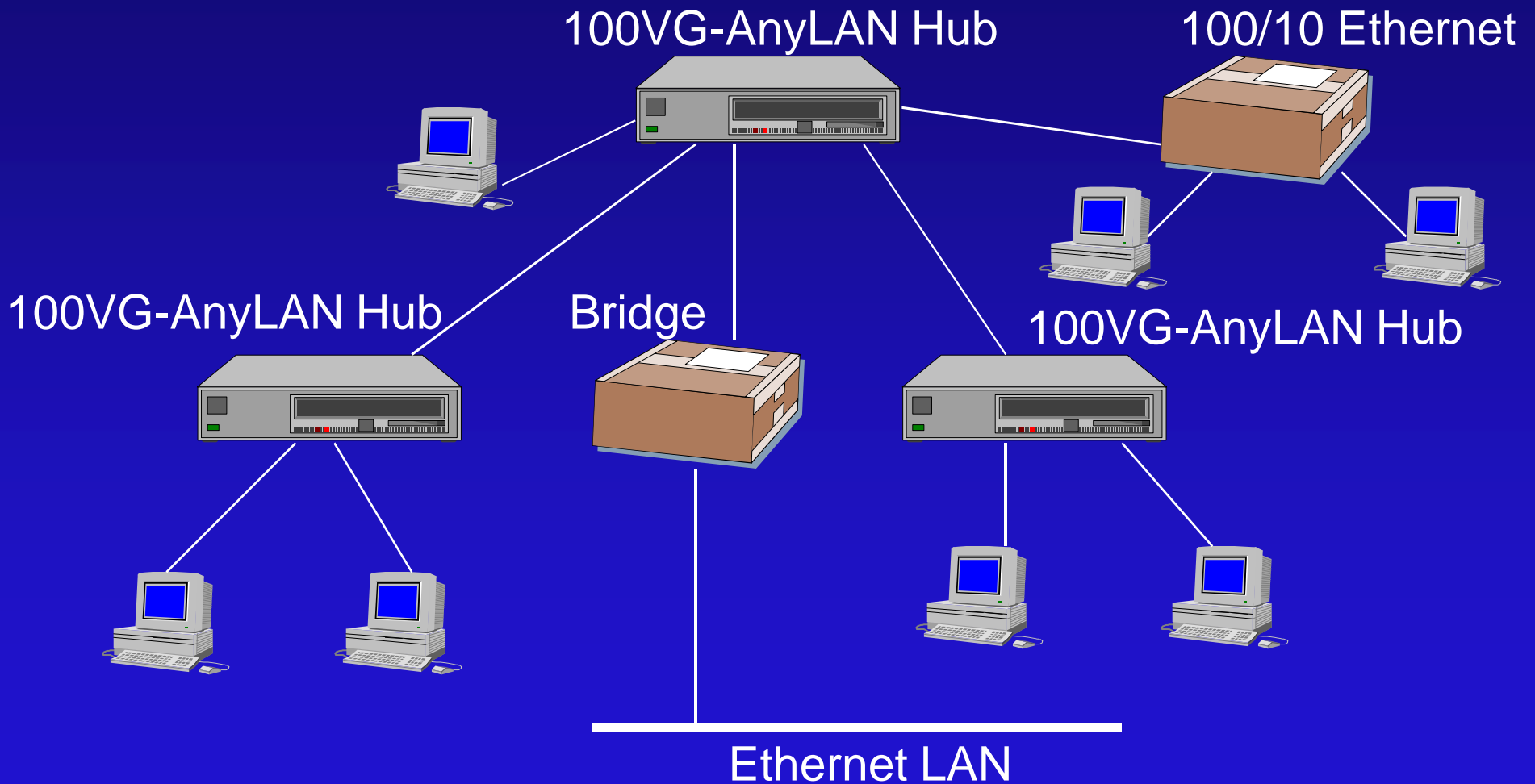
100 vG-AnyLAN (contd.)

