Lecture 21: Link Layer II

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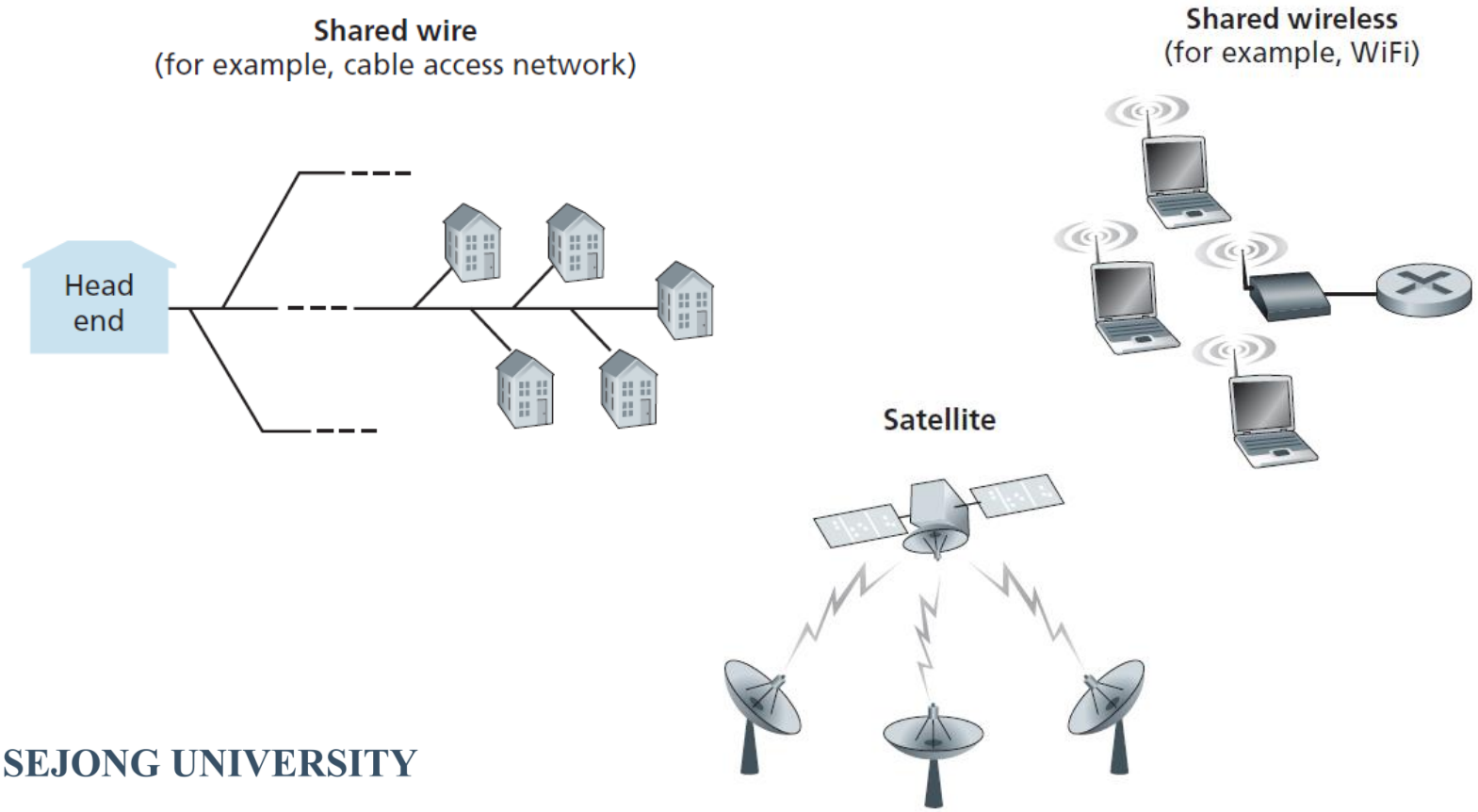
Multiple Access Links and Protocols

- **Multiple access protocol**
  - A protocol by which nodes regulate their transmission into the shared broadcast channel

