Local and Metropolitan Area Networks

- Local Area Networks (LAN)- Networks that optimized for a moderate-size geographic area, such as a single office building, a warehouse, or a campus.
  - low bit error rate and delay
- Metropolitan Area Networks (MAN) - Networks that optimized for a larger geographic area than a LAN, ranging from several blocks of buildings to entire cities.
  - bit error rate and delay higher than LAN
- Wide Area Networks (WAN) - Networks that optimized for connecting equipment separated by long distances, (hundreds or thousands of miles), typically use telephone lines leased from phone companies.
  - high bit error rate and delay.

Baseband vs. Broadband

- Baseband LAN/MANs
  - Use digital signalling.
  - Signals are inserted on the line as voltage pulses and use the entire frequency spectrum.
  - Bi-directional transmission.
  - Limited distance, ~1km, (due to attenuation.)
- FDM Broadband LAN/MANs
  - Use Analog signalling.
  - Use FDM to divide whole bandwidth into channels.
  - Uni-directional transmission
  - Use active amplifier.

Local/Wide Area Network Standards

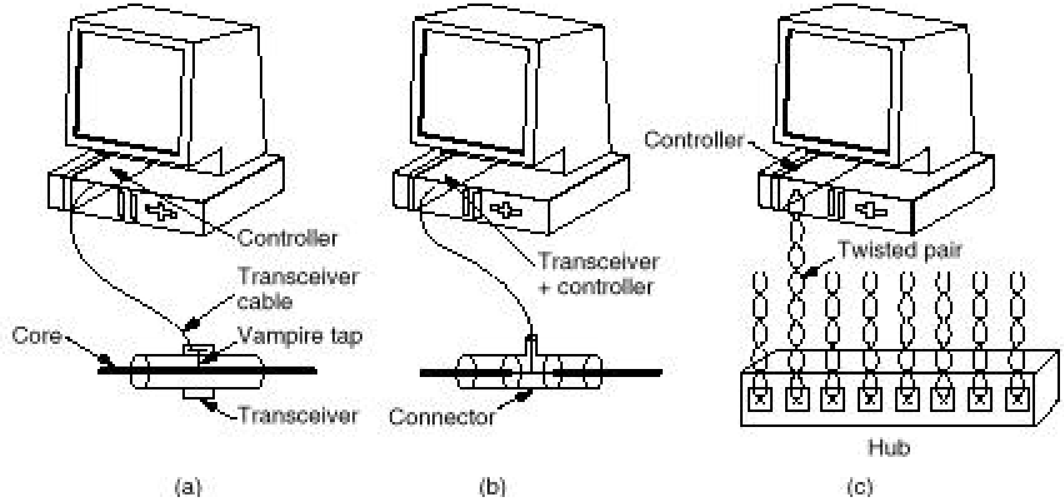
Logical Link Control (LLC)	IEEE 802.2 **–Unacknowledged connectionless service** **–acknowledged connectionless service** **–Connection-mode service**					
Medium Access Control (MAC)	802.3 CSMA/ CD	802.4 Token Bus	802.5 Token Ring	802.6 MAN (DQDB)	802.7? ATM BISDN	FDDI Token Ring
Physical Medium	**baseband: 10 Mbps (2versions);** **twisted pair: 1, 10 Mbps;** **broadband coaxial: 10Mbps**	**broadband coaxial: 1,5,10Mbps;** **carrierband: 1,5,10Mbps;** **Optical fiber: 5,10,20 Mbps**	**shield twisted pair: 1,4 Mbps**	**broad-bandco-axial: T1,T3 1.5,44.5 Mbps** **optical fiber: STS-3C, 155Mbps**	**optical fiber: 155,622 Mbps**	**optical fiber: 100 Mbps**
Topology:	**BUS**		**Ring**	**Dual Buses**		**2-counter Rotating Ring**

802.3 Ethernet

1-persistent CSMA/CD (Metcalfe and Boggs 1976)

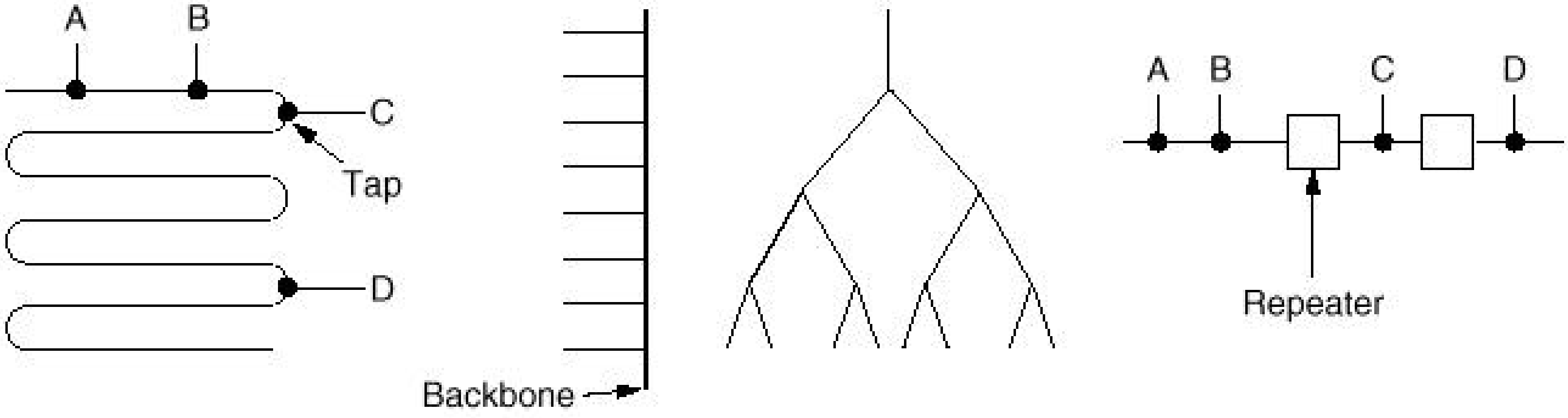
Name	Cable	Max. segment	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Good for backbone
10Base2	Thin coax	200 m	30	Cheapest system
10BaseT	Twisted pair	100 m	1024	Easy maintenance
10BaseF	Fiber optics	2000m	1024	Best between building

