MAC Sublayer

Media Access Control

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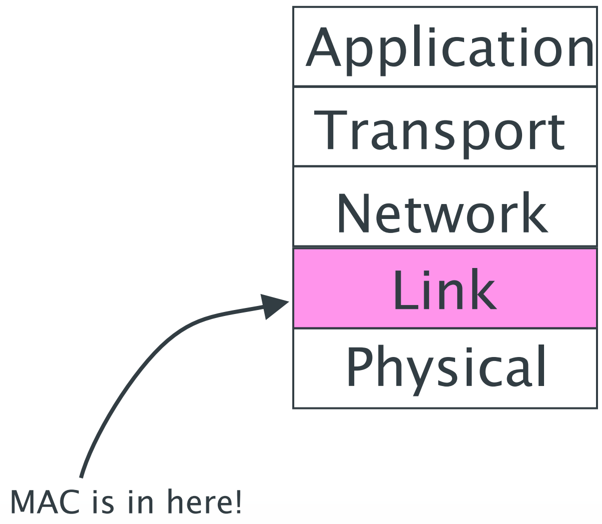
ELEC3222/ELEC6255: Networks

See Tanenbaum Chapter 4 (Medium Access Control Sublayer)

Image: http://tradinghub.co/wp-content/uploads/2014/03/BrightHorizonsTF.jpg

Outline

- Introduction
- Channel Allocation Techniques
- MAC Protocols
  - ALOHA
    - Pure
    - Slotted
  - CSMA
    - Persistent
    - Non-persistent
    - p-persistent
    - CSMA-CD
  - Collision-Free
    - Bitmap
    - Token passing
    - Binary countdown
  - Limited Contention
    - Adaptive tree walk
  - Wireless LAN
    - MACA/CSMA-CA: RTS and CTS



Source: https://www.youtube.com/watch?v=DYu_bGbZiiQ

Media Access Control

- Here, we consider broadcast links rather than point-to-point links
  - i.e. where multiple nodes are connected directly to the same medium
  - Broadcast channels sometime known as *random access* or *multi-access* channels
  - **Issue**: who gets to speak at any one time?
    - This is the role of the MAC sublayer
    - Technically sits at the ‘bottom’ of the Data Link Layer

Channel Allocation

- Static Channel Allocation (divide up available bandwidth)
  - E.g. FDMA: Frequency Division Multiple Access (e.g an FM radio)
  - E.g. TDMA: Time Division Multiple Access (i.e. a ‘time-slice’)

- Fine if traffic is predictable and constant

- However, if traffic is bursty/variable, it becomes inefficient
  - FDMA wastes unused spectrum
  - TDMA wastes unused time

Dynamic Channel Allocation

- Dynamic allocation gives the channel to a user when they need it.
  - Potentially N times as efficient for N users.
- Different schemes may make different assumptions:
  - **Independent traffic:** Network consists of N independent stations/nodes. Often not a good model, but permits analysis
  - **Single channel:** Only one communication channel exists, and it is shared. There is no external way to coordinate senders
  - **Continuous or slotted time?**: Continuous time may be divided down into discrete 'slotted' time. This may require time synchronization.
  - **Carrier sense**: Carrier sense allows a station to see if the channel is busy before transmitting.
  - **Observable collisions:** 2 frames transmitted at same time make both unreadable. These collisions can be detected. No other errors occur.

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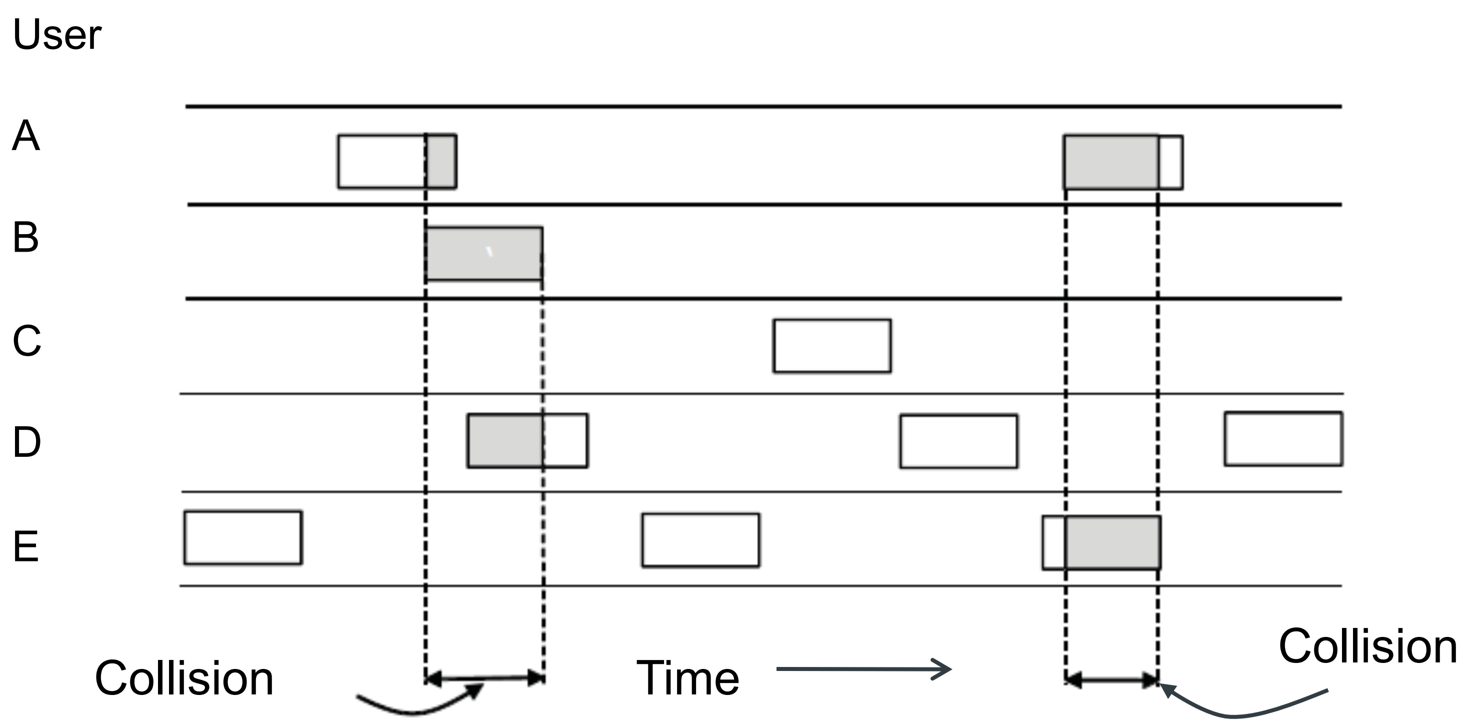
MAC Protocols

