Helsinki University of Technology
S-72.333 Postgraduate Seminar on Radio Communications

Multiple Access Methods

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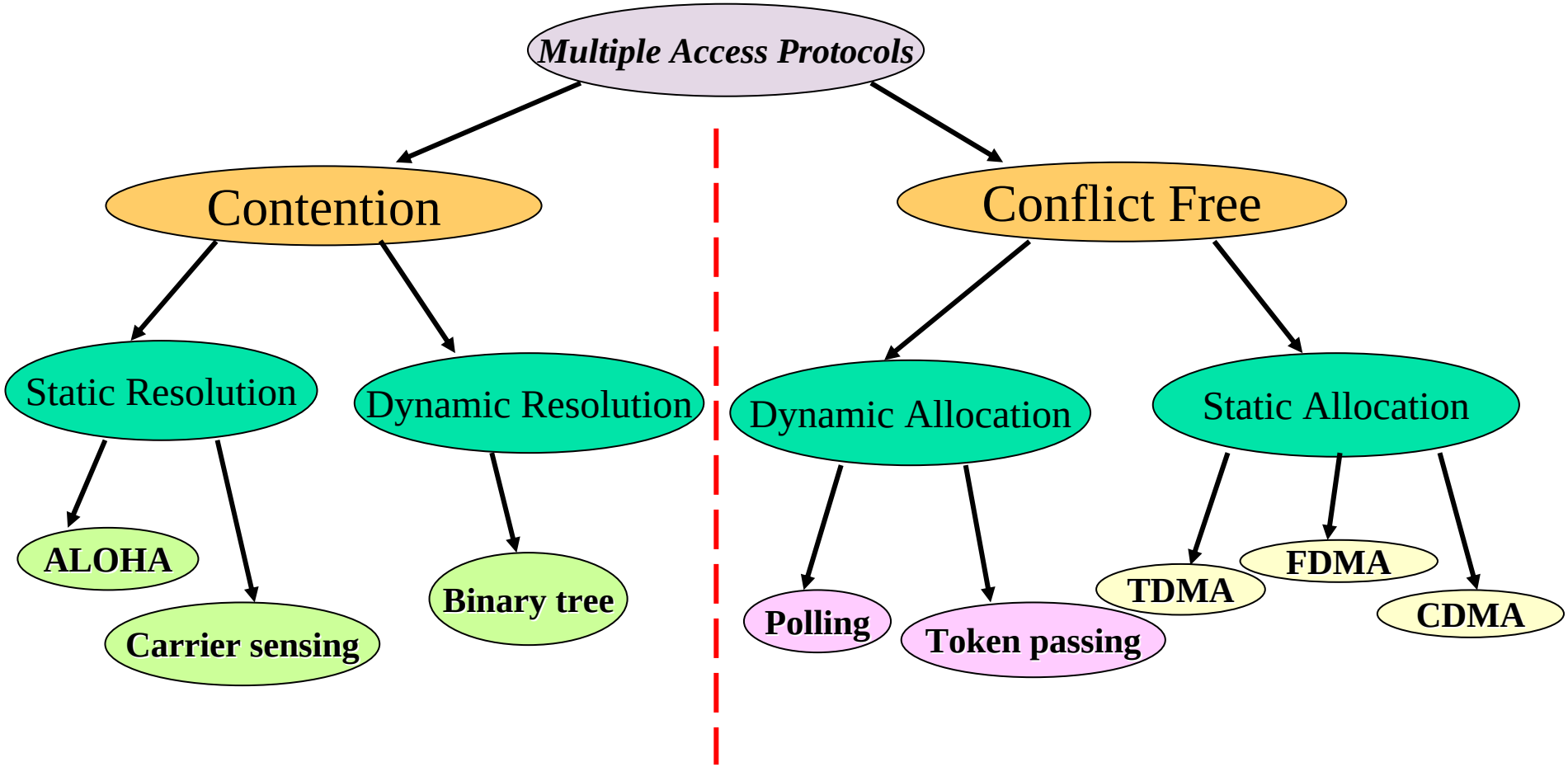
Content of presentation

- **Protocol Classification**
- **Conflict-Free Access Protocols**
  - Static Allocation
    - TDMA
    - FDMA
    - CDMA
  - Dynamic Allocation
    - Polling
    - Token passing
- **Contention Access Protocol**
  - Static Resolution
    - Aloha
    - Carrier sensing protocols
  - Dynamic Resolution
    - Binary Tree

Protocol Classification



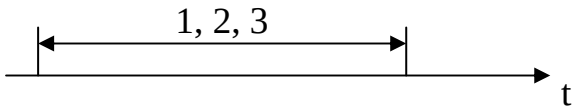
Conflict-Free Access Protocols

- Static Allocation = Fixed Assignment:
  - *I.e. fixed allocated channel resource*
  - *Resource can be frequency, or time, or both*
  - *Predetermined basis to a single user*
- Basic access methods:
  - *FDMA – Frequency-Division Multiple Access*
  - *TDMA – Time-division Multiple Access*
  - *CDMA – Code-Division Multiple access*
- Some other formats:
  - *Combination of the basic access methods*
  - *Implemented with various multi-user access algorithm*

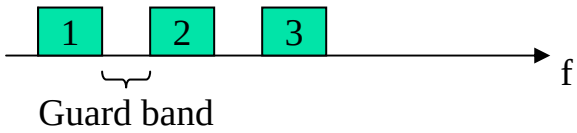
Frequency-Division Multiple Access

- Built upon *Frequency-division multiplexing* scheme
- It is the simplest and oldest form of multiplexing
- A fixed subchannel is assigned to a user terminal and is retained until released by the user
- At receiver, the user terminal filters the designated channel out if the composite signal

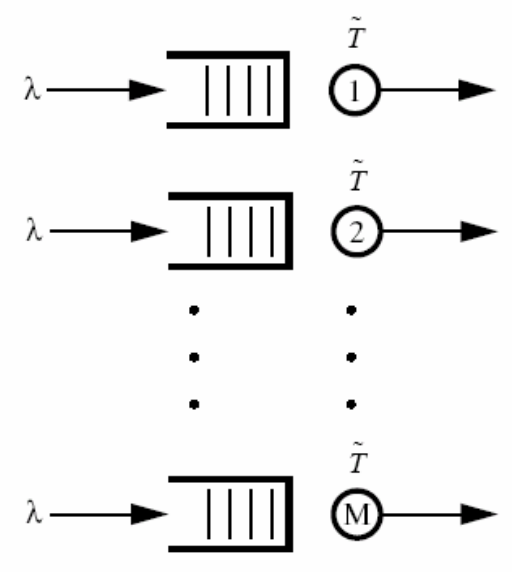
- Currently used in
  - Cellular mobile telephone
  - VHF & UHF land-mobile radio system
  - Satellite networks



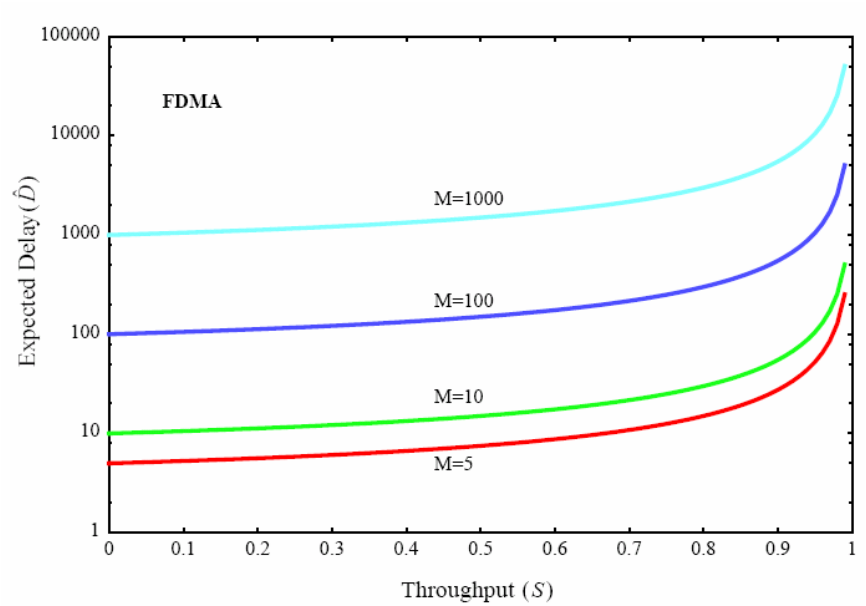
- Characteristics:
  - Efficient when information is steady flow
  - Inefficient when data are sporadic



