CS 640: Introduction to Computer Networks

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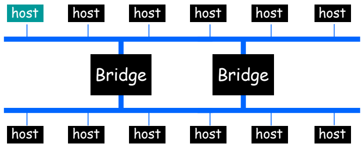
Lecture 7 -
IP: Addressing and Forwarding

From the previous lecture…

- We will cover spanning tree from the last lecture

Spanning Tree Bridges

- More complex topologies can provide redundancy.
  - But can also create loops.
    - E.g. What happens when there is no table entry?
  - Multiple copies of data
  - → Could crash the network → has happened often!



Spanning Tree Protocol Overview

Embed a tree that provides a single unique default path to each destination:

Bridges designate ports over which they will or will not forward frames

By removing ports, extended LAN is reduced to a tree

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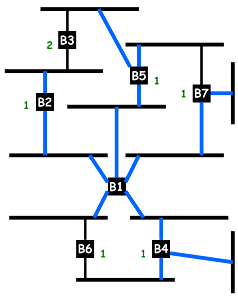
Spanning Tree Algorithm

- Root of the spanning tree is elected first → the bridge with the lowest identifier.
  - All ports are part of tree
- Each bridge finds shortest path to the root.
  - Remembers port that is on the shortest path
  - Used to forward packets
- Select for each LAN a designated bridge that will forward frames to root
  - Has the shortest path to the root.
  - Identifier as tie-breaker



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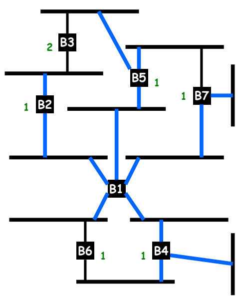
Spanning Tree Algorithm

- Each node sends configuration message to all neighbors.
  - Identifier of the sender
  - Id of the presumed root
  - Distance to the presumed root
- Initially each bridge thinks it is the root.
  - B5 sends (B5, B5, 0)
- When B receive a message, it decide whether the solution is better than their local solution.
  - A root with a lower identifier?
  - Same root but lower distance?
  - Same root, distance but sender has lower identifier?
- Message from bridge with smaller root ID
  - Not root; stop generating config messages, but can forward
- Message from bridge closer to root
  - Not designated bridge; stop sending any config messages on the port



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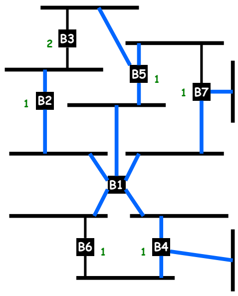
Spanning Tree Algorithm

- Each bridge B can now select which of its ports make up the spanning tree:
  - B's root port
  - All ports for which B is the designated bridge on the LAN
- States for ports on bridges
  - *Forward state* or *blocked state*, depending on whether the port is part of the spanning tree
- Root periodically sends configuration messages and bridges forward them over LANs they are responsible for



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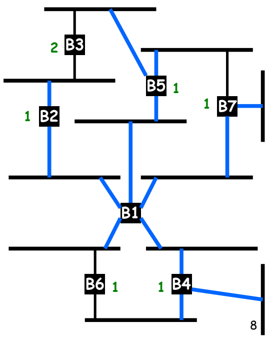
Spanning Tree Algorithm Example

- Node B2:
  - Sends (B2, B2, 0)
  - Receives (B1, B1, 0) from B1
  - Sends (B2, B1, 1) "up"
  - Continues the forwarding forever
- Node B1:
  - Will send notifications forever
- Node B7:
  - Sends (B7, B7, 0)
  - Receives (B1, B1, 0) from B1
  - Sends (B7, B1, 1) "up" and "right"
  - Receives (B5, B5, 0) - ignored
  - Receives (B5, B1, 1) – suboptimal
  - Continues forwarding the B1 messages forever to the "right"



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Ethernet Switches

- Bridges make it possible to increase LAN capacity.
  - Packets are no longer broadcasted - they are only forwarded on selected links
  - Adds a switching flavor to the broadcast LAN
  - Some packets still sent to entire tree (e.g., ARP)
- Ethernet switch is a special case of a bridge: each bridge port is connected to a single host.
  - Can make the link full duplex (really simple protocol!)
  - Simplifies the protocol and hardware used (only two stations on the link) – no longer full CSMA/CD
  - Can have different port speeds on the same switch
    - Unlike in a hub, packets can be stored

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A Word about "Taking Turn" Protocols

- First option: Polling-based
  - Central entity polls stations, inviting them to transmit.
    - Simple design – no conflicts
    - Not very efficient – overhead of polling operation
    - Still better than TDM or FDM
    - Central point of failure
- Second (similar) option: Stations reserve a slot for transmission.
  - For example, break up the transmission time in contention-based and reservation based slots
    - Contention based slots can be used for short messages or to reserve time
    - Communication in reservation based slots only allowed after a reservation is made
  - Issues: fairness, efficiency

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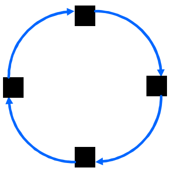
Token-Passing Protocols

- No master node
  - Fiber Distributed Data Interface (FDDI)
- One token holder may send, with a time limit.
  - known upper bound on delay.
- Token released at end of frame.
  - 100 Mbps, 100km
- Decentralized and very efficient
  - But problems with token holding node crashing or not releasing token



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This Lecture: IP addressing and Forwarding

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Simple Internetworking

- Focus on a single internetwork
  - Internetwork = combo of multiple physical networks
- How do I designate hosts?
  - Addressing
- How do I send information to a distant host?
  - Underlying service model
    - What gets sent?
    - How fast will it go? What happens if it doesn't get there?
  - Routing/Forwarding
    - **Global addresses-based** forwarding is used
    - What path is it sent on?
    - How is this path computed?