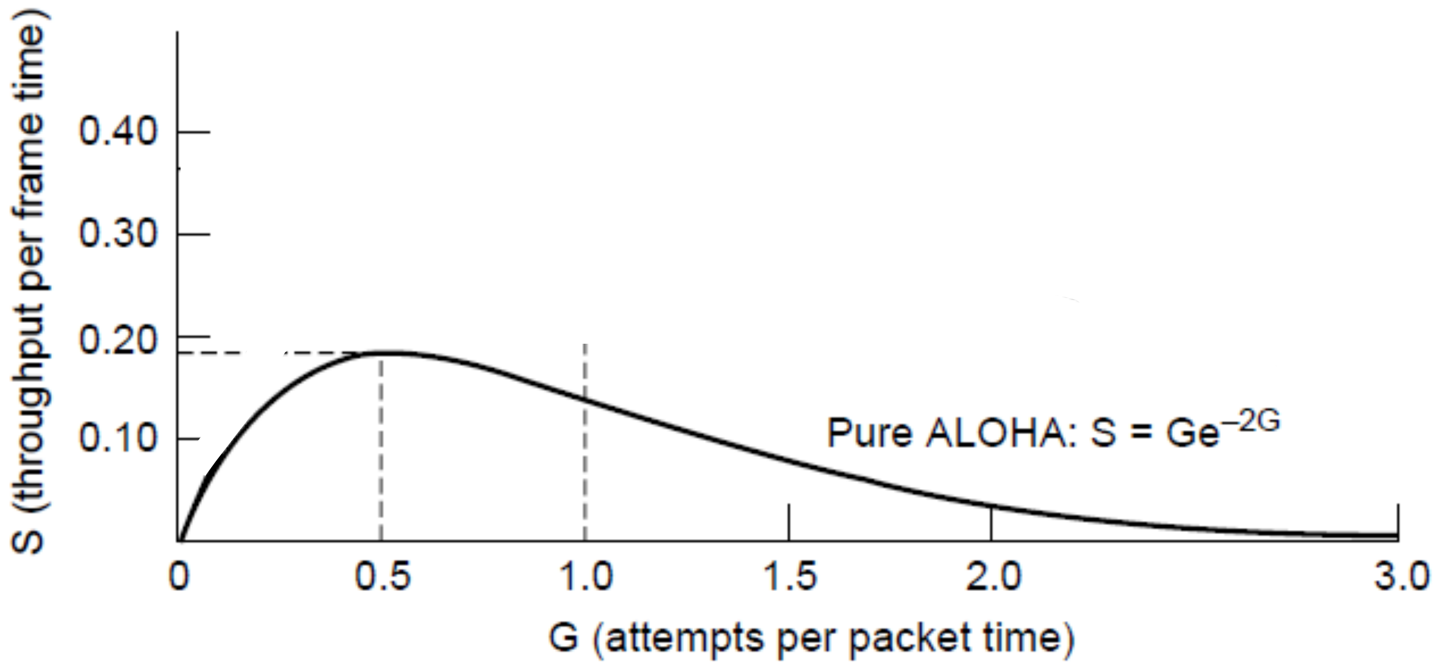
ALOHA

- In pure ALOHA, users transmit frames whenever they have data; users retry after a random time for collisions
  - Efficient and low-delay under low load



