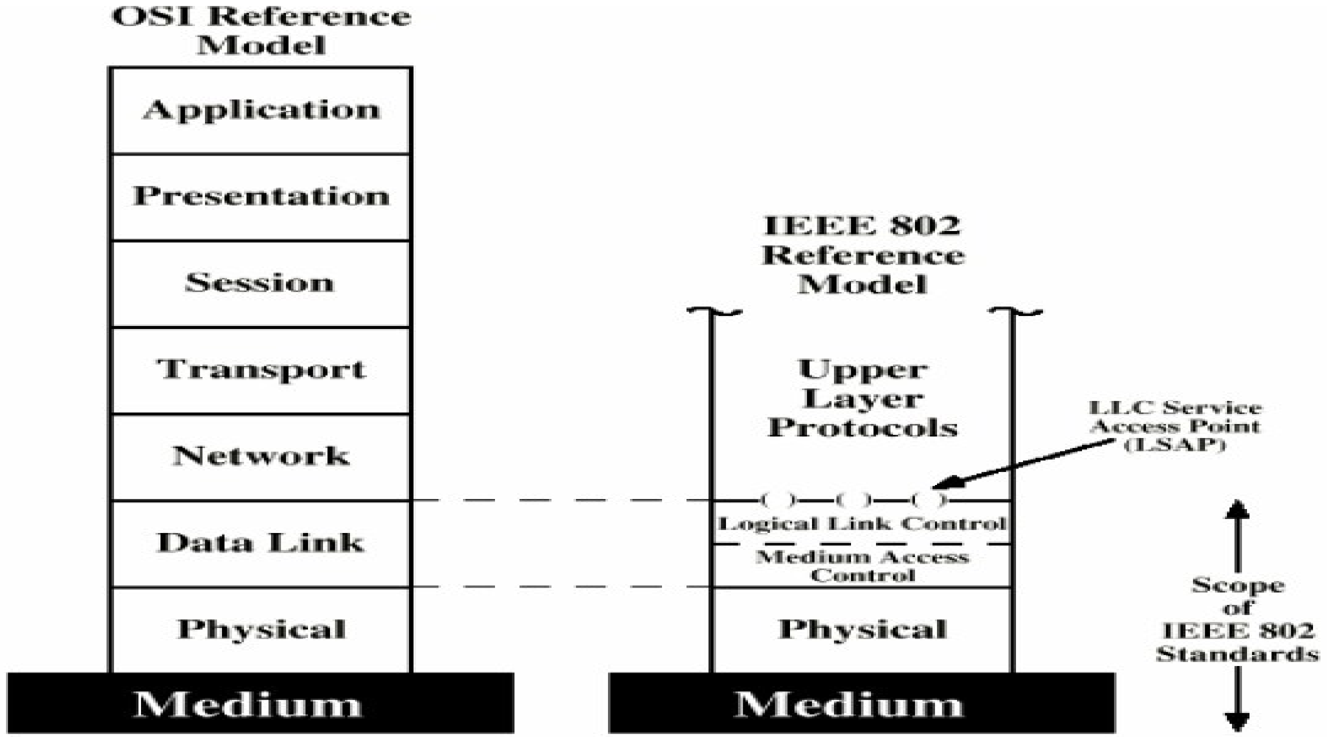
Chapter Five

Local Area Networking Technology

Introduction

- A local area network (LAN) is a data communication network that serves users in a confined geographic area and uses high transmission speeds (typically 10 **mbps** to few **gbps**)
- Designed and developed for communications and resource sharing in a local work environment (room, campus, building).
- A single *shared* medium, usually a cable, to which computers can attach.
- Because sharing occurs:
  - Cost decreases
  - Computers have to coordinate the use of the network
- LANs operate at the physical and data link layers

- In OSI terms, higher layer protocols (layer 3 or 4 and above) are independent of network architecture and are applicable to LANs, MANs, and WANs
- LAN protocols is concerned principally with lower layers (Layer 1 and 2) of the OSI model
- **IEEE 802 reference model**



- the lowest layer of the IEEE 802 reference model corresponds to the ***physical layer***
- Includes functions:
  - Encoding/decoding of signals
  - Preamble generation/removal (for synchronization)
  - Bit transmission/reception

- The functions associated with providing service to LAN users include:
  - **On transmission**, assemble data into a frame with address and error-detection fields.
  - **On reception**, disassemble frame, perform address recognition and error detection.
  - Govern access to the LAN transmission medium.
  - Provide an interface to higher layers and perform flow and error control