FDMA Performance



- System model:
  - *M independent queues*
  - *M/G/1 queueing system*

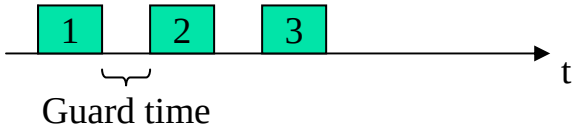


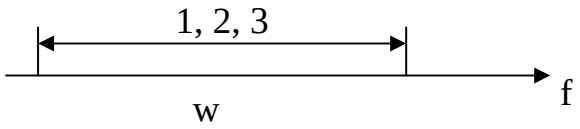
- Throughput-Delay

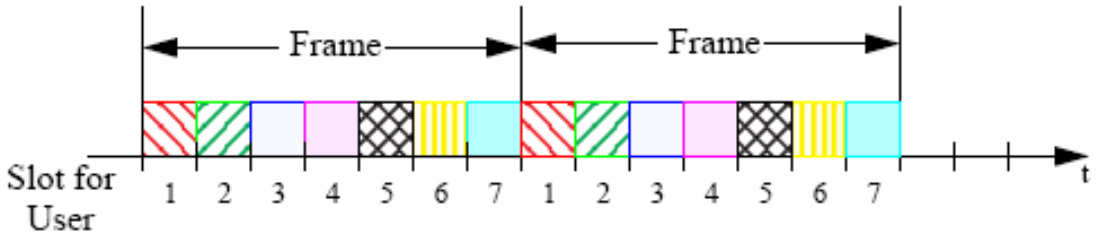
$$\hat{D} = \frac{D}{P/R} = \left[1 + \frac{S}{2(1-S)}\right]M = M\frac{2-S}{2(1-S)} = \frac{M}{2}\left(1 + \frac{1}{1-S}\right)$$

Time-Division Multiple Access

- Built upon *Time-division multiplexing* transmission format
- Deterministic allocation of time interval – *time-slots*
- Time slots are organized into frames
  - *T1 channel : 1.544 Mbits/s*
  - *Multiplexing 24 PCM encoded voice channel*
  - *Each channel is 64 kbits/s*
    - *Each channel sampled at an 8-kHz rate*
    - *Each sample is encoded into 8 bits*
- Used in new digital cellular network
  - *Europe (GSM)*
  - *Japan (JDC)*
  - *America (IS-54)*



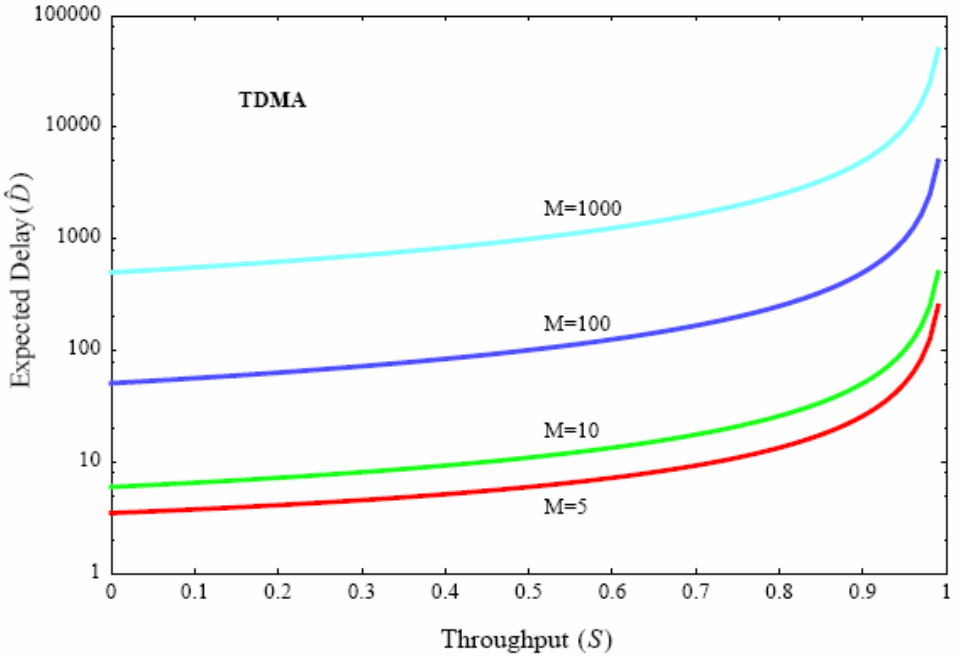




TDMA Performance

- System model:
  - *M independent queues*
  - *M/D/1 queueing system*
- Throughput-Delay

