Wireless Networks
Lecture 10: LAN MAC Protocols
Wireless versus Wired

Peter Steenkiste
CS and ECE, Carnegie Mellon University

Peking University, Summer 2016

Outline

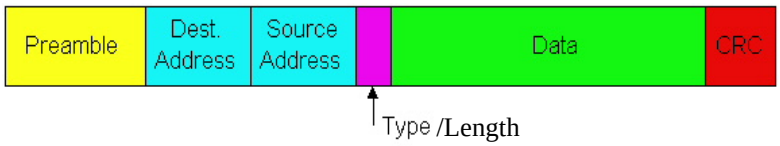
- **Data link fundamentals**
  - » **And what changes in wireless**
- **Ethernet**
- **Wireless-specific challenges**
- **Aloha**
- **802.11 and 802.15 wireless standards**

Datalink Functions

- **Framing: encapsulating a packet into a bit stream.**
  - » **Add header, mark and detect frame boundaries, …**
- **Logical link control: managing the transfer between the sender and receiver, e.g.**
  - » **Error detection and correction to deal with bit errors**
  - » **Flow control: avoid that the sender outruns the receiver**
- **Media access: controlling which frame should be sent over the link next.**
  - » **Easy for point-to-point links; half versus full duplex**
  - » **Harder for multi-access links: who gets to send?**

Framing

- **Typical structure of a "wired" packet:**
  - » **Preamble: synchronize clocks sender and receiver**
  - » **Header: addresses, type field, length, etc.**
  - » **The data to be send, e.g., an IP packet**
  - » **Trailer: padding, CRC, ..**



- **How does wireless differ?**
  - » **Different transmit rates for different parts of packet**
  - » **Explicit multi-hop support**
  - » **Control information for physical layer**
  - » **Ensure robustness of the header**

Error Control: Error Detection and Error Recovery

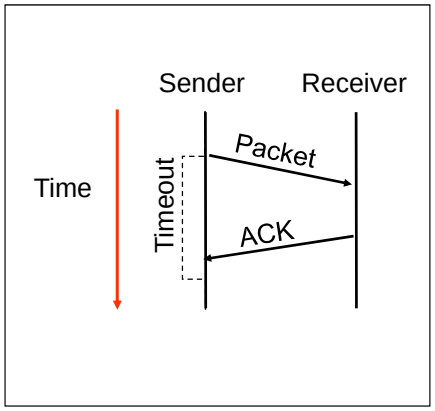
- Detection: only detect errors
  - » Make sure corrupted packets get thrown away, e.g. Ethernet
  - » Use of error detection codes, e.g. CRC
- Recovery: also try to recover from lost or corrupted packets
  - » Option 1: forward error correction (redundancy)
  - » Option 2: retransmissions
- How does wireless differ?
  - » Uses CRC to detect errors, similar to wired
  - » Error recovery is much more important because errors are more common and error behavior is very dynamic
  - » What approach is used?

Error Recovery in Wireless

- Use of redundancy:
  - » Very common at physical layer – see PHY lectures
  - » Spread spectrum, OFDM, etc.
- Use of Automatic Repeat Request (ARQ)
  - » Use time outs to detect loss and retransmit
- Many variants:
  - » Stop and wait: one packet at a time
  - » Go Back N: sender keeps sending and retransmits, starting with the unacknowledged packet
  - » Selective Repeat: only packets that are not acknowledged are retransmitted
- When should what variant be used?
  - » Noise versus bursty (strong) interference

Stop and Wait

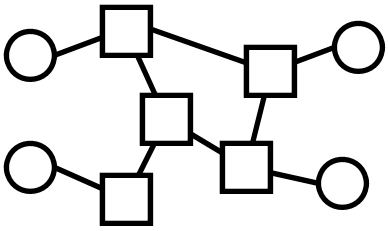
- Simplest ARQ protocol
- Send a packet, stop and wait until acknowledgement arrives
- Will examine ARQ issues later in semester



Media Access Control

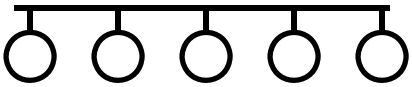
- How do we transfer packets between two hosts connected to the same network?
- Using point-to-point "links" with "switches" -- store-and-forward
  - » Very common in wired networks, at multiple layers
- Multiple access networks
  - » Multiple hosts are sharing the same transmission medium
  - » Need to control access to the medium
  - » Taking turn versus contention based protocols
- What is different in wireless?
  - » Is store and forward used?
  - » Is multiple access used?

Datalink Architectures



- Routing and packet forwarding.
- Point-to-Point error and flow control.