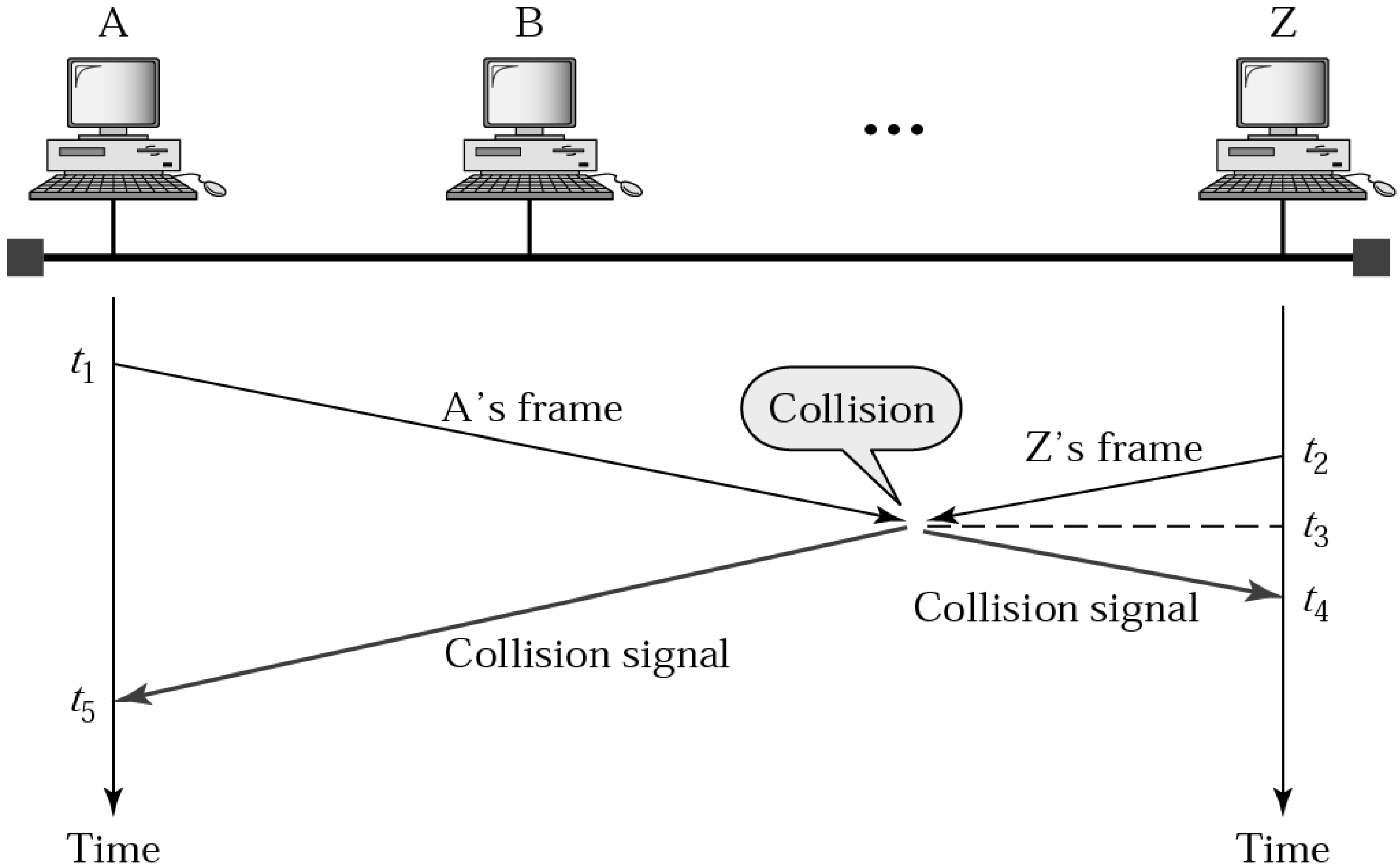
Access Methods

- ***broadcast channels*** are sometimes referred to as ***multi-access channels*** or ***random access channels.***
- The methods that can be used to determine how the shared media is accessed are called **Access methods.**
- The **protocols** used to determine who goes next on a multi-access channel.
  - It belongs to the sub-layer of the data link layer called **MAC** (***Medium Access Control***) sub-layer
- The MAC sub-layer is especially important in LANs,
  - many of LANs use a multi-access channel as the basis for communication.
  - WANs, in contrast, use point-to-point links, except for satellite networks

- **Pure ALOHA**
  - The earliest of access methods
  - was developed for packet radio networks
  - is also applicable to any shared transmission medium
  - is a **true free-for-all**
  - The station waits for
    - an amount of time (The maximum round-trip propagation delay on the network)
      - twice the time it takes to send a frame between the two most widely separated stations
    - plus a small fixed time increment
  - If the station fails to receive an acknowledgment after repeated transmissions, it gives up.
  - ***Collision*** happens if two stations send frame at the same time.
  - As the number of collisions rises rapidly with increased load, the maximum utilization of the channel is only about 18%

- **Slotted ALOHA**
  - time on the channel is organized into ***uniform slots*** whose size equals the frame transmission time.
  - Some central clock or other technique is needed to synchronize all stations.
  - Transmission is permitted to begin only at a slot boundary.
  - still collision is possible;
  - collided packets are retransmitted after a random delay

