Wireless Networks
Lecture 11: Wireless LANs
Aloha and 802 Wireless

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Outline

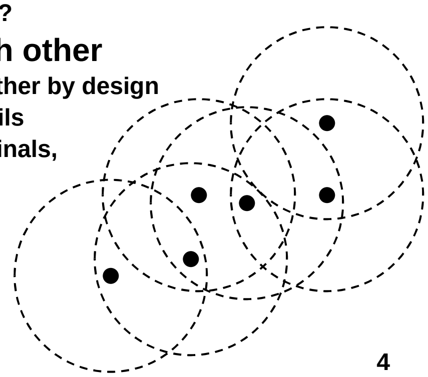
- Data link fundamentals
  - » And what changes in wireless
- Supporting data traffic
- Wireless-specific challenges
- Aloha
- 802.11 and 802.15 wireless standards

Wireless Ethernet is a Good Idea, but …

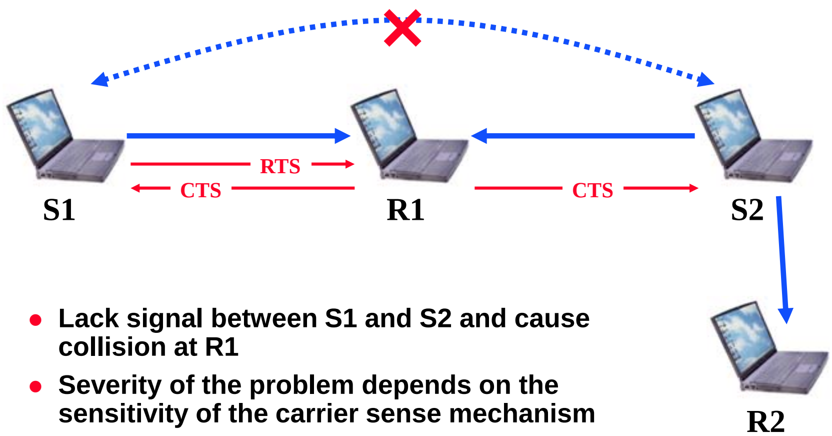
- Attenuation varies with media
  - » Also depends strongly on distance, frequency
- Wired media have exponential dependence
  - » Received power at d meters proportional to 10^{-kd}
  - » Attenuation in dB = *k d*, where *k* is dB/meter
- Wireless media has logarithmic dependence
  - » Received power at d meters proportional to d^{-n}
  - » Attenuation in dB = *n log d*, where *n* is path loss exponent; *n=2* in free space
  - » Signal level maintained for much longer distances?
- But we are ignoring the constants!
  - » Wireless attenuation at 2.4 GHz: 60-100 dB
  - » In practice numbers can be much lower for wired

Implications for Wireless Ethernet

- Collision detection is not practical
  - » Ratio of transmitted signal power to received power is too high at the transmitter
  - » Transmitter cannot detect competing transmitters (is deaf while transmitting)
  - » So how do you detect collisions?
- Not all nodes can hear each other
  - » Ethernet nodes can hear each other by design
  - » "Listen before you talk" often fails
  - » Hidden terminals, exposed terminals,
  - » Capture effects
- Made worse by fading
  - » Changes over time!



Hidden Terminal Problem



- Lack signal between S1 and S2 and cause collision at R1
- Severity of the problem depends on the sensitivity of the carrier sense mechanism
  - » Clear Channel Assessment (CCA) threshold

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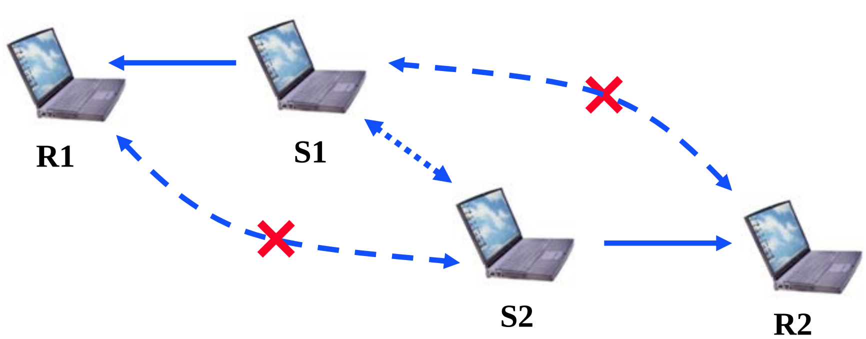
Exposed Terminal Problem



