High-Speed LANs Part II

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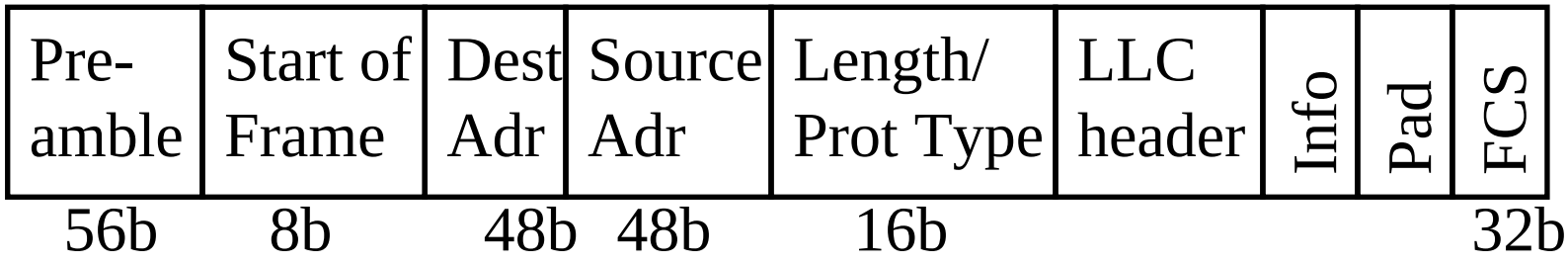
These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse473-05/

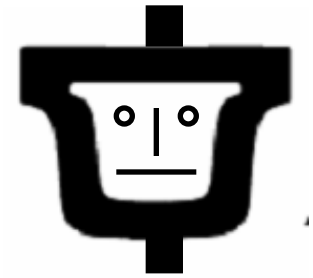
- Ethernet Frame Format
- Gigabit Ethernet
- 10G Ethernet
- Token Ring
- New Coding Schemes: 4b/5b-NRZI (FDDI), MLT-3 (100BASE-TX), 8b6t (100BASE-T4), 8b10b (Token Ring)

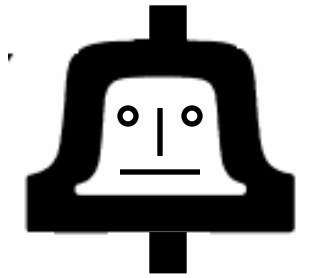
IEEE 802.3 Frame Format



- Preamble: 7 bytes of 0101 0101
- Start of Frame: 1010 1011
- LLC Header: Indicates higher layer
- Protocol Type: 2048 or higher
  Length: 64 through 2047
- Padding: Min frame size 64 bytes (DA thru FCS)
  Maximum Frame size = 1518 bytes
- No End of Frame delimiter