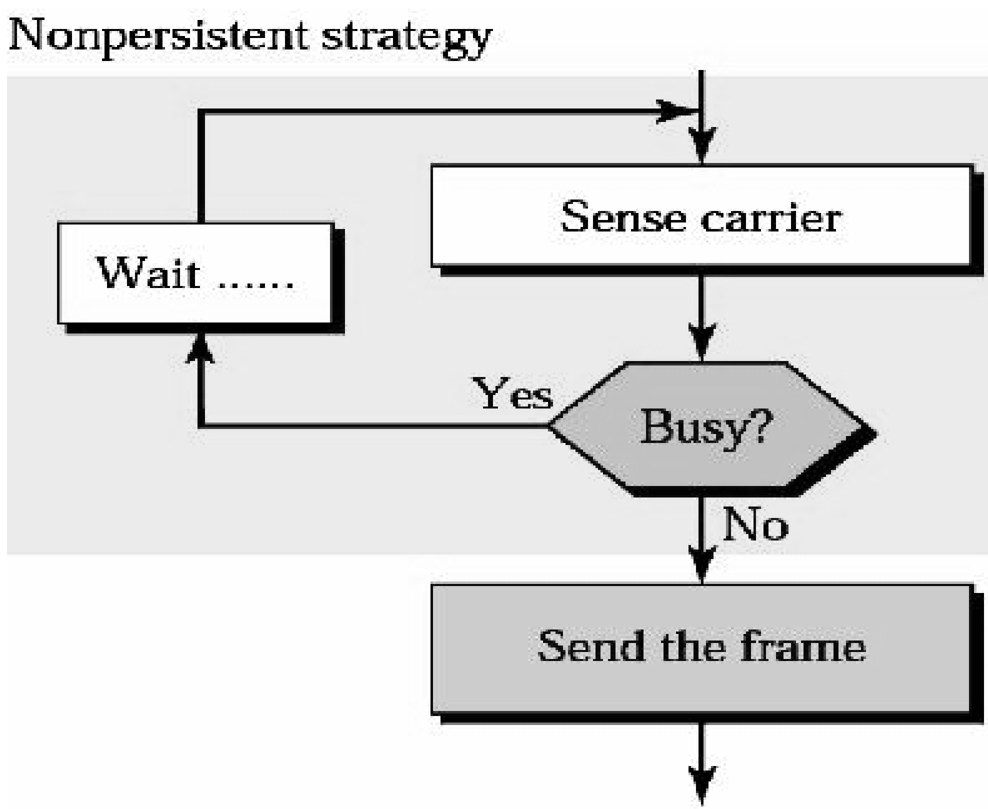
- **CSMA - Carrier Sense MA - polite version of ALOHA**
  - to minimize the chance of collision, each station first listens to the medium before sending; “**listen before talk**”
  - if the channel is busy, it waits until it is idle. Otherwise it transmits.
  - if a collision occurs, it waits a random amount of time and starts listening again.
  - the chance of collision is minimized, but may still occur because of
    - the propagation delay (a station doesn’t know if another one has just started transmitting);
    - or if two or more stations start transmitting at the same time



$$\mathbf{t_1 < t_2 < t_3 < t_4 < t_5}$$

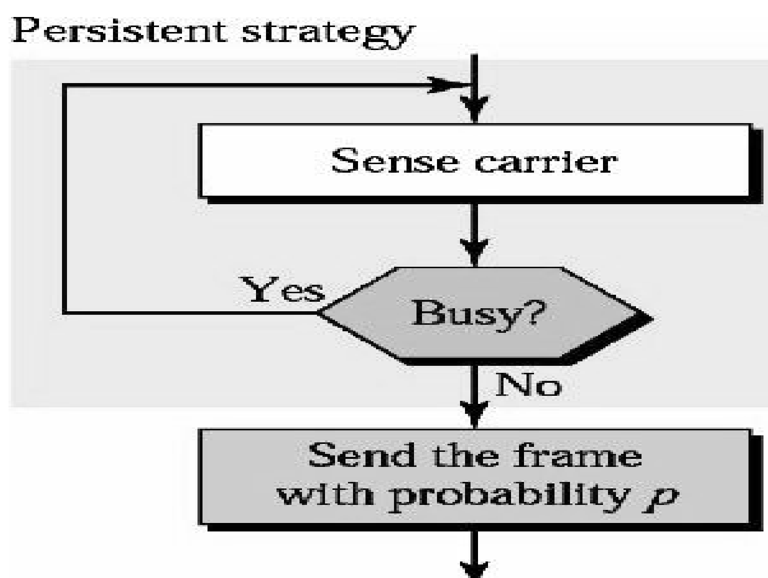
– Two sub-strategies have been defined

1. **Non-persistent**: sense a line and send if it is idle;
   - otherwise wait a random amount of time (hence less greedy than continuously listening);
   - reduces the chance of collision, but also reduces the efficiency of the network and has longer delays

