COMP476
Networked Computer Systems

Internetworking

Universal Service Concept

- Any computer can communicate with any other computer in the world.
- Multiple independently owned and operated networks can be interconnected to provide universal service.

Internetworking

- Scheme that uses both hardware and software to provide universal service among heterogeneous networks.

Physical Network Connection

- Routers are used to connect heterogeneous networks together.

Two physical networks connected by a router, which has a separate interface for each network connection.

Internet Architecture

- An internet consists of a set of networks interconnected by routers. The internet scheme allows each organization to choose the number and type of networks, the number of routers to use to interconnect them, and the exact interconnection topology.

An internet formed by using three routers to interconnect four physical networks. Each network can be a LAN or a WAN.

Internet Protocol

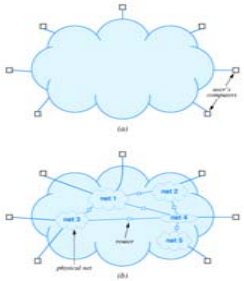
- To achieve universal service among all computers on an internet, routers must agree to forward information from a source on one network to a destination on another.
- A common protocol is needed on computers and routers to overcome the differing frame formats and addressing schemes used within each network.
- Because each network uses an different and incompatible addressing system, an independent addressing system is needed.

Virtual Network

- The Internet is a virtual network. We say this because the communication system is an abstraction. It provides the illusion of a seamless network where:

1. *Each computer is assigned an address.*
2. *Any computer can send a packet to any other computer.*
3. *Internet protocol software hides the details of the network.*

The Internet Concept



- The illusion of a single network
- Underlying physical structure in which routers interconnect the networks.

Network Identifiers

Computers on the Internet are referred to as hosts. Each host as at least three identifiers:

- **Internet name** for humans to use (i.e. garfield.ncat.edu)
- **Internet address**, a 32 bit binary number written in decimal as four bytes (i.e.152.8.240.16)
- **hardware address**, such as an Ethernet address (i.e. 00-e0-63-03-76-c0 for garfield)

Internet Names

- Hierarchical starting from the right
  `host.subnet.organization.type`
- Rightmost identifies the type or organization or country
  - edu, com, mil, org, net
  - us, ca, de, uk

Internet Addresses

- Internet Addresses map to Internet Names.
- An Internet Address is composed of two parts, a netid and a hostid.
- The hostid identifies the particular host on a network.
- The netid identifies the network where the host is connected.
- A computer physically connected to two networks needs two Internet addresses.

Internet Address Classes

class				
A	NetID	hostID	hostID	hostID
B	NetID	NetID	hostID	hostID
C	NetID	NetID	NetID	hostID

IP Addressing Classes

- The five classes of IP addresses in the classful scheme. The address assigned to a host is either class *A*, *B*, or *C*; the *prefix* identifies a network, and the suffix is unique to a host on that network.

Compute the Address Class

First Four Bits Of Address	Table Index (in decimal)	Class of Address
0000	0	A
0001	1	A
0010	2	A
0011	3	A
0100	4	A
0101	5	A
0110	6	A
0111	7	A
1000	8	B
1001	9	B
1010	10	B
1011	11	B
1100	12	C
1101	13	C
1110	14	D
1111	15	E

** A table that can be used to compute the class of an address. The first four bits of an address are extracted and used as an index into the table.*

Binary to Decimal Conversion

- Binary values appear in IP packets in *Big Endian* style (most significant byte first).

32-bit Binary Number	Equivalent Dotted Decimal
10000001 00110100 00000110 00000000	129 . 52 . 6 . 0
11000000 00000101 00110000 00000011	192 . 5 . 48 . 3
00001010 00000010 00000000 00100101	10 . 2 . 0 . 37
10000000 00001010 00000010 00000011	128 . 10 . 2 . 3
10000000 10000000 11111111 00000000	128 . 128 . 255 . 0

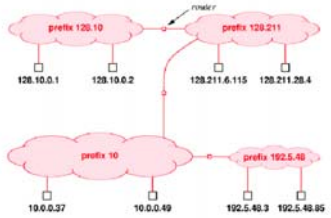
** Examples of 32-bit binary numbers and their equivalent in dotted decimal notation. Each octet is written in decimal with periods (dots) used to separate octets.*

Range of Values

First Byte	Address Class
0 - 127	A
128 - 191	B
192 - 223	C

The range of decimal values found in the first octet of each address class.

IP Assignment Address Example



** An example private internet with IP addresses assigned to hosts. The size of the cloud used to denote a physical network corresponds to the number of hosts expected on the network; the size of a network determines the class of address assigned.*

Special IP addresses

- all 1's broadcast on the local network
- all 0's this host
- hostid = all 0's the network (not a host)
- hostid = all 1's broadcast on given network
- netid = all 0's this network
- netid = 127 loop back (never appears on net)

Moving Computers

- Because the Internet address encodes the network to which the computer is connected, moving a computer to a different network requires giving it a new address.

Mapping Between Addresses

- Humans use Internet Names. The hardware uses the MAC addresses.
- Internet Names are converted to Internet Addresses by a Domain Name Server (DNS)
- Internet Addresses are converted to MAC addresses by using the Address Resolution Protocol (ARP).

Domain Name Servers

- Domain Name Servers (DNS) map Internet Names to Internet Addresses.
- A DNS maintains a distributed database of names and addresses.
- Computers can send a request to a DNS to get the IP address of a computer.
- Hosts and DNS cache addresses they have found.

MAC Addresses

- The actual network hardware must use the MAC or physical addresses.
- An Ethernet interface knows nothing of Internet addresses.
- To send a frame to another computer on the **same** network, you must know it's MAC address (or broadcast).
- Each network type uses different addresses.

Address Resolution Protocol (ARP)

- Used by a computer to find the MAC or physical address of another computer on the **same** network.
- Given a computer's IP address, ARP will find the computers MAC address.
- Distributed algorithm involving all computers on the network.

ARP

- Source broadcasts an ARP request including the IP address to all computers on the network.
- All computers receive the ARP request and compare the requested address to theirs.
- Only if the address matches, does the computer send a response back to the source.

IP Routing Procedure

Assume computer **A** wants to send one frame to computer **B**

1. **A** sends a DNS request to the local Domain Name Server asking for the IP address of **B**.
2. The DNS sends the IP address of **B** to **A**.
3. The netid portion of **B**'s IP address is extracted by ANDing **B**'s IP address with the subnet mask of **A**
4. If the netid of the sender and receiver are the same, then the destination is on the same network. **A** can send the packet directly to **B**.
5. If the netids are different, **A** must send the packet to the gateway.
6. The gateway will forward the packet to another gateway that is closer to the destination's domain.
7. The gateway at the destination's domain will send the frame to **B**

IP Routing Example