Wireless Networks

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Mike Freedman
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Widespread Deployment

- Worldwide cellular subscribers
  - 1993: 34 million
  - 2005: more than 2 billion
  - 2011: close to 6 billion
  (1.2B with mobile broadband)
  >> 1.2B landline subscribers

- Wireless local area networks
  - Wireless adapters built into laptops, tablets, & phones
  - As ubiquitous as broadband subscribers? 600M in 2011

Wireless Properties

- Interference / bit errors
  - More sources of corruption compared to wired

- Multipath propagation
  - Signal does not travel in a straight line

- Broadcast medium
  - All traffic to everyone

- Power trade-offs
  - Important for power constrained devices

http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/total-subscribers
Wireless Links: High Bit Error Rate

- Decreasing signal strength
  - Disperses as it travels greater distance
  - Attenuates as it passes through matter

- Interference from other sources
  - Radio sources in same frequency band
  - E.g., 2.4 GHz wireless phone interferes with 802.11b wireless LAN
  - Electromagnetic noise (e.g., microwave oven)

Wireless Links: High Bit Error Rate

- Multi-path propagation
  - Electromagnetic waves reflect off objects
  - Taking many paths of different lengths
  - Causing blurring of signal at the receiver

Dealing With Bit Errors

- Wireless vs. wired links
  - Wired: most loss is due to congestion
  - Wireless: higher, time-varying bit-error rate

- Dealing with high bit-error rates
  - Sender could increase transmission power
    - Requires more energy (bad for battery-powered hosts)
    - Creates more interference with other senders
  - Stronger error detection and recovery
    - More powerful error detection/correction codes
    - Link-layer retransmission of corrupted frames
**Wireless Links: Broadcast Limitations**

- Wired broadcast links
  - E.g., Ethernet bridging, in wired LANs
  - All nodes receive transmissions from all other nodes
- Wireless broadcast:
  - Hidden terminal problem
  - All nodes receive transmissions from all other nodes
  - A and B hear each other
  - B and C hear each other
  - But, A and C do not
  - So, A and C are unaware of their interference at B

**Example Wireless Link Technologies**

- Data networks
  - 802.15.1 (Bluetooth): 2.1 Mbps – 10 m
  - 802.11b (WiFi): 5-11 Mbps – 100 m
  - 802.11a and g (WiFi): 54 Mbps – 100 m
  - 802.11n (WiFi): 200 Mbps – 100 m
  - 802.16 (WiMax): 70 Mbps – 10 km
- Cellular networks, outdoors
  - 2G: 56 Kbps
  - 3G: 384 Kbps
  - 3G enhanced (“4G”): 4 Mbps
  - LTE

**Wireless Network: Wireless Link**

- Typically used to connect mobile(s) to base station
- Also used as backbone link
- Multiple access protocol coordinates link access
Wireless Network: Wireless Hosts

- Wireless host
  - Laptop, smartphone
  - Run applications
  - May be stationary (non-mobile) or mobile

Wireless Network: Base Station

- Base station
  - Typically connected to wired network
  - Relay responsible for sending packets between wired network and wireless host(s) in its "area"
  - E.g., cell towers, 802.11 access points

Wireless Network: Infrastructure

- Network infrastructure
  - Larger network with which a wireless host wants to communicate
  - Typically a wired network
  - Provides traditional network services
  - May not always exist

Infrastructure Mode (APs)

- Infrastructure mode
  - Base station connects mobiles into wired network
  - Network provides services (addressing, routing, DNS)
  - Handoff: mobile changes base station providing connection to wired network
Channels and Association

• Multiple channels at different frequencies
  – Network administrator chooses frequency for AP
  – Interference if channel is same as neighboring AP

Mobility Within the Same Subnet

• H1 remains in same IP subnet
  – IP address of the host can remain same
  – Ongoing data transfers can continue uninterrupted
• H1 recognizes the need to change
  – H1 detects a weakening signal
  – Starts scanning for stronger one
• Changes APs with same SSID
  – H1 disassociates from one
  – And associates with other
• Switch learns new location
  – Self-learning mechanism

Questions

• Loss is primary caused by bit errors
  (A) Ethernet (Wired)
  (B) 802.11 (Wireless)
  (C) Both
  (D) Neither

• All hosts on subnet see all communication
  (A) Ethernet (Wired)
  (B) 802.11 (Wireless)
  (C) Both
  (D) Neither
WiFi: 802.11 Wireless LANs

802.11 LAN Architecture

- **Access Point (AP)**
  - Base station that communicates with the wireless hosts
- **Basic Service Set (BSS)**
  - Coverage of one AP
  - AP acts as the master
  - Identified by a “network name” known as an SSID

SSID: Service Set Identifier

CSMA: Carrier Sense, Multiple Access

- **Multiple access:** channel is shared medium
  - Station: wireless host or access point
  - Multiple stations may want to transmit at same time
- **Carrier sense:** sense channel before sending
  - Station doesn’t send when channel is busy
  - To prevent collisions with ongoing transfers
  - But, detecting ongoing transfers isn’t always possible