Transceiver cable length <= 50m; No path contains more than 4 repeaters

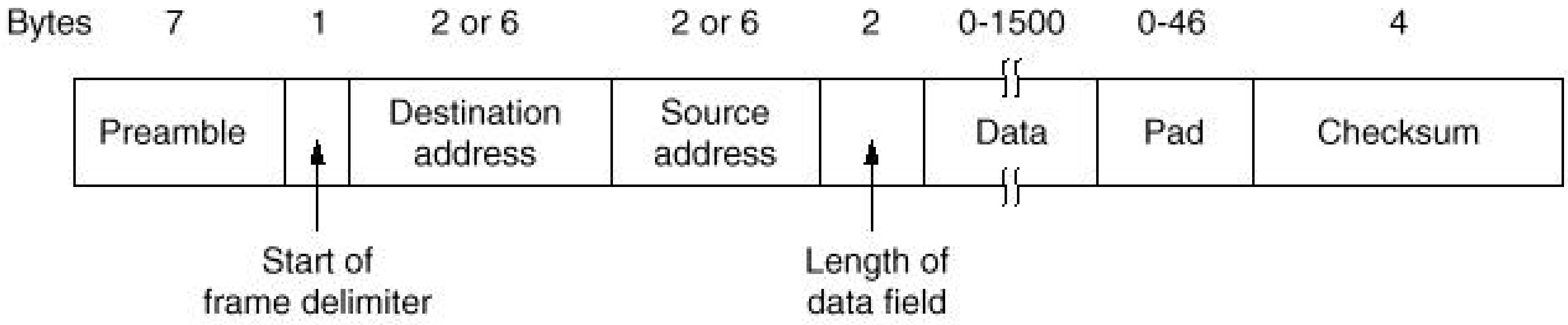


Cable Topologies

Bridge: selective repeaters, which examine the destination address only forward to the right direction.



Frame structure



Valid frame must be at least 64 bytes=512bits long, data+pad > 64-18=46 bytes

Why is that? (with 2τ time for collision detection)

For 2500 m max length and 4 repeaters, the round trip time is bounded by 51.2 μsec. The minimum allowed frame 512 bits with 10Mbps TX speed takes 51.2 μsec. This allows the sender to sense the collision of its first bit in the frame. If it is smaller than 512 bits, then the sender will finish sending its frame before the collision signal return and will think that it has successfully sent the frame.

Binary exponential backoff algorithm

After one collision, wait 0~(2^1-1) slots before retransmission.

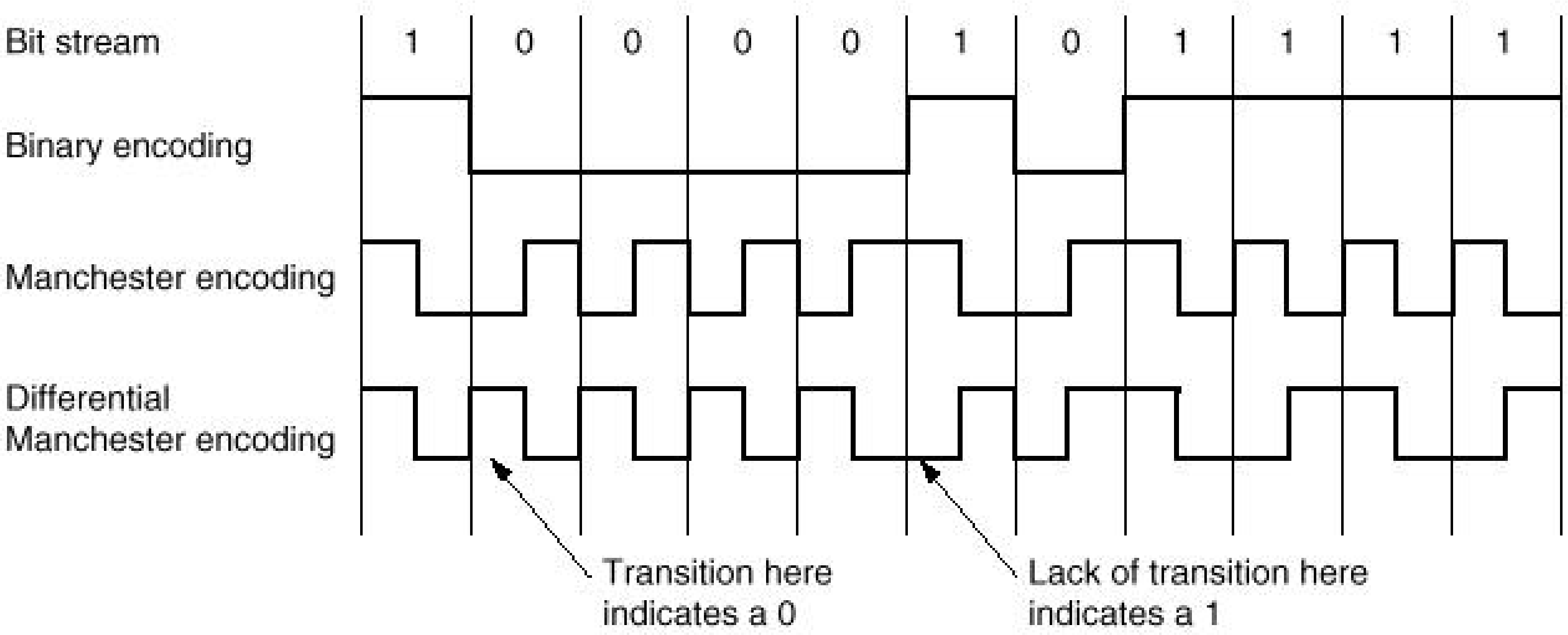
After n collisions (n<=10), wait 0~(2^n-1) slots before retransmission.

After n collisions (16>=n>10), wait 0~1023 slots.

After 16 collisions, report failure to upper layer.

Reserve the first slot after transmission for acknowledgement (Tokoro 1977).

Manchester encoding



All 802.3 baseband systems use Manchester ecnoding due to simplicity. with +0.85 v for high -0.85 volt for low.

802.3 Ethernet Performance

Assume that k stations always ready to transmit

p = Prob. of a station transmits during a contention slot.

A = Prob. of some station acquires the ether during a slot = $kp(1-p)^{k-1}$

A is maximized when p = 1/k, with $A \to 1/e$ as $k \to \infty$.

CI(j) = Prob. of contention interval is exactly j slots = $A(1-A)^{j-1}$.

n=The mean number of slots per contention = $\sum_{j=0}^{\infty} jA(1-A)^{j-1} = \frac{1}{A}$.