$$\hat{D} = \frac{D}{T} = 1 + \frac{M}{2(1-S)}$$

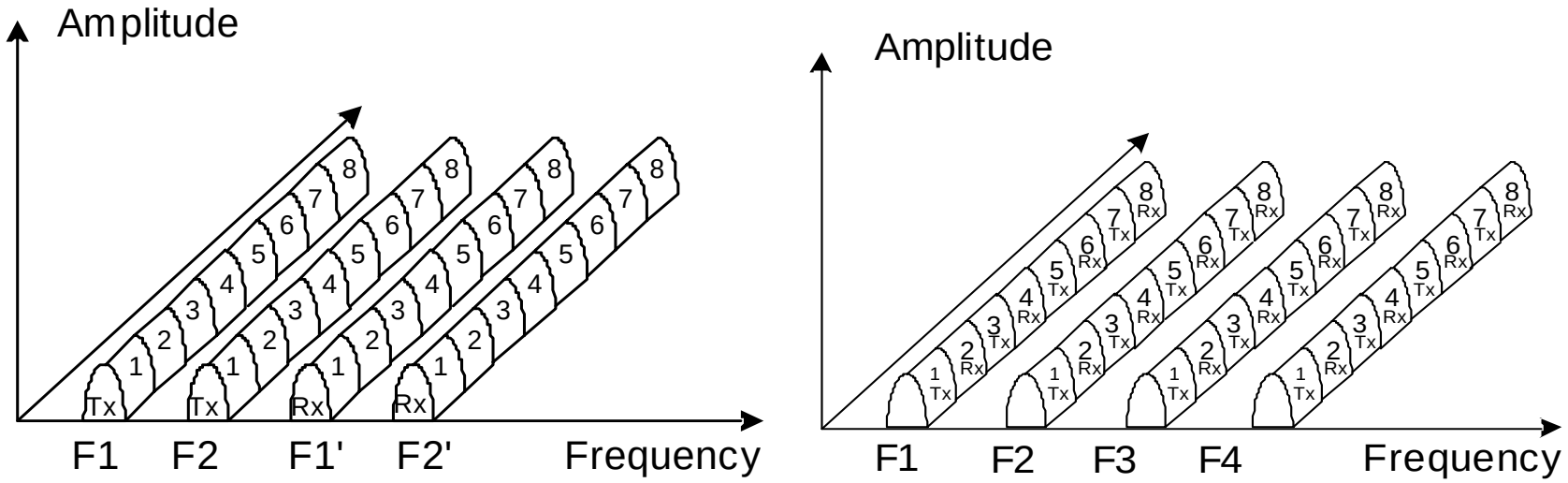


- Comparison between FDMA and CDMA

$$D_{FDMA} = D_{TDMA} + \frac{P}{R}\left[\frac{M}{2} - 1\right] \geq D_{TDMA}.$$

Hybrid of TDMA and FDMA

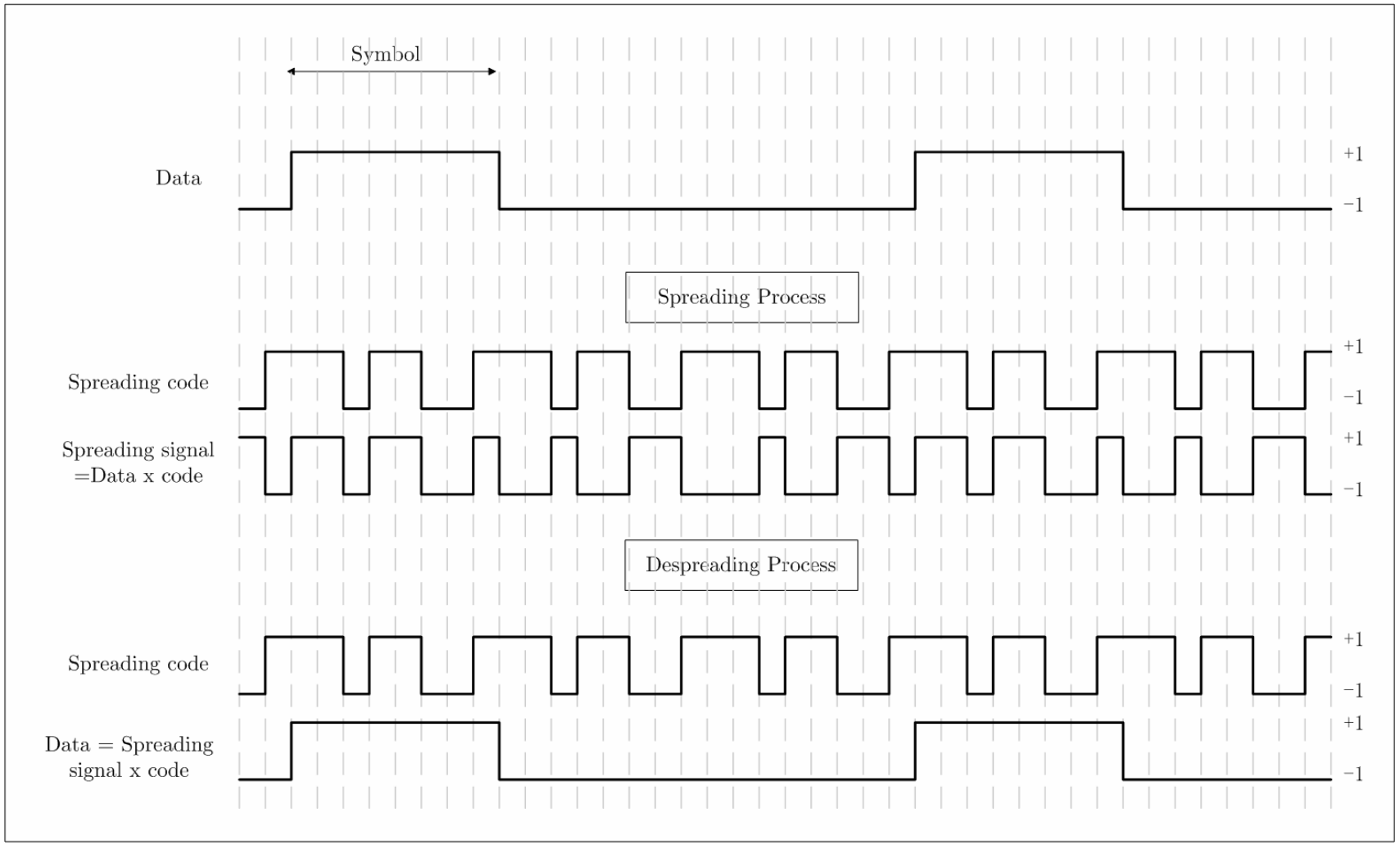
- TDMA and FDMA can be implemented together to get optimized function and performance
- For example
  - *TDMA/FDMA*
  - *TDMA/TDD/FDMA*



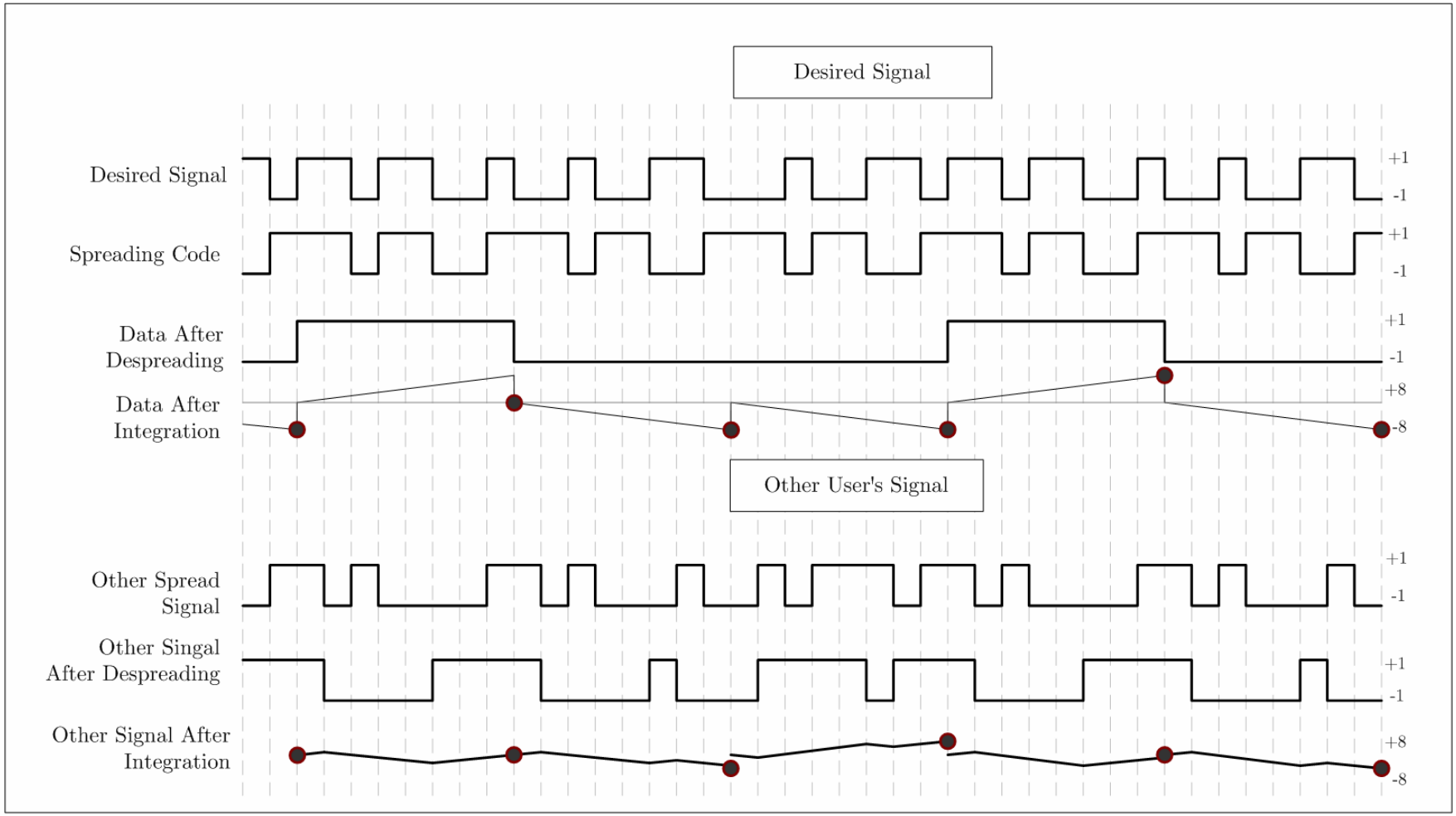
Code-Division Multiple Access

- Hybrids combination of FDMA and TDMA
- Characteristics
  - Multiple users
  - Simultaneously operating
  - Entire bandwidth of time-frequency domain
  - Separated by distinct user-signal codes (Spread spectrum)
- Two common CDMA
  - Direct sequence (DS) CDMA
  - Frequency Hopping (FH) CDMA
- Spreading code
  - ML (Maximum length) code
  - Gold code
  - Walsh-Hadamard code

