Week 5 - MAC Sub-Layer

COMP90007
Internet Technologies

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Introduction

- On point to point networks, there are only singular sender and receiver pairs, eliminating transmission contention
- On broadcast networks, determining right to transmit is a complex problem
- Medium Access Control (MAC) sub-layer is used to assist in resolving transmission conflicts

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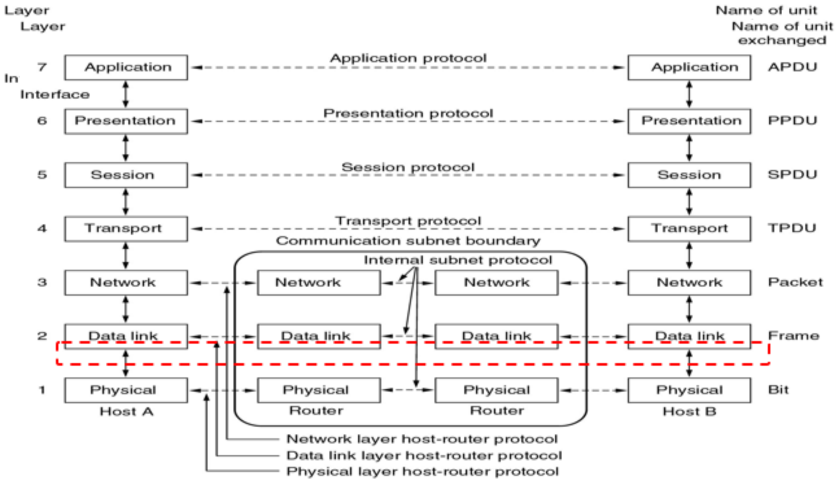
The MAC Sub-layer



Types of Channel Allocation Mechanisms

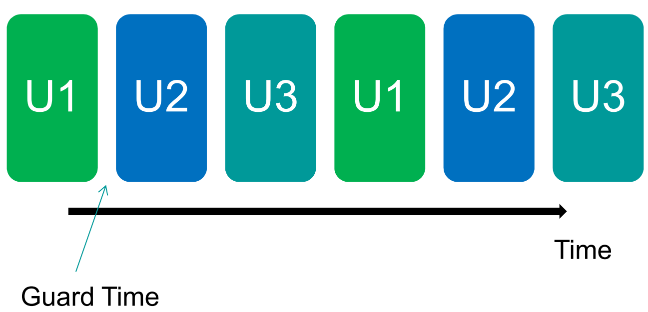
- Various methods exist for allocating a single broadcast channel amongst competing users
  - **Static Channel Allocation**
  - **Dynamic Channel Allocation**

Static Channel Allocation

- Arbitrary division of a channel into segments and each user allocated a dedicated segment for transmission
- Frequency Division Multiplexing (FDM) is typically used
- Significant inefficiencies arise when:
  - Number of senders > allocated segments
  - Number of senders is not static
  - Traffic is bursty

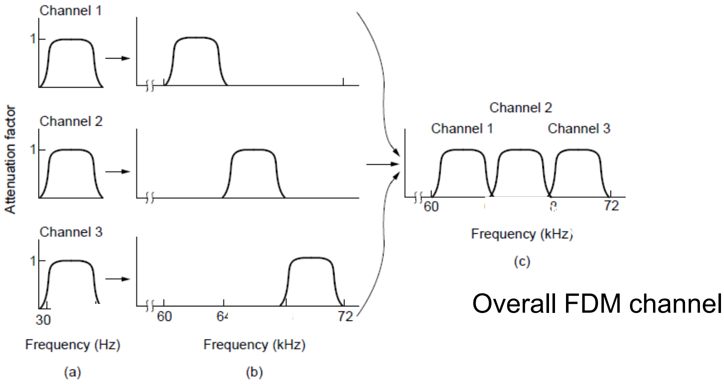
Time Division Multiplexing

Users take turns on a fixed schedule



Frequency Division Multiplexing

FDM (Frequency Division Multiplexing) shares the channel by placing users on different frequencies:



Downfalls

- Usually good for fixed number of users
- Network traffic is bursty
  - TDM and FDM try to give consistent access to the network leading to inefficiency in the use of network resources
- Where?
  - TV and Radio (FDM)
  - 2G uses TDM

Dynamic Channel Allocation

- Channel segmentation is dynamic, segment allocation is dynamic
- Assumptions for dynamic channel allocation:
  - Independent transmission stations
  - Single channel for all communication
  - Simultaneous transmission results in damaged frames
- Time
  - Transmission can begin at any time
  - Transmission can begin only within discrete intervals
- Carrier Sense
  - Detection of channel use prior to transmission
  - No detection of channel use prior to transmission

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Multiple Access Protocols

- ALOHA
- Carrier Sense Multiple Access
- Collision Free
- Limited Contention
- MACA/MACAW (for Wireless LANs)

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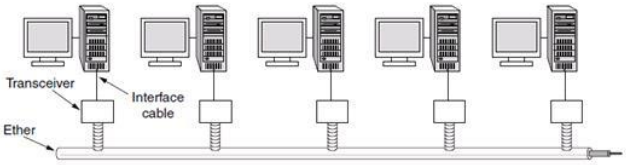
ALOHA

- Users transmit frames whenever they have data; users retry after a random time if there are collisions (or no Ack is arrived)
- Requires no central control mechanism
- Efficient under low load but inefficient under high traffic loads
- Slotted ALOHA: Allows the users to start sending only at the beginning of defined slots. Increase efficiency of pure ALOHA by reducing possibility of collisions

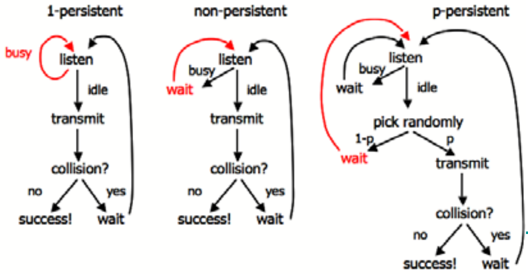
Carrier Sense Multiple Access (CSMA) Protocols

- In networks which require transmission state detection to determine transmission rights dynamically, there are specific protocols which are used
  - Persistent and Non-Persistent CSMA
  - CSMA with Collision Detection