- **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**:
 - . Visit the root
 - . 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

Example 100VG-AnyLAN Configuration



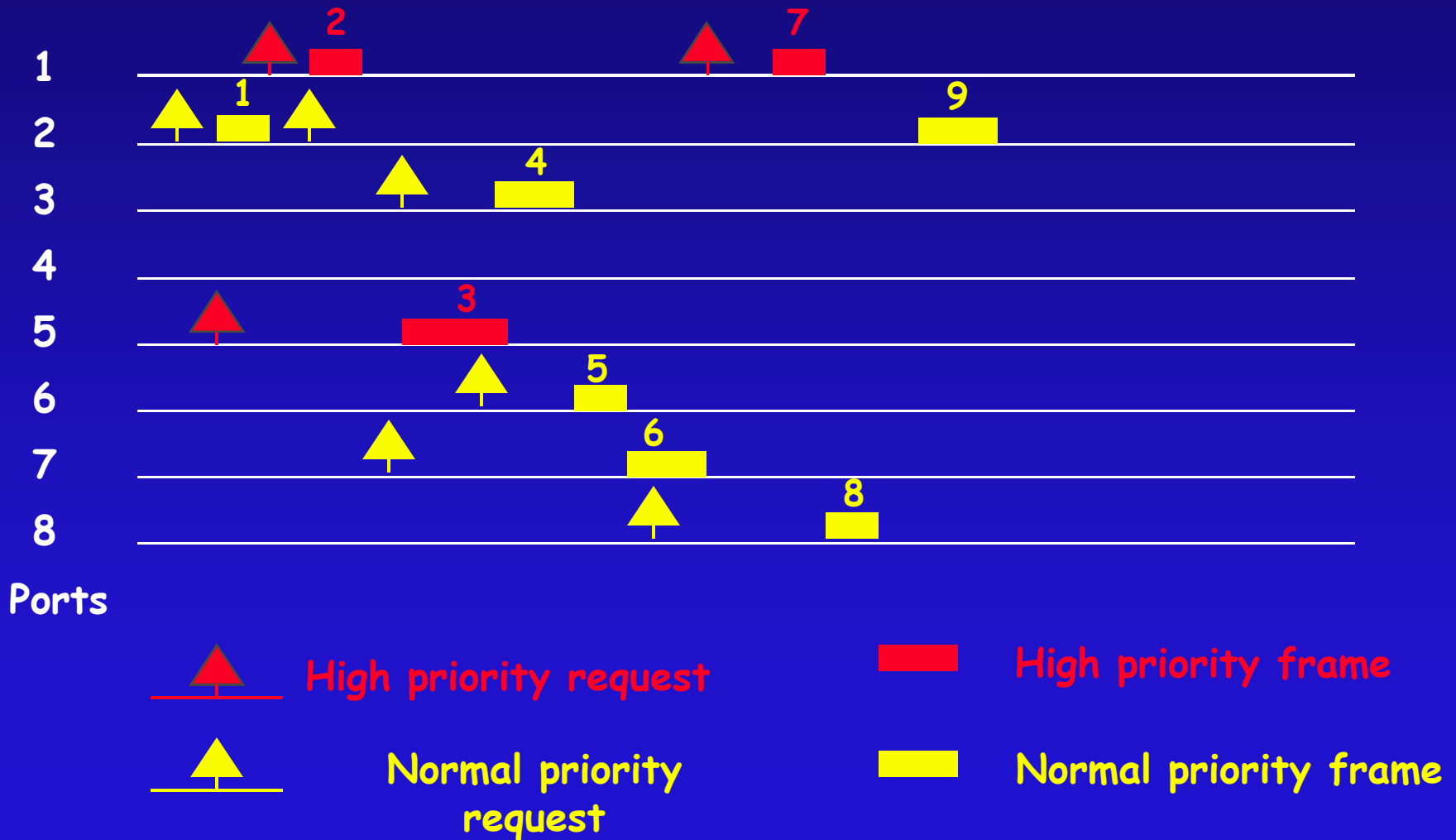
100VG-AnyLAN (Single hub network)

