Wireless Medium Access Control (MAC)

Wireless Networking

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Medium Access Control (MAC)

- Layer 2 in the layered architecture
- Determines when to transmit a packet to the channel
  - Dependent on the multiple access (MA) scheme
- Provides MAC-specific framing
  - Fragmentation, splitting into slots, ...
- Provides error control mechanism
  - How to detect the erroneous transmission
  - How to recover from the error if needed
    - ARQ, FEC, ...

Distributed vs. Centralized

- Distributed and contention-based
  - Typically, random access (see Token Passing)
  - Simple, robust to a single point failure
  - Good for bursty traffic in light load → possible lower delay
- Centralized and controlled
  - Controlled by an BS → well fit into cellular
  - More controllable → QoS support
  - Could be more efficient, esp., with many users in heavy load

Random Access MAC

- When node has packet to send
  - transmit without *a priori* coordination among nodes
  - two or more transmitting nodes -> "collision"
- Random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions
- Examples of random access MAC
  - Slotted ALOHA, ALOHA
  - CSMA, CSMA/CD, CSMA/CA

Slotted ALOHA

Assumptions

- all frames same size
- time is divided into equal size slots, time to transmit 1 frame
- nodes start to transmit frames only at beginning of slots
- nodes are synchronized
- collision is detected

Operation

- when node obtains fresh frame, it transmits in next slot
- no collision, node can send new frame in next slot
- if collision, node retransmits frame in each subsequent slot with prob. p until success

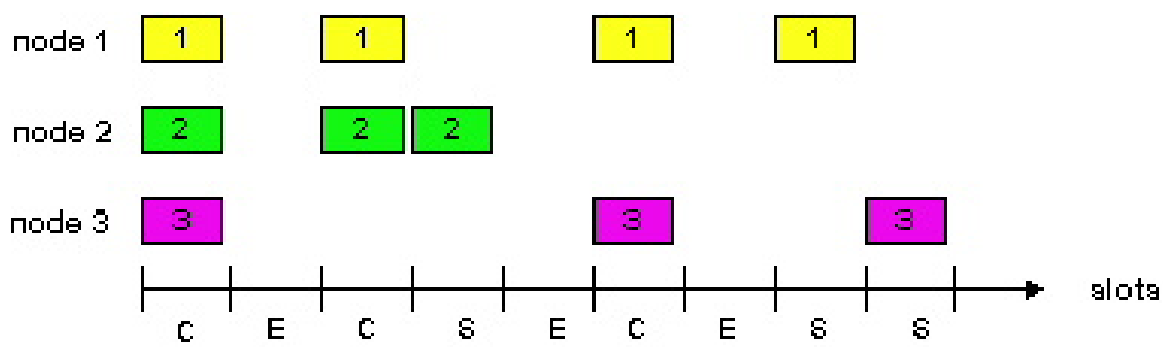
Slotted ALOHA

Pros

- single active node can continuously transmit at full rate of channel
- highly decentralized:
- simple