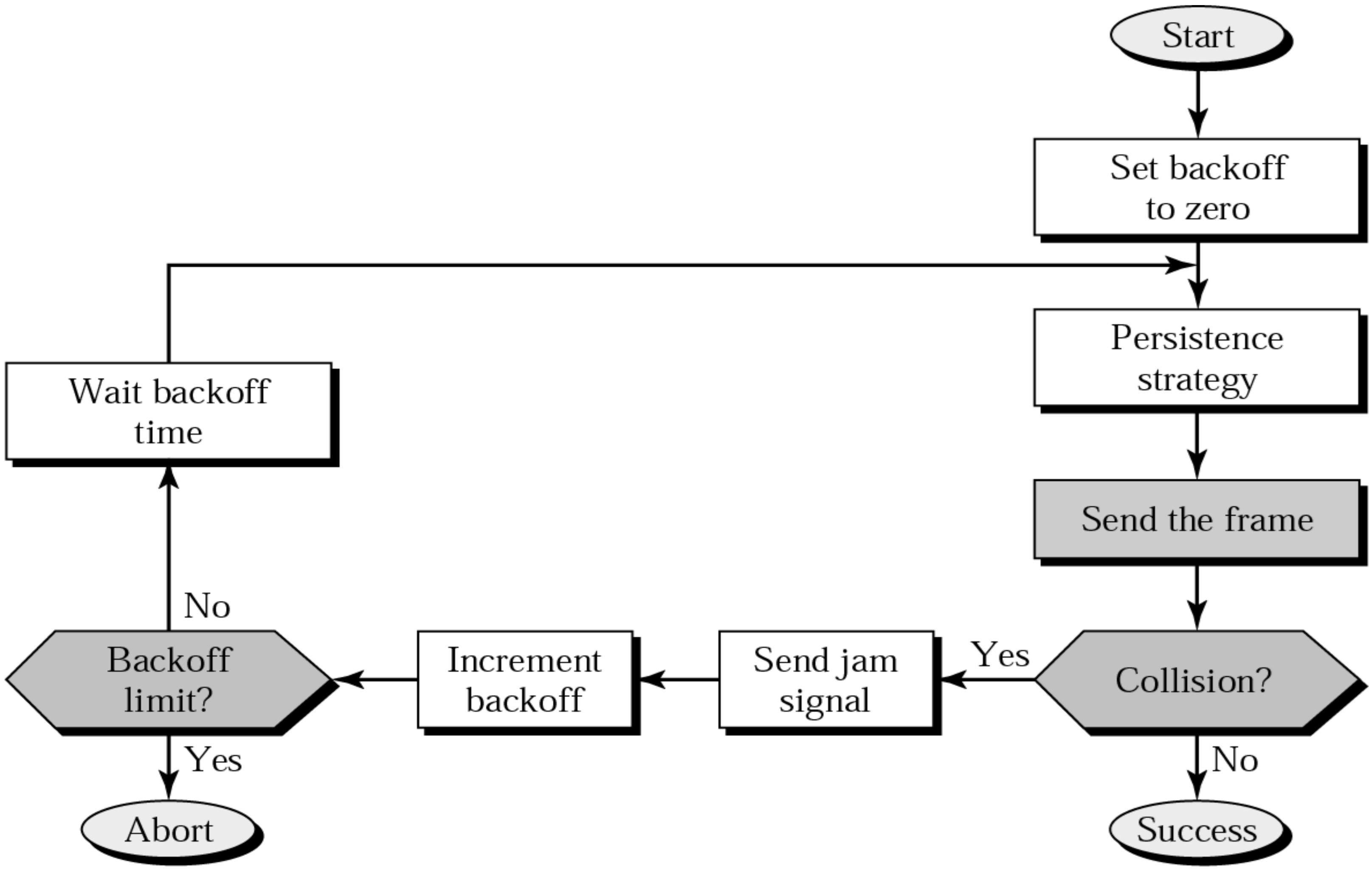


2. **persistent**: sense a line and "send" if it is idle; otherwise listen; two variations

- ***1-persistent***: if the line is idle, send immediately (with probability 1).
- ***p-persistent***: if the line is idle, send with probability **p** and refrain from sending with probability **1-p**; if p = 0.2, then a station sends 20% of the time that a line is idle, and refrains from sending 80% of the time
  - it reduces the chance of collision and improves efficiency; depends on the value of p

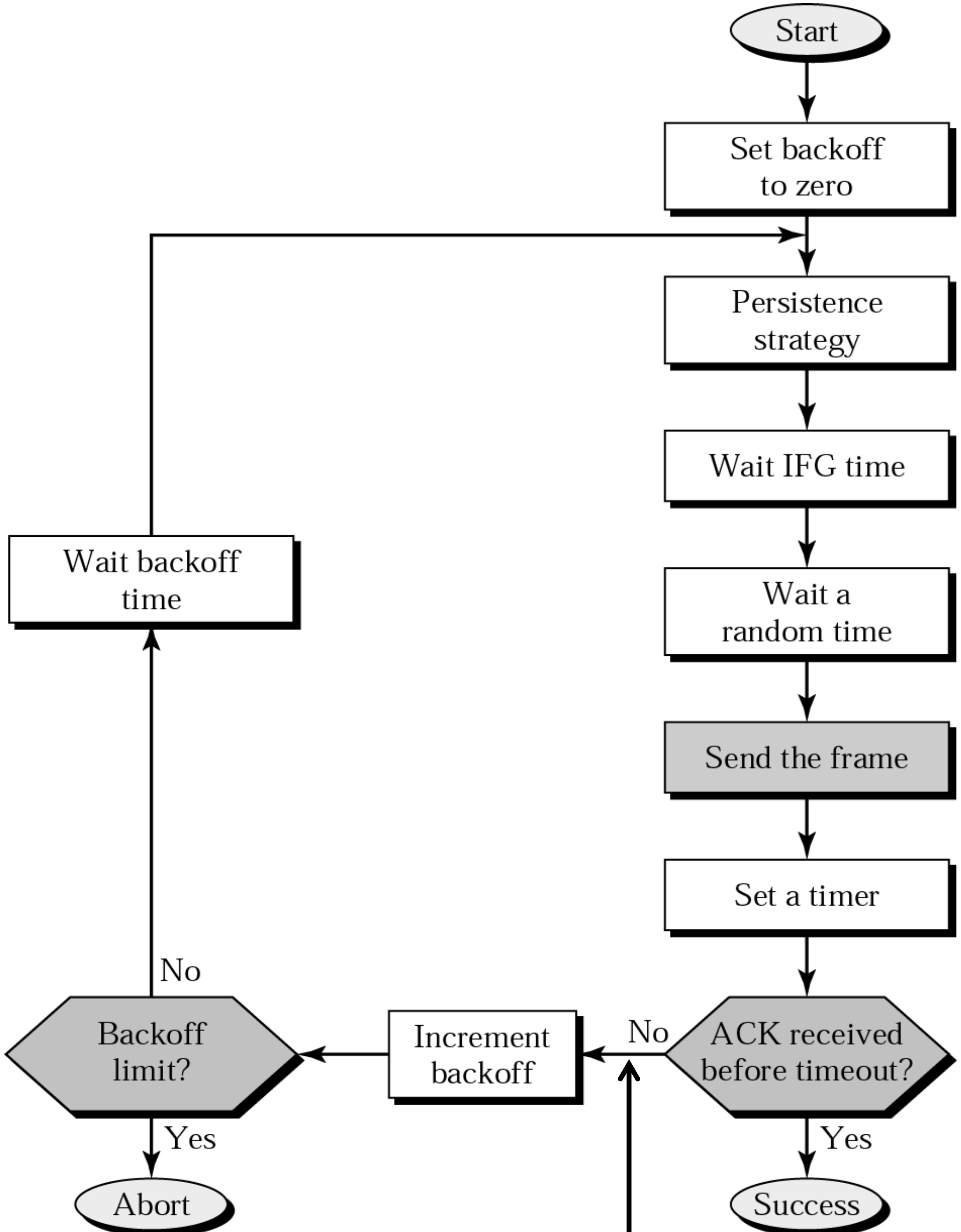


- **CSMA/CD - CSMA with Collision Detection**
  - adds a procedure to handle a collision
  - if a collision is detected and to reduce the probability of collision the second time, the sender waits; it has to back off
  - it waits a little the first time, more if a collision occurs again, much more if it happens a third time, and so on; finally gives up
  - in the exponential back off method, it waits an amount of time between ***0 and 2^N X maximum_propagation_time***,
    - where N is the number of attempted transmissions
  - line sensing is done using one of the persistent strategies



