More on Link Layer

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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 allows 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 Internet Server Center

- 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
  - Redundancy at backbone links

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
Reliability Services

- Error detection
- Error correction or recovery
- Loss recovery
- Flow control
  - pacing between sending and receiving nodes such that the sender does not overwhelm the receiver
- In-order delivery

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 PPP modem link?
- Why virtual link?
  - more efficient
  - link up legacy networks

Link Virtualization

ATM (asynchronous transfer mode)
- a multilayer network architecture at its own
- mainly designed for supporting real-time multimedia, with connection-oriented resource reservation
- deemed as link layer protocols in Internet architecture
  → IP over ATM

Frame relay
- origins in telephony world
- Like ATM, a network architecture at its own, with connection-oriented resource reservation
- can be used to carry IP datagrams → IP over frame relay

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