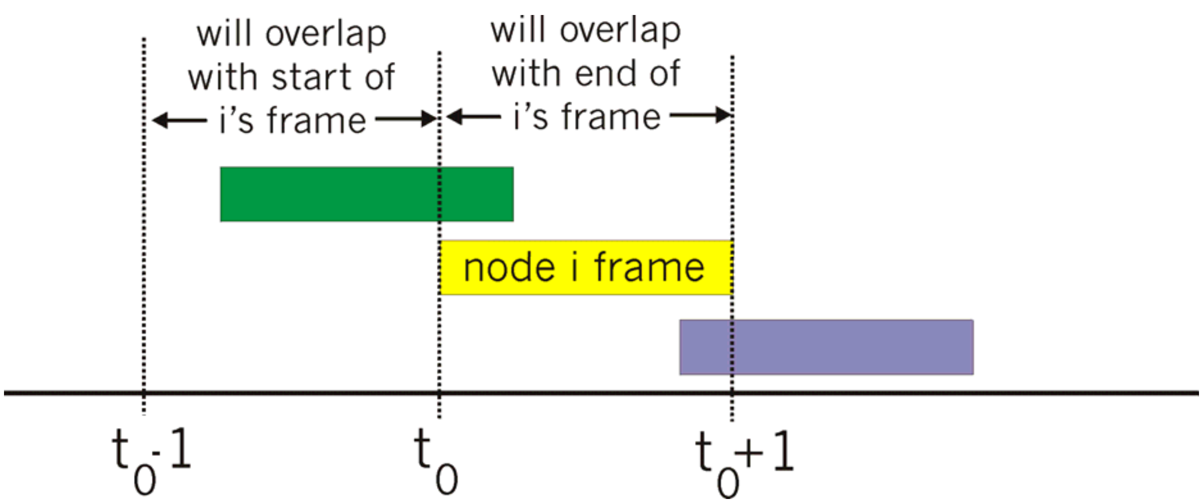
Cons

- collisions, wasting slots
- idle slots due to probabilistic retransmission



Pure (unslotted) ALOHA

- unslotted Aloha: simpler, no synchronization
- when frame first arrives
  - transmit immediately
- collision probability increases:
  - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$



Throughput of (slotted) ALOHA

- Throughput
  - Measures fracture of time channel is used
  - No power limitations
  - Doesn't measure true rate
- Assumptions
  - Normalize slot time to 1
  - Retransmission required for any packet overlap
  - Infinite number of nodes
  - Poisson packet arrivals at rate λ

Throughput of (slotted) ALOHA

- Slotted ALOHA
  - For randomized retransmissions, the sum of new and backlogged packet arrivals is Poisson with rate $G > \lambda$