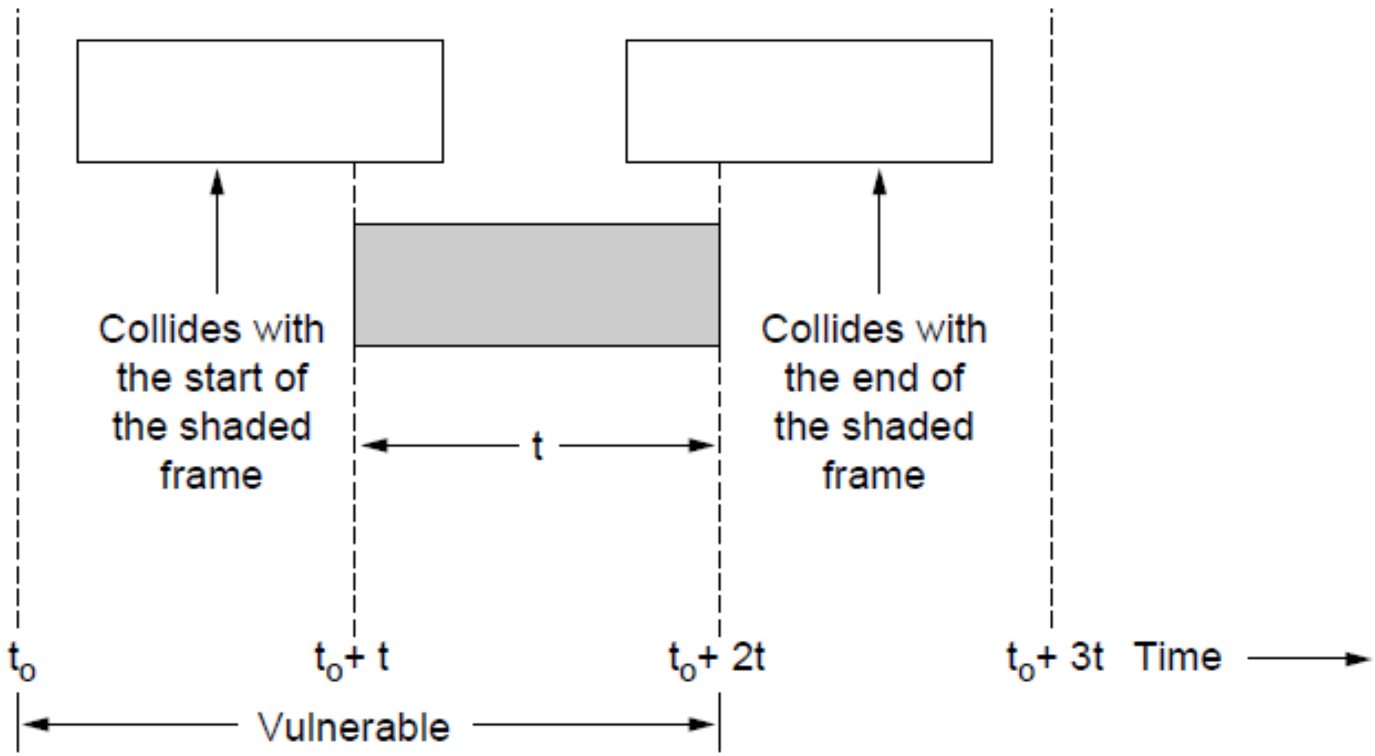
ALOHA

- ALOHA
  - High loads causes collisions
  - Efficiency up to 18% (when maximum throughput occurs)



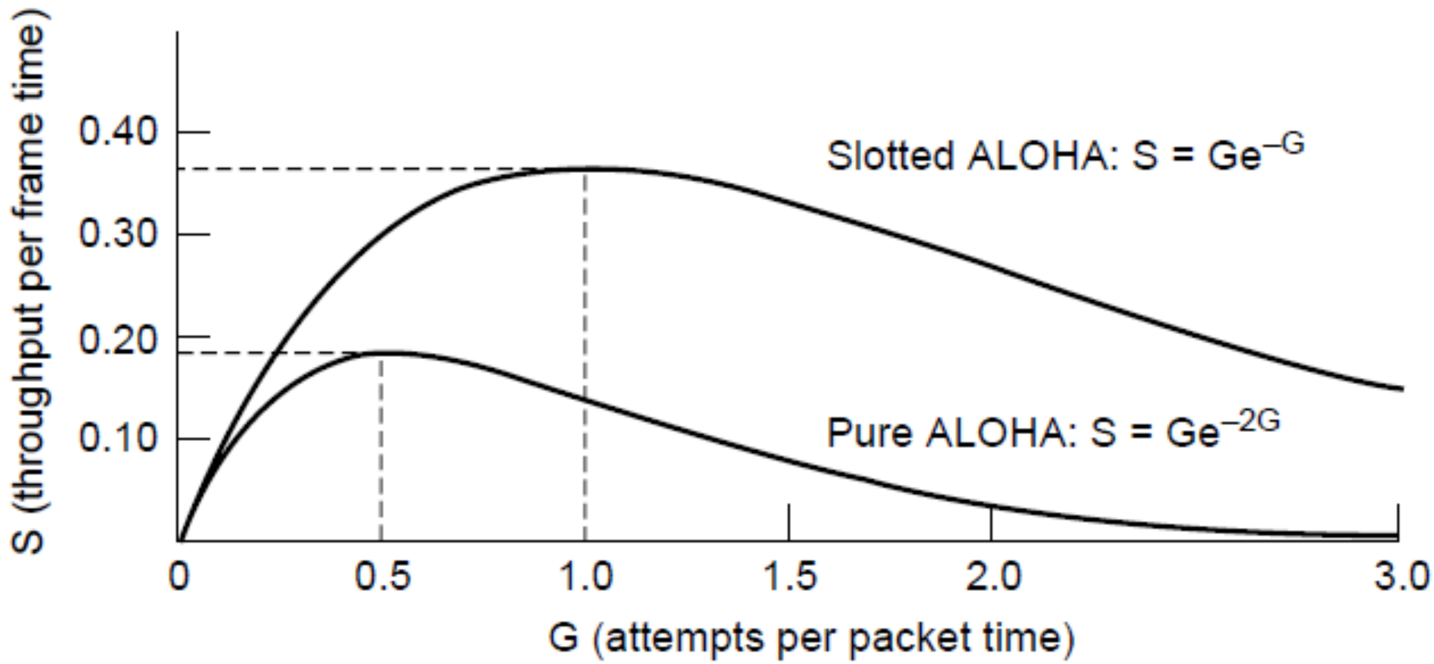
Slotted ALOHA

- Collisions happen when other users transmit during a vulnerable period that is twice the frame time
  - Synchronizing senders to slots can reduce collisions



Slotted ALOHA

- Slotted ALOHA is twice as efficient as pure ALOHA
  - Low load wastes slots, high loads causes collisions
  - Efficiency up to 1/e (37%) for random traffic models



CSMA: 1-persistent

CSMA Collision Avoidance improves on ALOHA by sensing the channel

- 1-persistent (greedy)
  - If the channel is idle:
    - the frame is transmitted
  - If the channel is busy:
    - Continues to monitor the channel and instantly sends when it becomes idle
    - *Multiple nodes might have the same idea (and hence collide) – and worsened with increasing propagation delays*

- Better performance than Slotted ALOHA due to carrier sense

CSMA: non-persistent

CSMA Collision Avoidance improves on ALOHA by sensing the channel

- non-persistent
  - If the channel is idle:
    - the frame is transmitted
  - If the channel is busy:
    - Waits for a random back-off time, before trying again