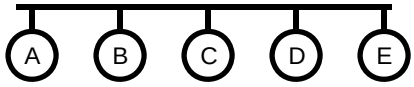
Switched ethernet, mesh and ad hoc networks



- Media access control.
- Scalability.

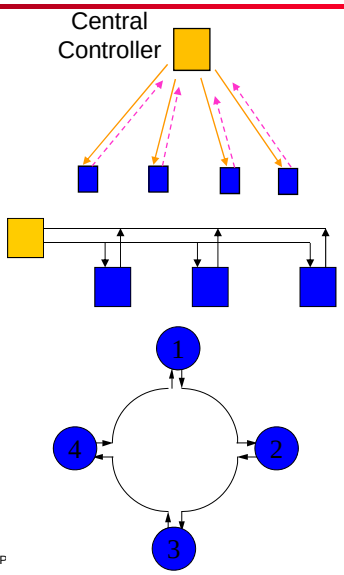
Traditional ethernet, Wifi, cellular, …

Multiple Access Networks



- Who gets to send a packet next?
- Scheduled access: explicit coordination ensures that only one node transmits
  - » Looks cleaner, more organized, but …
  - » Coordination introduces overhead – requires communication (oops)
- Random access: no explicit coordination
  - » Potentially more efficient, but …
  - » How does a node decide whether it can transmit?
  - » Collisions are unavoidable – also results in overhead
  - » How do you even detect a collision?

Scheduled Access MACs



- Polling: controller polls each nodes
- Reservation systems
  - » Central controller
  - » Distributed algorithm, e.g. using reservation bits in frame
- Token ring: token travels around ring and allows nodes to send one packet
  - » Distributer version of polling
  - » FDDI, …

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Outline

- Data link fundamentals
  - » And what changes in wireless
- Ethernet
- Wireless-specific challenges
  - » Ethernet review
  - » How wireless differs
- Aloha
- 802.11 and 802.15 wireless standards

Peter A. Steenkiste

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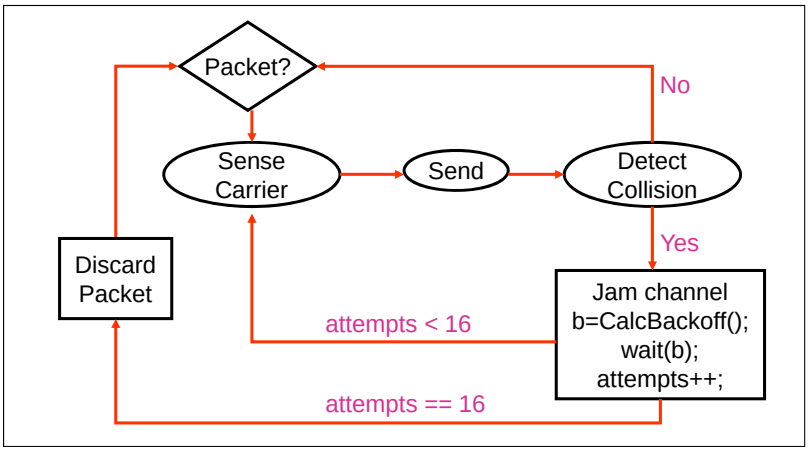
"Regular" Ethernet CSMA/CD

- Multiple Access: multiple hosts are competing for access to the channel
- Carrier-Sense: make sure the channel is idle before sending – "listen before you send"
- Collision Detection: collisions are detected by listening on the medium and comparing the received and transmitted signals
- Collisions results in 1) aborting the colliding transmissions and 2) retransmission of the packets
- Exponential backoff is used to reduce the chance of repeat collisions
  - » Also effectively reduces congestion

Carrier Sense Multiple Access/ Collision Detection (CSMA/CD)