CDMA --- Spreading



CDMA --- De-spreading

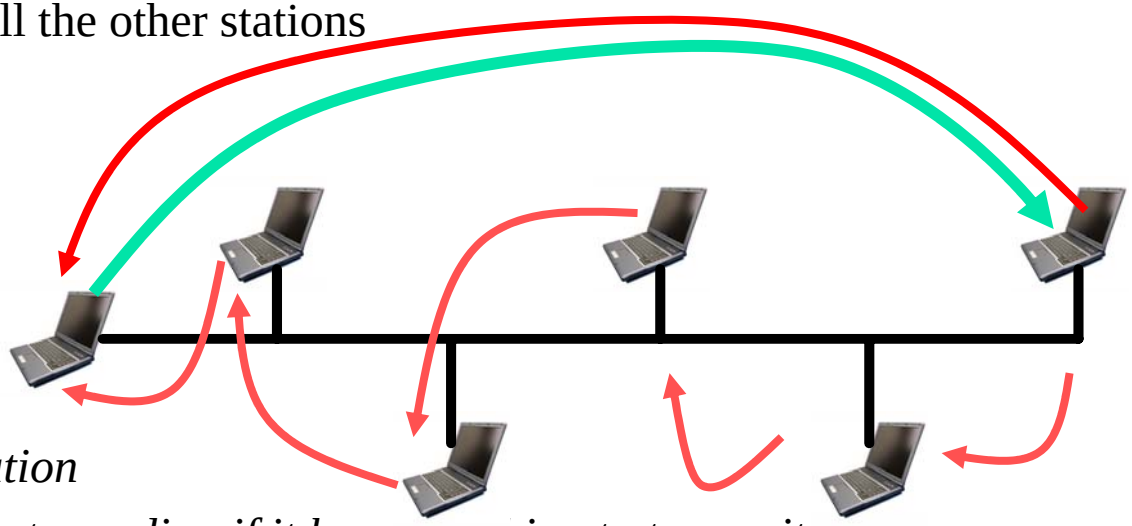


Dynamic Allocation Protocols

- Dynamic Allocation = On demand
- Realized via reservation schemes
- Basic access methods:
  - Polling
  - Token passing
- Others
  - MSAP
    - *MiniSlotted Alternative Priority*
  - BRAM
    - *Broadcast Recognition Access Method*

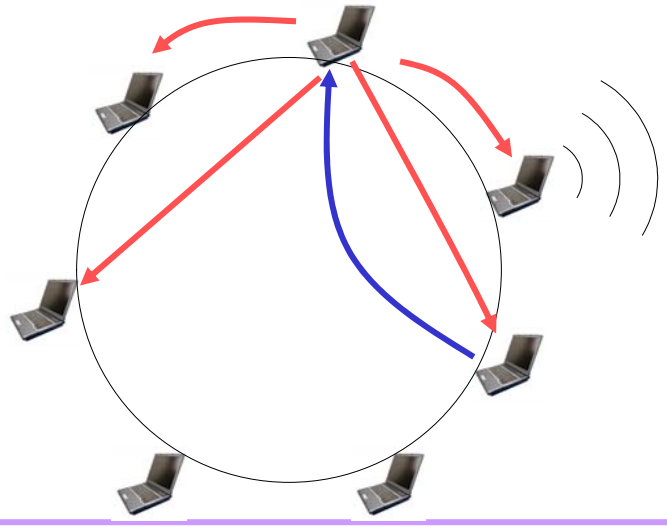
Polling Techniques (1)

- Centralized control
  - One station is equipped as a controller
  - Periodically polling all the other stations
- Classification
  - Hub polling
  - Roll polling
- Polling procedure
  - Hub polling
    - *From furthest station*
    - *Polled station starts sending if it has something to transmit*
    - *If not, a negative response is detected by the controller*
    - *The polled station transmits the poll mesage to its neighbor in upstream (control)*
    - *Control message finally is regained by the controller*



Polling Techniques (2)

- Roll polling
  - *Controller keeps a polling list, giving the order in which the terminals are polled*
  - *Polled station starts sending if it has something to transmit*
  - *If not, a negitve reply is detected by the controller*
  - *Controller then polls the next terminals in the sequence*
  - *Initial exchange of short messages required(between a station and the controler)*



Charactertistics and performance

- Polling protocols are efficient in systems
  - Propagtion delay is small
  - Overhead is low
  - Number of stations shouldn’t be large (proportional to overhead)
- Polling protocols are inefficient
  - Lightly loaded
  - Part of stations have data to transmit
  - Subdivide stations into subsets (variations)
- Hub polling overhead is much smaller than that of roll polling
- Applications:
  - Widely used in dedicated telephone networks for data communications
  - Generally not been adopted in existing mobile data network or WLAN

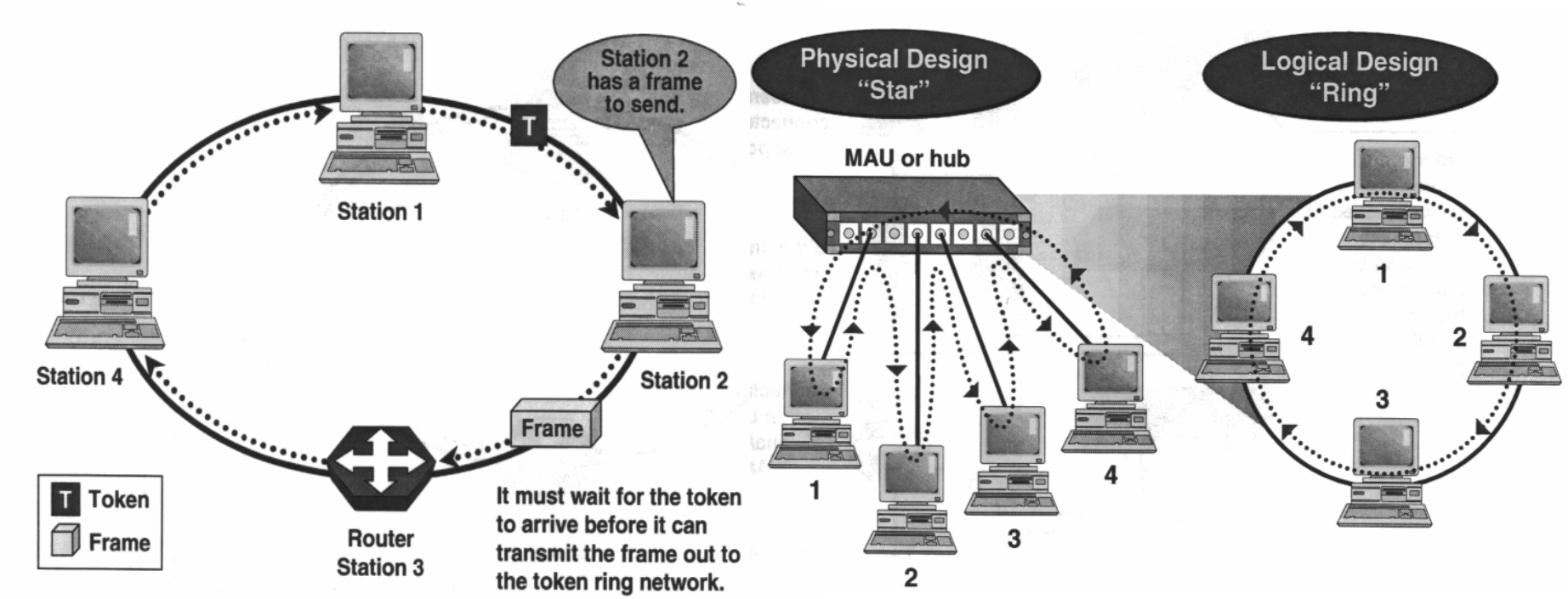
Token Passing Protocol (1)

