Introduction to Routers

TEL-335

Week 2 – IP Addressing & Static Routing

OSI Model

7. Application
6. Presentation
5. Session
4. Transport
3. Network
2. Data-Link
1. Physical

Last week, brief review

- Physical Layer:
  - Serial: (9600 bits per second, 8 data bits, no parity, and 1 stop bit, with no flow control)
  - Ethernet: 10BaseT/100BaseT

Cabling (continued)

- Four types of Cable in use:
  - Straight through
    - For connecting a host's Ethernet interface to a switch.
    - Only two pair are used: wires 1,2, 3, and 6 (two transmit and two receive)
    - 1 → 1, 2 → 2, 3 → 3, 4 → 4, 5 → 5, 6 → 6, 7 → 7, 8 → 8

- Cross over
  - For connecting two hosts' Ethernet interfaces together without a switch.
  - Same as straight through, except the transmit and receive pairs are crossed over to allow direct host-to-host communication.
  - 1 → 3, 2→ 6, 3 → 1, 4 → 4, 5 → 5, 6 → 2, 7 → 7, 8 → 8
  - Many newer Ethernet interfaces do this cross over internally automatically (it's part of the Gigabit Ethernet spec to do this automatically.)

Cabling (continued)

- Rolled or "Roll-over"
  - For connecting to the console port of a router or switch using a PC and a "cisco adapter" (the serial port adapter on the back of the PC)
  - 1 → 8, 2 → 7, 3→ 6, 4→ 5, 5 → 4, 6 → 3, 7 → 2, 8 → 1
- T-1 cross over
  - For connecting two hosts' Serial/T-1 interfaces together.
  - Just like an Ethernet cross over, except different pairs are used for transmit and receive (wires 1, 2, 4, and 5) and an additional pair (wires 3 and 6) is used for grounding.
  - 1 → 4, 2 → 5, 3 → 3, 4 → 1, 5 → 2, 6 → 6, 7 → 7, 8 → 8

Moving up the OSI Model

- Data-Link Layer
  - Deals with addressing
    - MAC (Media Access Control) addresses
      - No relation to Steve Jobs
      - Sometime called “Ethernet Address”
    - LLC (Logical Link Control)
      - Frame synchronization
      - Flow control
      - Error Checking

Moving up the OSI Model

- Network Layer:
  - Switching and routing technologies
  - Creating logical paths (virtual circuits) for transmitting data from node to node.
  - **Routing** and forwarding are functions of this layer, as well as **addressing**, internetworking, error handling (retries, etc), congestion control and packet sequencing.

IP Addressing and Subnetting

Oh my!

Addressing

- TCP/IP Model
  - Network Addresses are IP Addresses
    - IPv4 Most widely used
      - 2^{32} possible addresses (4 bytes)
    - IPv6 Next Generation
      - 2^{128} possible addresses (16 bytes)

IP Addressing

- IP addresses can be written in multiple ways
  - "Dotted decimal" notation
    - Periods between each byte
    - 10.20.30.40
  - Machines only recognize them as binary (32 bits)
    - 00001010 00010100 00011101 00101000
    - Chapter 2 of the book (refresher on converting decimal to binary)

IP Addressing

- IP addresses originally used concept of "class" (no subnet masks needed)

Class	Range	Implied Mask
A	0.0.0.0 – 127.255.255.255	255.0.0.0
B	128.0.0.0 – 191.255.255.255	255.255.0.0
C	192.0.0.0 – 223.255.255.255	255.255.255.0
D	224.0.0.0 – 239.255.255.255	N/A
E	240.0.0.0 – 255.255.255.255	N/A

Special Ranges

- Some addresses are reserved for special purposes (See RFC 3330 at http://www.ietf.org/rfc/rfc3330.txt for a complete listing)
  - The “private” address ranges
    - 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16
  - The loopback range
    - 127.0.0.0/8
  - Host auto-configuration
    - 169.254.0.0/16

Special Addresses

- Within an IP subnet, there are two special addresses
  - The network address
    - The first IP address in the network (the host portion is all binary zeros)
    - Represents the network
    - Example: 10.0.0.0 is the network address for the 10.0.0.0 network

Special Addresses (cont)

- The broadcast address
  - The last IP address in the network (the host portion is all binary ones)
  - Represents all hosts on the network
  - Example: 10.255.255.255 is the broadcast address for the 10.0.0.0 network

Special Addresses (cont)

- This means that each network has two unassignable IP addresses
  - A class C network has 256 IP addresses, but only 254 can be assigned to hosts, since one is reserved for the network address and one is reserved for the broadcast address

Classless Inter-Domain Routing

- Classless Inter-Domain Routing or “CIDR” (pronounced “cider”)
- Why:
  - Classful addressing wastes IP addresses
  - If an organization has 300 hosts, they need a class B network
- How:
  - Uses variable-length subnet masks (VLSM) to determine where the network portion ends and the host portion begins

CIDR (cont)