- Better channel utilization but longer delays

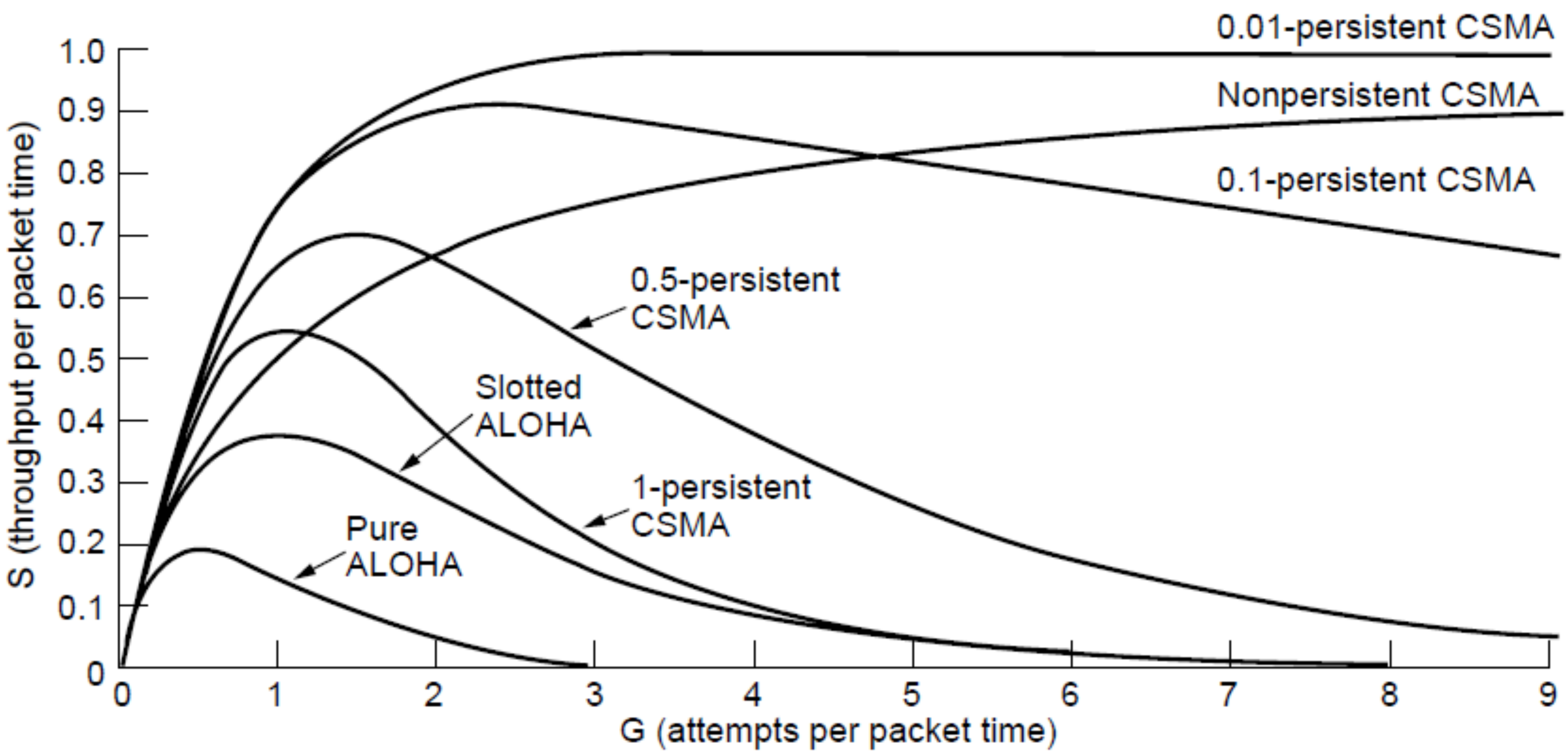
CSMA: *p*-persistent

CSMA Collision Avoidance improves on ALOHA by sensing the channel

- *p*-persistent (discrete/slotted time)
  - If the channel is idle:
    - Transmits with a probability *p* of transmitting
    - Therefore a probability of 1-*p* of not transmitting and waiting until the next slot
    - If, at the next slot, the channel is still idle
      - the process repeats
    - Else
      - it waits for a random back-off time, before starting again
  - If the channel is busy:
    - Waits for the next slot and tries again

CSMA

- CSMA outperforms ALOHA, and being less persistent is better under high load

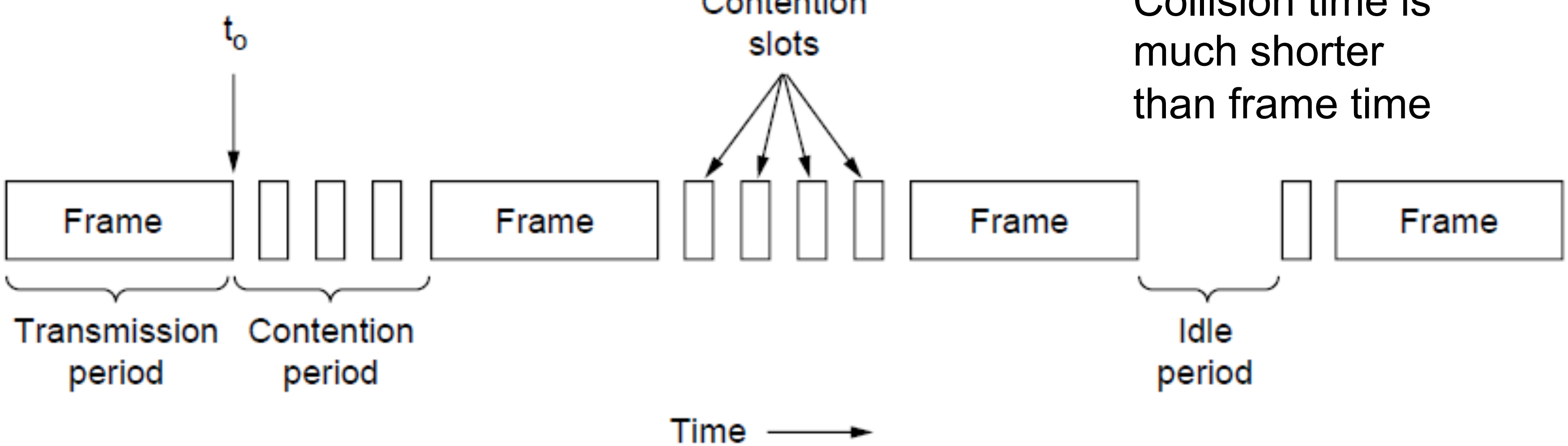


Discussion

- We’ve talked about throughput…
- What about the minimum/maximum/average latency?
- What’s the impact of this on energy consumption?