- 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**

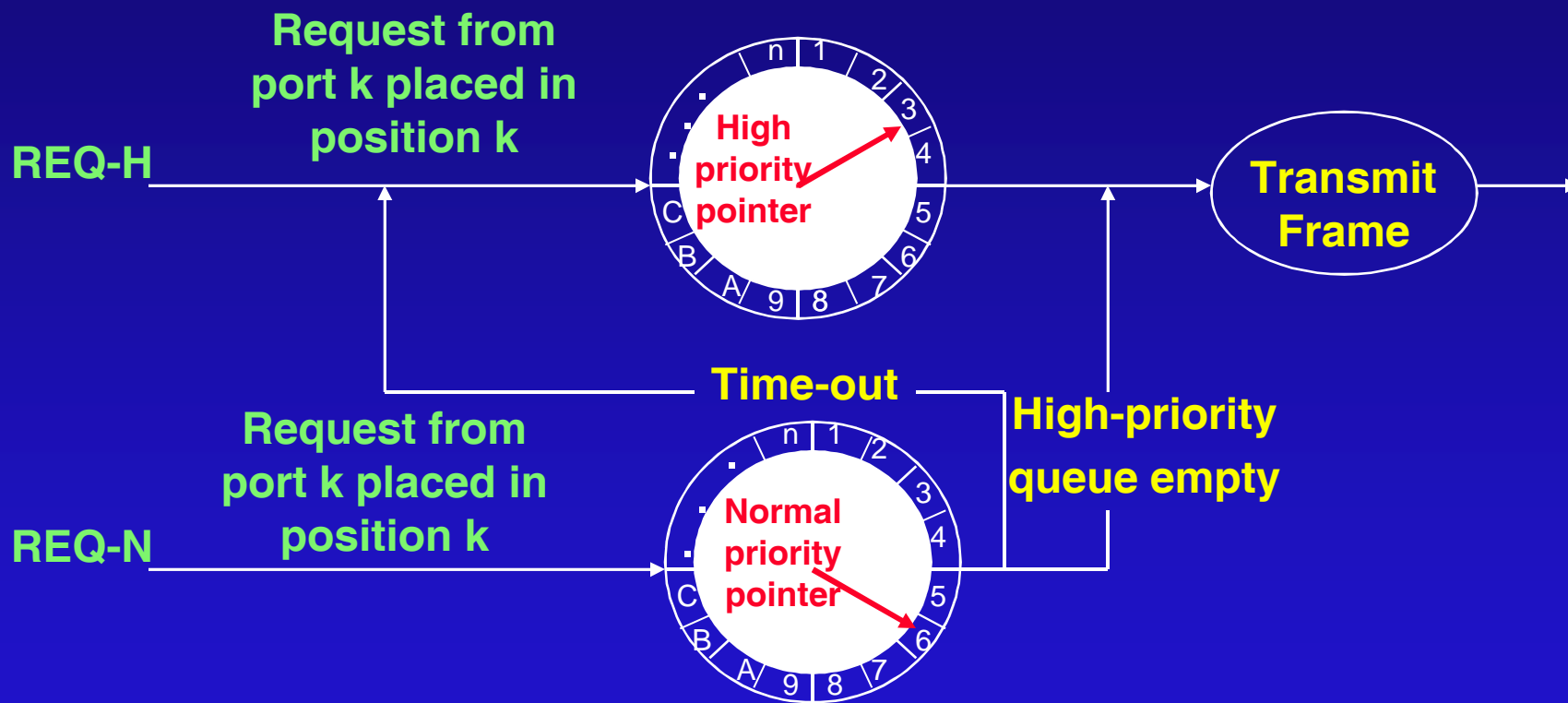
Single hub LAN (contd.)

- » The central hub continually scans all of its ports for request in round-robin fashion
- » The hub maintains two pointers
 - . a high priority pointer and
 - . 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

