

More on Link Layer

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Recap of Last Class

- Ethernet
 - "dominant" link layer technology for local-area networks
 - Ethernet frame structure
 - Ethernet multiple access control
 - CSMA/CD, exponential back-off
 - factors for its efficiency
 - At different speeds: 10, 100, 1000 Mbps
- Link-layer addresses
 - Static per-device, universally unique, different from IP addresses

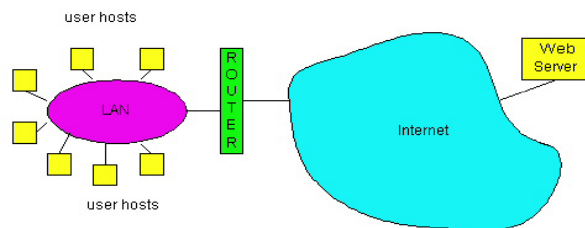
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Interconnecting Nodes in LAN (Local-Area Network)

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



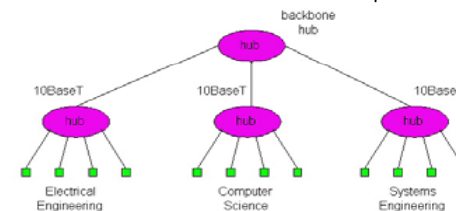
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Interconnecting with Hubs

- **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



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Bridges

- **Link layer** device
 - stores and forwards Ethernet frames
 - examines frame header and **selectively** forwards frame based on dest. address
 - when frame is to be forwarded to a network segment, uses CSMA/CD to access segment

How to determine to which LAN segment to forward frame?

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Self Learning

- A bridge has a **bridge table**
 - each entry: (Dest. address, bridge interface, timestamp)
 - stale entries in table dropped
- 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

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Bridge Example

address	port
A	1
B	1
E	2
H	3
J	3

- 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

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Bridges: Traffic Isolation

- Bridge understands and participates in CSMA/CD
- Bridge installation breaks LAN into LAN segments
- bridges **filter** packets:
 - same-LAN-segment frames **not usually** forwarded onto other LAN segments
 - segments become separate **collision domains**

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Important Bridge Features

- Transparent ("plug-and-play"): no configuration necessary
- Isolates collision domains resulting in higher total max throughput
- Buffering allow links of different speed on a single bridge: 10/100/1000 Mbps interfaces

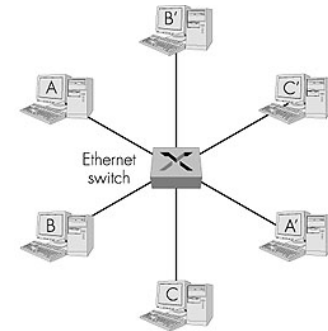
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Ethernet Switches

- essentially a bridge with a large number ports
 - ⇒ so many ports that each host can connect to one
 - high implementation complexity ⇒ costly to build
- After self-learning
 - A-to-A' and B-to-B' simultaneously, no collisions
 - Ethernet, but a shared link with dedicated channel to every node, no collisions!



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Ethernet Switches (cont.)

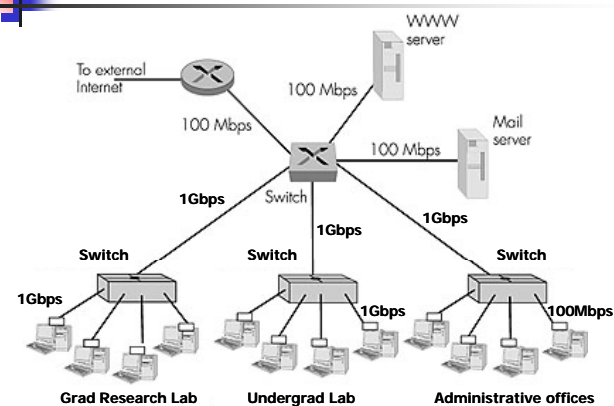
- switch allows simultaneous traffic at full link speed
 - even if each link can operate at full speed, congestion can still occur
- forwarding technologies:
 - **stop and forward**: frame is completely buffered before forwarded to the next hop
 - **cut-through switching**: frame forwarded from input to output port without awaiting for assembly of entire frame
 - reduction in latency
 - when can we start forwarding?

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Switch Interconnection Example



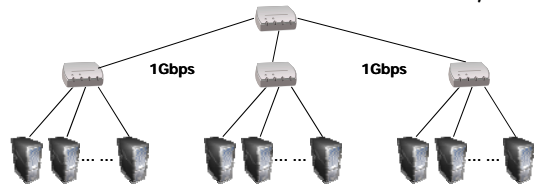
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Network Switching at Internet Server Center

- Thousands of servers, connected with hierarchical network switches, sometimes with redundancy



- Reduce congestions:
 - Network load balance across nodes
 - Place highly communicating server modules within same switch domain, or better yet, in same machines

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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!

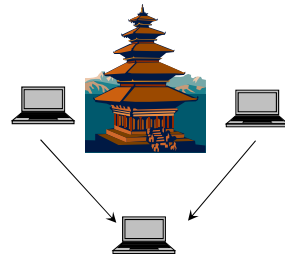
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Media Access Control in Wireless LAN -- IEEE 802.11

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



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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

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Reliability Services

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

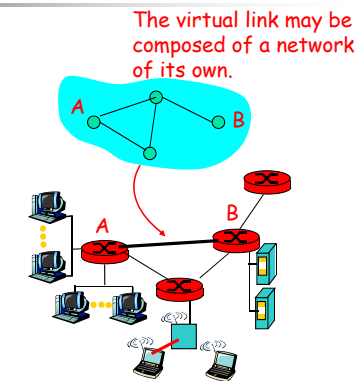
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Link Virtualization (concept)

- What is a link?
 - physical wire
 - connection between two adjacent network-aware nodes
- Virtual link
 - in the case of switched Ethernet?
 - in the case of PPP modem link?



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Link Virtualization (practices)

- 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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