CSMA–CD

- CSMA/CD = CSMA with Collision Detection
- CSMA/CD improvement is to detect/abort collisions
  - Reduced contention times improve performance

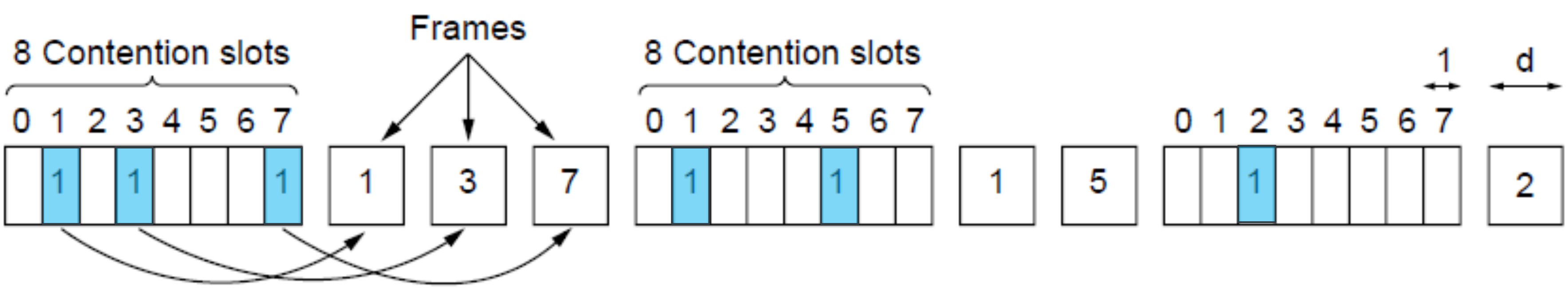


Collision time is much shorter than frame time

- This avoid collisions (once the channel is captured), but doesn't avoid contention altogether

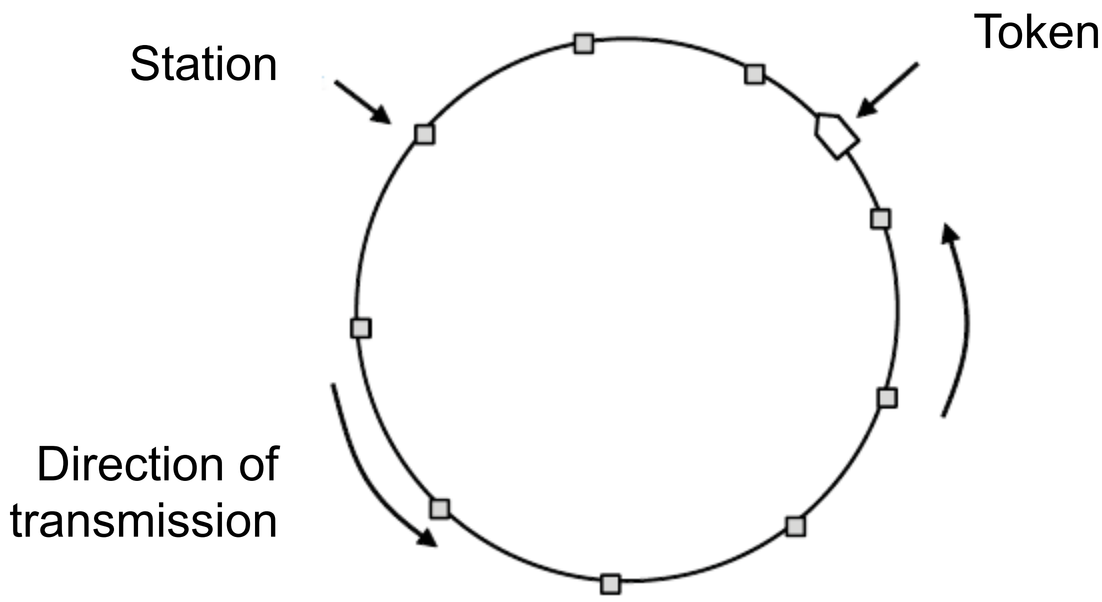
Collision-Free: Bitmap

- Collision-free protocols avoid collisions entirely
  - Senders must know when it is their turn to send
- The basic bit-map protocol:
  - Starts with a contention period consisting of *N* slots
  - If sender *n* has a frame to send, it sets the bit in contention slot *n*
  - After the contention period, senders who set their bit send their frames in turn