Each slot is 2τ time.

w=mean contention interval = $2\tau/A$

= $2\tau e \sim 5.4\tau$, (substitute 1/A with e, when p is optimal).

Let P=mean frame transmission time. It is related to the frame size and transmission speed.

Channel efficiency = $\frac{P}{P + (2\tau)/A}$.

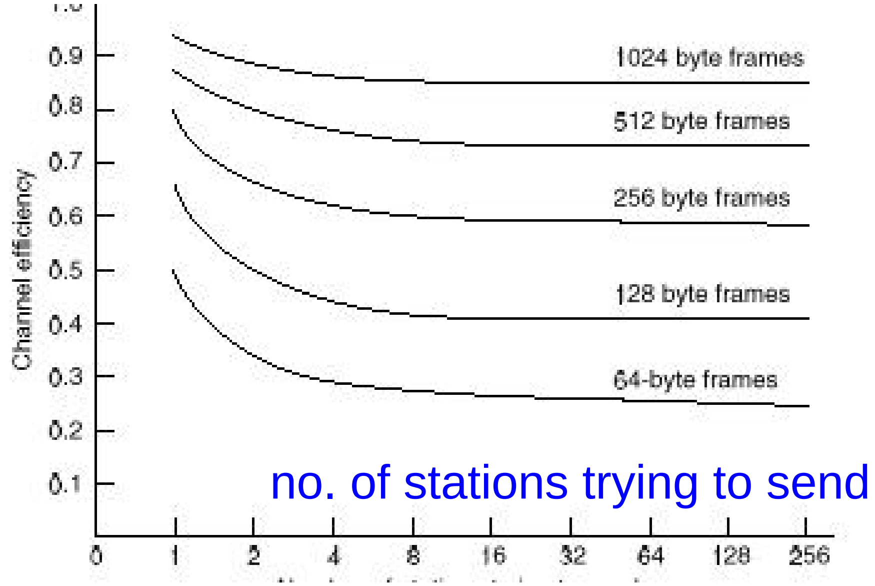
Channel efficiency of 802.3

Let F=frame length, B=network bandwidth, L=cable length, P=F/B, c=the speed of signal propagation, and optimal case of e contention slots per frame,

$$\Rightarrow \text{Channel efficiency} = \frac{P}{P+(2\tau)/A} = \frac{F/B}{F/B+\left(2\frac{L}{c}\right)/\left(\frac{1}{e}\right)} = \frac{1}{1+(2BLe)/(cF)}.$$

Increase B and L ⇒ lower the efficiency. Increase F ⇒ increase efficiency.

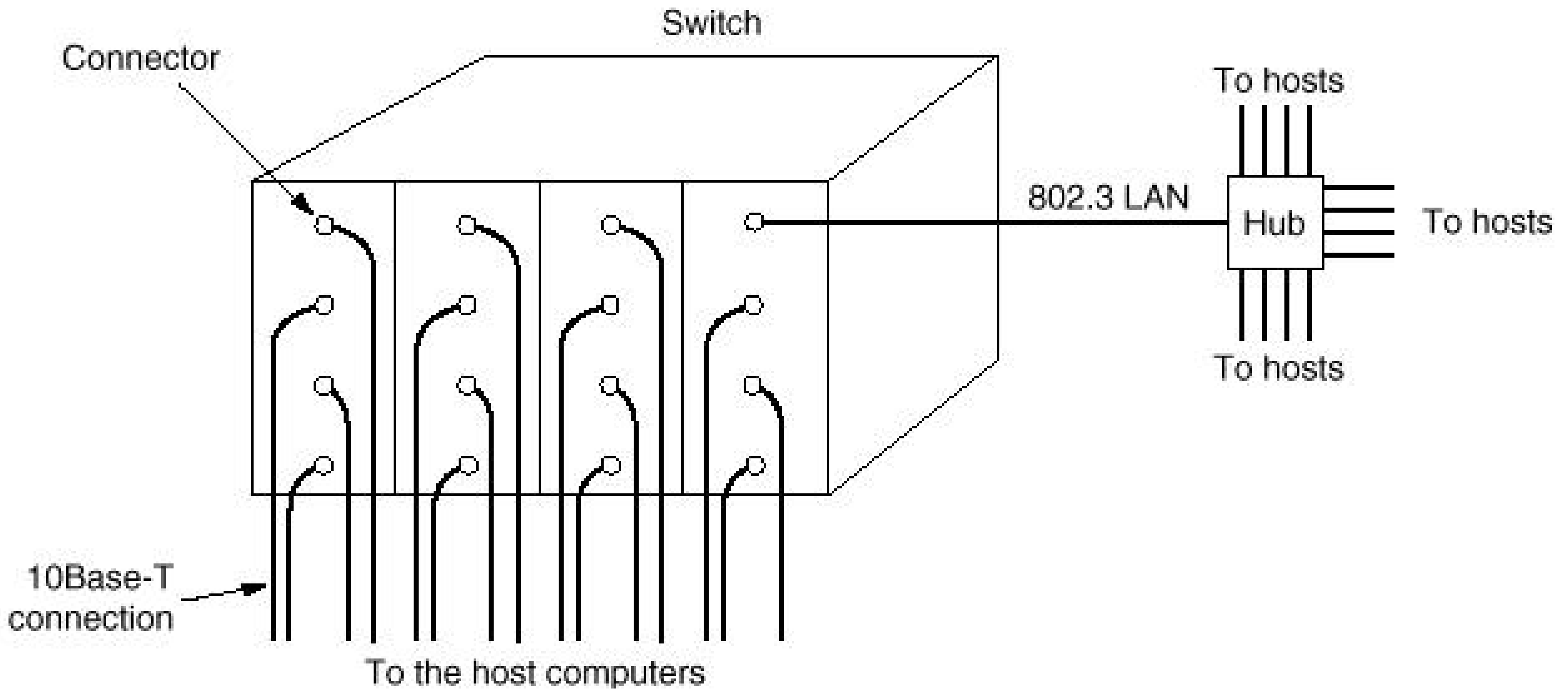
802.3 not good for high speed and long distance due to contention slot design.