- Two logical topologies
  - Bus
  - Ring
- Token ring is originally developed by IBM, specified in IEEE 802.5
- Token ring protocol operation
  - Networks move a small frame, called a token, around the network
  - Possession of the token grants the right to transmit.
  - If the node, receiving the token, has no information to send, it passes the token to the next station.
  - If the node, possessing the token does have information to transmit
    - *Seize the token*
    - *Alter 1 bit of the token*
    - *Append the information to be transmitted, and send to the next station in the ring*
  - The intended destination station flips the recognized address and frame-copied bits in frame status field in the frame, and sends the modified frame back out to the ring

Token Passing Protocol (2)

- When information reaches the sending station again, it examines and removed the frame from the ring
- The source station then transmits a new token

- Phycally ”star” topology, logically ”ring” topology



Token Ring Characteristics

- Token passing netowrks are deterministic, so the maximum propagation time is possibly calculated, more predictable than Ethernet
- Priority schemes can be deployed to improve the efficiency
  - User-designated, high priority station can use network more frequently
  - $Priority_{Station} >= Priority_{token}$ can capture the token
- Several mechanisms for detecting and compensating for network fault
  - One station is selected as *active monitor*
  - It provides centralized source of timing information for other stations
  - Ring-maintenance function
    - Removal of continously circlating frames
    - Generation of the new token
- No collisions occur, contention-free!

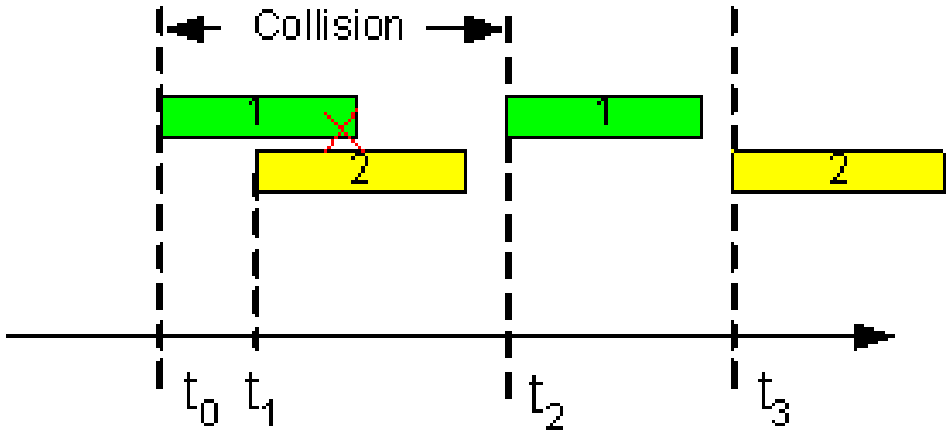
Contention Protocols

- No guarantee to be successful
  - Large users ->Contention-free schemes are impractical
  - Resolution schemes are needed
- Static resolution
  - Protocol actual behavior is not influenced by the dynamics of the system
  - Examples:
    - *Aloha family*
    - *CSMA family*
- Dynamic resolution
  - Tracking and taking the advantage of the system changes
  - Example:
    - *Binary-Tree CRP (collision Resolution Protocol)*

Pure Aloha

- It is the simplest contention protocol
- Whenever packet needs transmission:
  - Send without waiting
  - If collision occurs, then wait for a random time and resend, until successful

$$S = Ge^{-2G}$$

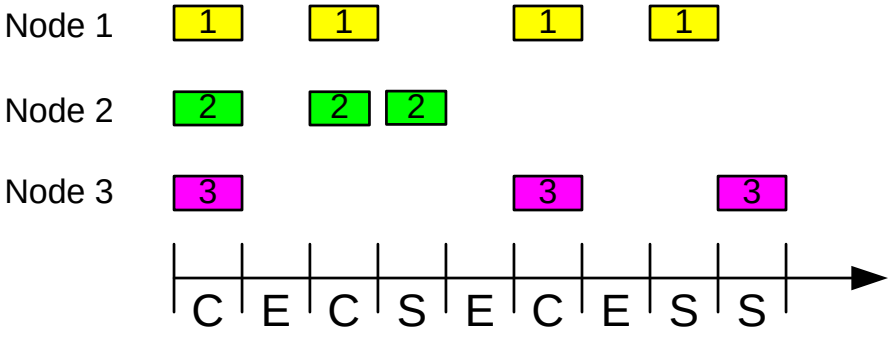


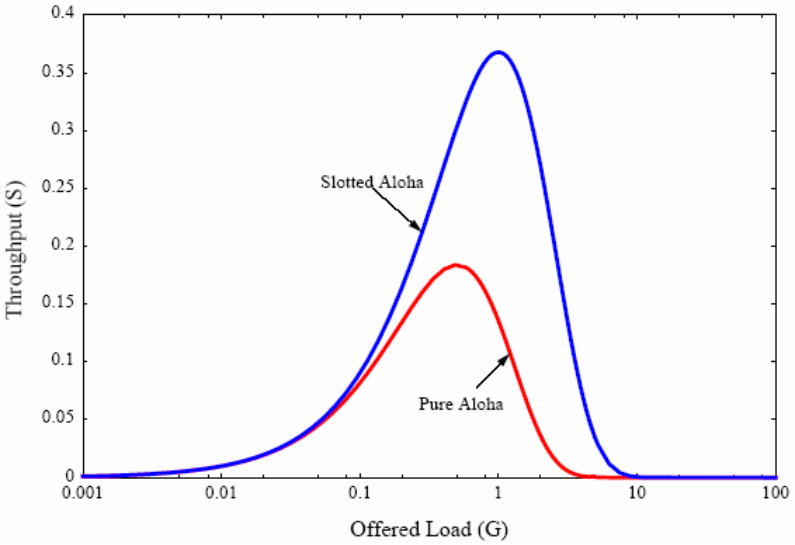
- Highly inefficient at large loads. Maximum utilization of 18% at a mean load of 0.5