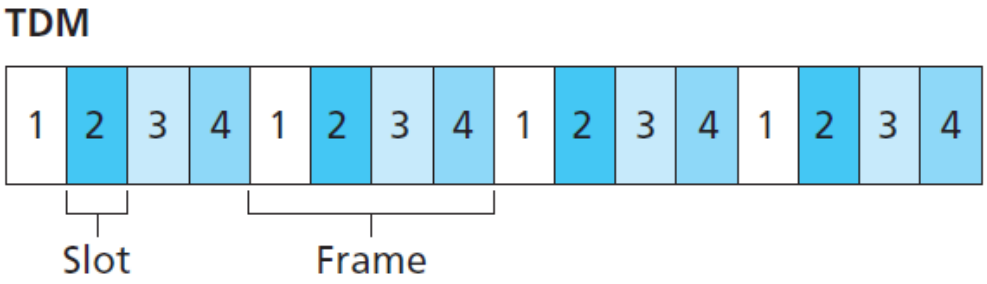


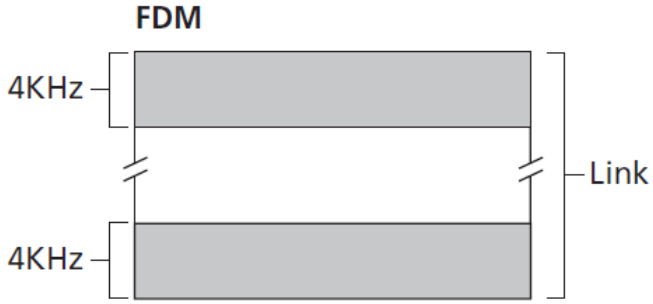
Multiple Access Links and Protocols

- **Classification of multiple access protocols**
  - Channel partitioning protocols
  - Random access protocols
  - Taking-turns protocols

Channel Partitioning Protocols

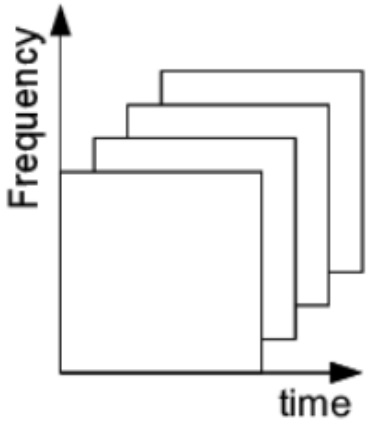
- **Time-division multiplexing (TDM)**
  - TDM divides time into multiple time slots, each of which is assigned to a sender-receiver pair.
- **Frequency-division multiplexing (FDM)**
  - FDM divides frequency into multiple frequencies, each of which is assigned to a sender-receiver pair.





Channel Partitioning Protocols

- **Code division multiple access (CDMA)**
  - CDMA assigns a different code to each sender-receiver pair.



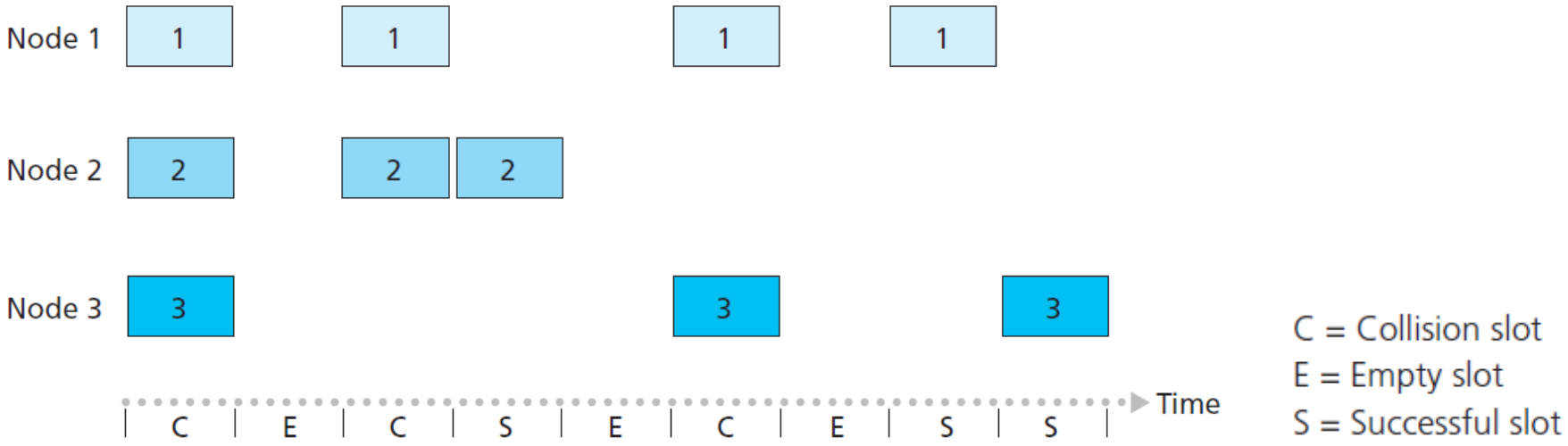
CDMA

- **Drawback of the channel partitioning protocols**
  - A node is limited to an average rate of R/N bps even when it is the only node with packets to send
    - R is the data rate of the channel and N is the number of partitions.