no. of stations trying to send

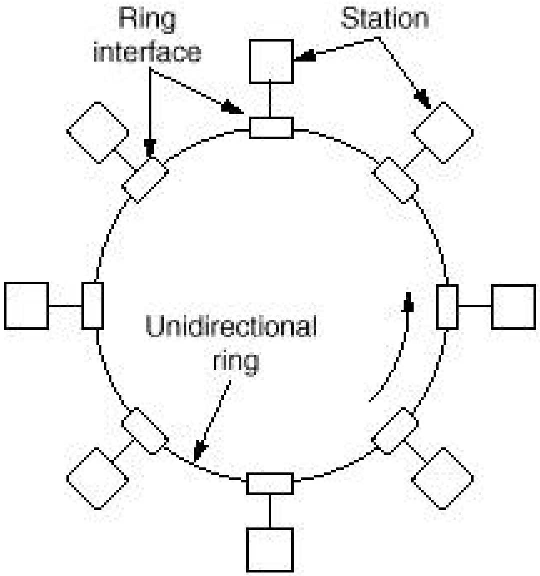
Switched 802.3 LAN

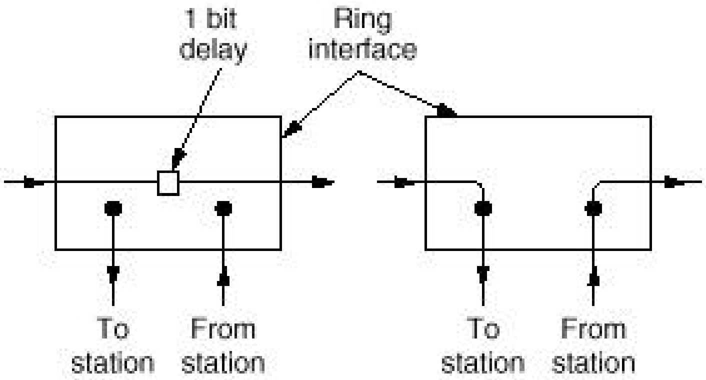
- High speed backplane(~1Gbps). 4-32 plug-in cards, each has1-8 connectors.
- Each connector has a 10Base-T connection to a host computer.
- Each card forms its own collision domain ⇒ A dedicated 10 Mbps line.
- Since no content among individual lines, it can higher performance (100%) than 100Mbps ethernet with shared bus(~80% due to contention).



802.5 Token Ring

- token=a special bit pattern which circulates while all stations are idle.
- Channel access method: seize the token, transmit data, remove data coming back, release the token.
- Use the token to slove the multiple access problem.
- The ring must have a sufficient delay to contain a complete token.
- Since there is only 1-bit delay in each ring interface, artifical delay may have to be introduced.

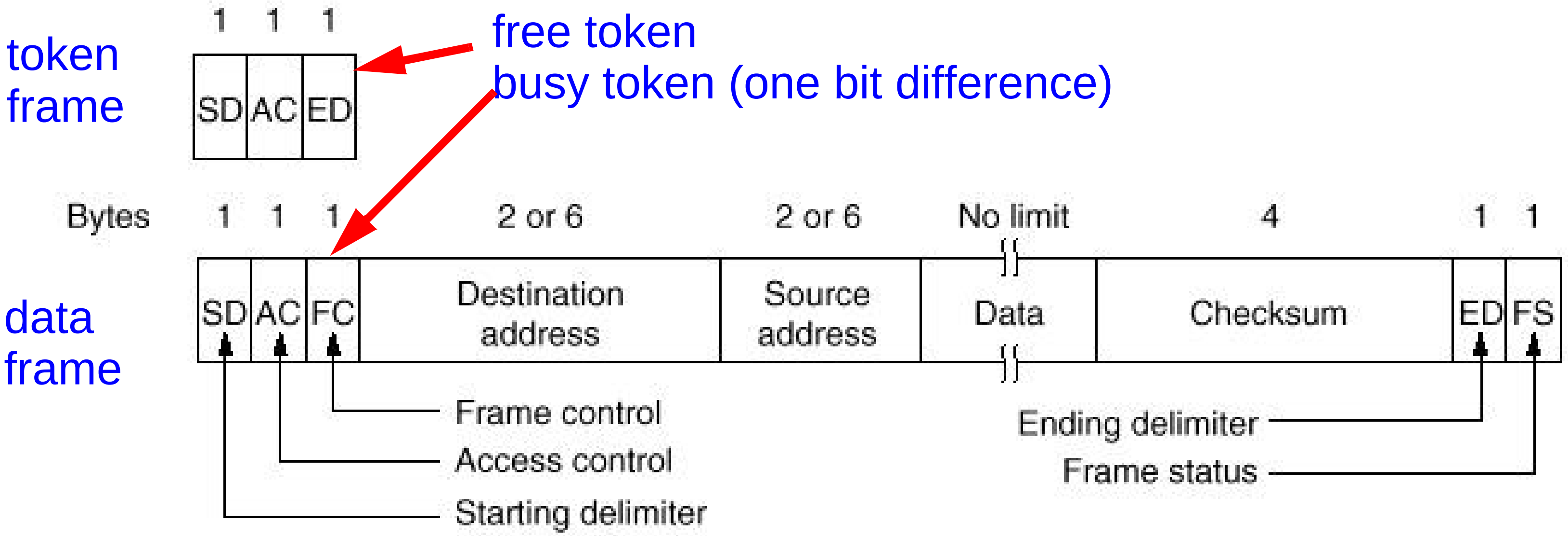




Listen mode

Transmit mode

- Note that when the station shuts down, the bypass relay will be released and the total delay reduces.
- Acknowledgement: the receiver sets bits in the frame status byte.
- Star-shape ring: solve the wire breaks problem by the use of wire center/ concentrator.
- Token holding time = 10msec? can send more than one frame.
- Frame types: data frame, token frame, control frames.
- A monitoring station is elected using a contention protocol.