Slotted Aloha

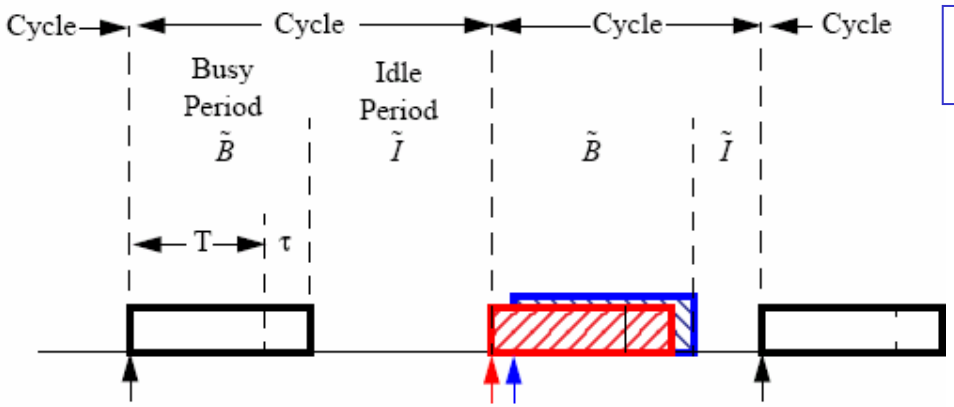
- Time is divided into equal size slots (= packet Tx time)
- Node with new arriving packet: transmit at beginning of next slot
- If collision: retransmit packet in future slots with probability *p*, until successful.
- Maximum utilization of 36% at a mean load of 1 transmission/slot

$$S = Ge^{-G}$$

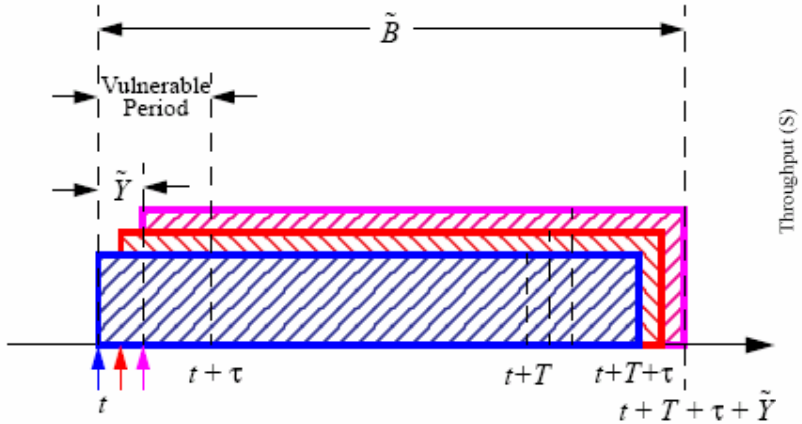




Nonpresistent (NP) CSMA



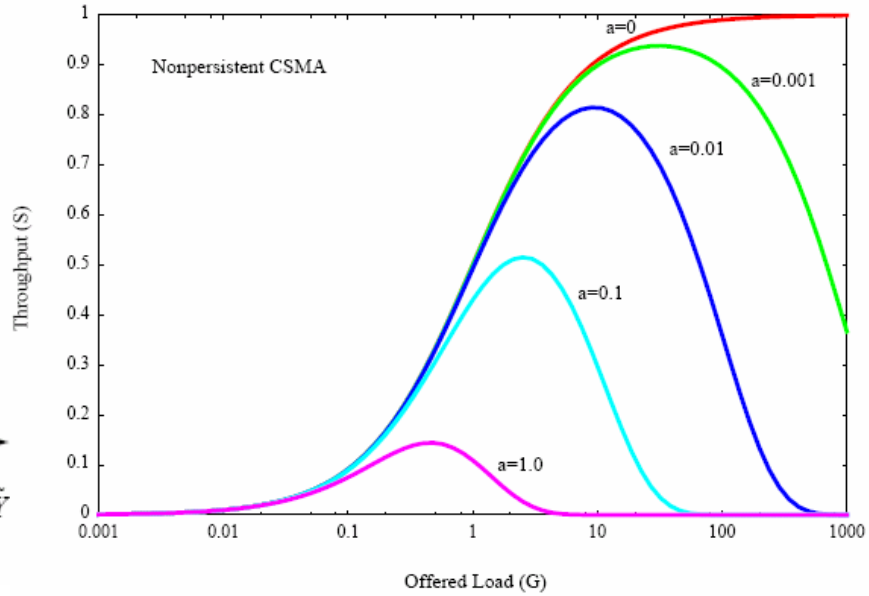
(a) Cycle Structure



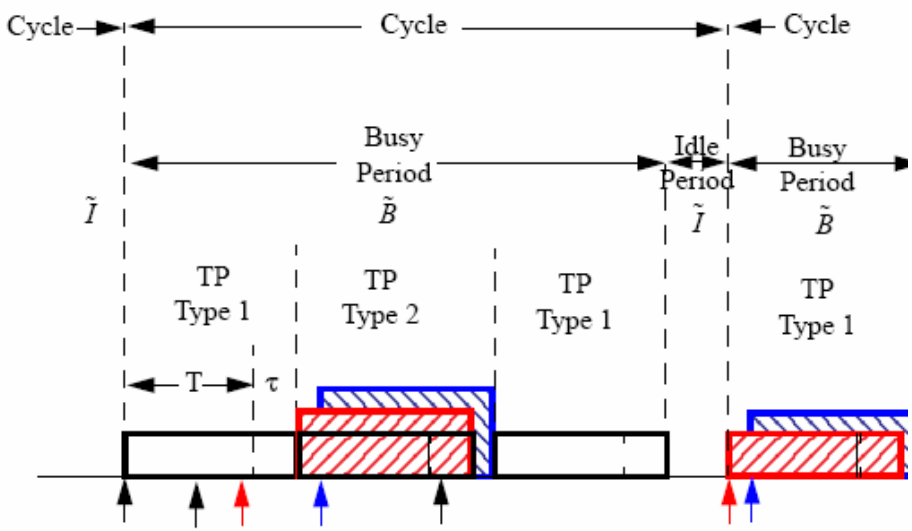
(b) Unsuccessful Transmission Period

Impolite -> ”listen before talk”

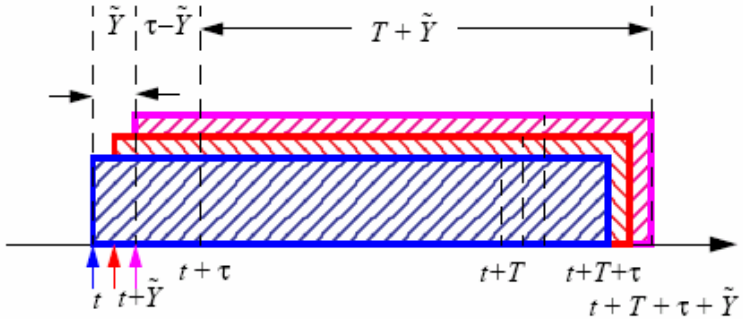
$$S = \frac{Ge^{-aG}}{G(1+2a)+e^{-aG}}.$$