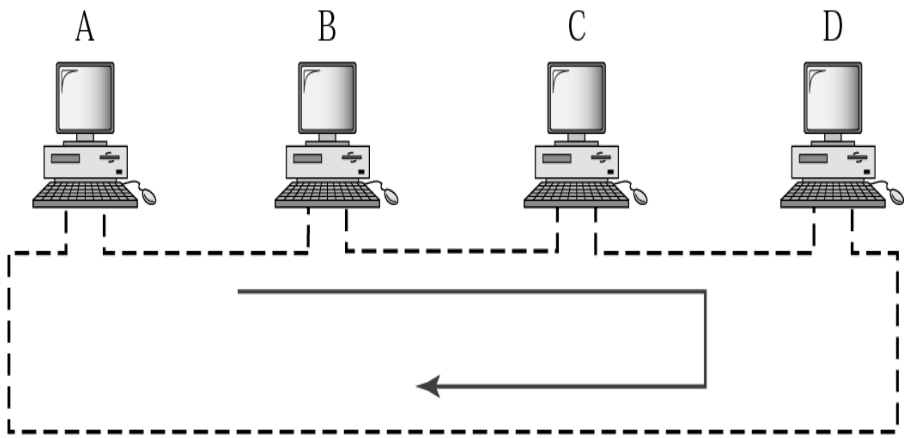
- sending a jam alerts to the other stations and also to discard the part of the frame received
- used in traditional Ethernet; CSMA was never implemented

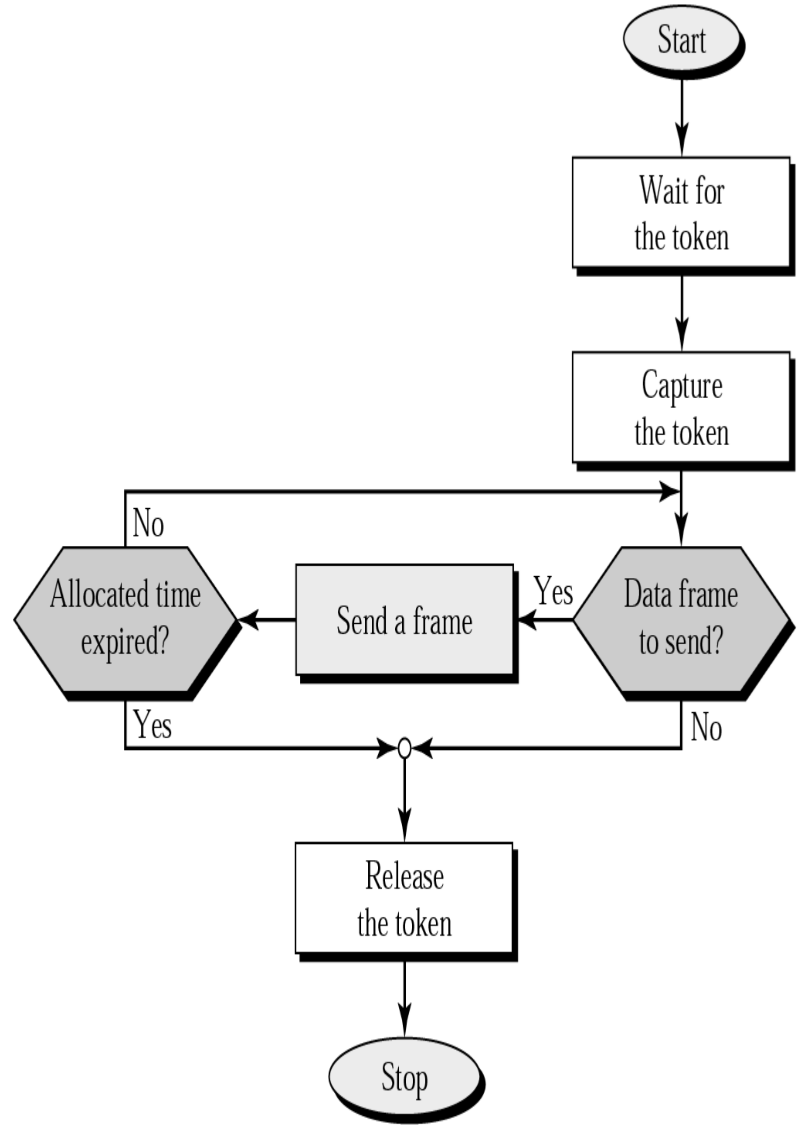
- **CSMA/CA - CSMA with Collision Avoidance**
  - avoids collision
  - uses one of the persistence strategies;
  - after it finds the line idle, it waits an ***IFG (interframe gap)*** amount of time;
    - it then waits another random amount of time;
    - after that it sends the frame and sets a timer;
    - if it receives an **ack** before the timer expires, the transmission is successful;
    - otherwise something is wrong (the frame or the ack is lost);
    - waits for a backoff amount of time and re-senses the line
  - used in wireless LANs



