G 364: Mobile and Wireless Networking

CLASS 2, Wed. Jan 7 2004

Stefano Basagni

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M-W, 11:40am-1:20pm, 109 Rob

Wireless Issues

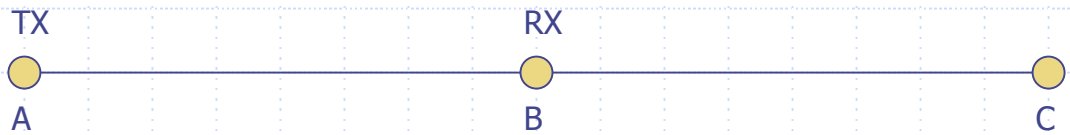
- Architecture, communication model and duplexing define the framework where wireless MAC (wMAC) protocols are defined
- wMAC protocol design must also take into accounts the unique characteristics of the wireless medium

Boundaries and Interference

- Due to physical layer problems
  - No definite boundaries for radio waves
  - → higher Bit Error Rate (BER)
  - Asymmetric channel qualities
- Concept of "neighbors:" nodes within each other transmission range. Only neighbors detect the carrier on the channel
- Attenuation of signal strength depends on node distance

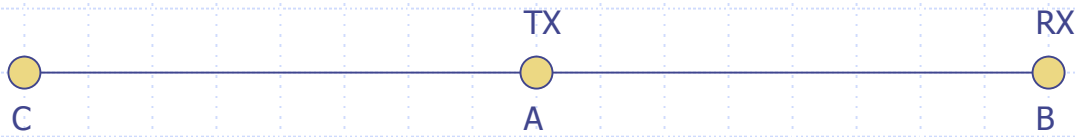
Hidden Terminal Problem

- A hidden node is a node in the range of the receiver and not in the range of the transmitter
- Node C is hidden to node A: Collisions limit the channel efficiency



Exposed Terminal Problem

- An exposed node is in the range of the transmitter and not in the range of the receiver
- Node C is exposed to node A: C can be denied access till A is done → bandwidth is under-utilized



Propagation Delay et Al.

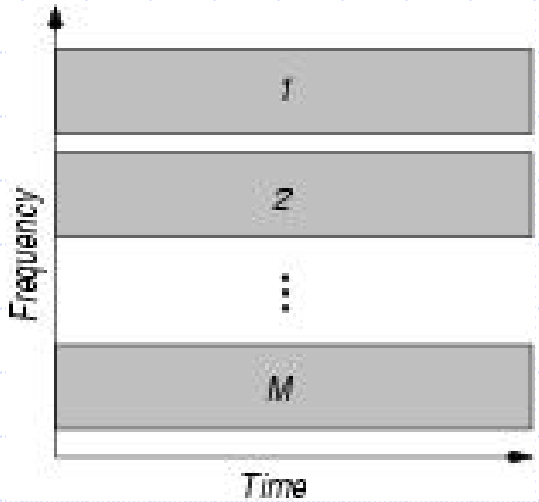
- Time needed for the transmitted packet to reach the receiver
  - Affect carrier sensing-based protocols
  - Affect slot size → Additional overhead
- Half duplexing: A node can either be in TX or in RX mode at a time
  - Collision detection is more involved
  - Hardware switching time becomes significant

Fundamental MAC Protocols

- Universal, basic techniques
  - Used by most wMAC protocols
  - Derived from wired MAC protocols or specific for the wireless domain
- Common goal: Multiple Access (MA)
  - FDMA
  - TDMA
  - CDMA
  - Aloha protocols

Frequency Division MA (FDMA)

- The available bandwidth is divided into M sub-channels (separated by guard bands)



FDMA: Capacity

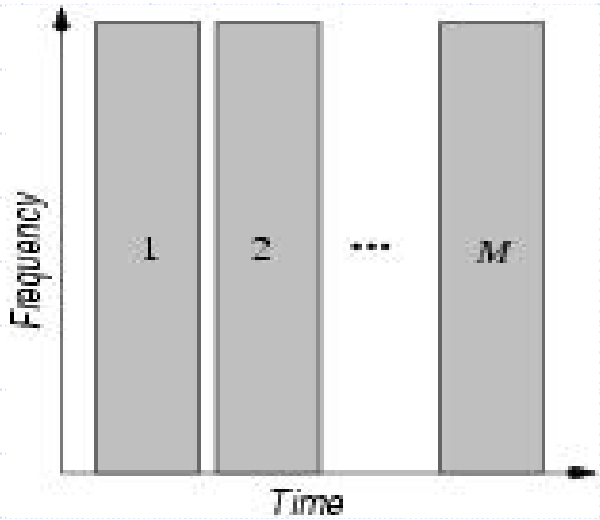
- C = capacity (bit per second) of the available bandwidth → C/M = capacity of each sub-channel
- Each TXing node is assigned one or more of the frequencies
- Each RXing node must listen in the proper frequence