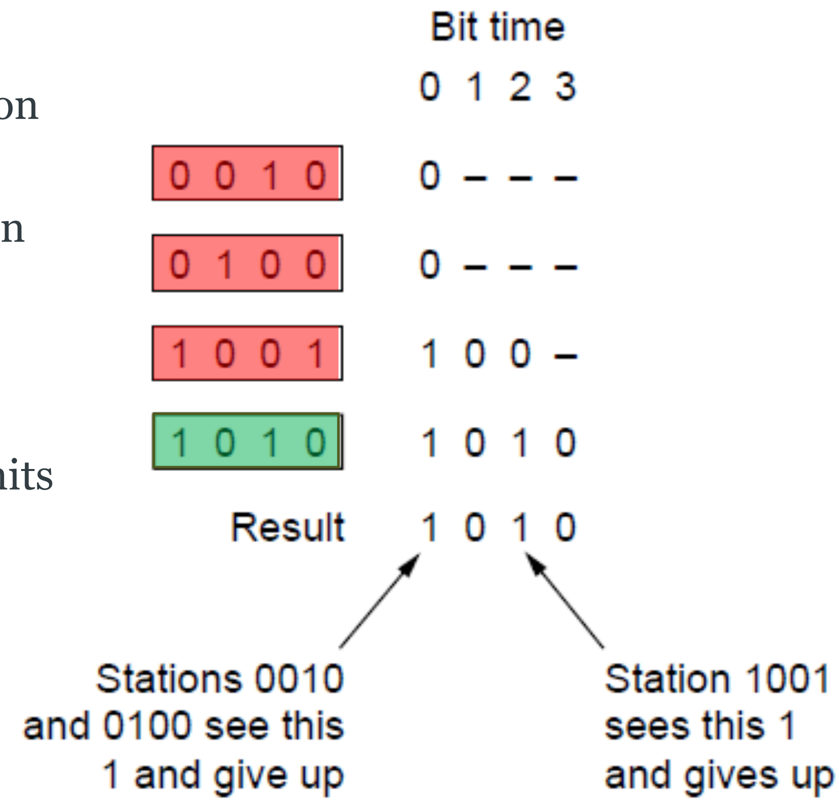
Collision-Free: Token Ring

- Token sent round ring defines the sending order
  - Station with token may send a frame before passing it on to the next station
  - Idea can be used without ring too, e.g., token bus



Collision-Free: Countdown

- Both of the above methods have a 1-bit overhead per station
- Binary countdown improves on this
  - Stations send their address in contention slot (log *N* bits instead of *N* bits)
  - Channel ORs bits; stations give up when they send a "0" but see a "1"
  - This gives priority to higher numbered stations
  - Station that sees its full address transmits its frame



Limited-Contention Protocols

- Contention protocols good for low load
- Contention-free protocols good for high load
- Idea is to divide stations into groups within which only a very small number are likely to want to send
  - Avoids wastage due to idle periods and collisions

N groups each
containing 1 station

Dynamically vary between
extremes based on load

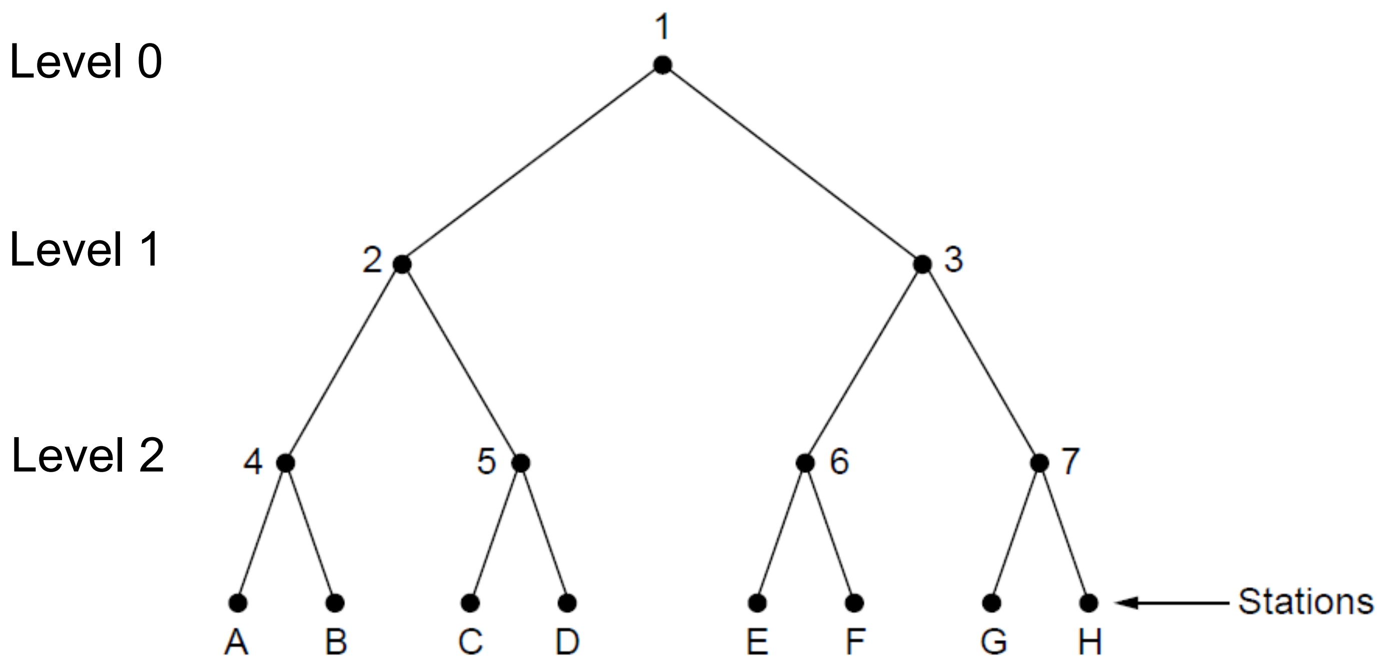
1 group
containing *N* stations

e.g. Binary Countdown

e.g. Slotted Aloha

Limited Contention: Adaptive Tree Walk

- Tree divides stations into groups (nodes) to poll
  - In a contention slot, if only one station in the entire tree tries to transmit, it will
  - Otherwise, a recursive depth-first search is done underneath the node with collisions



  - The search can be started at lower levels if >1 station expected (i.e. high load)