Frame Sequence in a Single-Repeater Network



100VG-AnyLAN Priority Scheme

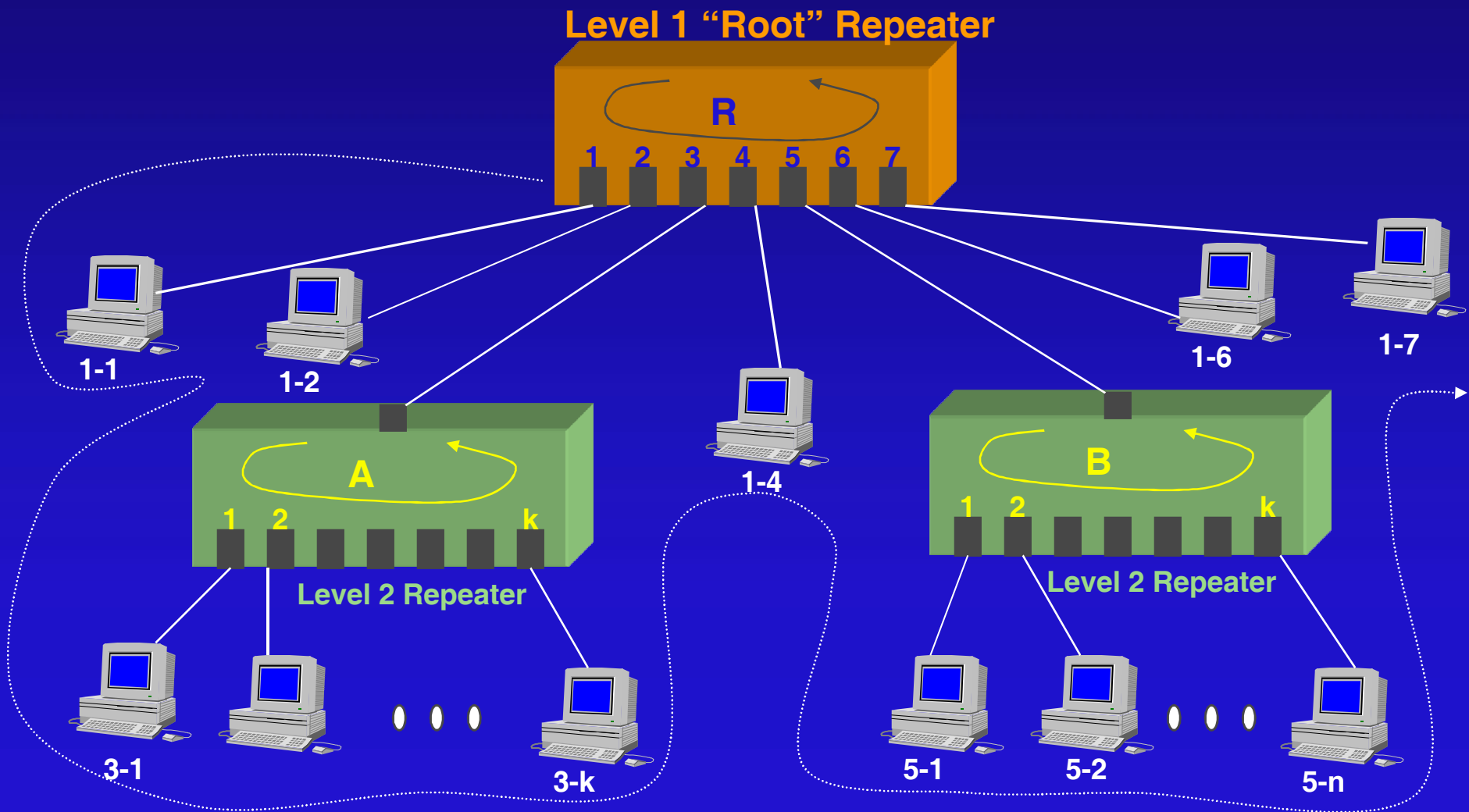


If a request remains in the normal priority buffer for too long (default=500 ms), it is moved to the corresponding position in the high-priority buffer.