FDMA, Pros and Cons

- Pros
  - Simultaneous packet TX can occur without collision
  - Less overhead (no switching, no synch)
- Cons: Increased TX time → Longer packet delay
  - L-bits long packet takes M * L / C seconds
  - M times longer than if we had the whole bandwidth

Time Division MA (TDMA)

- The available bandwidth is divided into M equal time slots organized into a synchronous frame



TDMA: Capacity

- Each node is assigned one time slot for its exclusive use (either TX or RX)
- Transmission is non-continuous (buffer-and-burst)
- In that time slot it has the whole bandwidth
- L-bits long packet takes L / C seconds
- Long delays: Consecutive packets are separated M-1 slots (basic TDMA)

Code Division MA (CDMA), 1

- More than one TX in the same frequency at the same time
- No interferences
- Special coding technique: Orthogonal codes
- Information retrieved from combined signal

CDMA, 2

- Information bits are spread across a broadened channel
  - Less susceptible to fading
  - Require more sophisticated hardware
- Problem: How is the channel broadened?
  - Spread spectrum modulation techniques

Spread spectrum modulation techniques for CDMA, 1

- Direct Sequence Spread Spectrum (DSSS)
  - Original message is multiplied by a pseudo-noise sequence
  - Increase the amount of bandwidth occupied (spreading factor)
  - SF is used at the receiving node to "raise" the signal from the interference

Spread spectrum modulation techniques for CDMA, 2

- Frequency Hopping Spread Spectrum (FHSS)
  - The TX frequency is shifted according to a specific hopping sequence
  - Aim is interference reduction: Short time in each frequency (dwelling time)
  - Example: Bluetooth

MA Techniques in Communication Systems

- Advanced Mobile Phone System (AMPS)→ FDMA/FDD
- Global System for Mobile (GSM) → TDMA/FDD
- US Digital Cellular (USDC) → TDMA/FDD
- Pacific Digital Cellular (PDC) → TDMA/FDD
- CT2 (Cordless Telephone) → FDMA/TDD
- Digital Euro. Cordless Telephone (DECT)→FDMA/TDD
- US Narrowband Spread Spect. (IS-95) → CDMA/FDD
- W-CDMA (3GPP) → CDMA/FDD and /TDD
- Cdma2000 (3GPP2) → CDMA/FDD and /TDD

Aloha Protocols

- (AlohaNet, Hawaii, Abramson)
- Brute force MA
  - Lack of channel access
- A node transmit a packet when it has it
- Packet delivery needs feedback mechanism (like ARQ=Automatic Repeat Request)
- If the packet gets lost, it is retransmitted
- Poor channel utilization

Slotted Aloha

- Packets are transmitted when needed, at the beginning of a slot
- Reduces the time a packet is vulnerable to collision
- Variant: p-persistent slotted aloha
  - Persistence parameter p, $0 < p < 1$
  - Probability of a node transmitting in a slot
  - Tradeoff between collisions and delay

Carrier Sense MA (CSMA)

- Carrier sensing to avoid collisions with ongoing transmissions
  - Busy channel → wait (keep testing)
  - Idle channel → transmit
- Many nodes can be waiting → collisions
- Collisions are reduced by using randomization:
  - Busy channel → compute a random time before testing again (random time increases exponentially)

p-Persistent CSMA

- Channel is slotted, BUT
- Nodes are NOT synchronized
- Slot length = max propagation delay
- Sensing occur at the beginning of each slot
  - Busy channel → wait a random number of slots
  - Idle channel → TX with probability p

MAC for Specific Architectures

- Centralized MAC Protocols
  - Cellular telephony: Predominant form of wireless systems
  - Wireless ATM: Broadband multimedia services
- Ad Hoc MAC Protocols
  - Wireless MAC protocols specifically designed for ad hoc networks

Assignments

- Wireless MAC handout, to page x
- Updated information on the class web page:

  www.ece.neu.edu/courses/eceg364/2004sp