Hubs, Bridges, and Switches (oh my)

- Used for extending LANs in terms of geographical coverage, number of nodes, administration capabilities, etc.
- Differ in regards to:
  - collision domain isolation
  - layer at which they operate
- Different than routers
  - plug and play
  - don't provide optimal routing of IP packets

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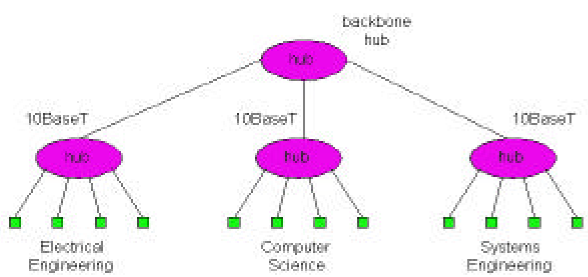
Hubs

- Physical Layer devices: essentially repeaters operating at bit levels: repeat received bits on one interface to all other interfaces
- Hubs can be arranged in a hierarchy (or **multi-tier design**), with a **backbone** hub at its top



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Hubs (more)

- Each connected LAN is referred to as a LAN **segment**
- Hubs **do not isolate** collision domains: a node may collide with any node residing at any segment in the LAN
- Hub Advantages:
  - Simple, inexpensive device
  - Multi-tier provides graceful degradation: portions of the LAN continue to operate if one of the hubs malfunction
  - Extends maximum distance between node pairs (100m per Hub)

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Hubs (more)

- Hub Limitations:
  - Single collision domain results in no increase in max throughput; the multi-tier throughput same as the the single segment throughput
  - Individual LAN restrictions pose limits on the number of nodes in the same collision domain (thus, per Hub); and on the total allowed geographical coverage
  - May not connect different Ethernet types (e.g., 10BaseT and 100baseT)

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Bridges

- **Link Layer devices**: they operate on Ethernet frames, examining the frame header and selectively forwarding a frame base on its destination
- Bridge **isolates collision** domains since it buffers frames
- When a frame is to be forwarded on a segment, the bridge uses CSMA/CD to access the segment and transmit

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Bridges (more)

- Bridge advantages:
  - Isolates collision domains resulting in higher total max throughput, and does not limit the number of nodes nor geographical coverage
  - Can connect different type Ethernet since it is a store and forward device
  - Transparent: no need for any change to hosts LAN adapters

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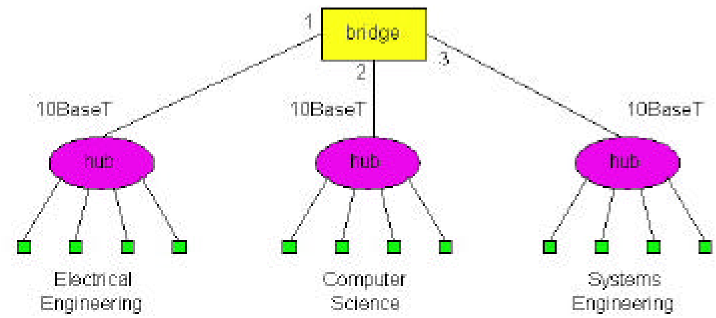
Backbone Bridge



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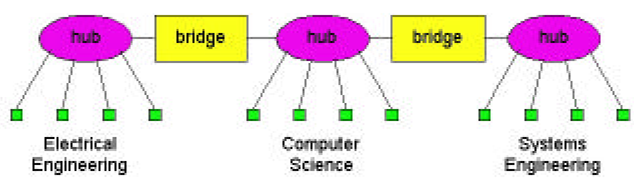
Interconnection Without Backbone



- **Not recommended** for two reasons:
  - Single point of failure at Computer Science hub
  - All traffic between EE and SE must path over CS segment

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Bridge Filtering

- Bridges learn which hosts can be reached through which interfaces and maintain filtering tables
- A filtering table entry:

  (Node LAN Address, Bridge Interface, Time Stamp)
- Filtering procedure:

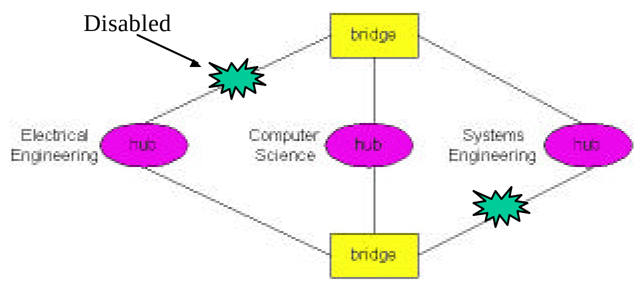
```
if destination is on LAN on which frame was received
    then drop the frame
    else { lookup filtering table
           if entry found for destination
              then forward the frame on interface indicated;
              else flood;    /* forward on all but the interface on
                                which the frame arrived*/
         }
```


Bridge Learning

- When a frame is received, the bridge "learns" from the source address and updates its filtering table (Node LAN Address, Bridge Interface, Time Stamp)
- Stale entries in the Filtering Table are dropped (TTL can be 60 minutes)