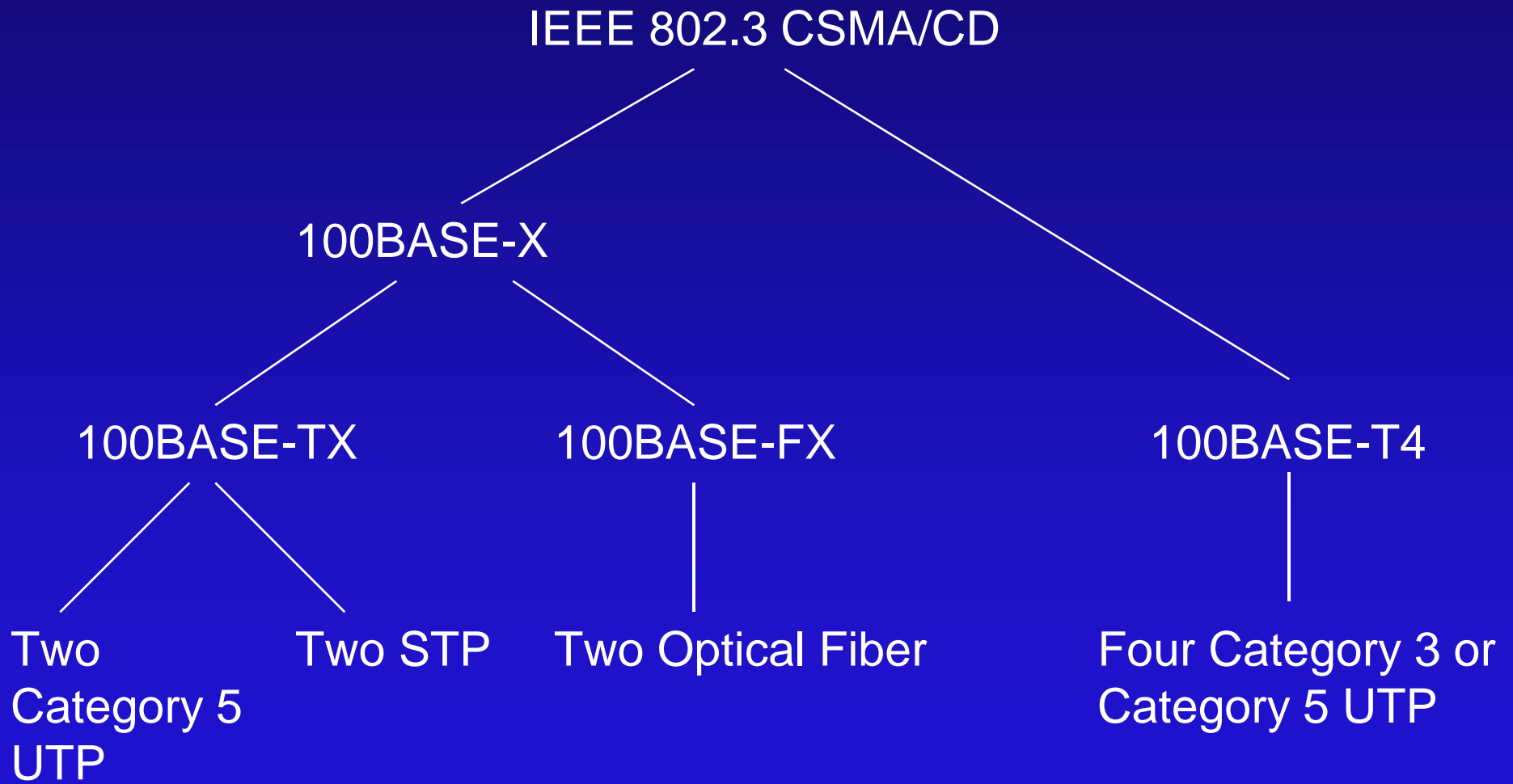
Hierarchical LAN

- 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)
 - . Visit the root
 - . traverse the subtrees from left to right
 - » Each hub is running its own round-robin algorithm to service end-systems directly attached to it.

Routing in a Two-Level IEEE 802.12 Network



IEEE 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 1s
 - » 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

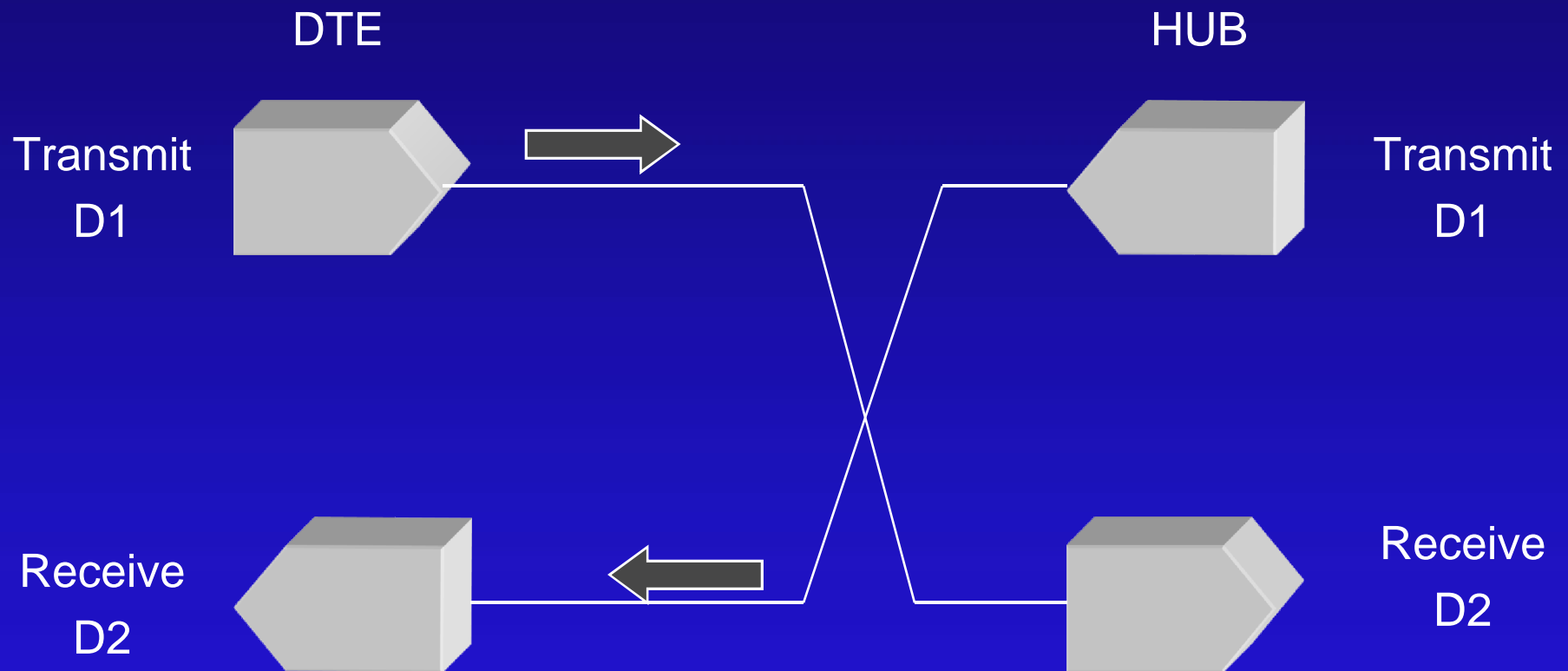
- Effect of MLT-3 is to concentrate most of the energy in the transmitted signal below 30 MHz, which reduces radiated emission
- MLT-3 encoding
 - . produces a transition for every $\pm q$
 - . uses three levels (+V, 0, -V)