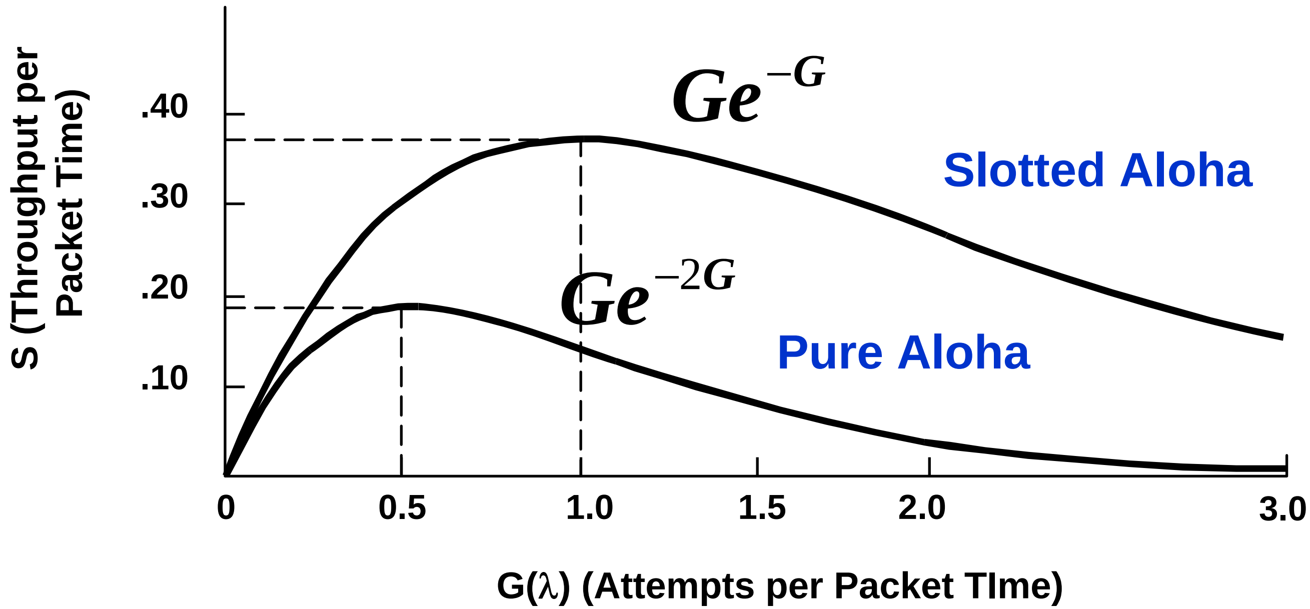
$$\text{Throughput} = Ge^{-G}$$

- Pure ALOHA

$$\text{Throughput} = Ge^{-2G}$$

Throughput Plot

- Slotted (Pure) ALOAH up to 37% (18%)
- Inefficient for heavily loaded systems



Comments

- Slotted ALOHA is often used as part of TDMA and CDMA for random access channel
  - To associate with the BS
  - To send a short message
- For pure distributed wireless systems, more efficient random access schemes are used as follows

CSMA (Carrier Sense Multiple Access)

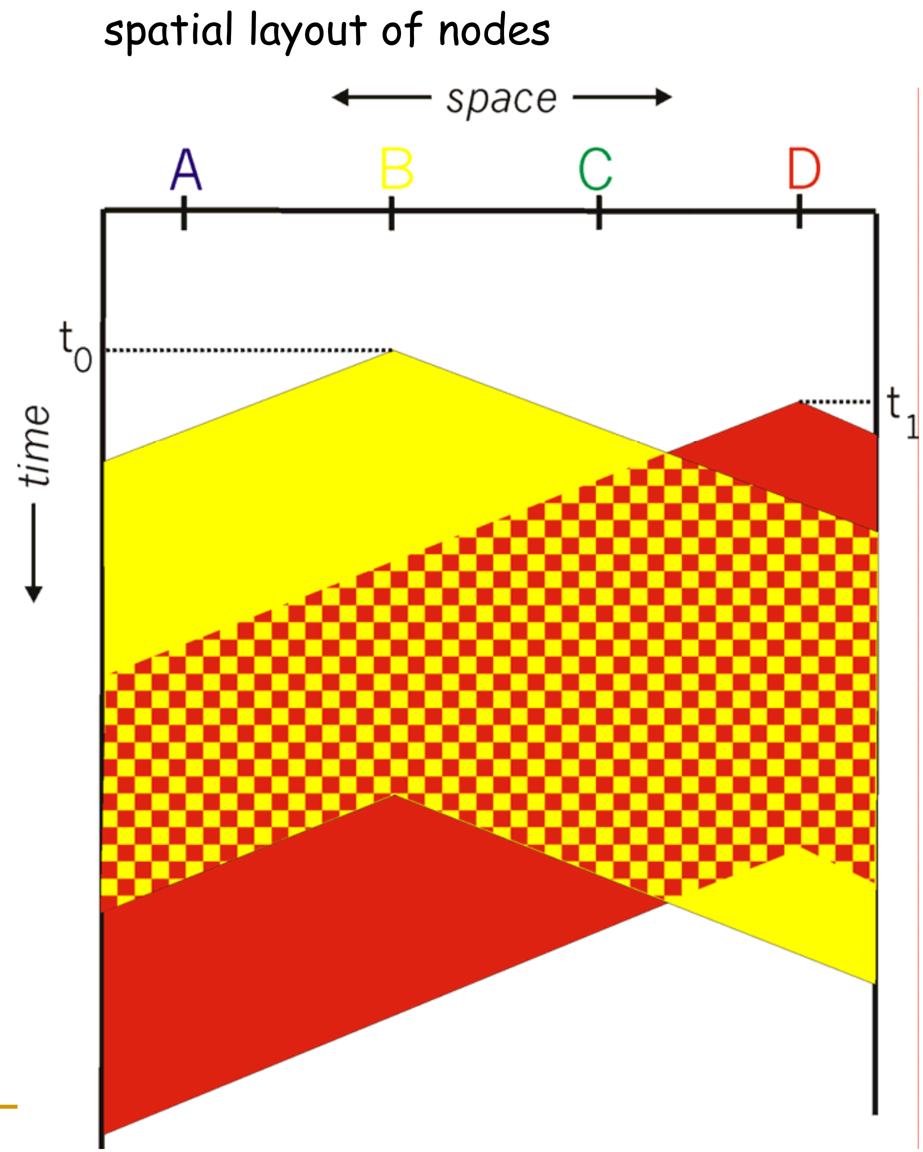
- Listen before transmit:
- If channel sensed idle: transmit entire frame
- If channel sensed busy, defer transmission
- Human analogy: don't interrupt others!