- **the frame or the ack is lost**

- **Token Passing**
  - a station is authorized to send data when it receives a special frame called a **token.**
  - the stations are arranged around a ring (each station has a predecessor and a successor)
  - a token circulates around the ring when no data is transmitted
  - token: a bit sequence
    - free token: 01111110
    - busy token: 01111111
  - when a node wants to transmit
    - wait for free token
    - remove token from ring (replace with busy token)
    - transmit message
    - when done transmitting, replace free token on ring


A
B
C
D


Start
Wait for the token
Capture the token
Data frame to send?
Yes
Send a frame
Allocated time expired?
No
Yes
No
Release the token
Stop

- **token failures**: tokens can be created or destroyed by noise
- distributed solution
  - nodes are allowed to recognize the loss of a token and create a new token
  - collision occurs when two or more nodes create a new token at the same time => need collision resolution algorithms
- **node failures**: since each node must relay all incoming data, the failure of a single node will disrupt the operation of the ring

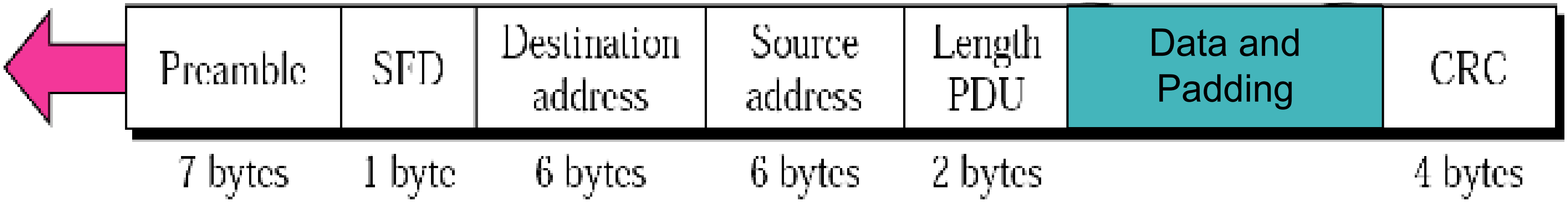
Ethernet

1. Traditional Ethernet (IEEE 802.3)

- the most popular LAN physical network architecture in use today
- originally created in 1976 at **Xerox's Palo Alta Research Center** (not a commercial success for itself) to operate at **10 Mbps**
  - usually called **traditional Ethernet**.
- uses **1-persistent** CSMA/CD
- an Ethernet frame contains 7 fields

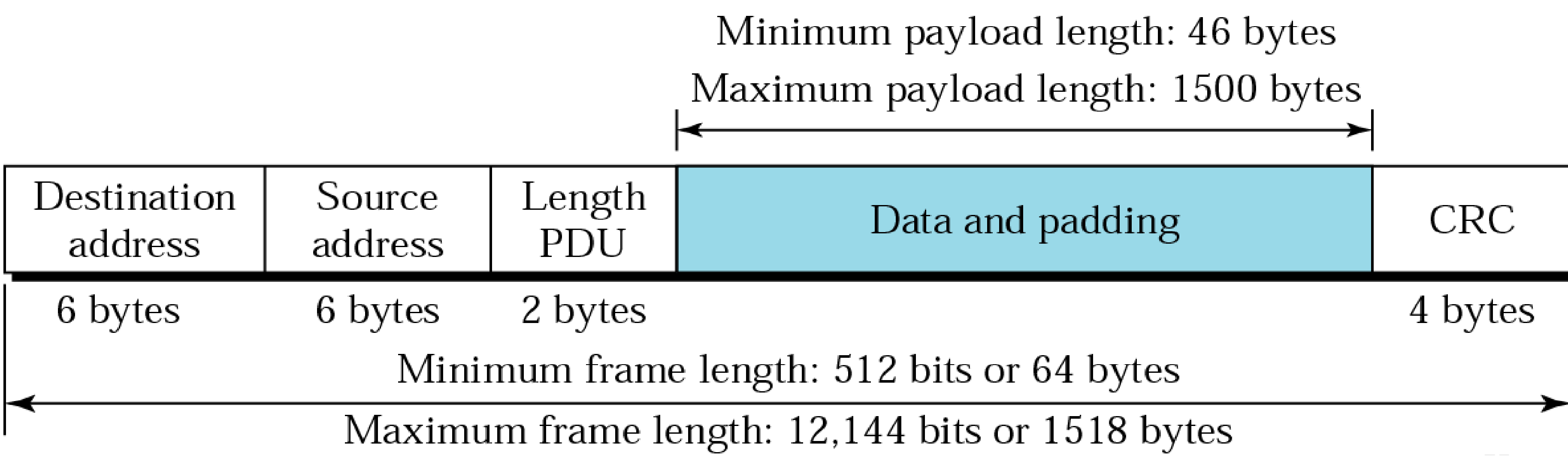
Preamble 56 bits of alternating 1s and 0s to alert the recieving system to the coming frame

SFD Start field delimiter, flag (10101011)