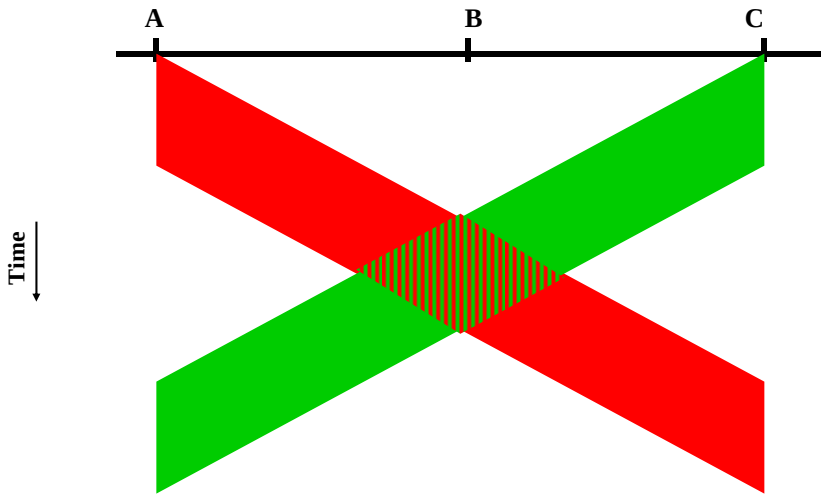
Ethernet Backoff Calculation

- Challenge: how do we avoid that two nodes retransmit at the same time collision
- Exponentially increasing random delay
  - » Infer "number" senders from # of collisions
  - » More senders → increase wait time
- First collision: choose K from {0,1}; delay is K x 512 bit transmission times
- After second collision: choose K from {0,1,2,3}
- After ten or more collisions, choose K from {0,1,2,3,4,…,1023}

How to Handle Transmission When Line is Sensed Busy

- *p-persistent scheme*:
  - » Transmit with probability p once the channel goes idle
  - » Delay the transmission by t_{prop} with the probability (1-p)
- *1-persistent scheme*: p = 1
  - » E.g. Ethernet
- *nonpersistent scheme*:
  - » Reschedule transmission for a later time based on a retransmission delay distribution (e.g. exp backoff)
  - » Senses the channel at that time
  - » Repeat the process
- When is each solution most appropriate?

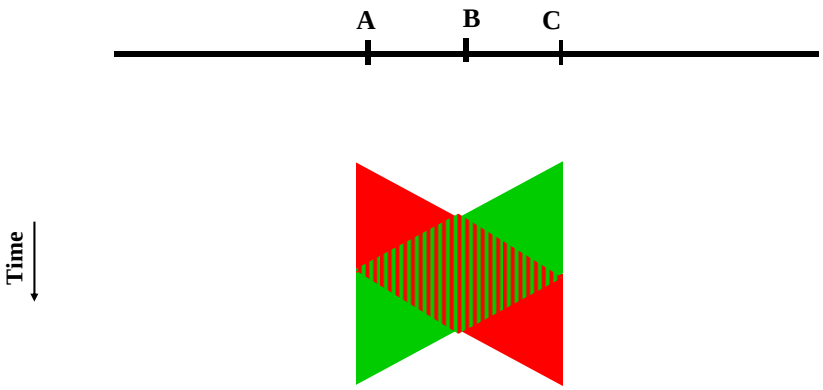
Collisions



Dealing with Collisions

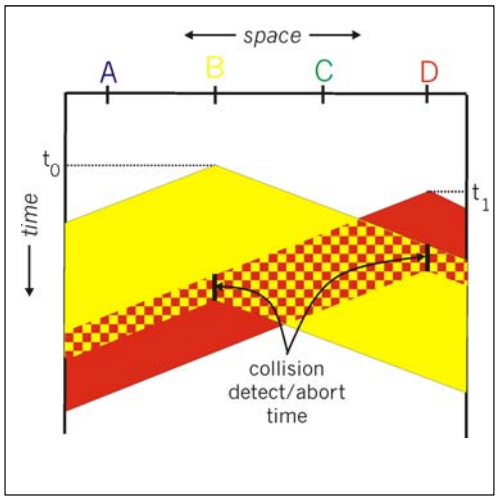
- Collisions will happen: nodes can start to transmit “simultaneously”
  - » Vulnerability window depends on length of wire
- Recovery requires that both transmitters can detect them reliably
  - » Clearly a problem as shown on previous slide
- How can we guarantee detection?

Detecting Collisions



Minimum Packet Size

- Packets must be long enough to guarantee all nodes observe collision
- Depends on packet size and length of wire
  - » Propagation delay
- Min packet length > 2x max prop delay



So What about WiFi?

- Or more general: unprovisioned data services in the unlicensed spectrum
- Cellular uses scheduled access
  - » Designed for provisioned services in licensed spectrum
  - » More on this later in the course
  - » Not a good fit for bursty traffic
- Random access solutions are a better fit for unlicensed spectrum
  - » Lower control complexity, especially for contention-based protocols (e.g., Ethernet)
  - » There may not always be a centralized controller
  - » May need to support multi-hop
  - » Optimized for bursty traffic

Summary

- Wireless uses the same types of protocols as wired networks
  - » But it is inherently a multiple access technology
- Some fundamental differences between wired and wireless may result in different design choices
  - » Higher error rates
  - » Must support variable bit rate communication
  - » Signal propagation and radios are different