CSMA collisions

collisions *can* still occur:
propagation delay means two nodes may not hear each other's transmission

collision:
entire packet transmission time wasted

note:
role of distance & propagation delay in determining collision probability

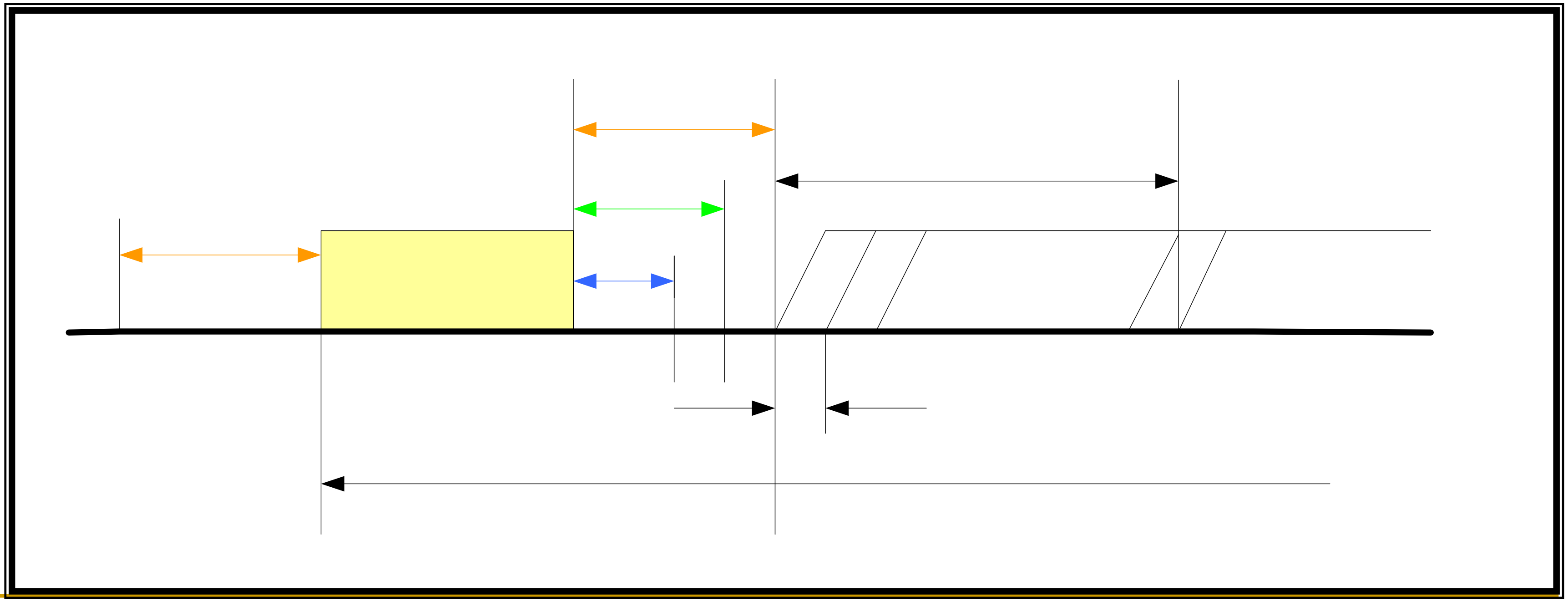


CSMA/CD (Collision Detection)