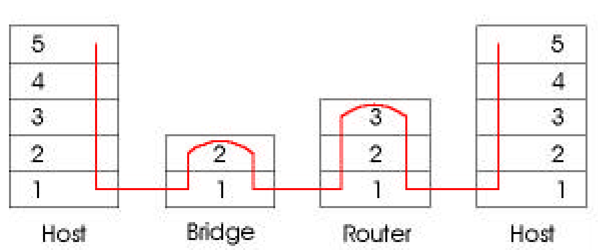
Bridges Spanning Tree

- For increased reliability, it is desirable to have redundant, alternate paths from a source to a destination
- With multiple simultaneous paths however, cycles result on which bridges may multiply and forward a frame forever
- Solution is organizing the set of bridges in a spanning tree by disabling a subset of the interfaces in the bridges:



WWF Bridges vs. Routers Smackdown

- Both are store-and-forward devices, but Routers are Network Layer devices (examine network layer headers) and Bridges are Link Layer devices
- Routers maintain routing tables and implement routing algorithms, bridges maintain filtering tables and implement filtering, learning and spanning tree algorithms



Routers vs. Bridges

- Bridges + and -

+ Bridge operation is simpler requiring less processing bandwidth

- Topologies are restricted with bridges: a spanning tree must be built to avoid cycles

- Bridges do not offer protection from broadcast storms (endless broadcasting by a host will be forwarded by a bridge)

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Routers vs. Bridges

- Routers + and -

+ Arbitrary topologies can be supported, cycling is limited by TTL counters (and good routing prots)
+ Provide firewall protection against broadcast storms
- Require IP address configuration (not plug and play)
- Require higher processing bandwidth

- Bridges do well in small (few hundred hosts) while routers are required in large networks (thousands of hosts)

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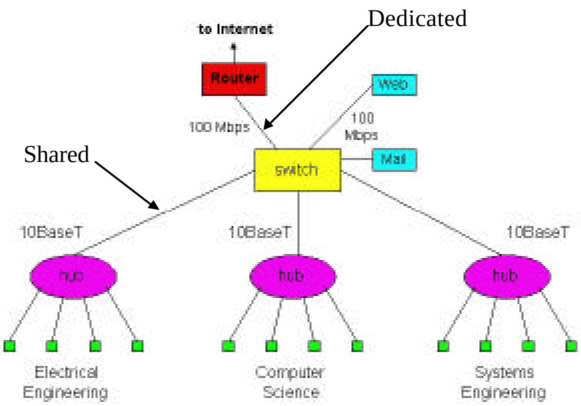
Ethernet Switches

- A switch is a device that incorporates bridge functions as well as point-to-point 'dedicated connections'
- A host attached to a switch via a dedicated point-to-point connection; will always sense the medium as idle; no collisions ever!
- Ethernet Switches provide a combinations of shared/dedicated, 10/100/1000 Mbps connections

Ethernet

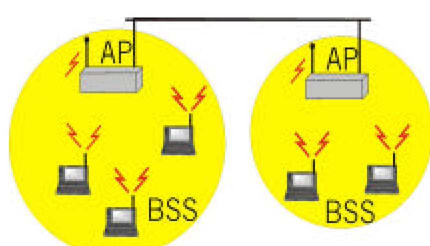
- Some E-net switches support cut-through switching: frame forwarded immediately to destination without awaiting for assembly of the entire frame in the switch buffer; slight reduction in latency
- Ethernet switches vary in size, with the largest ones incorporating a high bandwidth interconnection network

Ethernet Switches (more)



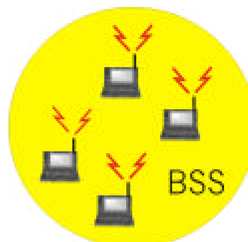
IEEE 802.11 Wireless LAN

- Wireless LANs are becoming popular for mobile Internet access
- Applications: nomadic Internet access, portable computing, ad hoc networking (multihopping)
- IEEE 802.11 standards defines MAC protocol; unlicensed frequency spectrum bands: 900Mhz, 2.4Ghz
- **Basic Service Sets + Access Points => Distribution System**
- Like a bridged LAN (flat MAC address)



Ad Hoc Networks

- IEEE 802.11 stations can dynamically form a group without AP
- Ad Hoc Network: no pre-existing infrastructure
- Applications: “laptop” meeting in conference room, car, airport; interconnection of “personal” devices (see bluetooth.com); battelfield; pervasive computing (smart spaces)
- IETF MANET (Mobile Ad hoc Networks) working group



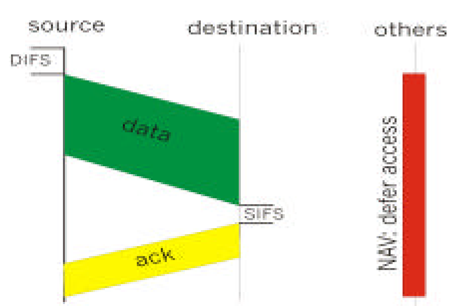
IEEE 802.11 MAC Protocol

CSMA Protocol:

- sense channel idle for **DISF** sec (Distributed Inter Frame Space)
  - transmit frame (no Collision Detection)
  - receiver returns ACK after **SIFS** (Short Inter Frame Space)

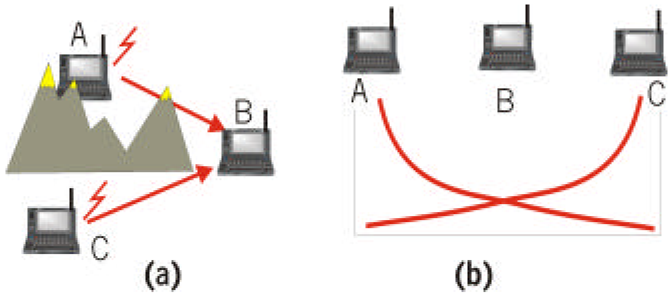
-if channel sensed busy then binary backoff

NAV: Network Allocation Vector (min time of deferral)



Hidden Terminal effect

- CSMA inefficient in presence of hidden terminals
- Hidden terminals: A and B cannot hear eachother because of obstacles or signal attenuation; so, their packets collide at B
- Solution? **CSMA/CA**
- **CA** = Collision Avoidance



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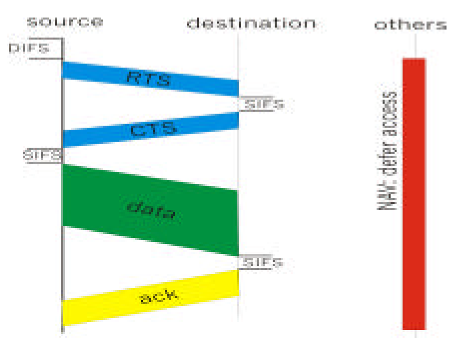
Collision Avoidance: RTS-CTS exchange

• **CTS** "freezes" stations within range of receiver (but possibly hidden from transmitter); this prevents collisions by hidden station during data
• **RTS** and **CTS** are very short: collisions during data phase are thus very unlikely (the end result is similar to Collision Detection)

•Note: IEEE 802.11 allows **CSMA, CSMA/CA** and "**polling**" from AP



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Point to Point protocol (PPP)

- Point to point, wired data link easier to manage than broadcast link: no Media Access Control
- Several Data Link Protocols: PPP, HDLC, SDLC, Alternating Bit protocol, etc
- PPP (Point to Point Protocol) is very popular: used in dial up connection between residential Host and ISP; on SONET/SDH connections, etc
- PPP is extremely simple (the simplest in the Data Link protocol family) and very streamlined

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PPP Requirements

- Pkt framing: encapsulation of packets
- bit transparency: must carry any bit pattern in the data field
- error detection (no correction)
- multiple network layer protocols
- connection liveness
- Network Layer Address negotiation: Hosts/nodes across the link must learn/configure each other's network address

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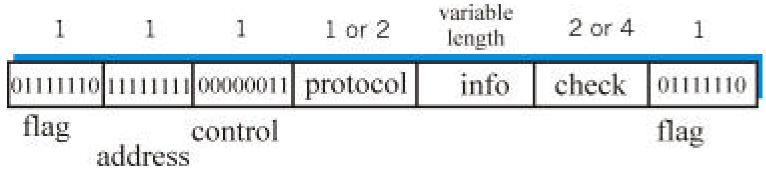
Not Provided by PPP

- error correction/recovery
- flow control
- sequencing
- multipoint links (e.g., polling)

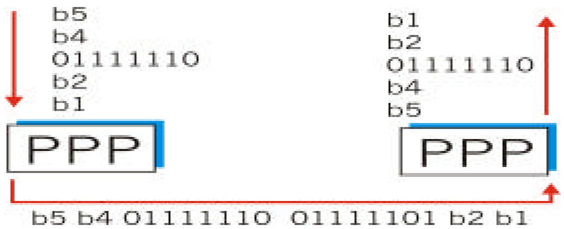
PPP Data Frame

- Flag: delimiter (framing)
- Address: does nothing (only one option)
- Control: does nothing; in the future possible multiple control fields
- Protocol: upper layer to which frame must be delivered (eg, PPP-LCP, IP, IPCP, etc)



Byte Stuffing

- For "data transparency", the data field must be allowed to include the pattern <01111110> ; ie, this must not be interpreted as a flag
- to alert the receiver, the transmitter "stuffs" an extra < 01111110> byte after each < 01111110> data byte
- the receiver discards each 01111110 followed by another 01111110, and continues data reception



PPP Data Control Protocol

- PPP-LCP establishes/releases the PPP connection; negotiates options
- Starts in DEAD state
- Options: max frame length; authentication protocol
- Once PPP link established, IPCP (Control Protocol) moves in (on top of PPP) to configure IP network addresses etc.