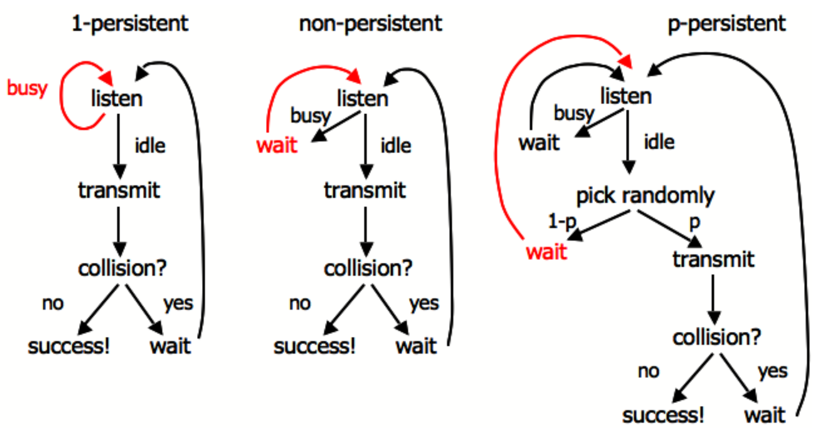


Persistent and Non-Persistent CSMA

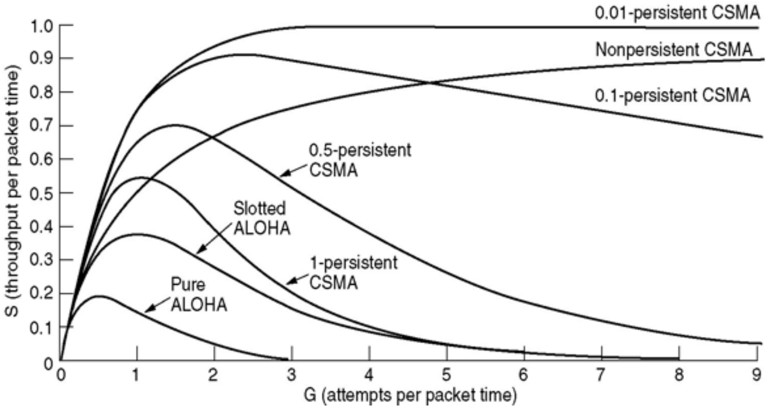
- When a sender has data to transmit, first check channel to detect other active transmission
- 1-persistent CSMA
  - Wait until channel idle; transmit one frame and check collisions; if collision, wait for a random time and repeat
- Non-persistent CSMA
  - If channel busy, wait random period and check again; if not, start transmitting
- p-persistent CSMA
  - If channel idle, transmit with probability p, or wait with probability (1-p) and check again



Persistent and Non-Persistent CSMA



CSMA Variants

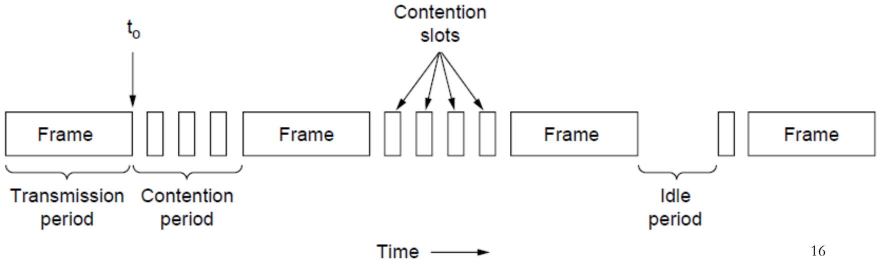


CSMA outperforms ALOHA, and being less persistent is better under high load

CSMA with Collision Detection

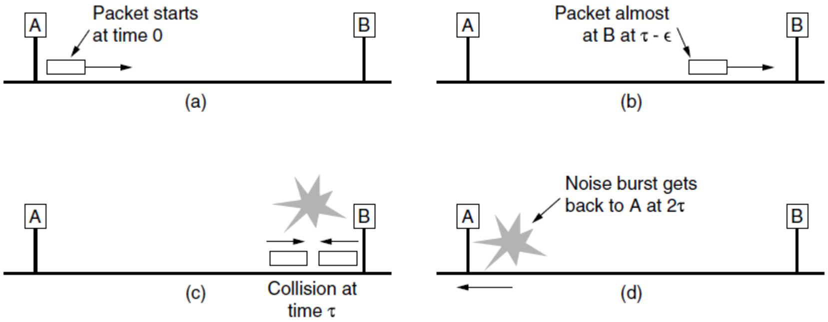
- Principle that transmission aborted when collision detected
- After collision detected, abort, wait random period, try again
- Channel must be continually monitored
- Used in half-duplex system (e.g., with Hub or repeater)

Reduced contention times improve performance



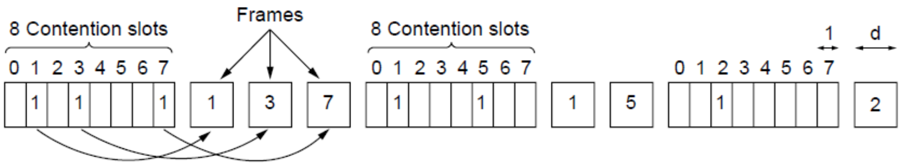
Classic Ethernet Minimum Packet Size

- Collisions can occur and take as long as 2τ to detect
  - τ is the time it takes to propagate over the Ethernet
  - Leads to minimum packet size for reliable detection