- Carrier sense prevents two senders from sending simultaneously although they do not reach each other’s receiver
- Severity again depends on CCA threshold
  - » Higher CCA reduces occurrence of exposed terminals, but can create hidden terminal scenarios

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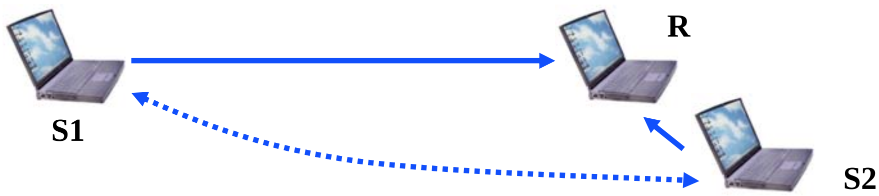
Capture Effect



- Sender S2 will almost always “win” if there is a collision at receiver R.
- Can lead to extreme unfairness and even starvation.
- Solution is power control
  - » Very difficult to manage in a non-provisioned environment!

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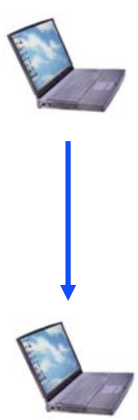
Wireless Packet Networking Problems



- Some nodes suffer from more interference than others
  - » Node density
  - » Traffic volume sent by neighboring nodes
- Leads to unequal throughput
- Similar to wired network: some flows traverse tight bottleneck while others do not

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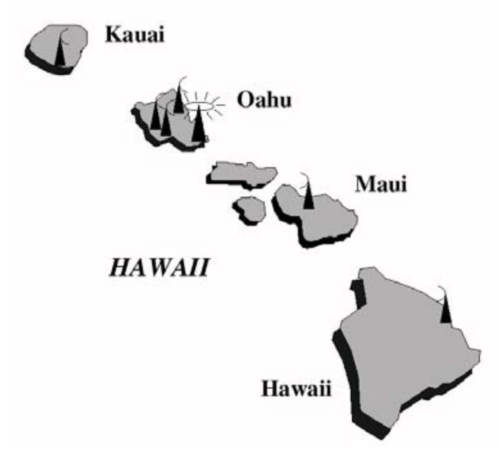
Why ALOHA



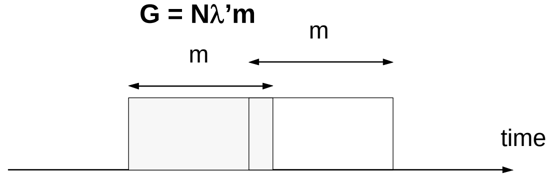
Pure ALOHA

- Developed in University of Hawaii in early 1970's.
- It does not get much simpler:
  1. A user transmits at will
  2. If two or more messages overlap in time, there is a collision – receiver cannot decode packets
  3. Receive waits for roundtrip time plus a fixed increment – lack of ACK = collision
  4. After a collision, colliding stations retransmit the packet, but they stagger their attempts randomly to reduce the chance of repeat collisions
  5. After several attempts, senders give up
- Although very simple, it is wasteful of bandwidth, attaining efficiency of at most 1/(2e) = 0.18

Pure Aloha: Vulnerability

- Simplification: assume the retransmitted messages are independent Poisson process as well
- The total rate of packets attempting transmission = newly generated packets + retransmitted ones = $\lambda' > \lambda$
- The total traffic intensity (including retransmissions) is ,

$$G = N\lambda' m$$

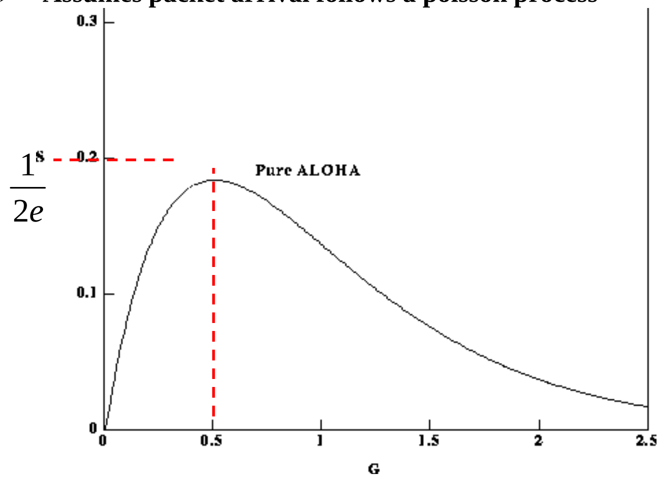


Collision between two messages

- The "vulnerable period" in which a collision can occur for a given packet is 2 x m sec

