More on Link Layer

Kai Shen

Recap of Last Class

- Ethernet
  - dominant link layer technology for local-area networks
  - Ethernet frame size
  - Ethernet multiple access control
    - CSMA/CD, exponential back-off
    - factors for its efficiency
    - Speed: 10Mbps, 100Mbps, 1Gbps, 10Gbps, ...
- Link-layer addresses
  - Static per-device, universally unique
  - ARP
  - Why multiple addresses at multiple layers?

Interconnecting Nodes in Local-Area Networks

- Hubs: physical-layer signal repeaters.
- Bridges: smarter, understands link-layer protocol (Ethernet).
- Switches: essentially bridges with large number of ports.

Interconnecting with Hubs

- Physical-layer repeater
  - Repeat signal on all outgoing links
  - Doesn’t care whether links are busy or not
  - No buffering
- Problems:
  - Simultaneous traffic from multiple segments may collide
  - Can’t interconnect links at different speeds
Bridges
- Link layer device
  - understands and participates in Ethernet
  - buffers frame, uses CSMA/CD to access link
  - traffic isolation
  - selectively forwards frame based on dest. address (avoid flooding all links)

How to determine to which LAN segment to forward frame?

Self Learning
- A bridge has a bridge table
  - each entry: (Dest. address, bridge interface, timestamp)
- bridges learn which host is connected through which interface
  - when frame received, bridge "learns" location of sender: incoming LAN segment
  - records sender/location pair in bridge table

Bridge Example
- Bridge receives frame from C destined to D
  - bridge learns C is on interface 1
  - because D is not in table, bridge floods
- Another frame from C to D?
  - Frame received by D, then a reply is sent back to C
    - bridge learns D is on interface 2
    - in bridge table C is on interface 1, so bridge selectively forwards frame to interface 1

Bridge Forwarding
- When to start forwarding?
  - stop and forward: frame is completely buffered before forwarded to the next hop
  - cut-through forwarding: frame forwarded from input to output port without awaiting for assembly of entire frame
    - reduction in latency
    - implication on Ethernet frame structure?
**Important Bridge Features**

- Isolates collision domains resulting in higher total throughput
- “Plug-and-play”: no configuration necessary
- Buffering allow links of different speeds on a single bridge: 100Mbps/1Gbps interfaces
- Cut-through forwarding

**Ethernet Switches**

- Essentially a bridge with a large number of ports
  - so many ports that each host can connect to one
- After self-learning
  - A-to-A’ and B-to-B’ simultaneously at full link speed, no collisions
  - Ethernet but no collisions for simultaneous uses
  - How about congestion?

**Ethernet Switch Scalability**

- Switch allows simultaneous traffic at full link speed How does it scale?
- Switch architectures
  - Bus
  - Crossbar
- A switch with a large number of ports
  - High implementation complexity ⇒ costly to build

**Switch Interconnection**

(no enough ports on a single switch)
Network Switching at Multi-Server Data Centers

- Thousands of servers with hierarchical network switching
- Reduce congestions:
  - Network load balance across nodes
  - Place highly communicating server modules within same switch domain, or better yet, in same machines
  - Redundant backbone links → Equal-Cost Multi-Path (ECMP) routing

Summary Comparison

- Hubs
  - little more than a physical-layer signal repeater, no traffic isolation, buffering
- Bridges
  - understands link-layer protocol (Ethernet), supports smarter forwarding, traffic isolation
  - supports different Ethernet speeds with buffering
- Switches
  - essentially bridges with large number of ports
  - no collision, but congestion is possible at individual links
  - widespread usage today!

Media Access Control in Wireless LAN -- IEEE 802.11

- Collision if 2 or more nodes transmit at same time
- Can we use CSMA/CD?
  - hidden terminal problem → carrier sense and collision detection don’t work
- Repair carrier sense:
  - carrier probing
- Repair collision detection:
  - success acknowledgement

PPP (point-to-point protocol)

- one sender, one receiver, one link:
  - no media access control
  - no need for explicit MAC addressing
  - simpler than broadcast link
- deployed in:
  - dialup links over telephone lines
  - long-haul fiber-optics links
**Link Virtualization**

- What is a link?
  - physical wire
  - connection between two IP network-aware nodes
- Virtual link
  - in the case of switched Ethernet?
  - in the case of phone/modem link?
- Why virtual link?
  - flexibility of technology evolution
  - link up legacy networks

The virtual link may be composed of multiple physical wires, or even a network of its own.

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