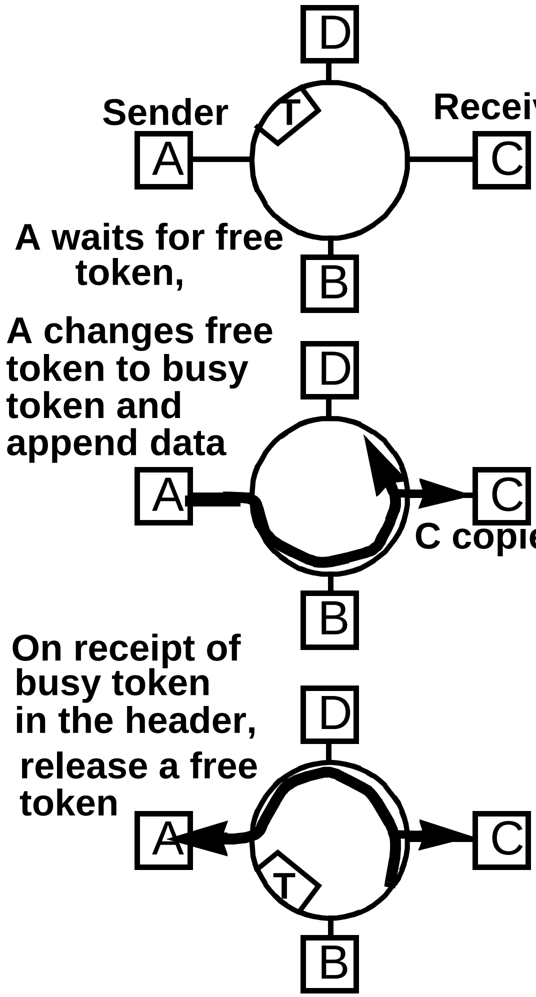
token frame

free token
busy token (one bit difference)

data frame

Comparison of Token Operation Modes

Single token mode (802.5)



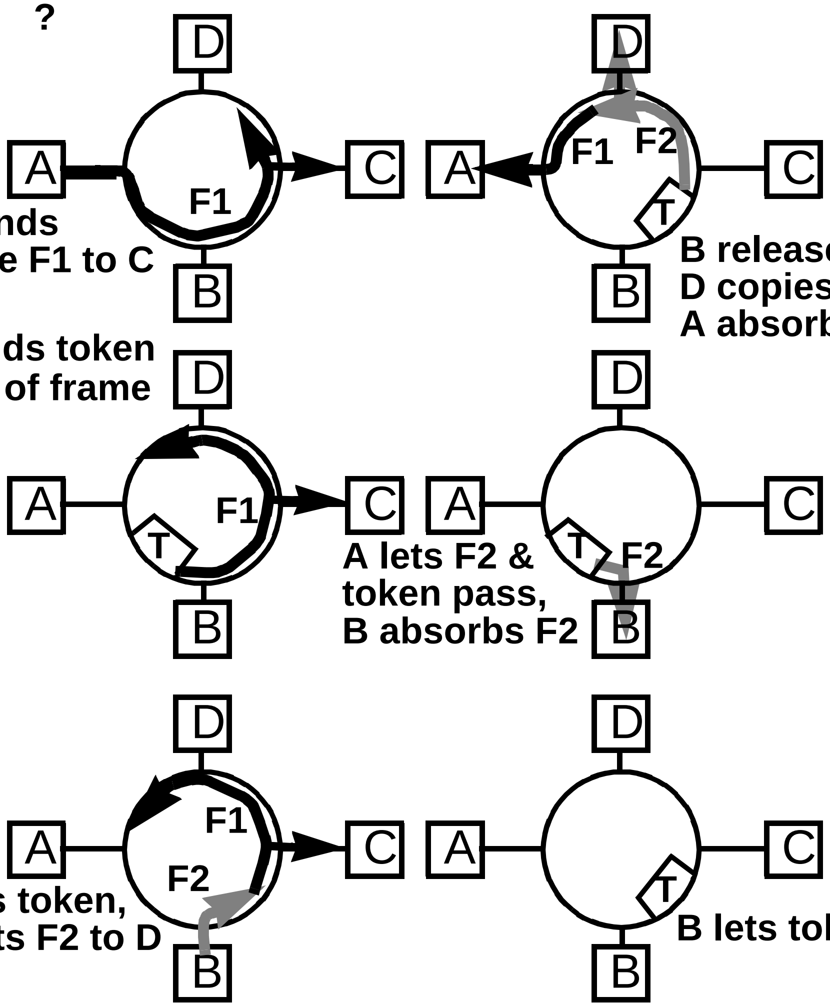
A waits for free token,

A changes free token to busy token and append data

C copies data

On receipt of busy token in the header, release a free token

Multiple token mode (early release mode) FDDI



A sends frame F1 to C

A appends token to end of frame

B seizes token, transmits F2 to D

B releases token
D copies F2
A absorbs F1

A lets F2 & token pass,
B absorbs F2

B lets token pass

Fault Management of Token Ring

Each ring has a **monitoring station**. It sends out ***ActiveMonitorPresent*** control frame periodically.

- Time-outs when token is lost and regenerate the token.
- Cleans up the garbled frame by opening the rings, removing the frame next round, and regenerating the token.
- Detects the orphan frame by setting monitor bit on each frame passing by. A frame with the monitor bit set is the orphan frame and will be drained.
- Inserts artificial delay so that the total delay > 24 bits.

  The ring must have a sufficient delay to contain a complete token (avoid the bits overrun in token). Since there is only 1-bit delay in each ring interface, artificial delay may have to be introduced.

Contention protocol for electing a new monitoring station:

Any station detecting the loss of a monitoring station (how?) sends out ***ClaimToken*** control frame.

The first station with its ***ClaimToken*** frame coming back becomes the new monitor station.

When the ring breaks, the neighbors of the dead station send out ***BEACON*** frame with the dead station id

The dead stations can then be identified and bypassed relays released.

Drawbacks—a monitor station can not be impeached.

Exercise #7

Prob. 1. A 10Mbps token ring with 5 stations equally separated. Assume the signal propagation speed is 200m/μsec.

a) What is the minimum length of ring that can avoid the insertion of artificial delay?

Ans: The bit interval is 1/10M=10^{-7} sec.

Two bits are separated by $10^{-7}*2*10^{8}$=20m.

With the 5 1-bit delays, which accommodate 5 bits,

the ring length needs to accommodate at least 24-5=19 bits in transit in order to avoid

the insertion of the artificial delay.

The minimum length of the ring = 19*20 = 380 m.

Let the length of the ring be 100km. Assume that the each station sends only 10000 bit frame each time and all stations have data to send.

b) What is the throughput of the token ring?
(How many frames are delivered per second?)

Ans: The length of the ring can accommodate 100km/20m = 5k bits. Therefore no artificial delay is needed. By the time the first bit of the token returns to the sending station, the station is still sending the rest of the frame. The token needs to be held and waits for the station to finish sending the frame. Once the last bit of the frame is sent, the first bit of the token can be sent after one-bit interval and will traverse 100km/5 = 20 km to reach the next station. Note that the token is the first three bytes of a frame.