Random Access Protocols

Slotted ALOHA

- Nodes start to transmit frames only at the beginnings of slots.
- Assume that each node transmits a frame in each slot with probability *p*.



Random Access Protocols

Efficiency of the slotted ALOHA

- Assume that there are N nodes.
- The probability a given node has a success is

$$p(1-p)^{N-1}$$

- The efficiency of slotted ALOHA

$$Np(1-p)^{N-1}$$

- The maximum efficiency for N nodes

$$Np^*(1-p^*)^{N-1} \qquad p^* = \arg\max_p Np(1-p)^{N-1}$$

- The maximum efficiency as N approaches infinity

$$\lim_{N\to\infty} Np^*(1-p^*)^{N-1} = \frac{1}{e} \approx 0.37$$

Random Access Protocols

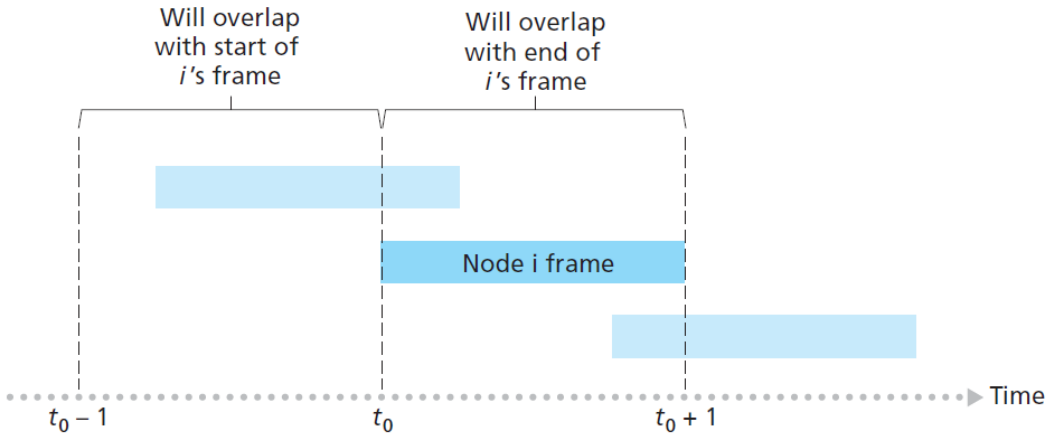
Pure (or unslotted) ALOHA

- The probability that all other nodes do not begin a transmission in the interval $[t_0\text{-}1, t_0]$: $(1-p)^{N-1}$
- The probability that all other nodes do not begin a transmission in the interval $[t_0, t_0+1]$: $(1-p)^{N-1}$
- The probability that a given node has a successful transmission