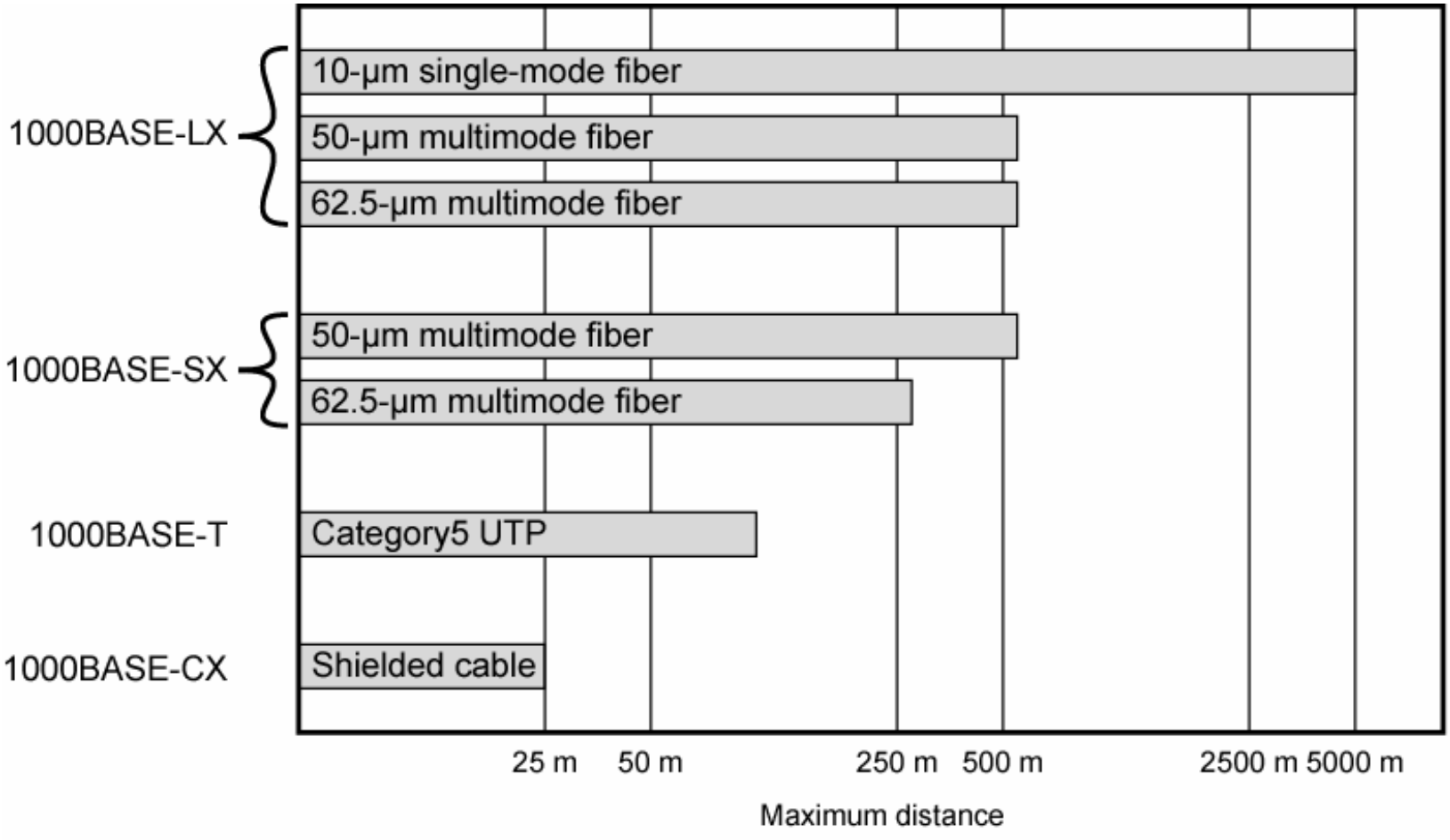
Ethernet: 1G vs 10G Designs



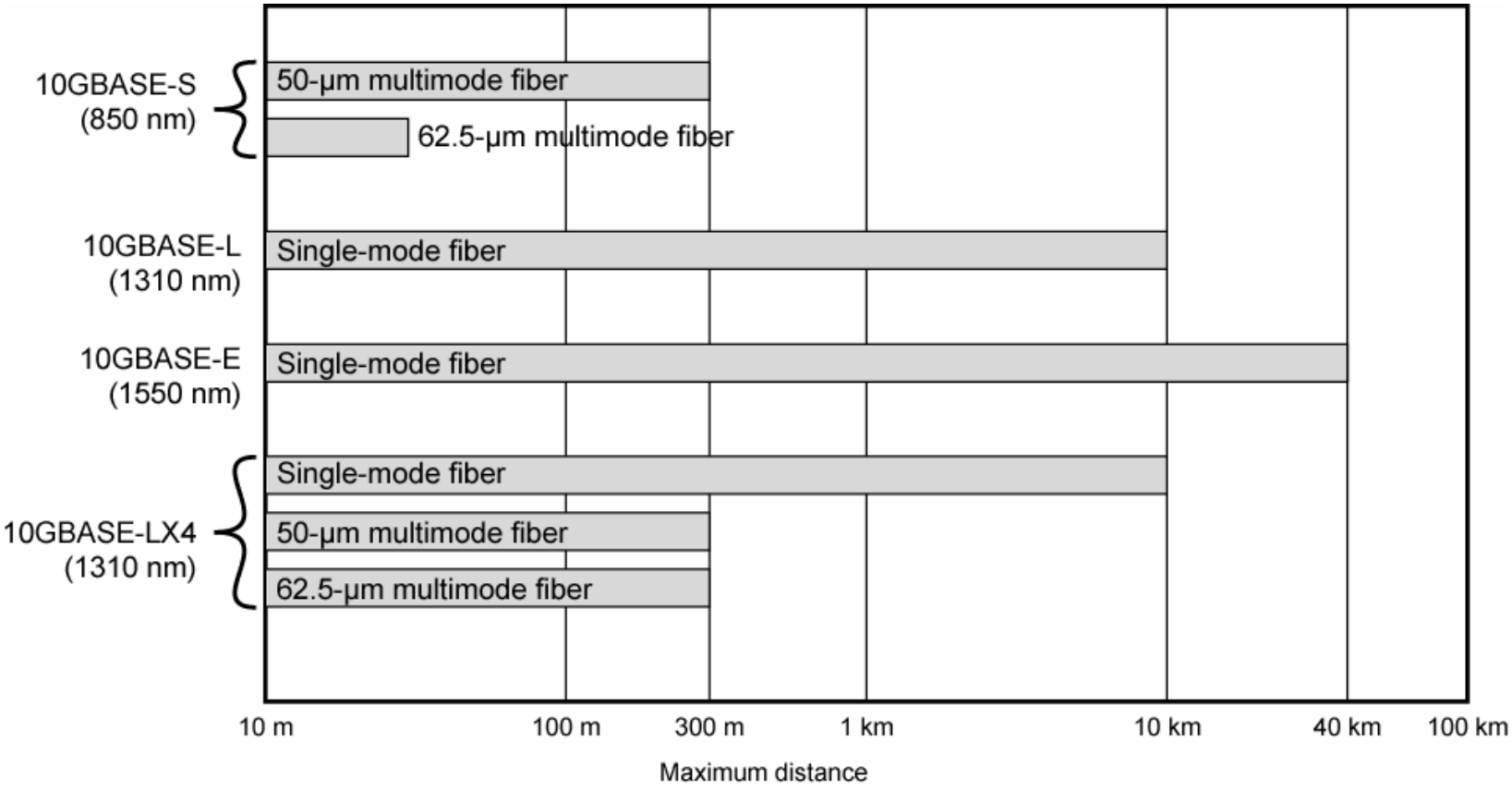


1G Ethernet	10G Ethernet
q 1000 / ~~800~~ / ~~622~~ Mbps **Single** data rate	❑ 10.0/9.5 Gbps **Both** rates.
q **LAN** distances only	❑ LAN and **MAN** distances
q No Full-duplex only ⇒ **Shared** Mode	❑ Full-duplex only ⇒ **No Shared** Mode
q Changes to **CSMA/CD**	❑ **No CSMA/CD** protocol ⇒ No distance limit due to MAC ⇒ *Ethernet* End-to-End