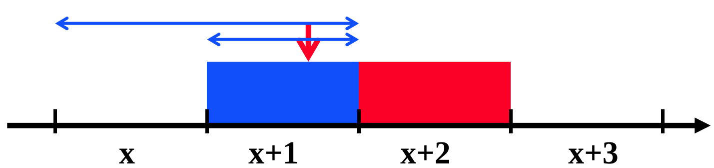
Aloha Performance

- **Aloha's performance can be analyzed easily**
  - **Assumes packet arrival follows a poisson process**

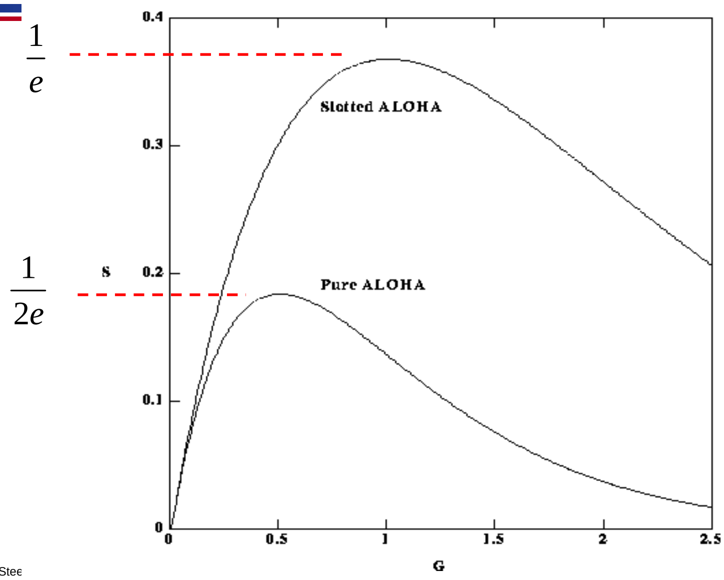


Slotted ALOHA

- **Transmission can only start at the beginning of each slot of length T**
- **Vulnerable period is reduced to T**
  - » **Instead of 2xT in Aloha**
- **Doubles maximum throughput.**



Analysis Results Slotted ALOHA



Discussion of ALOHA

- Maximum throughput of ALOHA is only very low 1/(2e) = 18%, but
- Has very low latency under light load
- Slotted Alohas has twice the performance of basic Aloha, but performance is still poor
  - » Slotted design is also not very efficient when carrying variable sized packets!
  - » Slightly longer delay than pure Aloha
- Still, not bad for an absolutely minimal protocol!
- How do we go faster?

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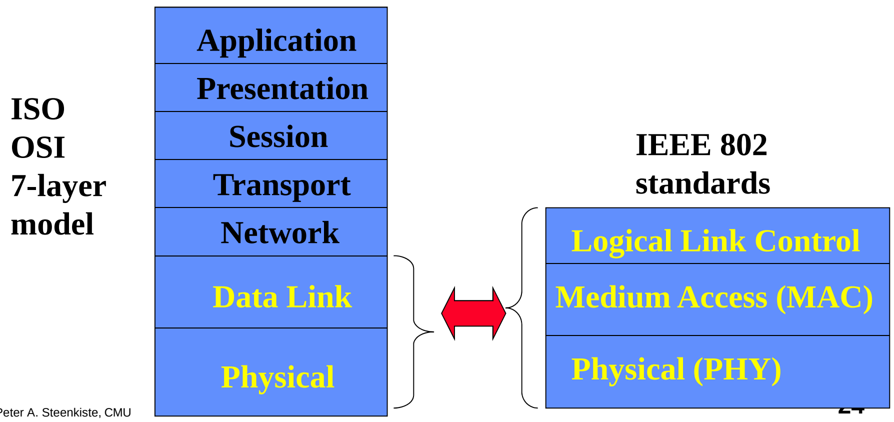
- Ethernet
- Wireless-specific challenges
- Aloha
- 802.11 and 802.15 wireless standards
  - » 802 protocol overview
  - » Wireless LANs – 802.11
  - » Personal Area Networks – 802.15