Wireless LANs

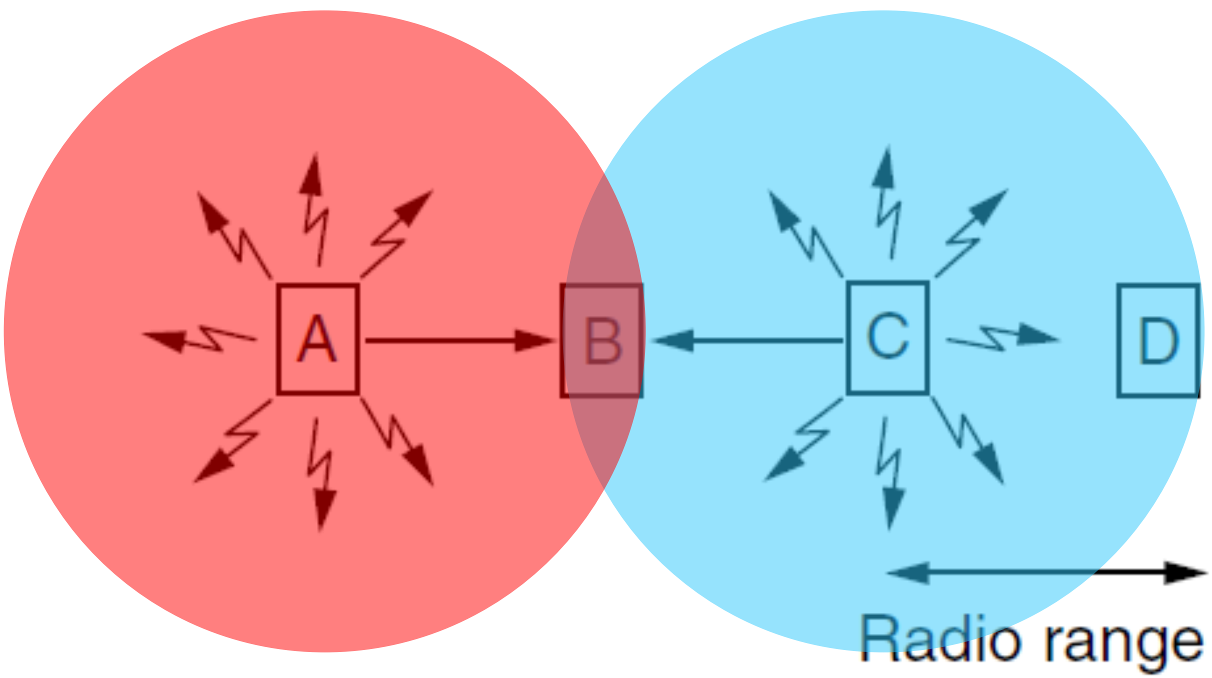
- Wireless has complications compared to wired.

- Nodes may have different coverage regions
  - One station/node may not be able to transmit directly to all others
  - Leads to hidden and exposed terminals

- Nodes can't detect collisions, i.e., sense while sending
  - Instead, use acknowledgements
  - Makes collisions expensive and to be avoided

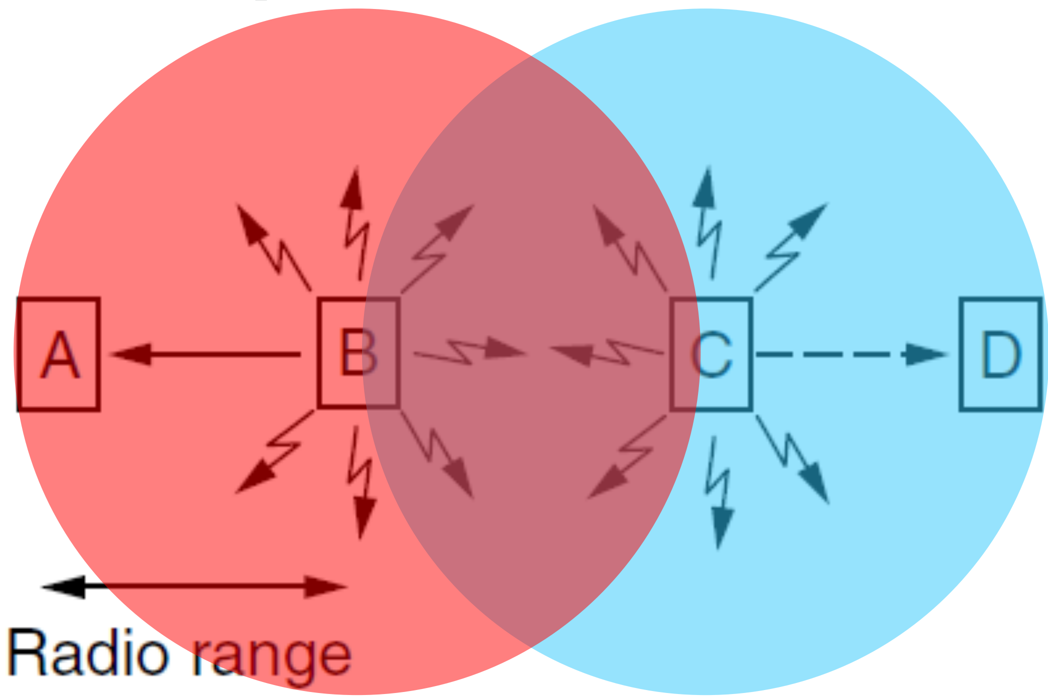
Wireless LANs: Hidden Terminals

- Hidden terminals are senders that cannot sense each other but nonetheless collide at intended receiver
  - Want to prevent; loss of efficiency
  - A and C are hidden terminals when sending to B