Gigabit Ethernet PHYs



10Gbps Ethernet PHYs



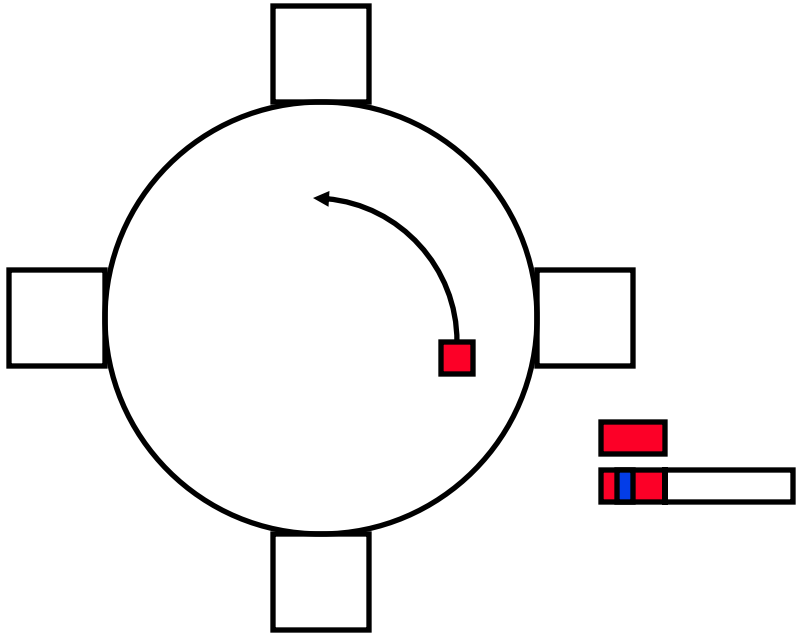
10 GbE PMD Types

PMD	Description	MMF	SMF
10GBASE-R:			
10GBASE-SR	850nm Serial LAN	300 m	N/A
10GBASE-LR	1310nm Serial LAN	N/A	10 km
10GBASE-ER	1550nm Serial LAN	N/A	40 km
10GBASE-X:			
10GBASE-LX4	1310nm WWDM LAN	300 m	10 km
10GBASE-W:			
10GBASE-SW	850nm Serial WAN	300 m	N/A
10GBASE-LW	1310nm Serial WAN	N/A	10 km
10GBASE-EW	1550nm Serial WAN	N/A	40 km
10GBASE-LW4	1310nm WWDM WAN	300 m	10 km

- S = Short Wave, L=Long Wave, E=Extra Long Wave
- R = Regular reach (64b/66b), W=WAN (64b/66b + SONET Encapsulation), X = 8b/10b
  - 4 = 4 λ's

Token Ring (IEEE 802.5)

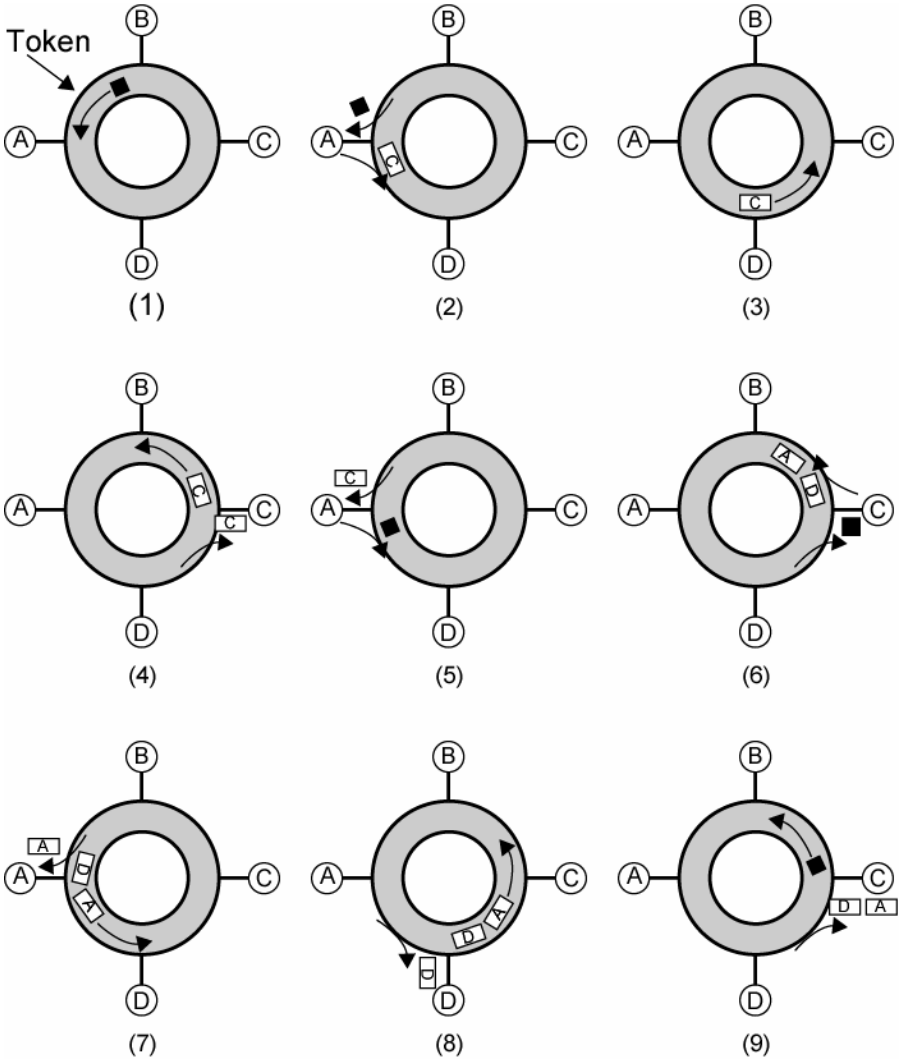
- Developed from IBM's commercial token ring
- Each repeater connects to two others via unidirectional transmission links. Single closed path
- Data transferred bit by bit from one repeater to the next
- Packet removed by transmitter after one trip around the ring