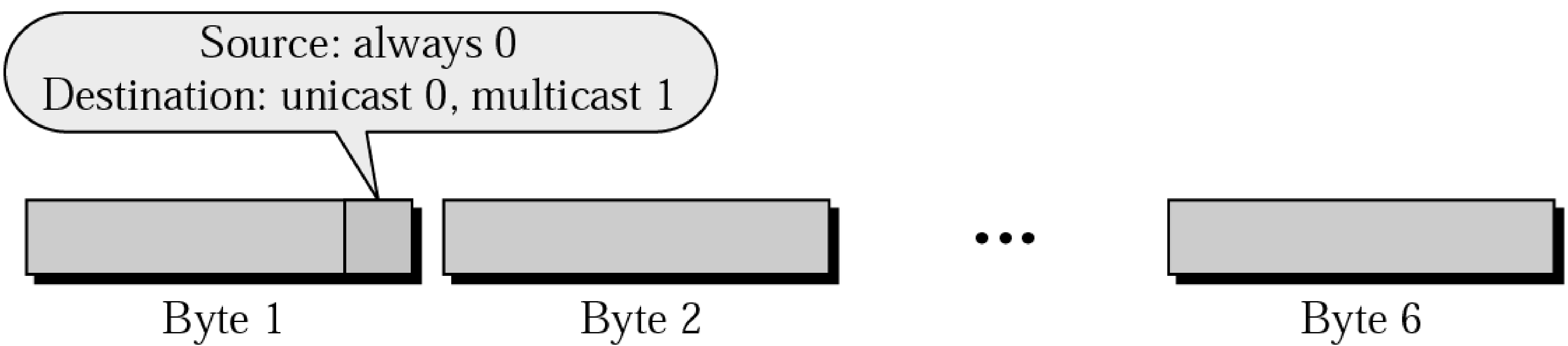
- **PDU - Protocol Data Unit**

- minimum and maximum frame lengths are defined without the preamble and the SFD.
- **padding** is used if the packet size is less than the minimum packet size.



- **Addressing**
  - a NIC provides a **6-byte** physical address or MAC (Media Access Control address) in hexadecimal;
    - there are 2^{48} possible LAN addresses;
  - a NIC's address is permanent - a LAN address is burned into its ROM during manufacturing

    06-01-02-01-2C-4B
  - **Unicast, Multicast, and Broadcast addresses**:
    - a source address is always a unicast address;
    - the destination address can be **unicast** (only one destination), **multicast** (multiple destinations), or **broadcast** (all the stations on the network - 48 1s)



- **four most common kinds of 10 Mbps Ethernet cabling**

Name	Cable	Max. seg.	Nodes/seg.	Advantages
10Base5	Thick coax	500 m	100	Original cable; now obsolete
10Base2	Thin coax	185 m	30	No hub needed
10Base-T	Twisted pair	100 m	1024	Cheapest system
10Base-F	Fiber optics	2000 m	1024	Best between buildings

- Where
  - **10** - 10 Mbps
  - **Base** - Baseband (against broadband with more bandwidth than standard telephone service)
  - **5 (2)** - maximum segment length; rounded to units of 100 meters (for coax)
  - **T** - Twisted Pair, **F** - Fiber

- a hub is used in 10Base-T and 10Base-F to which each station is connected by a dedicated cable.
- 10Base5 is also called **Thick Ethernet** and 10Base2 is **Thin Ethernet**
- 10Base5 and 10Base2 use bus topology;
- 10Base-T and 10Base-F use star topology
- **Segmentation** (of a network not a frame)
  - performance depends on the number of stations.
  - the more stations we have the less will be the performance.
  - when a lot of stations have data to transmit, the network gets congested, and many collisions occur
  - in a network with severe congestion, there may actually be more collisions occurring on the network than data being transmitted

- Solution: **Segmentation**
  - the process of splitting a large Ethernet network into two or more segments linked by routers
  - the resulting segments have fewer stations to contend with for access to the network
  - the router transfers data from one segment to the other only when the destination for the data is on the other segment
  - the rest of the network traffic stays within the segment where it belongs

2. Fast Ethernet (IEEE 802.3u)

- the need for a higher data rate resulted in the design of the Fast Ethernet protocol (100 Mbps)
- basic idea: keep all the old frame formats, interfaces, and procedural rules, but reduce the bit time from **100 ns (10 Mbps) to 10 ns (100 Mbps)**
- a new feature, called ***auto-negotiation***, is added to allow
  - incompatible devices to communicate with one another,
    - e.g. one with 10 Mbps and one with 100 Mbps - backward compatibility)
  - one device to have multiple capabilities
  - a station to check a hub's capabilities

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

3. Gigabit Ethernet (IEEE 802.3z)

- recent need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps)
- basic idea: make Ethernet go 10 times faster yet remain backward compatible with all existing Ethernet standards
- the four most common kinds of Gigabit Ethernet cabling

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 µ) or multimode (50, 62.5 µ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

The Evolution of Ethernet

It's been more than 30 years since the first Ethernet standard was approved. Where Ethernet has been, where it is today and where its backers believe it will be in the years to come.

1983

10 MBPS: The first iteration of Ethernet, 10Base 5, is released, three years after the IEEE first commissioned the project 802.3 working group to design the standard. In 1985, thin coaxial cable, or thinnet, was also approved and the group made other changes to the specification in 1987, 1990 and 1993.

1995

100 MBPS: So-called Fast Ethernet introduced. Introduction of auto-negotiation, enabling two connected devices to transmit data through shared communication parameters, such as speed and duplex mode.

1998

1 GBPS: 1 Gbps over fiber optic cable makes its debut; the IEEE approves 1 Gbps over twisted pair one year later.

2002

10 GBPS: Ethernet hits the 10 Gbps milestone for fiber transmission; twinaxial support comes two years later while 10 Gbps over unshielded twisted pair becomes a reality in 2006.

2010

40/100 GBPS: Based on meshing multiple lanes of 10 Gbps technology to create higher speeds, the 802.3a standard supports transmission over multiple physical layer specifications.