Let T1 be the time the first bit of the free token arrives at station 1 (s1).

Let T2 be the time the first bit of the free token arrives at station 2 (s2) after T1.

Figure 1 shows the events happened between T1 and T2 from two observation angles. Note that while the 1st bit is in transit, other bits are sent by s1.

Ttd = the transmission delay of 10000 bits = $10000*10^{-7}= 10^{-3}$ sec.

Tpd = the propagation delay for a bit to traverse from s1 to s2 = $20km/ 2*10^{8}m=10^{-4}sec$

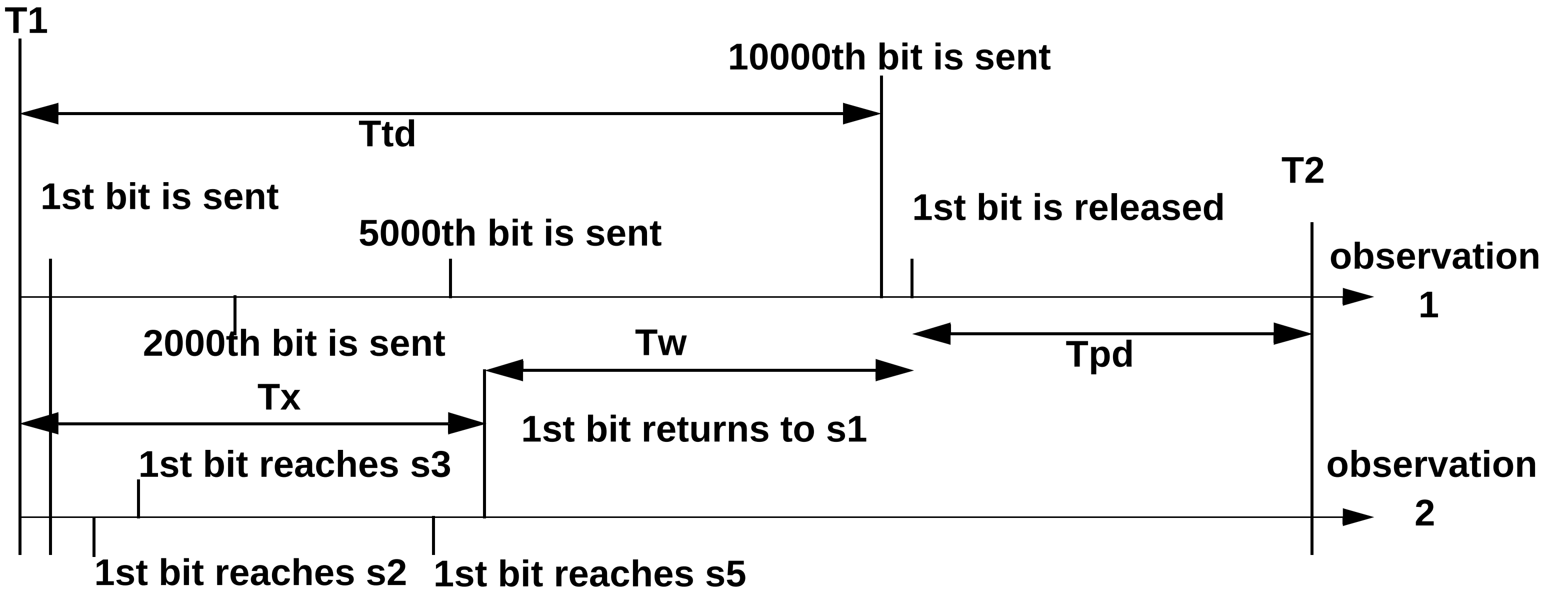


Figure 1.

T = T2-T1 = Ttd + Tpd + 10^{-7} = 1.1001 msec.
Throughput = 1/T = 909.008 frames/sec

Note that even though T = Tx + Tw + Tpd, it is not a formula of choice since Tw depends on Ttd. For your information, Tx = $5*10^{-7}$ + 100km/$2*10^{8}$m/sec = $5.005*10^{-4}$ sec=0.5005 msec.
Tx includes 5 1-bit delays.

c) How long is the interval between the start-sending times of
two consecutive frames from a station?
Ans: Since other stations follow the same pattern,
the time between sends = 5*T=5.5005 msec.

Prob. 2. Repeat the above problems a), b), c), with a 100Mbps token ring that operates on single token mode.
Ans:

a) Ans:The bit interval is 1/100M=10^{-8} sec.
Two bits are separated by $10^{-8}*2*10^{8}$=2m.
With the 5 1-bit delays, which accommodate 5 bits,
the ring length needs to accommodate at least 24-5=19 bits in transit in order to avoid
the insertion of artificial delay.
The minimum length of the ring = 19*2 = 38 m.

b) Ans:Ttd = the transmission delay of 10000 bits = $10000*10^{-8}= 10^{-4}$ sec.
Tx = $5*10^{-8}$ + 100km/$2*10^{8}$m = $5.0005*10^{-4}$ sec.
Tx > Ttd
Therefore, with the single token mode, by the time station 1 finishes sending the

10000th bit, the first bit of the token has not come back. Station 1 has to wait for the first bit to come back. Figure 2 shows the events between T1 and T2.