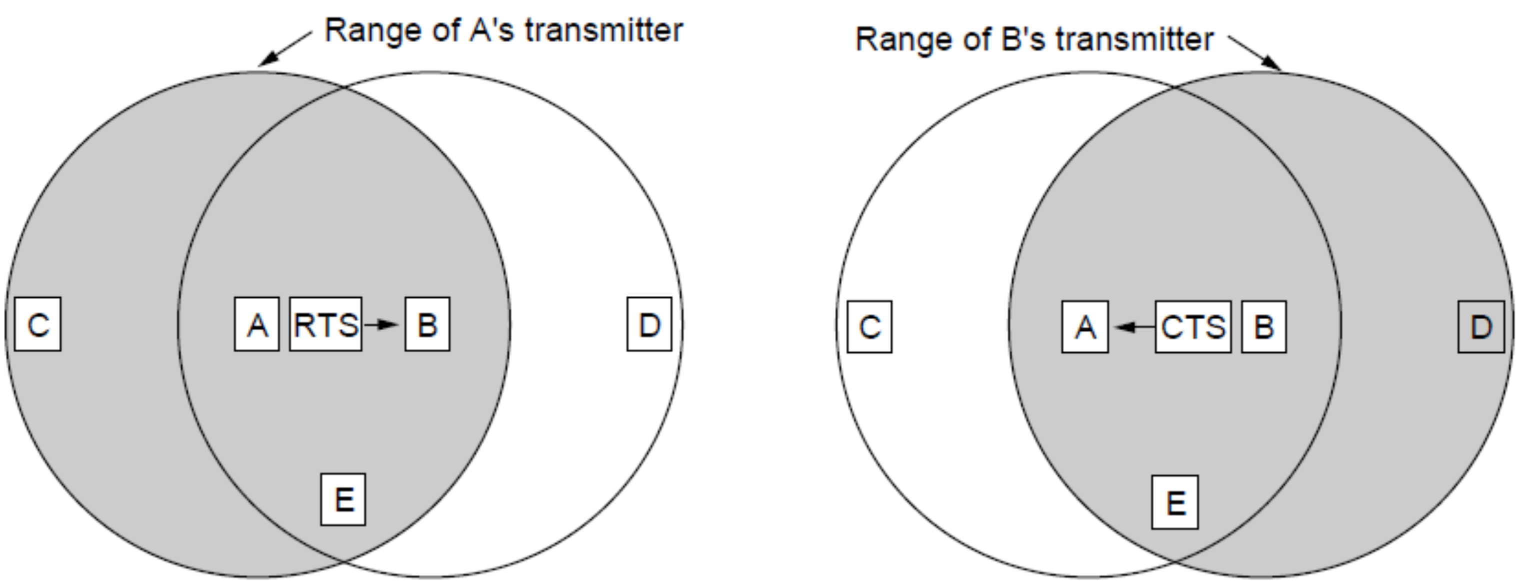
Wireless LANs: Exposed Terminals

- Exposed terminals are senders who can sense each other, but can still transmit safely (to different receivers)
  - Desirably concurrency; improves performance
  - B → A and C → D are exposed terminals



Wireless LANs: MACA

- MACA (Multiple Access with Collision Avoidance) grants access for **A** to send to **B**
  - **A** sends *RTS* (Request To Send) to **B** – *RTS contains frame length it wants to send*
  - **B** replies with *CTS* (Clear To Send) – *CTS contains the same frame length*

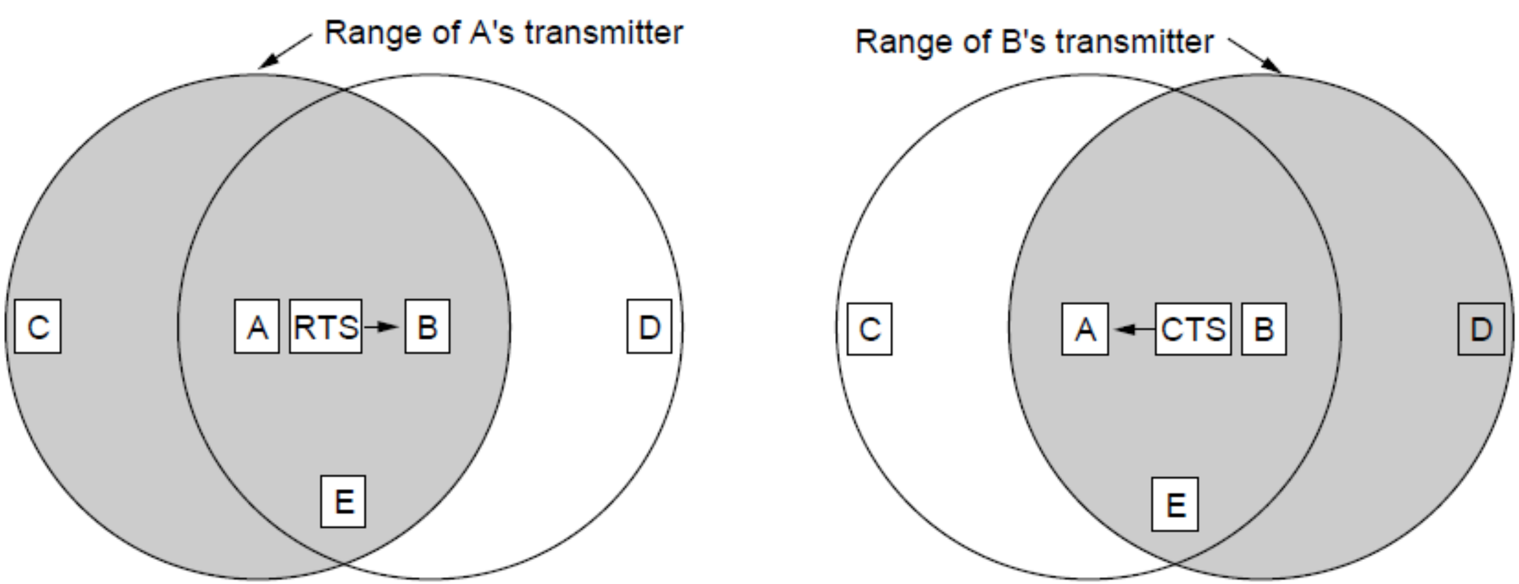


A sends RTS to B; C and E hear and defer for CTS

B replies with CTS; D and E hear and defer for data

Wireless LANs: MACA

- Exposed Terminals
  - C is within the range of A, but not B (hence is an *exposed terminal*)
  - It keeps quiet long enough for a CTS to be returned, which it does not hear
  - Therefore, it is free to transmit (this is fine, as won't interfere with B's reception)
- Hidden Terminals
  - D is within the range of B, but not A (hence it is a *hidden terminal*)
  - When it hears the CTS, it knows a nearby station is about to receive, and so stays quiet



ELEC3222 2018/19 Exam Question

(a) State the role of the MAC sublayer

(b) A LAN contains 10 stations arranged in a ring topology, with a fixed frame size of 1024 bytes, and a data-rate of 1 Mbps. Calculate the worst-case (longest) time that a station might have to wait before it can begin transmitting its frame when:

- (i) using the basic bit-map MAC protocol;
- (ii) using the token ring MAC protocol.

Questions?