2016

2.5 GBPS, 5 GBPS, 25 GBPS: The next step in the evolution of Ethernet, 25 Gbps, is slated to be ratified in fall 2016. It's aimed at data centers, enabling single-lane 25 Gbps throughput via multimode optical fiber, twinaxial cable or printed circuit backplanes. Meanwhile, 2.5 and 5 Gbps Ethernet is engineered to run over Cat 5e and Cat 6 twisted pair cables and serve as a stepping stone for enterprises migrating to higher-speed wireless technologies.

2017

400 GBPS: Since the first meeting of the 400 GbE Task Force in May 2014, network architects have anticipated the new standard, expected to be released in late 2017. The next evolution of Ethernet, based on 50 Gbps single lanes grouped together, will serve the fast-growing data center interconnection and cloud market.

2018-2020

50 GBPS, 200 GBPS: Also based on 50 Gbps single lanes; 50 GbE is tailored for storage networking, replacing current 40 GbE conduits.

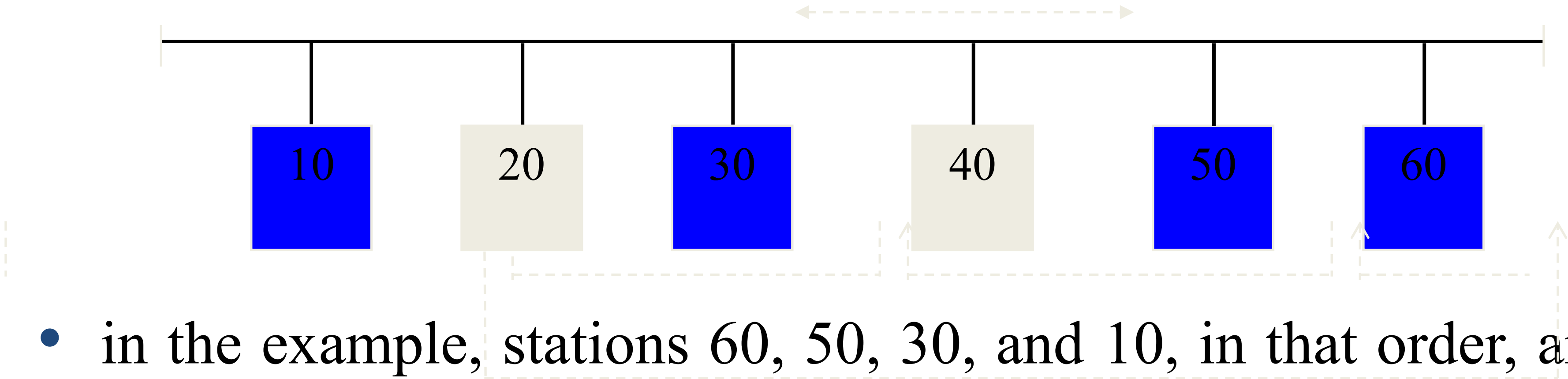
2020 and beyond

800 GBPS, 1 TBPS, 1.6 TBPS, 6.4 TBPS, 10 TBPS: Terabit speeds will depend on the development of single lanes that can be modulated at 100 Gbps. These lanes, grouped together, will serve as a foundation for multiterabit throughput, but require significant investment before they are economically viable.

COMPILED BY EAMON EARLS; DESIGN BY LINDA KOURY

Token Bus (IEEE 802.4)

- proposed by ***General Motors***
- the stations on the bus form a logical ring,
  - i.e., the stations are assigned logical positions in an ordered sequence, with the last member followed by the first
- the physical ordering of the stations on the bus is irrelevant and independent of the logical ordering;
- it has ring logical topology and bus physical topology
- it uses ***token passing*** medium access control protocol



- in the example, stations 60, 50, 30, and 10, in that order, are part of the logical ring
  - station 60 passes the token to 50, which in turn passes it to 30, then to 10, then back to 60;
  - stations 20 and 40 are not part of the logical ring
- each participating station knows the address of its predecessor and successor
- the logical ring is created and maintained dynamically in such a way that the stations are logically ordered in numerically descending order of MAC address,
  - except that the station with the lowest address is followed by the station with the highest address

- the token bus system requires considerable maintenance;
- one or more stations must perform the following functions, at minimum:
  - **addition to the ring**:
    - periodically non-participating stations must be granted the opportunity to join the logical ring
  - **deletion from the ring**:
    - a station can remove itself from the logical ring
  - **ring initialization**:
    - when the network is started, some procedure is needed to sort out who goes first, who goes second, and so on
  - **token recovery**:
    - if the token is lost due to a transmission error or station failure, some means of recovery is needed
- nobody uses it ☺

Token Ring (IEEE 802.5)

- introduced by **IBM** in early 1980's
- has ring logical topology;
- the physical topology can be **ring** or **star**
- it uses **token passing** medium access control protocol
- Only a host that holds a token can send data, and tokens are released when receipt of the data is confirmed.
- Token ring networks prevent data packets from colliding on a network segment.
- The IEEE standard version provides for data transfer rates of 4, 16 or 100 Mbps.

- was once widely used on LANs, but has been nearly entirely displaced by Ethernet thanks to pricing.
  - token ring products tended to be more expensive than Ethernet at similar speeds
- still in use at some IBM sites; but virtually nowhere else

- **Ethernet Vs. Token Ring**

Ethernet	Token Ring
Access is non-deterministic (contention-based CSMA/CD)	Access is deterministic
Supports a direct-cable connection between two NICs	Doesn’t support direct cable connection. Requires additional software and hardware
Alleviates collision by CSMA and by the use of an intelligent switch	Eliminates collision by the use of a single-use token and early token release to alleviate the down time
Less expensive	More expensive

References

1. https://searchnetworking.techtarget.com/definition/Token-Ring
2. https://searchnetworking.techtarget.com/definition/Ethernet
3. https://en.wikipedia.org/wiki/Token_ring