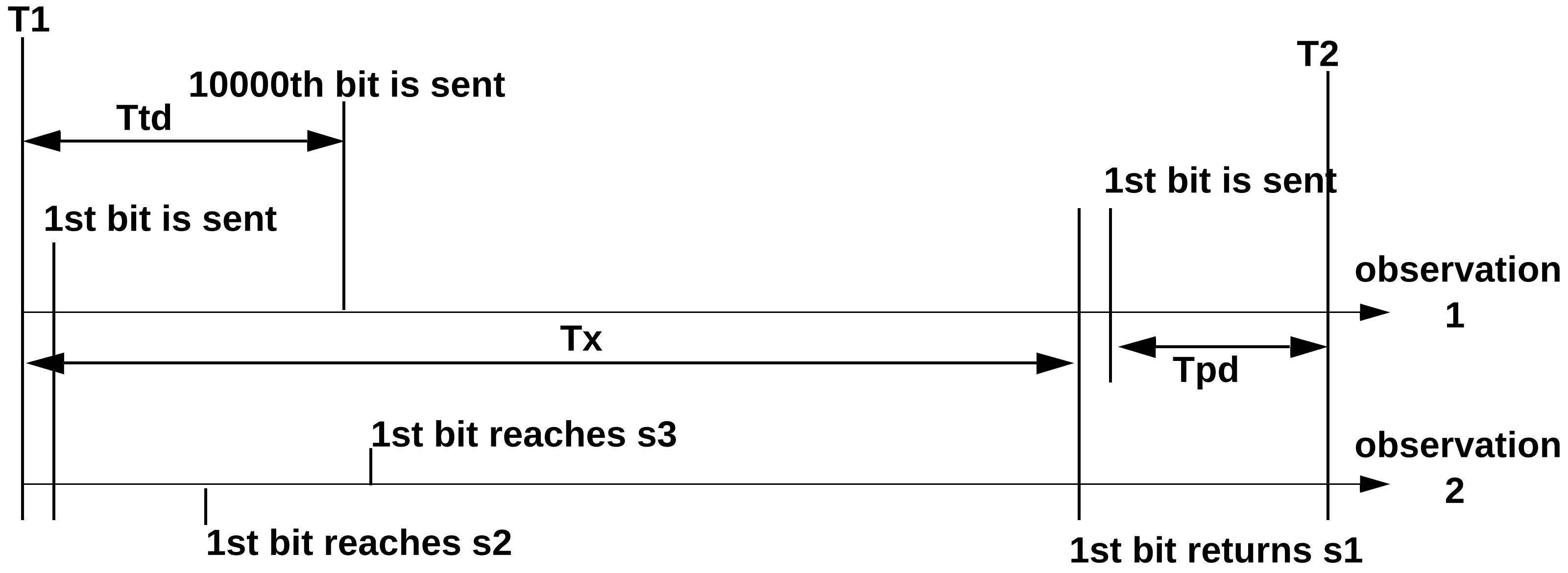


Figure 2.

$T = Tx + 10^{-8} + Tpd = 5.0005*10^{-4} + 10^{-8} + 10^{-4} = 0.60006$ msec.

Throughput = 1/T = 1666.5 frames/sec.

This is about 0.273 of the throughput achieved using the multiple token mode.

c) How long is the interval between the start-sending times of two consecutive frames from a station?

Ans: Since other stations follow the same pattern, the time between sends = 5*T=3.0003 msec.

Prob. 3. Repeat the above problems a), b), c), with a 100Mbps token ring that operates on multiple token mode.

a) same as Prob. 2a.

b) Ans: The length of the ring can accommodate 100km/2m = 50k bits. It is enough to hold five frames. Therefore, by the time the last bit of the frame is sent, the first bit of the token is near station 3 and will take some time before it returns to s1. However, since this ring operates on the multiple token mode, station 1 is allowed to release the token right after frame sending. A free token is sent to the station 2 immediately. The first bit of the free token will traverse 100km/5 = 20 km to reach the next station. Note that here we may see multiple busy tokens and one single free token in transit in the ring.

Figure 3 shows the events happened between T1 and T2 from two observation angles.

Ttd = the transmission delay of 10000 bits = 10000*10^{-8}= 10^{-4} sec.

Tpd = the propagation delay for a bit to traverse from s1 to s2 = 20km/2*10^{8}m=10^{-4}sec

T = T2-T1 = Ttd + Tpd + 10^{-8} = 0.20001 msec.

Throughput = 1/T = 4999.75 frames/sec

c) How long is the interval between the start-sending times of two consecutive frames from a station?

Ans: Since other stations follow the same pattern,

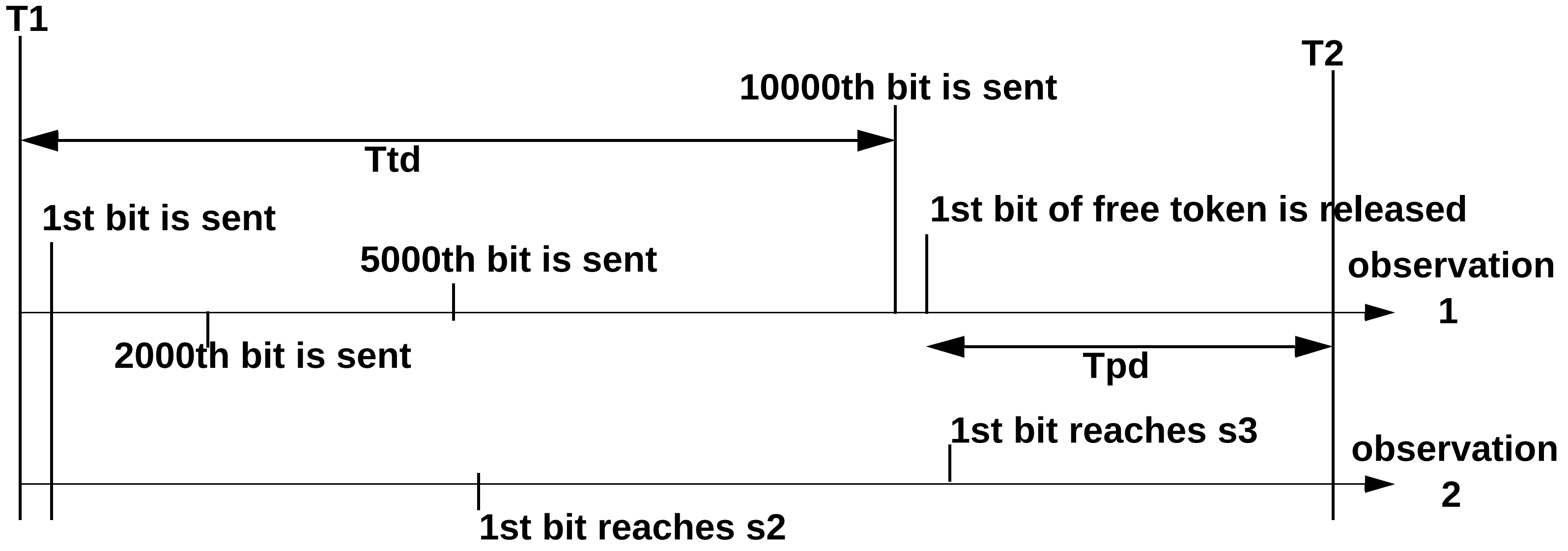


Figure 3.

the time between sends = 5*T=1.00005 msec.