1-persistent CSMA



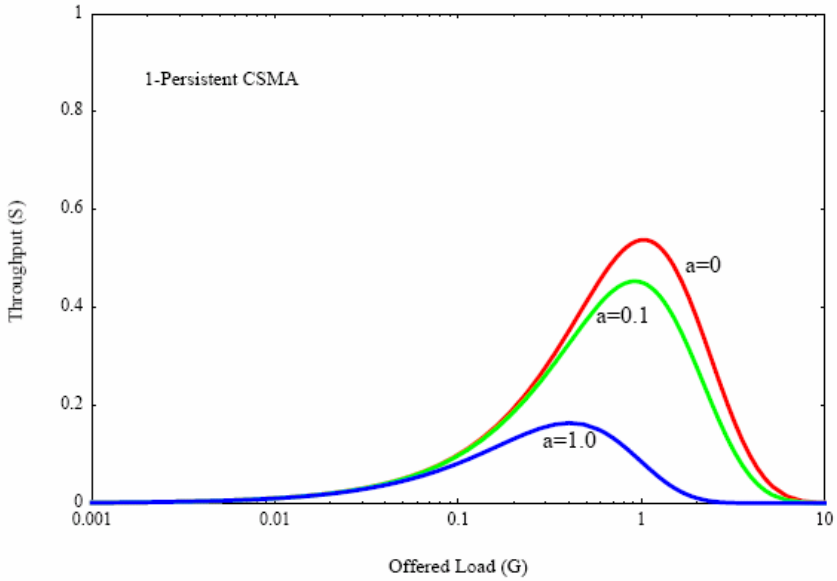
(a) Cycle Structure



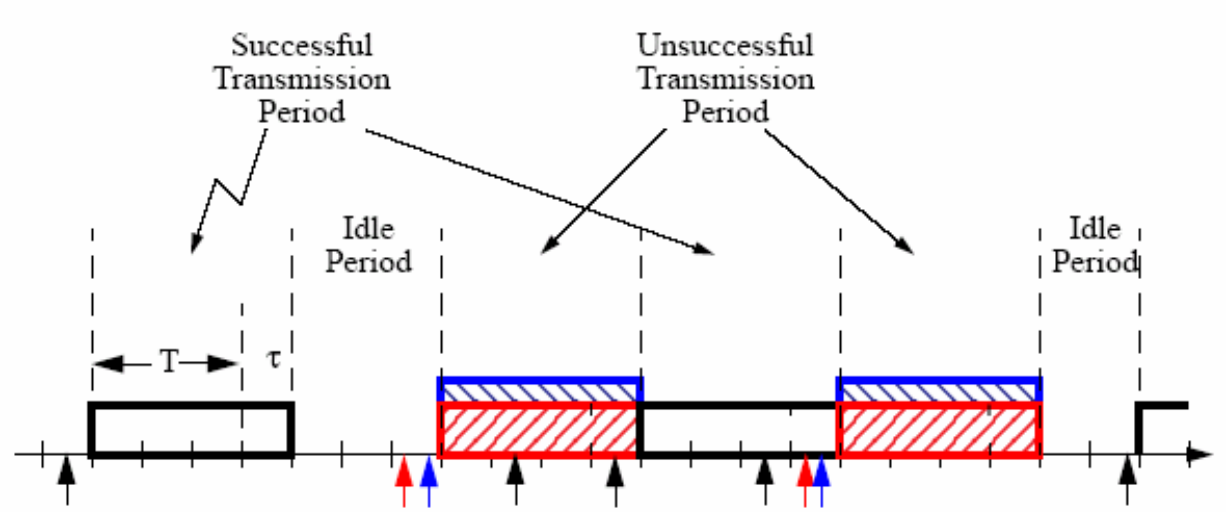
(b) Unsuccessful Transmission Period

Transmit as soon as when it detect the channel is idle

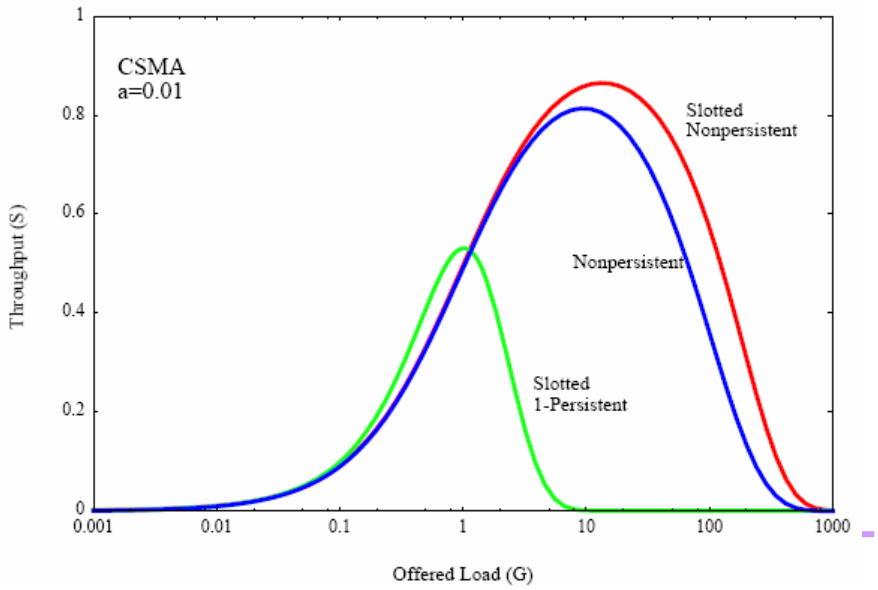
$$S = \frac{Ge^{-G(1+2a)}[1+G+aG(1+G+aG/2)]}{G(1+2a)-(1-e^{-Ga})+(1+Ga)e^{-G(1+a)}}$$



Slotted Carrier Sensing Protocols

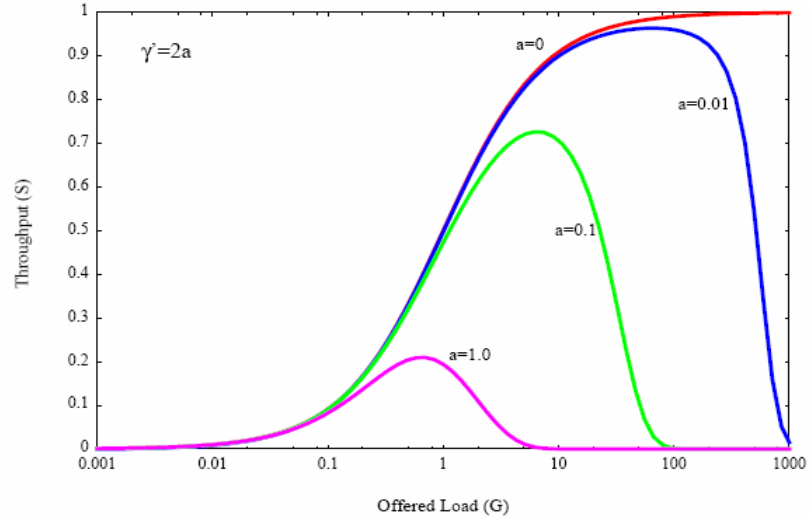


$$S = \frac{Ge^{-(1+a)G}[1 + a - e^{-aG}]}{(1+a)[1 - e^{-aG}] + ae^{-(1+a)G}}$$

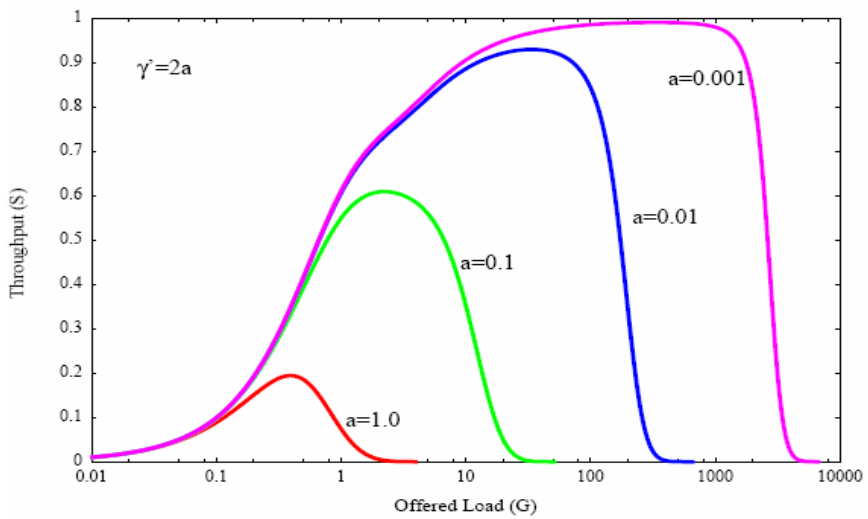


CSMA/CD

- Carrier sense multiple access with collision detection
- Same as CSMA except a collision is detected
  - Ternimate transmission immediately
- Time slot and non/1-persistent concepts can also be applied