802.5 MAC Protocol

- Small frame (token) circulates when idle
- Station waits for token
- Changes one bit in token to make it Start of Frame (SOF)
  Append rest of data frame
- Frame makes round trip and then removed by transmitting station
- Station then inserts new token when transmission has finished and leading edge of returning frame arrives
- Delayed token release vs Immediate token release
  Under light loads, some inefficiency
- At 100 Mbps and up, only point-to-point operation using switches $\Rightarrow$ No tokens = Switched Mode = Dedicated Token Ring (DTR)

Token Ring Operation

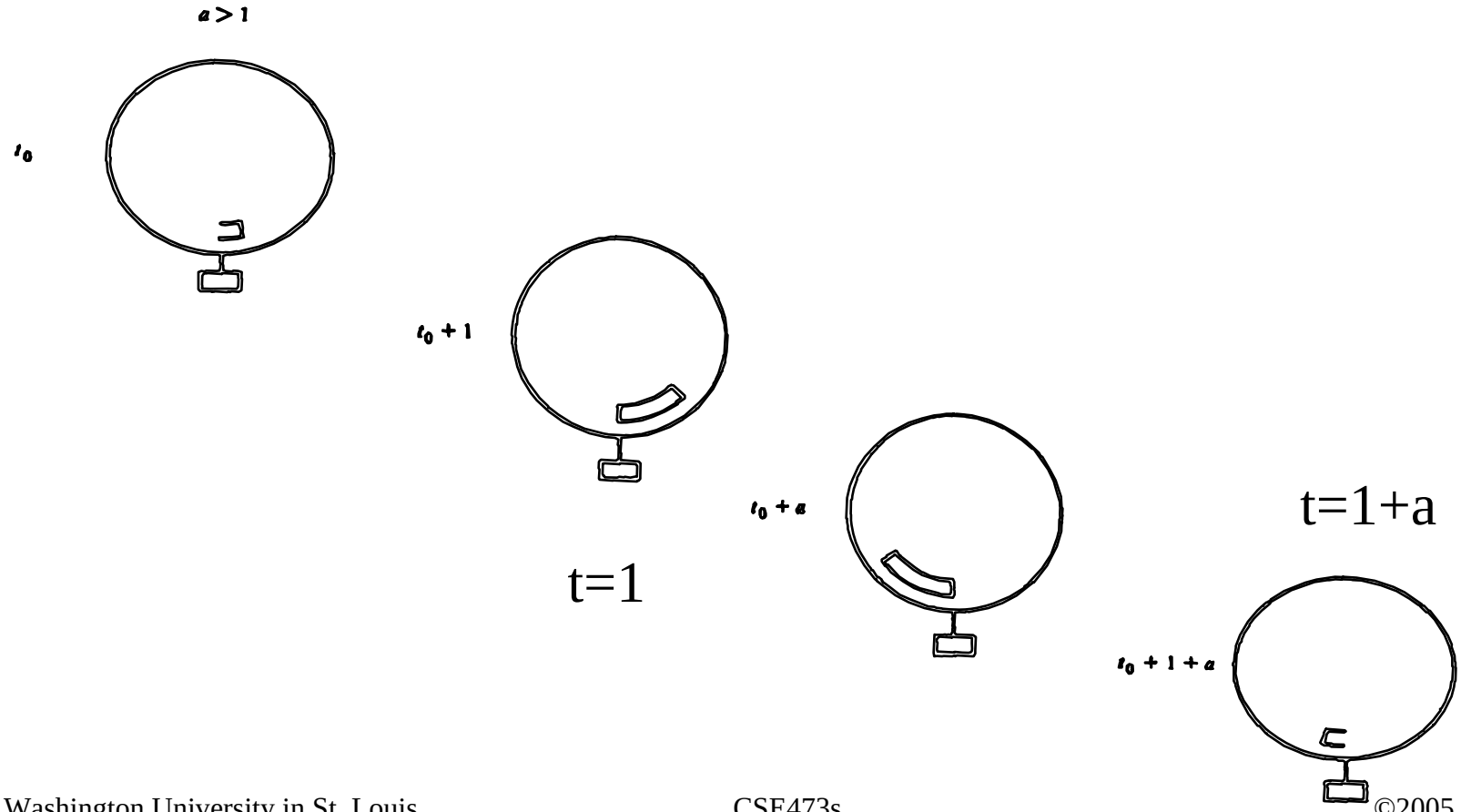


IEEE 802.5 PHYs

Data Rate	4 Mbps	16 Mbps	100 Mbps	100 Mbps	1 Gbps
Trans. Medium	UTP, STP, Fiber	UTP, STP, Fiber	UTP or STP	Fiber	Fiber
Signaling	Diff. Manches.	Diff. Manches.	MLT-3	4b5b-NRZI	8b/10b
Max Frame	4550 B	18,200 B	18,200 B	18,200 B	18,200 B
Access Control	TP or DTR	TP or DTR	DTR	DTR	DTR

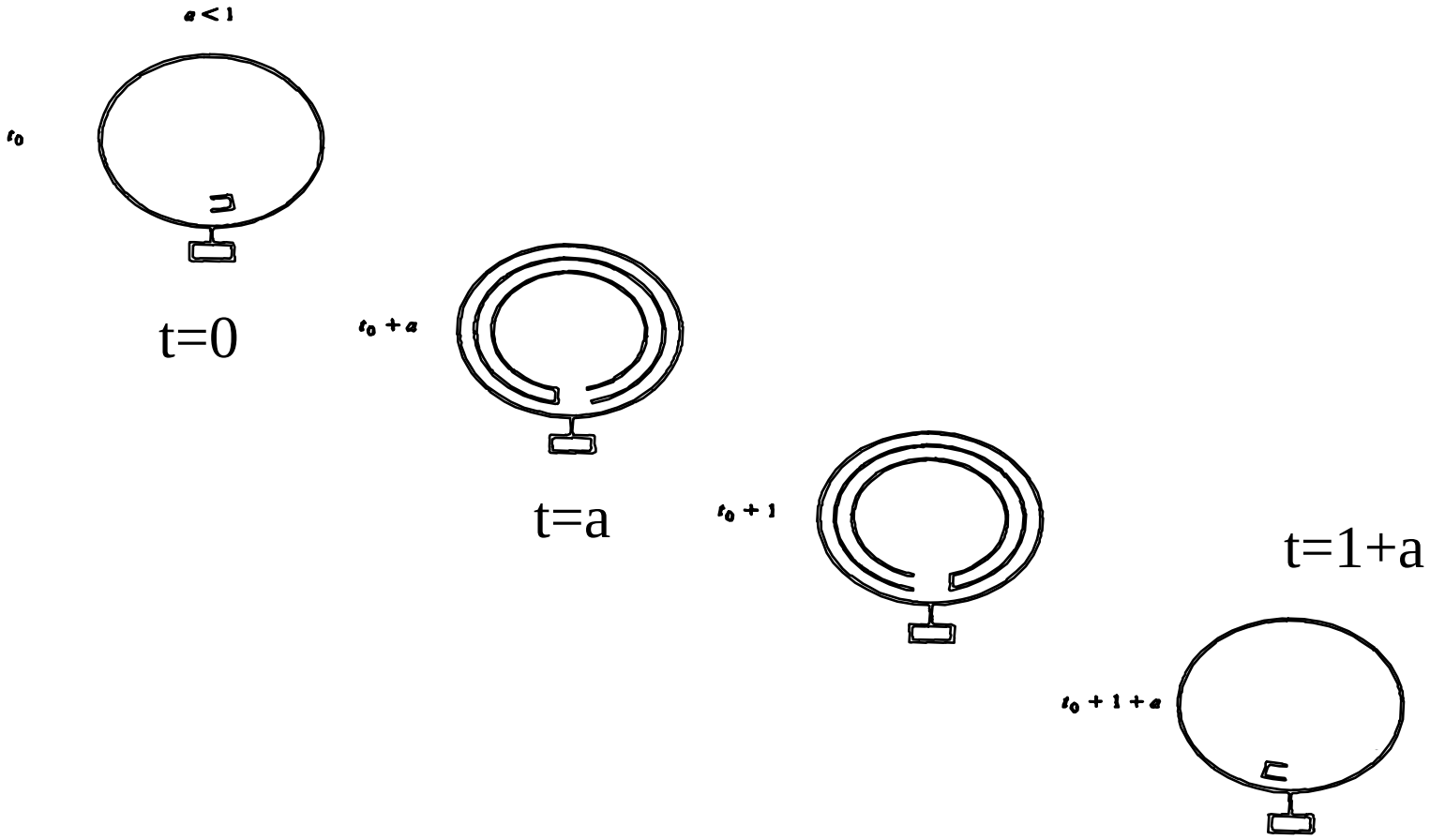
Token Ring Performance

- a>1, token is released at t_0+a, reaches next station at t_0+a+a/N, U=1/(a+a/N)