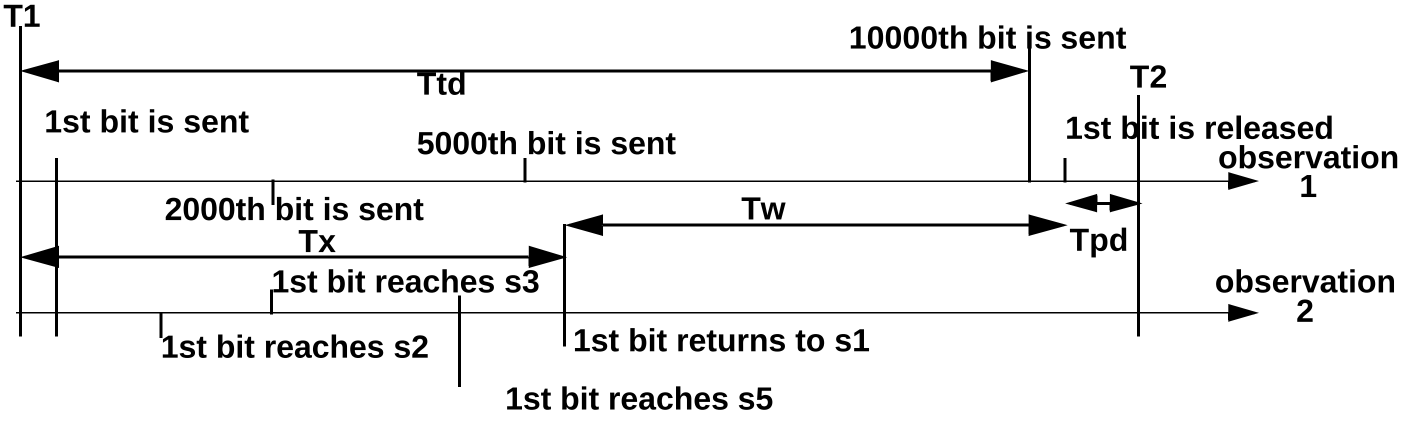


Figure 1. single token mode, 10Mbps

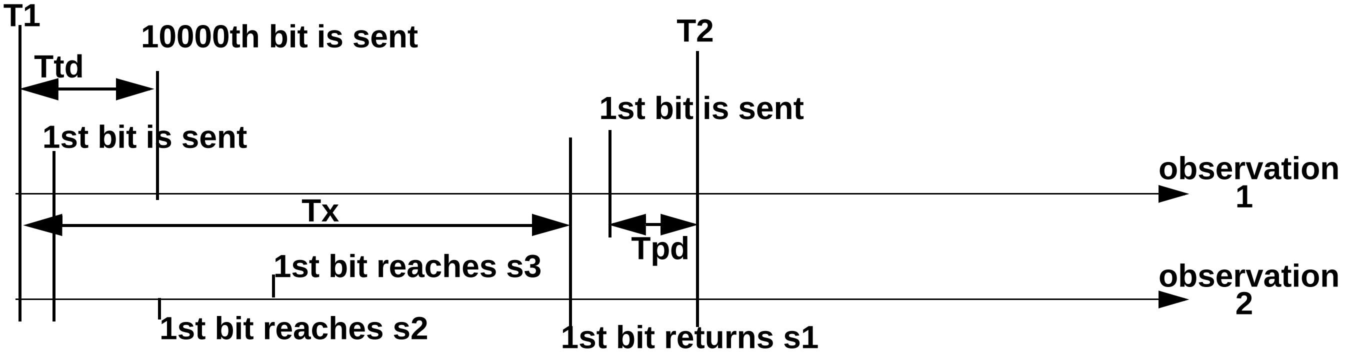


Figure 2. single token mode, 100 Mbps

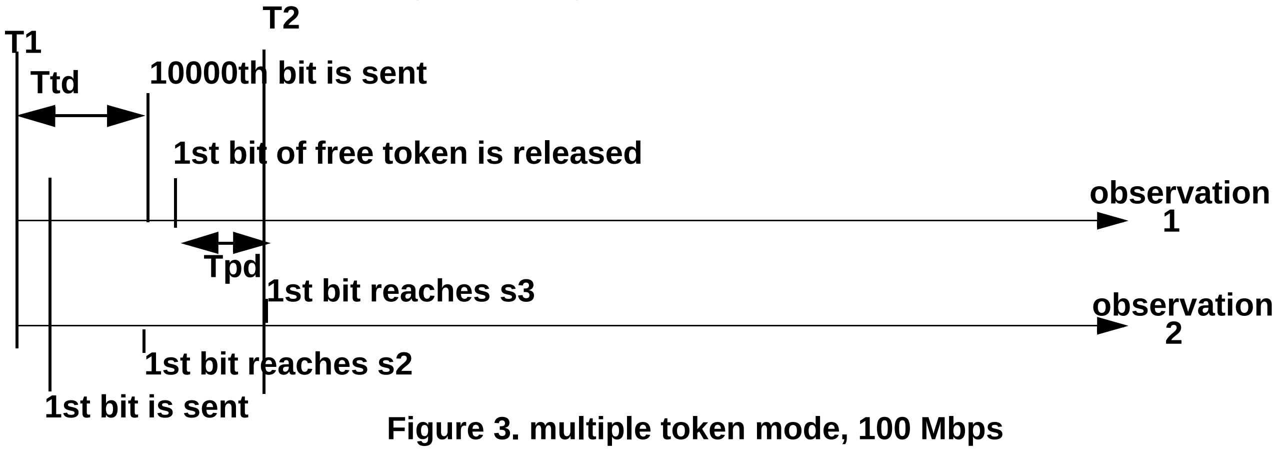


Figure 3. multiple token mode, 100 Mbps

observation 1 describes the timing event station 1 observed.

observation 2 describes the timing event the lst bit of token observed.

Tx is the time for the 1st bit to traverse the ring and return to station 1.

Ttd is the transmission delay, i.e., the time to send out 10000 bits.

Tpd is the propagation delay, i.e., the time for a bit to go from station 1 to station 2.

Tw is the time that lst bit of the token needs to wait inside station 1 after return and before got released.

Homework #6

- Problems 5, 7, 16, 21.
- Hint: Prob. 5. 10% of the slot are idle $\Rightarrow$ Pr[0]=0.1.