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

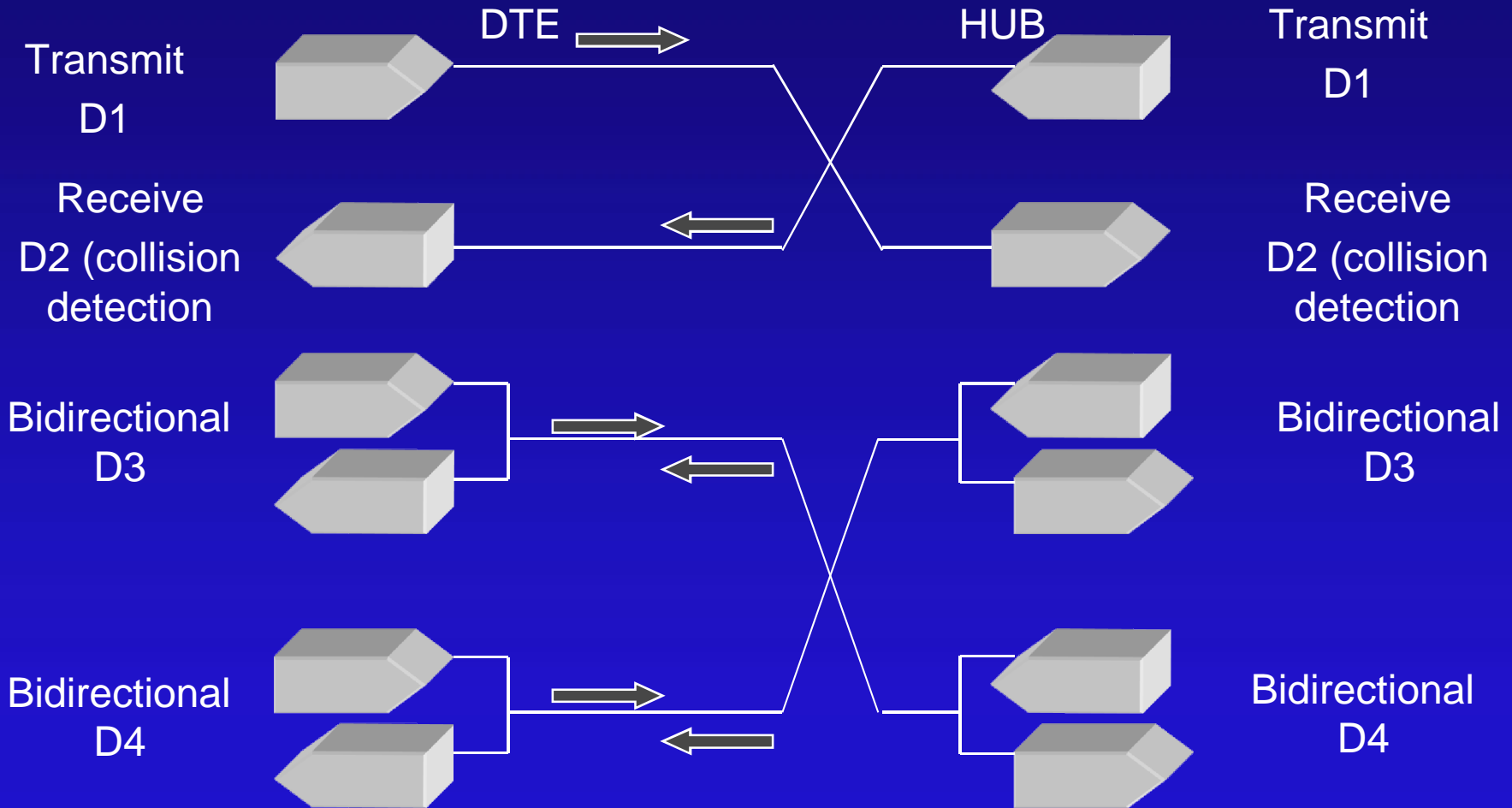


100BASE-X Configuration

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
 - . data transmitted using pairs labeled D1, D3, and D4
 - . data received on pairs D2, D3, and D4.
 - . D3 and D4 are bi-directional and D2 is used for reception as well as for collision detection