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Addressing in IP: Considerations

- Uniquely designate hosts
  - MAC addresses may do, but they are useless for scalable routing
- Hierarchical vs. flat
  - Wisconsin / Madison / UW-Campus / Aditya
    vs.
    Aditya:123-45-6789
  - Ethernet addresses are flat
  - IP addresses are hierarchical
- Why Hierarchy?
  - Scalable routing
  - Route to a general area, then to a specific location

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IP Addresses

- Fixed length: 32 bits
- Total IP address size: 4 billion
- Initial class-ful structure (1981)
  - Class A: 128 networks, 16M hosts
  - Class B: 16K networks, 64K hosts
  - Class C: 2M networks, 256 hosts

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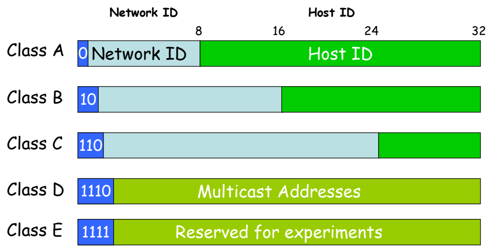
IP Address Classes
(Some are Obsolete)



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Original IP Route Lookup

- Address would specify prefix for forwarding table
  - Simple lookup
- www.cmu.edu address 128.2.11.43
  - Class B address – class + network is 128.2
  - Lookup 128.2 in forwarding table
  - Prefix – part of address that really matters for routing
- Forwarding table contains
  - List of class+network entries
  - A few fixed prefix lengths (8/16/24)
- Large tables
  - 2 Million class C networks

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Example

- Host: Get n/w number for destination: Nd → compare with sending host n/w number

N/W number	Outgoing Interface
N	Eth0
Default	R1

- Router: Compare dest n/w number with n/w number of each interface → either put on interface, or send to next hop router

N/W number	Outgoing Interface
N0	Eth0
N1	Eth1
N2	R2
N3	R3

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Subnet Addressing: RFC917 (1984)

- Original goal: network part would uniquely identify a single physical network
- Inefficient address space usage
  - Class A & B networks too big
    - Also, very few LANs have close to 64K hosts
    - Easy for networks to (claim to) outgrow class-C
  - Each physical network must have one network number
- Routing table size is too high
- Need simple way to reduce the number of network numbers assigned
  - Subnetting: Split up single network address ranges
  - Fizes routing table size problem, partially

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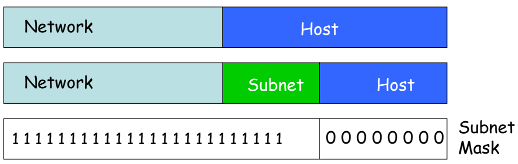
Subnetting

- Add another "floating" layer to hierarchy
- Variable length subnet masks
  - Could subnet a class B into several chunks



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Subnetting Example

- Assume an organization was assigned address 150.100 (class B)
- Assume < 100 hosts per subnet (department)
- How many host bits do we need?
  - Seven
- What is the network mask?
  - 11111111 11111111 11111111 10000000
  - 255.255.255.128

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Forwarding Example

- Host configured with IP adress and subnet mask
- Subnet number = IP (AND) Mask
- (Subnet number, subnet mask) → Outgoing I/F

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D = destination IP address
For each forwarding table entry (SN, SM → OI)
  D1 = SM & D
  if (D1 == SN)
    if nexthop is interface
            Deliver on INTERFACE
    Else
            Forward to default router
```

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Inefficient Address Usage

- Address space depletion
  - In danger of running out of classes A and B
  - Why?
    - Class C too small for most domains
    - Very few class A – very careful about giving them out
    - Class B poses greatest problem
  - Class B sparsely populated
    - But people refuse to give it back

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Classless Inter-Domain Routing (CIDR) – RFC1338

- Allows arbitrary split between network & host part of address
  - Do not use classes to determine network ID
  - Use common part of address as network number
  - Allows handing out arbitrary sized chunks of address space
  - E.g., addresses 192.4.16 - 192.4.31 have the first 20 bits in common. Thus, we use these 20 bits as the network number → 192.4.16/20
- Enables more efficient usage of address space (and router tables)
  - Use single entry for range in forwarding tables
  - Combine forwarding entries when possible

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CIDR Example

- Network is allocated 8 contiguous chunks of 256-host addresses 200.10.0.0 to 200.10.7.255
  - Allocation uses 3 bits of class C space
  - Remaining 21 bits are network number, written as 201.10.0.0/21
- Replaces 8 class C routing entries with 1 combined entry
  - Routing protocols carry prefix with destination network address

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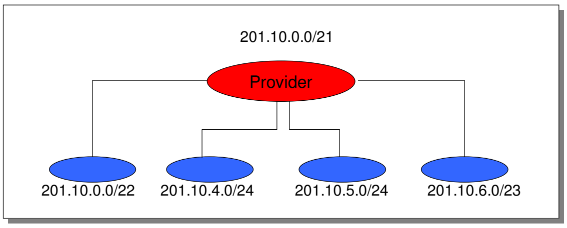
CIDR Illustration



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CIDR Implications

- Longest prefix match
  - 7 contiguous Class C's given to network A:
    - 200.10.0.0 – 200.10.6.255
    - N/w number – 200.10.0.0/21
  - 8th class C given to network B:
    - 200.10.7.0 – 200.10.7.255
    - N/w number – 200.10.7.0/24
  - Packet with destination address 200.10.7.1 matches both networks
    - Must pick the most specific match!

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