College of Computer and Information Sciences, KSU
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CEN445 – Network protocols and algorithms

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Notes are in LMS web site

Network Layer Services

Chapter 1

Network Layer

- **Recall:**
  - The network layer is responsible for the routing of packets
  - The network layer is responsible for congestion control

Contents

- Connection-Oriented and Connectionless Service
- The IP Protocol: an overview

1. Connection-Oriented and Connectionless Service

- Network layers can offer two types of service to the transport layer:
  - Connection-oriented service
    - Network layer provides the Transport layer with a reliable service: all packets will be delivered (flow control), in-sequence delivery
    - Connection setup required before communication begins
  - Connectionless service
    - No guarantee
    - No prior connection setup required; packets are stored and forwarded one at a time by IMPs

1.1 Connection-Oriented Service

- How to provide connection-oriented service:
  - Set up a route (virtual circuit) between source and destination
  - That route is used for all traffic flowing over the virtual circuit
  - IMP maintains an internal table to tell which outgoing line to forward packet on for each active virtual circuit
  - Packets must contain a virtual circuit number (not destination address) so that IMP can figure out how to forward them

Connection-Oriented Service: Analogy

- Public Telephone Network
  - Set up a virtual circuit (dial a number)
  - Transmit data on the circuit (conversation)
  - Close down the virtual circuit (hang up)
- Two users are provided with the illusion of a dedicated point-to-point channel
- Information is delivered to the receiver in the same order in which it is transmitted by the sender

1.2 Connectionless Service

- How to provide connectionless service:
  - Send the packet into the network and allow the network to forward it however it likes
  - IMPs maintain routing tables to look up the next IMP for each arriving packet
  - Each packet must contain a destination address so the IMPs can make routing decisions

Connectionless Service: An Analogy

- Postal service:
  - Each packet (letter) is transported as an individual entity
  - Each packet (letter) must carry the complete destination address
  - If a packet (letter) is lost, error control is the user's responsibility
  - Packets (letters) do not necessarily arrive in the order sent

1.3 Comparison between Connectionless and Connection-Oriented Services

- Connection Setup Procedure:
  - Connection-oriented service
    - Explicit setup and tear-down required
    - For short transaction oriented communication, the delay of connection setup may be expensive
  - Connectionless service
    - No setup or tear-down required
    - For long continuous communication, the overhead of packet headers may be expensive

Comparison *(cont'd)*

- Header Overhead
  - Connection-oriented service
    - Only the virtual circuit number
  - Connectionless service
    - The full destination address is required

Comparison *(cont'd)*

- Message Sequence:
  - Connection-oriented service
    - Sequence automatically maintained
  - Connectionless service
    - Destination may have to re-sequence out-of-sequence messages

Comparison *(cont'd)*

- Robustness
  - Connection-oriented service
    - Vulnerable: If IMP crashes, all virtual circuits passing through it have to be aborted and re-established
  - Connectionless service
    - Robust: If IMP goes down, only hosts whose packets were queued at the time of the crash are lost. Other packets will be rerouted dynamically.

Comparison *(cont'd)*

- Guaranteed service:
  - Connection-oriented service
    - Can provide guarantees on the delays and throughput of packets being sent
  - Connectionless service
    - It is very difficult to provide guarantees for timely packet delivery

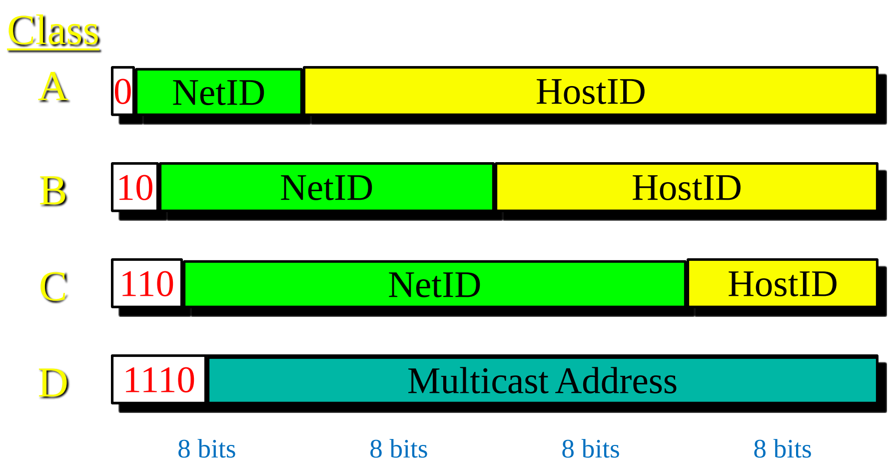
Summary

- Connection-oriented service
  - Is useful for applications which prefer in-sequence delivery of packets. It is also preferable for applications that require guaranteed service
- Connectionless service
  - Provides flexibility in the routing and handling of individual packets and is robust in the face of IMP crashes

IP Addresses

- IP addresses are *logical* addresses (not physical)
- 32 bits. ← IPv4 *(version 4)*
- Includes a network ID and a host ID.
- Every host must have a unique IP address.
- IP addresses are assigned by a central authority (*American Registry for Internet Numbers for North America*).