History

- Aloha wireless data network
- Car phones
  - » Big and heavy "portable" phones
  - » Limited battery life time
  - » But introduced people to "mobile networking"
  - » Later turned into truly portable cell phones
- Wireless LANs
  - » Originally in the 900 MHz band
  - » Later evolved into the 802.11 standard
  - » Later joined by the 802.15 and 802.16 standards
- Cellular data networking
  - » Data networking over the cell phone
  - » Many standards – throughput is the challenge

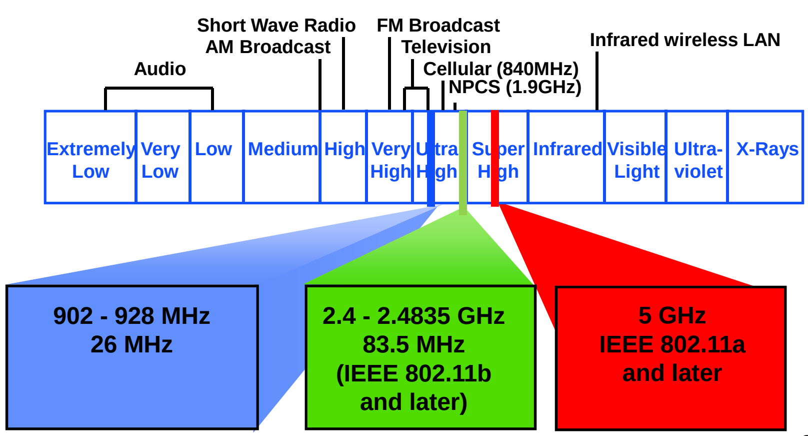
Standardization of Wireless Networks

- Wireless networks are standardized by IEEE
- Under 802 LAN MAN standards committee



Frequency Bands

- Industrial, Scientific, and Medical (ISM) bands
- Unlicensed, 22 MHz channel bandwidth



The 802 Class of Standards

- List on next slide
- Some standards apply to all 802 technologies
  - » E.g. 802.2 is LLC
  - » Important for inter operability
- Some standards are for technologies that are outdated
  - » Not actively deployed anymore
  - » E.g. 802.6

- 802.1 Overview Document Containing the Reference Model, Tutorial, and Glossary
- 802.1 b Specification for LAN Traffic Prioritization
- 802.1 q Virtual Bridged LANs
- 802.2 Logical Link Control
- 802.3 Contention Bus Standard 1 Obase 5 (Thick Net)
  - » 802.3a Contention Bus Standard 10base 2 (Thin Net)
  - » 802.3b Broadband Contention Bus Standard 10broad 36
  - » 802.3d Fiber-Optic InterRepeater Link (FOIRL)
  - » 802.3e Contention Bus Standard 1 base 5 (Starlan)
  - » 802.3i Twisted-Pair Standard 10base T
  - » 802.3j Contention Bus Standard for Fiber Optics 10base F
  - » 802.3u 100-Mb/s Contention Bus Standard 100base T
  - » 802.3x Full-Duplex Ethernet
  - » 802.3z Gigabit Ethernet
  - » 802.3ab Gigabit Ethernet over Category 5 UTP
- 802.4 Token Bus Standard
- 802.5 Token Ring Standard
  - » 802.5b Token Ring Standard 4 Mb/s over Unshielded Twisted-Pair
  - » 802.5f Token Ring Standard 16-Mb/s Operation
- 802.6 Metropolitan Area Network DQDB
- 802.7 Broadband LAN Recommended Practices
- 802.8 Fiber-Optic Contention Network Practices
- 802.9a Integrated Voice and Data LAN
- 802.10 Interoperable LAN Security
- 802.11 Wireless LAN Standard
- 802.12 Contention Bus Standard 1 OOVG AnyLAN
- 802.15 Wireless Personal Area Network
- 802.16 Wireless MAN Standard

Summary

- Wireless signal propagation creates problems for “wireless Ethernet”
  - » Collision Detection is not possible
  - » Hidden and exposed terminals
  - » Capture effect
- Aloha was the first wireless data communication protocol
  - » Simple: send whenever you want to
  - » Has low latency but low capacity