- Carrier sensing, deferral as in CSMA
  - collisions *detected* within short time
  - colliding transmissions aborted, reducing channel wastage
- Collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
    - Used in the popular Ethernet
  - rather impossible in wireless LANs:
    - receiver shut off while transmitting
    - even if not, impossible due to high path loss

CSMA/CA (Collision Avoidance)

- Used in IEEE 802.11 mandatory MAC
- Transmit after a backoff even if an idle channel is detected



p–persistent CSMA

- A decision to transmit a packet in an idle slot is determined with probability *p*
- Similar to 802.11 MAC statistically, but is different as will be clearer later
- They are statistically similar when the transmitter has frames to transmit all the time

Centralized: Static vs. Dynamic

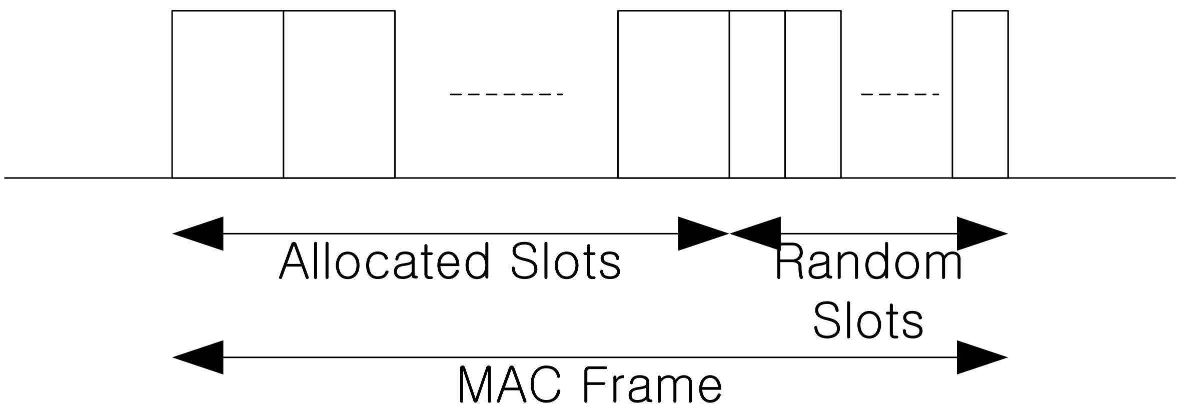
- Static MAC well suited for circuit switching
  - Voice-oriented 1G/2G cellular system
  - Inefficient for packet switching – bandwidth is wasted when not utilized
- Dynamic MAC is needed to handle variety of traffic pattern and QoS requirement
  - Polling scheme
  - Dynamic TDMA

Polling MAC

- A master polls a slave station for the transmission
  - based on the polling order scheduling
  - TDD inherently
- Used in IEEE 802.11 MAC as an optional mode
- Concern:
  - polling overhead
  - latency, esp. when lightly loaded
  - single point of failure (master)

Dynamic TDMA

- Frames divided into resource request (in mini slots) and data slots
  - ALOHA variation be used for request
  - Data slots are allocated based on requests and scheduling



Comments

- Different MAC approaches should be used depending on the system requirements
  - Target application
  - Target environment, e.g., licensed or unlicensed bands
- Many detailed features should be considered
  - QoS provisioning, power consumption, ...

Acknowledgement

- This material was partly adapted from
  - Course material of Goldsmith@Stanford
  - Computer Networking: A Top-Down Approach Featuring the Internet, 2nd Ed. by J. Kurose & K. Ross
  - Data Networks, 2nd Ed. by Bertsekas and Gallager