The four formats of IP Addresses



Class A

- 128 possible network IDs
- over 4 million host IDs per network ID

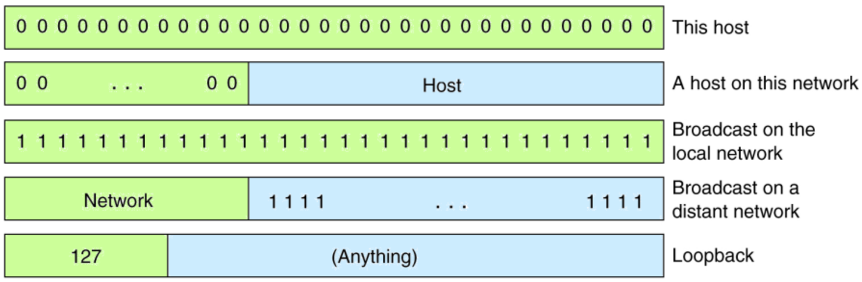
Class B

- 16K possible network IDs
- 64K host IDs per network ID

Class C

- over 2 million possible network IDs
- about 256 host IDs per network ID

IP Addresses



Address	Meaning
0.0.0.0	This host
255.255.255.255	Broadcast on local network
127.0.0.1	Loopback, processed locally, not put onto wire

Network and Host IDs

- A Network ID is assigned to an organization by a global authority.
- Host IDs are assigned locally by a system administrator.
- Both the Network ID and the Host ID are used for routing.

IP Addresses

- IP Addresses are usually shown in *dotted decimal* notation:

1.2.3.4 → **00000001 00000010 00000011 00000100**

- ksu.edu.sa is 212.57.194.232

11010100 11010101 00000001 00000001

KSU has a class C network

Host and Network Addresses

- A single network interface is assigned a single IP address called the *host* address.
- A host may have multiple interfaces, and therefore multiple *host* addresses.
- Hosts that share a network all have the same IP *network* address (the network ID).

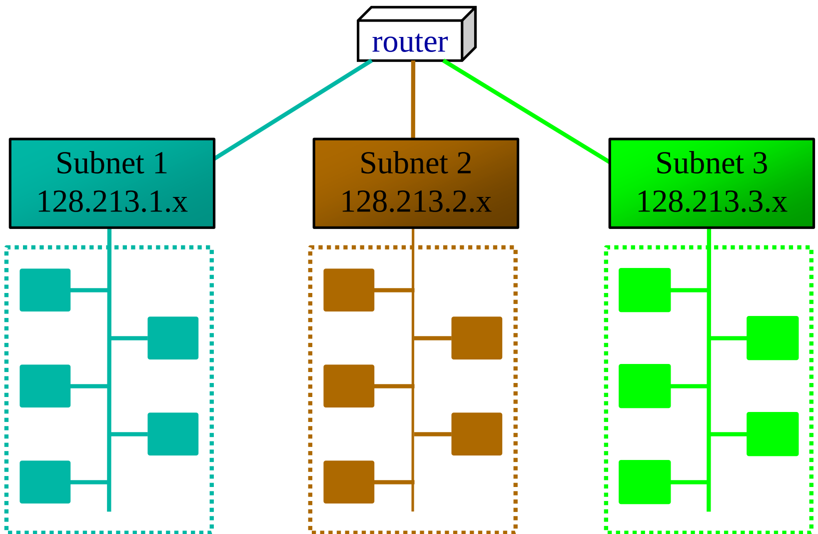
IP Broadcast and Network Addresses

- An IP broadcast addresses has a host ID of all 1s.
- IP broadcasting is not necessarily a true broadcast, it relies on the underlying hardware technology.
- An IP address that has a host ID of all 0s is called a *network address* and refers to an entire network.

Subnet Addresses

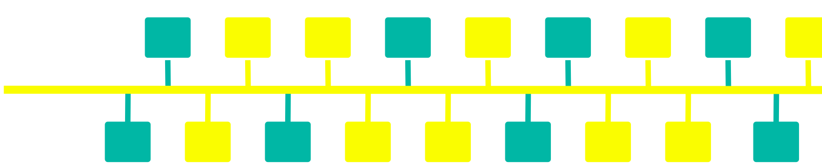
- An organization can subdivide it's host address space into groups called subnets.
- The subnet ID is generally used to group hosts based on the physical network topology.

Subnetting



Subnetting

- Subnets can simplify routing.
- IP subnet broadcasts have a host ID of all 1s.
- It is possible to have a single wire network with multiple subnets.



Subnetting

Example: Class B address with 8-bit subnetting

16 bits	8 bits	8 bits
Network id	Subnet id	Host id

Example Address:	165.230	.24	.8

Class	32 bits		
B	10	Net	Host

Subnet Masks

Subnet masks allow hosts to determine if another IP address is on the same subnet or the same network

16 bits	8 bits	8 bits
Network id	Subnet id	Host id

Mask:	1111111111111111	11111111	00000000
	255.255	.255	.0

Subnet Masks *(cont'd)*

Assume IP addresses A and B share subnet mask M.

Are IP addresses A and B on the same subnet?

1. Compute (A and M). (Boolean AND)
2. Compute (B and M). (Boolean AND)
3. If (A and M) = (B and M) then A and B are on the same subnet.

Example: A and B are class B addresses

A = 165.230.82.52
B = 165.230.24.93
M = 255.255.255.0

Same network?
Same subnet?

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- Note
  - 0 AND 0 = 0
  - 0 AND 1 = 1 AND 0 = 0
  - 1 AND 1 = 1
- Thus, computing (A and M) results in
  - Network ID = Network ID of A
  - Subnet ID = Subnet ID of A
  - Host ID = 0

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- Why do we need subnet mask?
  - When subnetting is introduced, a routing table is modified to include:

(this-network, subnet, 0)

and

(this-network, this-subnet, host)

- Routing table

network ID	subnet ID	host ID
this network	this subnet	A
this network	this subnet	B
this network	different subnet	0
this network	different subnet	0
different network	0	0

- Subnet mask helps quickly identifying which routing table entry to look up

IP Routing Process

- When packet arrives, look up dest addr
  - distant network?
    →forward to next router on the interface given in routing table
  - local network?
    →send immediately to destination
  - not in the routing table?
    →forward to default gateway

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