100BASE-T4 Use of Wire Pairs



100BASE-T4 Configuration

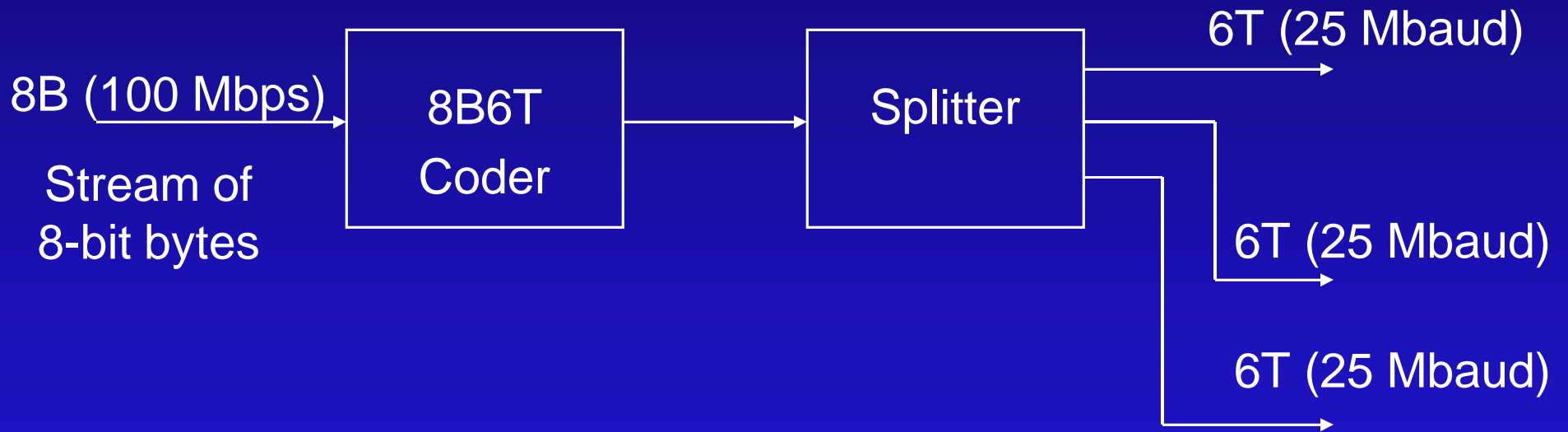
100Base-T4 (contd.)

- 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 $(6/8) \times 33.333 = 25$ Mbaud

Transmission 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	+ - 0 0 + -	10	+ 0 + - - 0	20	0 0 - + + -	30	+ - 0 0 - +
01	0 + - + - 0	11	+ + 0 - 0 -	21	- - + 0 0 +	31	0 + - - + 0
02	+ - 0 + - 0	12	+ 0 0 - 0 -	22	+ + - 0 + -	32	+ - 0 - + 0
03	- 0 + + - 0	13	0 + + - 0 -	23	+ + - 0 - +	33	- 0 + - + 0
04	- 0 + 0 + -	14	0 + + - - 0	24	0 0 + 0 - +	34	- 0 + 0 - +
05	0 + - - 0 +	15	+ + 0 0 - -	25	0 0 + 0 + -	35	0 + - + 0 -
06	+ - 0 - 0 +	16	+ 0 + 0 - -	26	0 0 - 0 0 +	36	+ - 0 + 0 -
07	- 0 + - 0 +	17	0 + + 0 - -	27	- - + + + -	37	- 0 + + 0 -
08	- - + 0 0 + -	18	0 + - 0 + -	28	- 0 - + + 0	38	- - + 0 0 +
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 + - 0 0 +	2B	0 - - + 0 +	3B	+ 0 - - + 0
0C	+ 0 - 0 + -	1C	0 - + 0 0 +	2C	0 - - + + 0	3C	+ 0 - 0 - +
0D	0 - + - 0 +	1D	0 - + + + -	2D	- - 0 0 + +	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 -

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.)