Collision Free Protocols

- Bit Map Protocol
  - Reservation-based protocol
  - 1 bit per station overhead
  - Division of transmission right, and transmission event - no collisions as this is a reservation based protocol

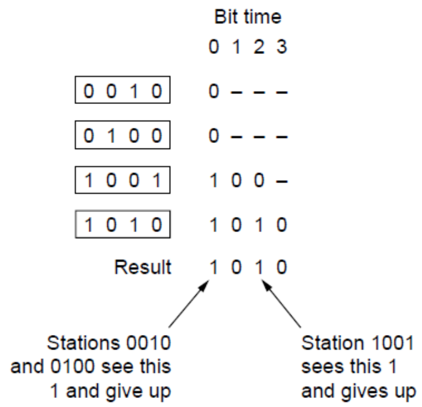


Collision Free Protocols

- Binary Countdown Protocol
  - Avoid the 1 bit per station scalability problem by using binary station addressing
  - No collisions as higher-order bit positions are used to arbitrate between stations wanting to transmit
  - Higher numbered stations have a higher priority

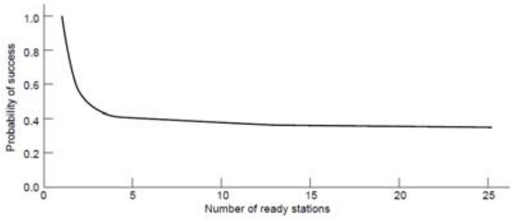
Binary Countdown Protocol

- Stations send their address in contention slot (log N bits instead of N bits)
- Channel medium ORs bits; stations give up when they send a "0" but see a "1"
- Station that sees its full address is next to send



Limited Contention Protocols

- 2 strategies - contention and collision free - both become inefficient at different points
- Under low loads, collision free is less attractive because of a higher delay between transmissions
- Under higher loads, contention is less attractive because overhead associated with channel arbitration becomes greater
- Limited Content Protocols increase the probability of stations acquiring transmission rights by arbitrarily dividing stations and using a binary algorithm to determine rights allocation
  - 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



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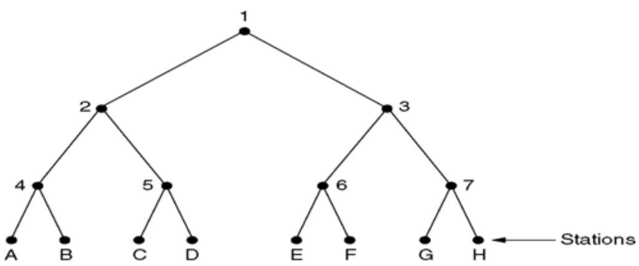
Adaptive Tree Walk Protocol

- All stations compete for right to transmit, if a collision occurs, binary division is used to resolve contention
- Tree divides stations into groups (nodes) to poll
  - Depth first search under nodes with poll collisions
  - Start search at lower levels if >1 station expected



Example 1: D G
Slot 1 → D, G – collision
Slot 2 → D
Slot 3 → G

Example 2: B D G
Slot 1 → B, D, G – collision
Slot 2 → B, D - collision
Slot 3 → B
Slot 4 → D
Slot 5 → G

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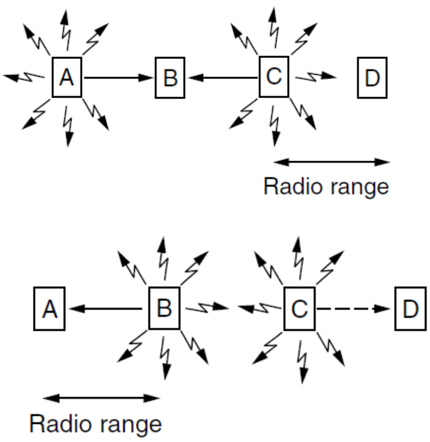
Wireless LAN Protocols