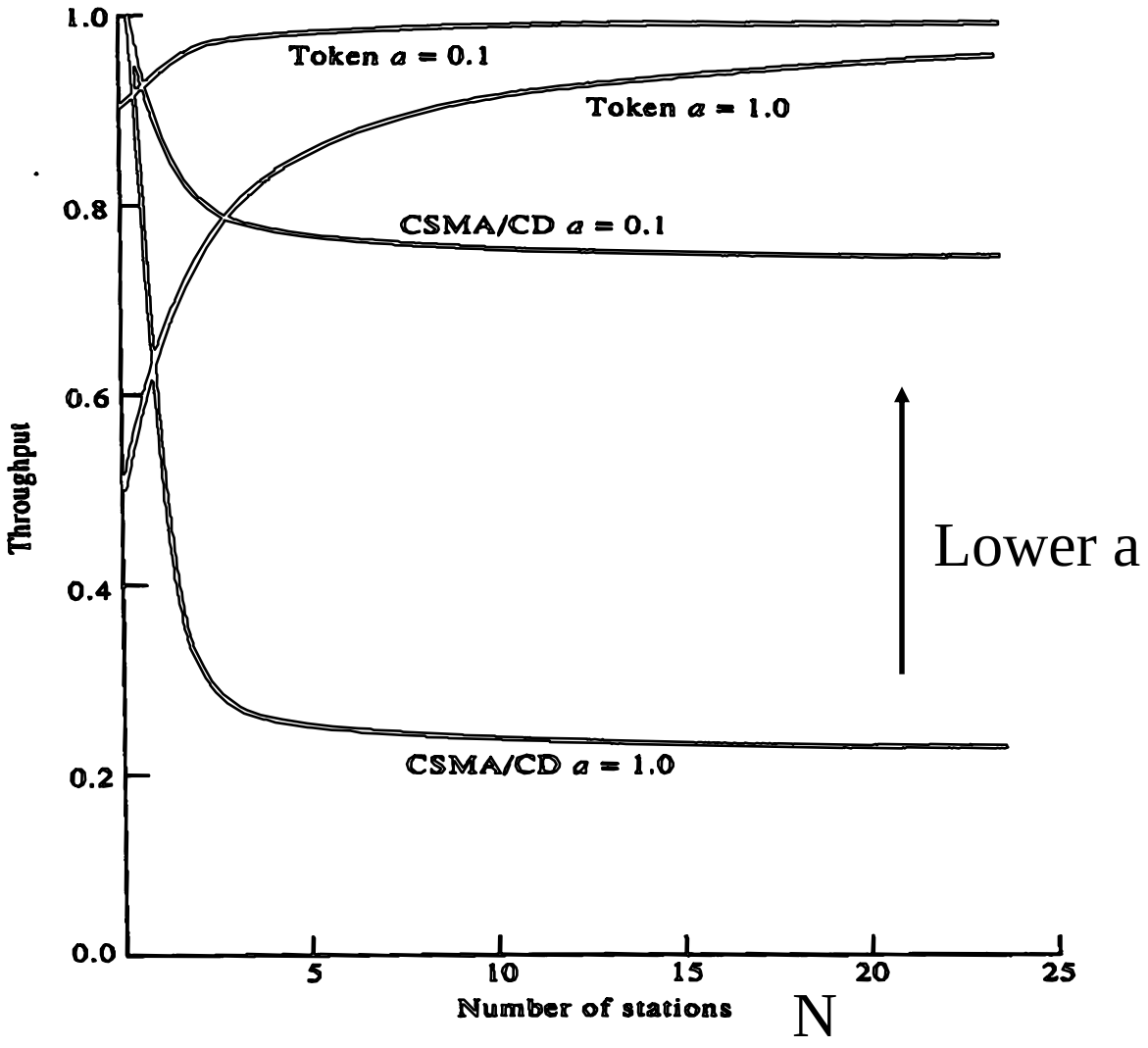


Performance (Continued)

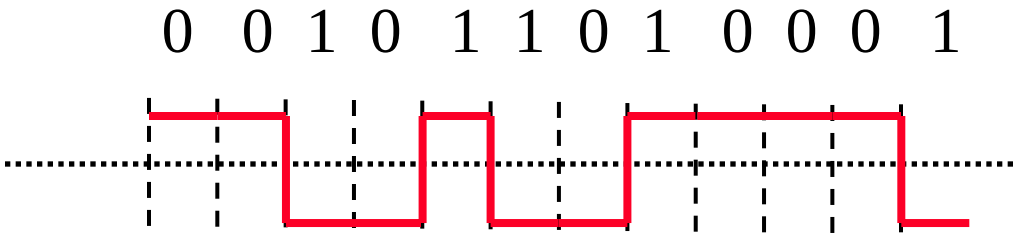
- a<1, Token is released at t_0+1, U=1/(1+a/N)



Performance (continued)



4b/5b-NRZI

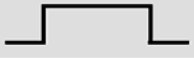
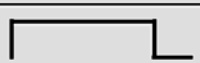
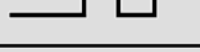