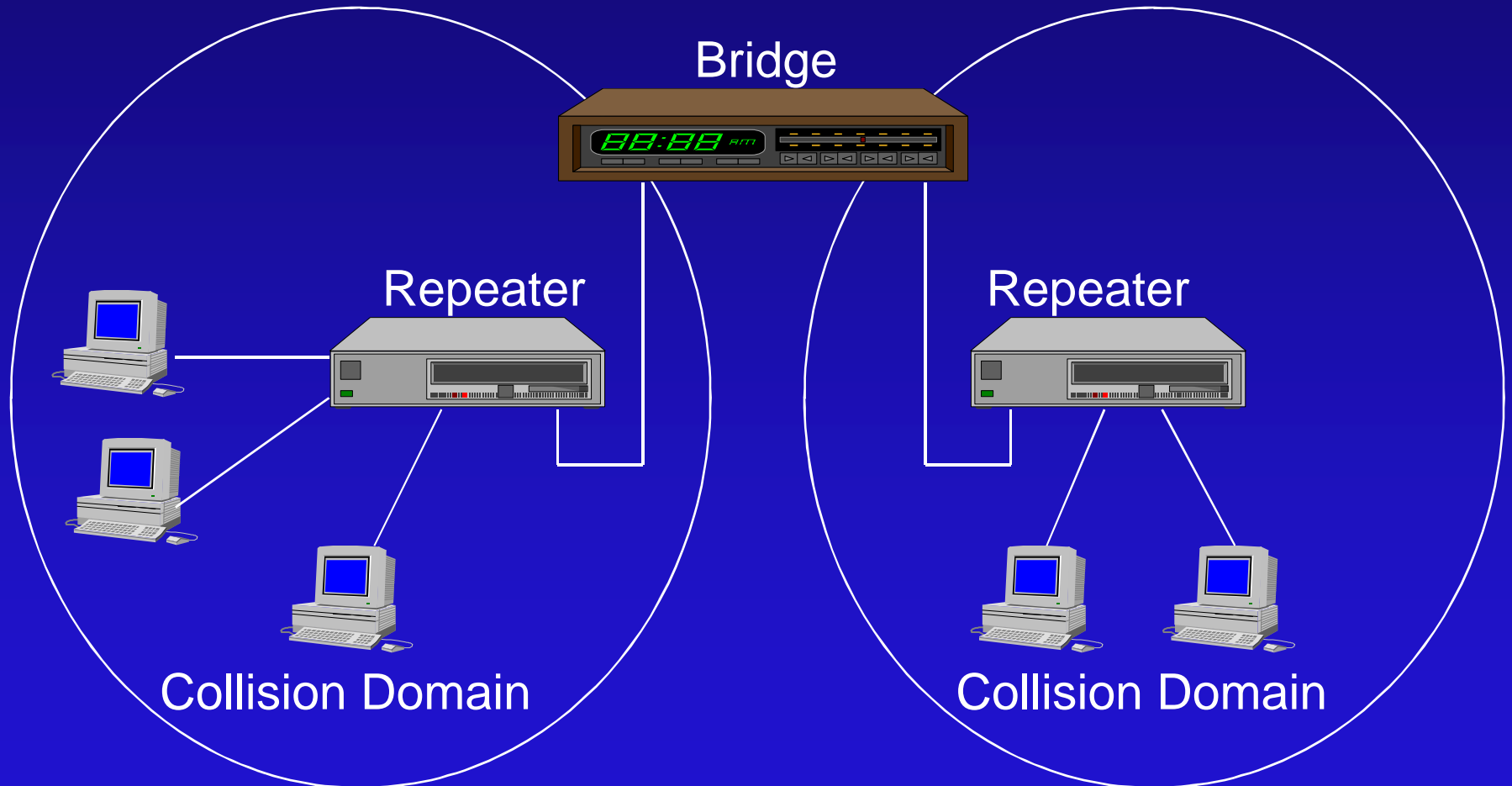
- The 100BASE-T standard defines two types of repeaters
 - » Class I repeater:
 - . can support unlike physical media segments, e.g. 100BASE-T4 and 100BASE-TX
 - . increased delay because of signal conversion
 - . Only a single Class I repeater is allowed per collision domain

100BASE-T Repeater (contd.)

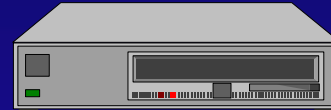
» Class II Repeater:

- . Limited to a single type of physical media
- . Two Class II repeaters may be used in a single collision domain

Collision Domains



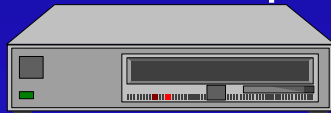
100BASE-T Repeater Types



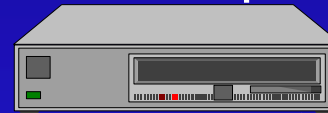
Class I Repeater



Class II Repeater



Class II Repeater



Maximum 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

Wavelength 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.



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