- Wireless Complications: when a station is in the range of two transmitters or relays, interference affects signal reception
- Leads to hidden and exposed terminal problems
- Require detection of transmissions to receiver, not just carrier sensing
- Transmission Protocols for Wireless LANs (802.11)
  - Multiple Access with Collision Avoidance for Wireless (MACAW)

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



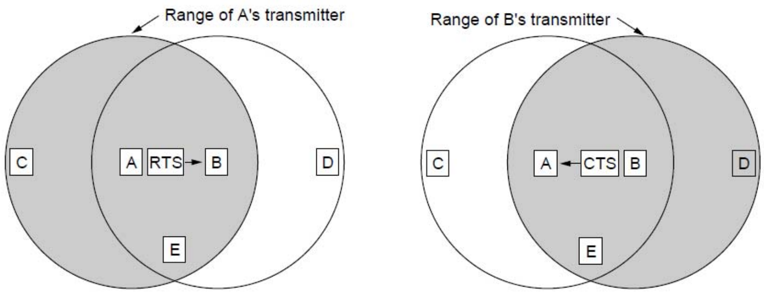
Multiple Access with Collision Avoidance (MACA)

- Sender asks receiver to transmit short control frame
- Stations near receiver hear control frame
- Sender can then transmit data to receiver

MACA

MACA protocol grants access for A to send to B:

- A sends RTS to B [left]; B replies with CTS [right]
- A can send with exposed but no hidden terminals



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

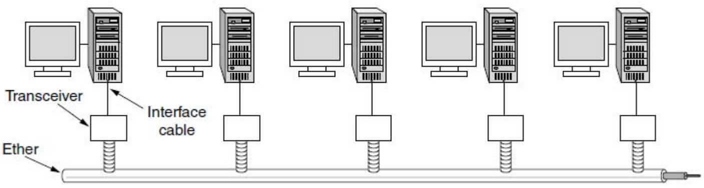
B replies with CTS; D and E hear and defer for data

Ethernet: A Famous MAC Sub-Layer Case Study

- Classical Ethernet
- Switched Ethernet

Classic Ethernet

- Each type of Ethernet has a maximum cable length per segment.
- Multiple cable lengths can be connected by repeaters - a physical device which receives, amplifies and retransmits signals in both directions.



Ethernet Frame Format

- MAC protocol is 1-persistent CSMA/CD (earlier)
  - Random delay (backoff) after collision is computed with BEB (Binary Exponential Backoff, i.e., random number 0 and $2^i - 1$)
  - Frame format is still used with modern Ethernet.

IEEE 802.3

Preamble	SoF	Destination address	Source address	Length	Data	Pad	Check-sum

Preamble (7B) – synchronisation between sender and receiver
Start of Frame (1B) – FLAG bytes
Dest. & Source addresses – to identify who send, who receive
Type & Length (2B) – specifies which process to give the frame to (0x0800 means data contains IPv4)
Pad(0~46B) – Minimum size of the message of the Ethernet – 64 Bytes
CRC (4B) – 32 bits checksum

MAC ADDRESSING

- Source and Destination Addressing can be done at a local or global levels
- The MAC Address provides the unique identifier for a physical interface
- MAC Address is a 48-bit number encoded in the frame
  - eg 00:02:2D:66:7C:2C

Ethernet Performance

Definition

$$\text{Channel Efficiency} = \frac{1}{1 + 2BLe/cF}$$

- F : frame length
- B : bandwidth
- L : cable length
- c : speed of light
- optimal case of e contention slots per frame

- When cF is large, the channel efficiency will be high.
- Increasing network bandwidth or distance (BL) reduces the efficiency for a given frame size

Switched Ethernet

- Hubs wire all lines into a single CSMA/CD domain
- Switches isolate each port to a separate domain
  - Much greater throughput for multiple ports
  - No need for CSMA/CD with full-duplex lines