- VLSM:
  - Can be in dotted-decimal format
    - 255.255.255.0
  - Or in “slash notation”, also called “prefix notation” or “CIDR notation”
    - /24
    - Represents the number of contiguous binary ones in the subnet mask
    - Again, machines only recognize binary
      - 11111111 11111111 11111111 00000000
      - The ones portion represents the network portion of the address
      - The zeros portion represents the host portion of the address
- This is determined by performing a logical AND of the subnet mask and the IP address

More CIDR

- Allows subnets to be “split” into smaller subnets
  - One /24 = two /25 networks = four /26 networks
  - One /26 = one /27 network and two /28 networks
  - A large number of possible combinations of network sizes
    - Tree method of design
    - Start with the root leaf of the tree representing the size of the network (/23)
    - You are only allowed to create two branches from any leaf, which splits the leaf in half (/23 → two /24 networks)

More CIDR

- Design goals:
  - To retain the largest amount of continuous free space as possible at the end of the original network

How To:

- Convert from slash notation to dotted decimal
  - Procedure
    - Write out the slash notation in binary
    - Convert the result to dotted decimal
  - Example
    - /14 = 11111111 11111100 00000000 00000000 = 255.248.0.0
    - /24 = 11111111 11111111 11111111 00000000 = 255.255.255.0

How To:

- Convert from dotted decimal to slash notation
  - Procedure
    - Write out the dotted decimal in binary
    - Count the number of contiguous ones
  - Example
    - 255.255.192.0 = 11111111 11111111 10000000 00000000 = /17
    - 255.255.255.128 = 11111111 11111111 11111111 1 = /25

How To:

- Given an IP address and subnet mask, determine the network address
  - Procedure
    - Convert both the address and netmask to binary
    - Perform a logical AND
  - Example
    - 10.49.53.21/22 →
      00001010 00110001 00110101 00010101
      11111111 11111111 11111100 00000000
      00001010 00110001 00110100 00000000 = 10.49.52.0

How To:

- Given an IP address and subnet mask, determine the broadcast address
  - Procedure
    - Convert both the address and netmask to binary
    - Perform a logical AND
    - For every bit where the netmask is zero, replace the result with a one
  - Example
    - 10.49.53.21/22 →
      00001010 00110001 00110101 00010101
      11111111 11111111 11111100 00000000
      00001010 00110001 00110100 00000000 →
      00001010 00110001 001101**11 11111111** = 10.49.55.255

Bigger Blocks, How To:

- Procedures for working with entire networks
  - Given a prefix, determine the number of IP addresses in the corresponding network
    - Remember that the network and broadcast address come from this number, so there are really two less assignable addresses than the result you get
    - Procedure
      - Determine the number of contiguous binary zeroes in the subnet mask
      - Take two and raise it to the result
    - Example
      - /26 → 32 - 26 = 6 → $2^6 = 64$
      - /29 → 32 - 29 = 3 → $2^3 = 16$

More Subnetting, How To:

- Given a prefix, determine the number of networks of a certain size that can fit in it
  - Procedure
    - Subtract the shorter prefix from the longer prefix
    - Take two and raise it to the result
  - Example
    - The number of /25 networks in a /18 → 25 - 18 = 7 → $2^7 = 128$

Subnet Design

- Designing a subnetting scheme from a statement of requirements is a bit trickier, since it requires using all of the above information and skills

Subnet Design

- Example:
  - Given 192.168.1.128/26, create a subnetting scheme that can hold one network of 5 hosts, one network of 15 hosts, one network of 3 hosts, and one network of 10 hosts
  - 5 hosts = /29, 15 hosts = /27, 3 hosts = /29, 10 hosts = /28
  - Use tree method to segment /26 into two /27s, then two /28s, then two /29s, until all networks are allocated
  - Notate .128 to the /26, then .128 and .160 to the two /27s, then .160 and .176 to the two /28s, then .176 and .184 to the two /29s, until all networks have network addresses assigned to them
- Result:
  192.168.1.128/27 for the network of 15 hosts
  192.168.1.160/28 for the network of 10 hosts
  192.168.1.176/29 for the network of 5 hosts
  192.168.1.184/29 for the network of 3 hosts

Routing

Routing

- One of the functions of the network/IP layer is routing
  – Provides directions about how to get to a particular host or network
  – Stored in a table called a routing table that every host has:
    - The table is made up of
      – Network and subnet mask (implied if classful, specified if classless)
      – Direction (usually next-hop IP or network interface)
      – Metric(s) for choosing the “best” route among multiple possibilities

Routing

- Stored in a table called a routing table that every host has (continued):
  - Automatically contains directly connected routes that correspond with network interfaces
  - The most specific prefix wins
    - If destination is 10.50.1.33 and the routing table has routes for both 10.50.0.0/16 and 10.50.1.0/24, the /24 wins.
  - Special route is the default route that matches everything
    - Typically specified as network 0.0.0.0 with subnet mask 0.0.0.0
  - Can manually modify the routing table with static routes

Lab!