CA: Collision Avoidance, Not Detection

- **Collision detection in wired Ethernet**
  - Station listens while transmitting
  - Detects collision with other transmission
  - Aborts transmission and tries sending again
- **Problem #1:** cannot detect all collisions
  - Hidden terminal problem
  - Fading
CA: Collision Avoidance, Not Detection

- Collision detection in wired Ethernet
  - Station listens while transmitting
  - Detects collision with other transmission
  - Aborts transmission and tries sending again
- Problem #1: cannot detect all collisions
  - Hidden terminal problem
  - Fading
- Problem #2: listening while sending
  - Strength of received signal is much smaller
  - Expensive to build hardware that detects collisions
- So, 802.11 does collision avoidance, not detection

Hidden Terminal Problem

- A and C can’t see each other, both send to B
- Occurs b/c 802.11 relies on physical carrier sensing, which is susceptible to hidden terminal problem

Virtual carrier sensing

- First exchange control frames before transmitting data
  - Sender issues “Request to Send” (RTS), incl. length of data
  - Receiver responds with “Clear to Send” (CTS)
- If sender sees CTS, transmits data (of specified length)
- If other node sees CTS, will idle for specified period
- If other node sees RTS but not CTS, free to send

Hidden Terminal Problem

- A and C can’t see each other, both send to B
- RTS/CTS can help
  - Both A and C would send RTS that B would see first
  - B only responds with one CTS (say, echoing A’s RTS)
  - C detects that CTS doesn’t match and won’t send
Exposed Terminal Problem

- B sending to A, C wants to send to D
- As C receives packets, carrier sense would prevent it from sending to D, even though wouldn’t interfere
- RTS/CTS can help
  - C hears RTS from B, but not CTS from A
  - C knows it’s transmission will not interfere with A
  - C is safe to transmit to D

Impact on Higher-Layer Protocols

- Wireless and mobility change path properties
  - Wireless: higher packet loss, not from congestion
  - Mobility: transient disruptions, and changes in RTT
- Logically, impact should be minimal ...
  - Best-effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- But, performance definitely is affected
  - TCP treats packet loss as a sign of congestion
  - TCP tries to estimate the RTT to drive retransmissions
  - TCP does not perform well under out-of-order packets
- Internet not designed with these issues in mind

Questions

- RTS/CTS more like:
  A. Statistical multiplexing
  B. Time-division multiplexing
  C. Frequency-division multiplexing
- Which of following is NOT true?
  A. Collisions are minimized when RTS/CTS used.
  B. Sender can always detect a collision without feedback from receiver.
  C. TCP congestion control works poorly in wireless without link-layer retransmission.
  D. Wireless generally has higher loss rates than wired.

Bluetooth: 802.15.1 “personal-area-networks”
Bluetooth piconets

- Up to 7 “slave devices and 225 “parked” devices
- Operates on unlicensed wireless spectrum
  - How to prevent interference?

PHY: Spread Spectrum – Frequency Hopping

- Nodes rapidly jump between frequencies
- Sender and receiver coordinated in jumps
  - How coordinate? Pseudorandom number generator, with shared input known to sender/receiver
- If randomly collide with other transmitted, only for short period before jump again
- Bluetooth
  - 79 frequencies, on each frequency for 625 microseconds
  - Each channel also uses TDMA, with each frame taking 1/3/5 consecutive slots.
  - Only master can start in odd slot, slave only in response

Ad-Hoc Networks

- No base stations
- Nodes can only transmit to other nodes within link coverage
- Nodes self-organize and route among themselves
- Can create multi-hop wireless networks, vs. wired backend

Infrastructure vs. Ad Hoc

- Infrastructure mode
  - Wireless hosts are associated with a base station
  - Traditional services provided by the connected network
  - E.g., address assignment, routing, and DNS resolution
- Ad hoc networks
  - Wireless hosts have no infrastructure to connect to
  - Hosts themselves must provide network services
- Similar in spirit to the difference between
  - Client-server communication
  - Peer-to-peer communication
Delay Tolerant Networking

- Nodes can both route and store
  - Next hop is available, forward
  - Otherwise, store packets
- Useful for data collection with no time limit
  - e.g., sensors in the field
- Analogous to email
  - Hold onto packets until another hop can take it from you
  - Eventually reach its destination

The Upside to Interference

- Some systems leverage interference
- If packets collide once, likely will again
  - Can use both collisions to construct original packets
  - Reduce effective error rate significantly
- If two hosts send to each other through an AP, and collide, AP can broadcast collision to both
  - Both know what they sent, can “subtract” that from collision to get the other
  - Improves throughput of system!

Conclusions

- Wireless
  - Already a major way people connect to the Internet
  - Gradually becoming more than just an access network
- Mobility (not discussed)
  - Today’s users tolerate disruptions as they move
  - … and applications try to hide the effects
  - Tomorrow’s users expect seamless mobility
- Challenges the design of network protocols
  - Wireless breaks the abstraction of a link, and the assumption that packet loss implies congestion
  - Mobility breaks association of address and location
  - Higher-layer protocols don’t perform as well