- NRZI:
  - + Differential ⇒ Polarity mix up is not an issue
  - – No transitions for a string of all zeros
  - – No line state or control symbols
  - – No error detection
- Manchester encoding used in 10 Mbps Ethernet results in 200 MBaud at 100 Mbps
- 4b/5b is used to fix the deficiencies of NRZI

4b/5b Coding

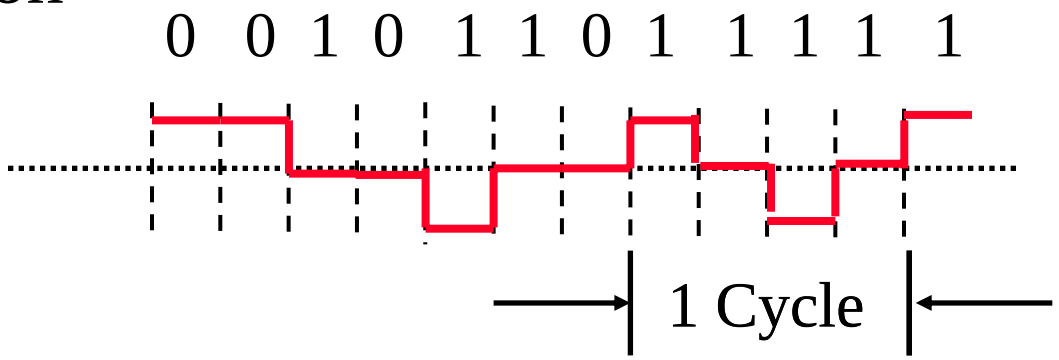
- **4b/5b**: 5 bits are transmitted for every 4 bits of data
  - 16 of 32 possible combinations are used for data
  - The data symbols have zero dc balance and good transition density (No more 3 zeros in a row)
  - Six of the remaining combinations are used for control:
    - Idle: 11111
    - Start of Stream: 11000-10001
    - End of Stream: 01101-00111
    - Transmit error: 00100
  - 10 Symbols with poor transition density or DC imbalance are not used
- Selected for 100 Mbps Fiber optic LAN:
  Fiber Distributed Data Interface (FDDI), 100BASE-FX
- 100 Mbps data rate $\Rightarrow$ 125 MBaud signal

4b/5b Coding (Cont)

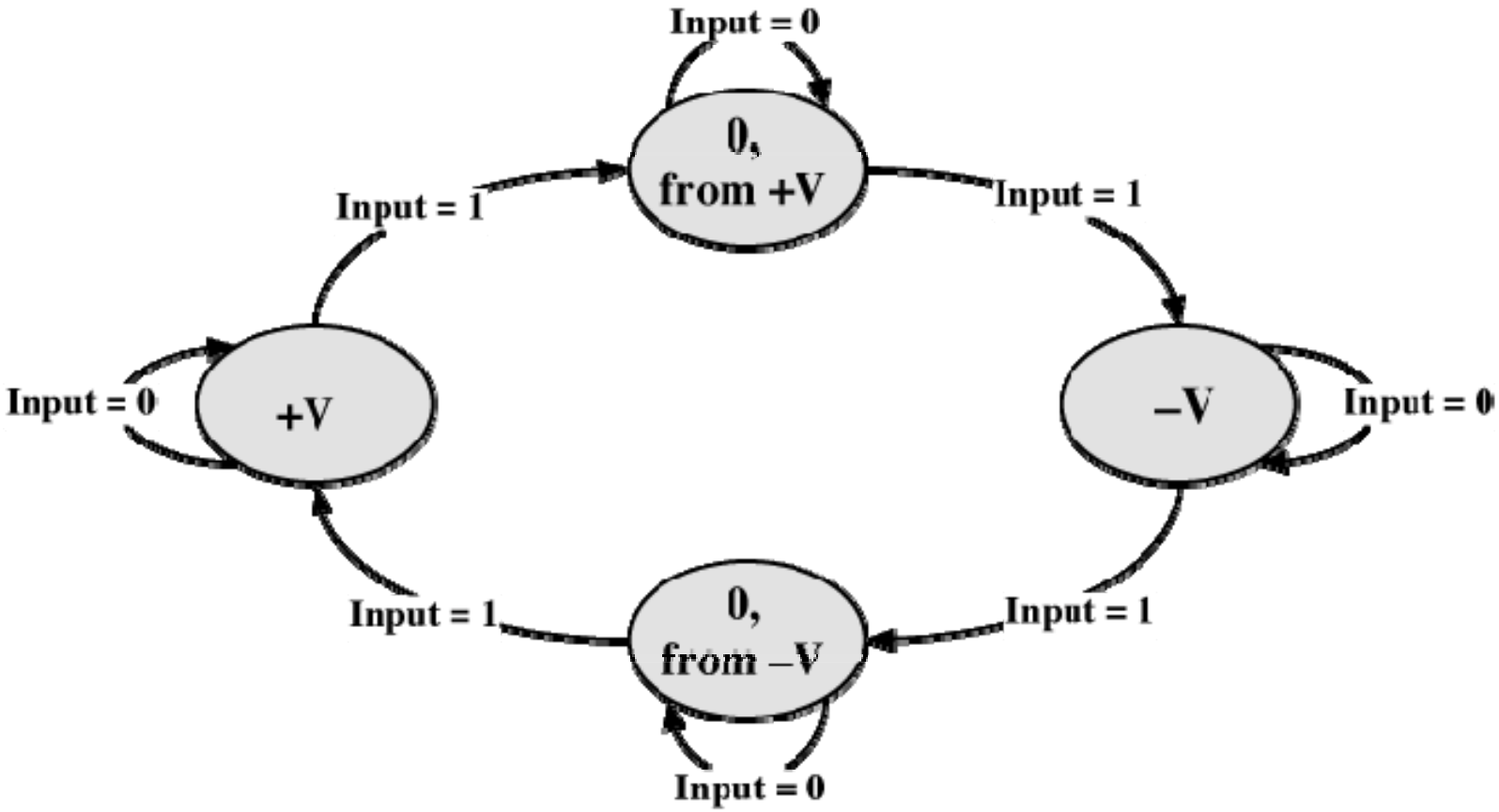
Data Input (4 bits)	Code Group (5 bits)	NRZI pattern	Interpretation
0000	11110		Data 0
0001	01001		Data 1
0010	10100		Data 2
0011	10101		Data 3
0100	01010		Data 4
0101	01011		Data 5
0110	01110		Data 6
0111	01111		Data 7
1000	10010		Data 8
1001	10011		Data 9
1010	10110		Data A
1011	10111		Data B
1100	11010		Data C
1101	11011		Data D
1110	11100		Data E
1111	11101		Data F
	11111		Idle
	11000		Start of stream delimiter, part 1
	10001		Start of stream delimiter, part 2
	01101		End of stream delimiter, part 1
	00111		End of stream delimiter, part 2
	00100		Transmit error
	other		invalid codes