Slotted nonpersistent CSMA/CD

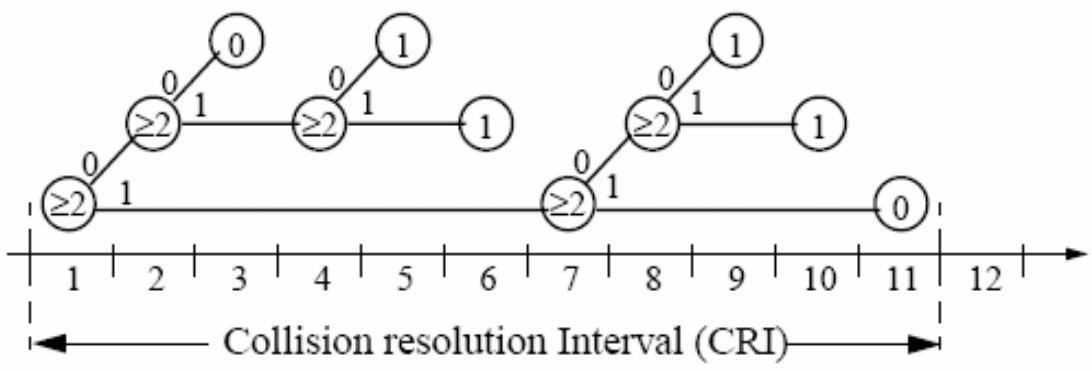


Slotted 1-persistent CSMA/CD

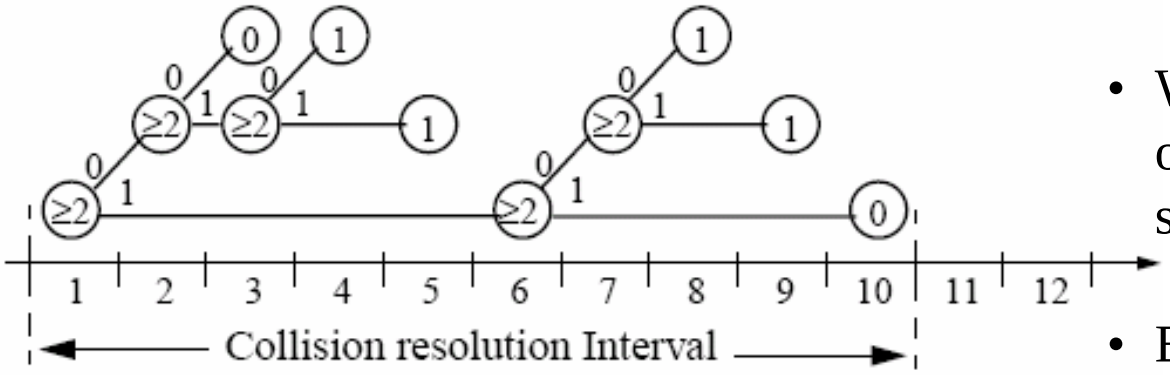
Collision Resolution Protocol (CRP)

- Concentrate on Resolving Collisions as soon as they occurs
- Exploit feedback information to control the retransmission
- System model:
  - Similar to slotted Aloha
- Typical protocol:
  - Binary-Tree CRP

Binary-Tree Protocol (CRP)



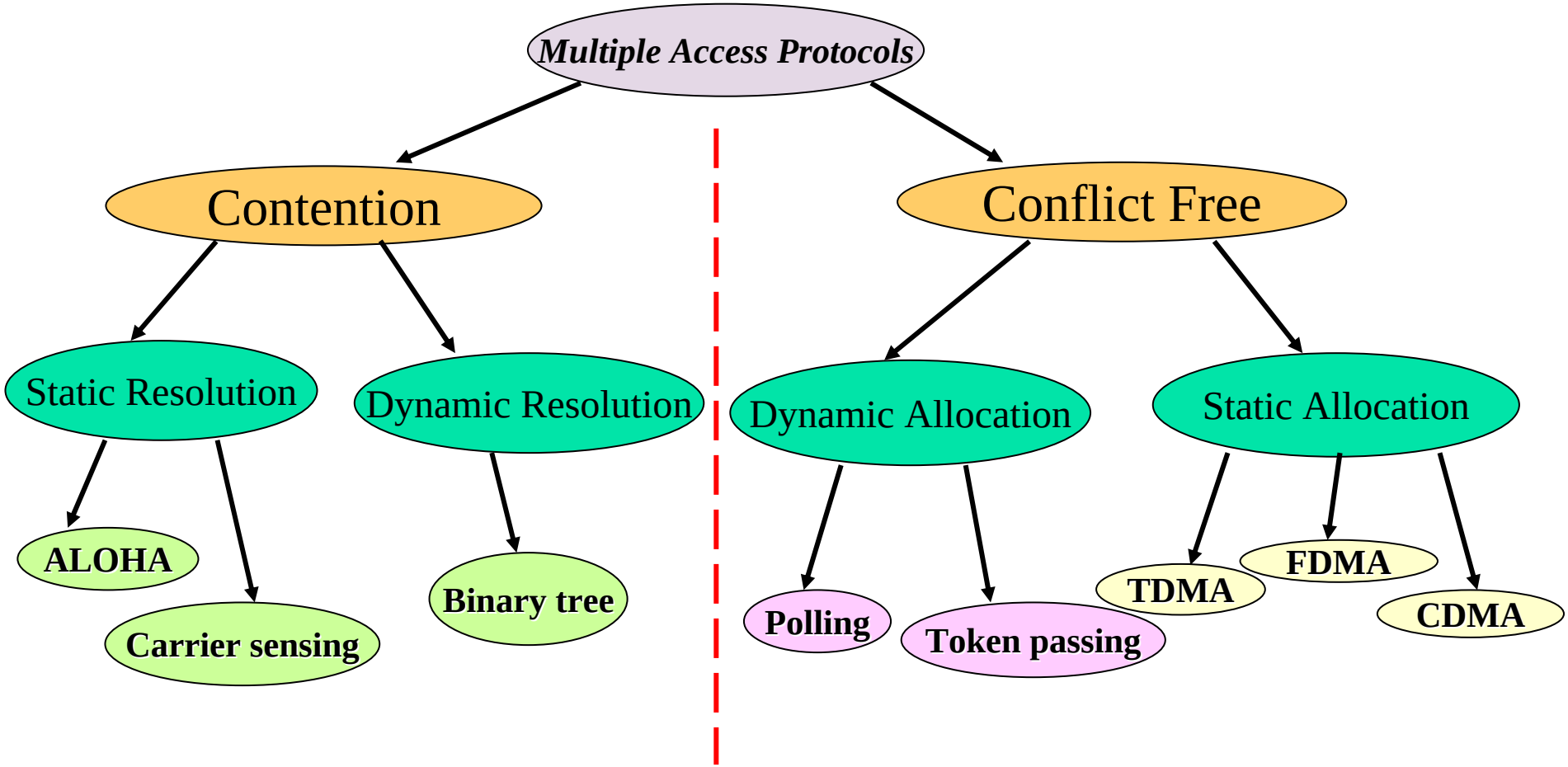
Binary-Tree CRP



Enhanced Binary-Tree CRP

- When collision occurs, the users are divided in two subsets
- Divided method can be like flipping coin
- One subset should wait until the other set has finished transmission
- Within one subset, if collision occurs again, performace in the similar way again
- Enhanced method: ”flipping beforehand”

Conclusion


Multiple Access Protocols
Contention
Conflict Free
Static Resolution
Dynamic Resolution
Dynamic Allocation
Static Allocation
ALOHA
Carrier sensing
Binary tree
Polling
Token passing
TDMA
FDMA
CDMA

Reference

[1] Raphael Rom, Moshe Sidi, " Multiple Access protocols: Performance and Analysis"

www-comnet.technion.ac.il/rom/PDF/MAP.pdf

[2] Simon Haykin, Michael Moher, "Modern Wireless Communications" ISBN 0-13-124697-6, Prentice Hall 2005

Homework

- Please explain what is bit-map protocol? What's the advantage and disadvange of this protocol?

- What is FDDI, how it works. Please give a brief description on its MAC protocol structure and operation.

Any questions?

Thanks!