$$p(1-p)^{2(N-1)}$$

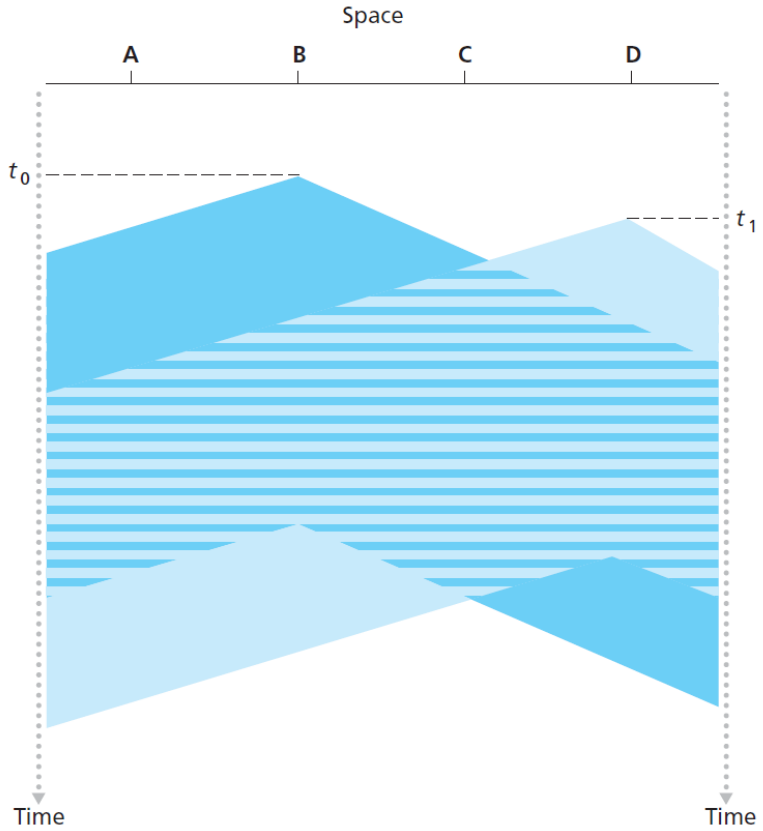
- The maximum efficiency

$$\frac{1}{2e}$$



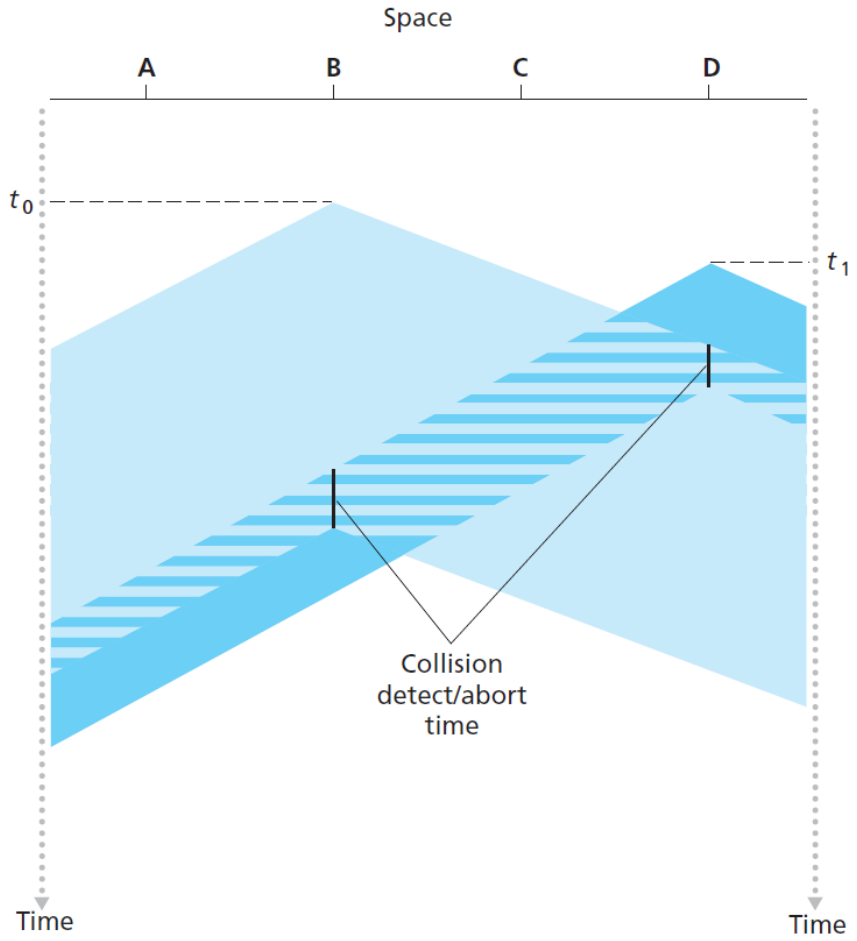
Random Access Protocols

- **Carrier sense multiple access (CSMA)**
  - Listen before talk
    - Before transmitting, each node performs the carrier sensing, i.e., determining whether another nodes are transmitting or not
  - Collision



Random Access Protocols

- **Collision detection**



Random Access Protocols

- **CSMA with collision detection (CSMA/CD)**
  - A node ceases transmission as soon as it detects a collision.
  - If a node detects signal energy from other nodes while transmitting, it aborts the transmission.
  - After aborting, the node waits a random amount of time and then transmit the frame if the channel is idle.
- **Binary exponential backoff algorithm**
  - Used in Ethernet
  - When transmitting a frame that has already experienced *n* collisions, a node chooses the value of *K* at random from $\{0,1,2,\ldots,2^n-1\}$.

Random Access Protocols

Efficiency of the CSMA/CD

$$\text{Efficiency} = \frac{1}{1 + 5d_{\text{prop}} / d_{\text{trans}}}$$

- d_{prop} : The maximum time it takes signal energy to propagate between any two nodes
- d_{trans} : The time to transmit a maximum-size frame (e.g., 1.2 ms for a 10 Mbps Ethernet)

Taking-Turns Protocols

- **Polling protocol**
  - One of the nodes is designated as a *master* node.
  - The master node *polls* each of the nodes in a round-robin fashion.
  - Introduce a polling delay (the amount of time required to notify a node that it can transmit)
- **Token-passing protocol**
  - There is no master node.
  - A small, special-purpose frame known as a *token* is exchanged among the nodes in some fixed order.
  - If a node does have frames to transmit when it receives the token, it sends up to a maximum number of frames and then forwards the token to the next node.