MLT-3

- 4b/5b-NRZI produces 62.5 MHz signal (when the line is idle) Too high for UTP
- MLT-3: Replace NRZI with a 3-level coding similar to AMI
  - Zero ⇒ No transition
  - One ⇒ Transition to next level in the same direction



MLT-3 State Transition Diagram



- Maximum Frequency is 31.25 MHz

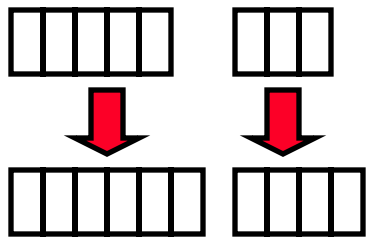
8b6t

- Ternary symbols = 3 levels + - 0
- 8b are coded as 6 ternary-symbols
- 6 Ternary symbols = 3^6 = 729 possible combinations
  256 combinations are used for data
- In 100BASE-T4, three wire pairs are used
  Two symbols are transmitted on each pair
- Baud Rate = 100 Mbps ÷ 8 bits × 6 Baud ÷ 3
  = 25 MBaud per pair

8b6t Code Table (Partial)

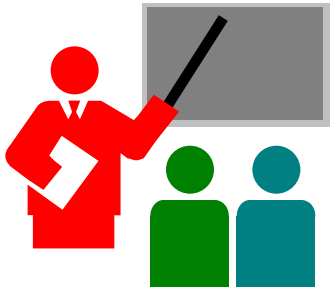
Data octet	6T code group	Data octet	6T code group	Data octet	6T code group	Data octet	6T code group
00	+−00+−	10	+0+−−0	20	00−++−	30	+−00−+
01	0+−+−0	11	++0−0−	21	−−+00+	31	0+−−+0
02	+−0+−0	12	+0+−0−	22	++−0+−	32	+−0−+0
03	−0++−0	13	0++−0−	23	++−0−+	33	−0+−+0
04	−0+0+−	14	0++−−0	24	00+0−+	34	−0+0−+
05	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−

8b/10b



- Used in Fiber Channel (100 MB/s interconnect used in storage) and in Gigabit Ethernet
- 8 data bits are coded as 10 signaling bits
  - First 5 data bits are coded as 6 signaling bits
  - Last 3 data bits are coded as 4 signaling bits
- **Disparity Control**:
  - Too many ones or too many zeros = Disparity
  - If the next block will increase the disparity, the signaling bits are complemented
    10101 00101 10101 01101 01010 10010
    No Disparity Disparity

Summary



- Gigabit Ethernet standard allows shared mode but
- 10 G runs at 10G and 9.5G
- Token ring at 4/16/100/1000 Mbps.
- New Signaling for 100 Mbps and up:
  - NRZI does not have line state, control symbols
  - 4b/5b provides line state, control symbols, and error detection
  - MLT-3 reduces the bandwidth requirements for UTP
  - 8b6t reduces the Baud rate to 75 MBaud
  - 8b/10b provides disparity control

Reading Assignment

- Read Appendix 16A, Appendix 16B of Stallings 7th Edition.

Homework

- 1a. List 3 differences between 10BASE5 and 10BASE2

  1b. List 3 differences between 100BASE-TX and 100BASE-T4 when both are using UTP.
- 2. Draw the 4b/5b-NRZI, 4b/5b-MLT-3, 8b6t signal waveforms for the data byte 00010111 assuming that the signal is at +V and no disparity.