Connectionless Delivery Service

- The goal of internetworking is to provide a seamless communication system.
- The virtual network thing again.
- An internet uses an extension of the LAN abstraction.
  - Universal addressing.
  - Data is delivered in packets.
- TCP/IP designers chose to provide both a connection-oriented protocol (TCP) and a connectionless protocol (UDP).
- The underlying delivery service (IP) is connectionless.
Virtual Packets

• Internet packets serve the same purpose on an internet as frames on a LAN.
• Each packet travels independently.
• Routers (formerly gateways) forward packets from one physical network to another.
• Since physical networks are heterogeneous, packets must have a uniform hardware-independent format.
• To move across a physical network, an internet packet is encapsulated in a hardware frame.
IP Datagrams

- **datagram** - the name used to refer to an IP packet.

- A datagram includes a header area and a data area.

- A datagram header contains IP addresses; a frame header contains hardware addresses.

- Datagrams can have different sizes. The current version of IP (IPv4) specifies:
  - The header area is usually fixed (20 octets) but can have options.
  - The data area can contain between 1 octet and 65,535 octets.
Forwarding Datagrams

- The header contains all information needed to deliver a datagram to the destination computer.
  - Destination address.
  - Source address.
  - Identifier.
  - Other delivery information.

- A router along the path examines the header of a datagram and forwards the datagram according to information in its routing table.
Routing Tables

- **routing table** - a table used by a router to determine the next hop for a packet.
- Routing tables are used for efficiency.
- A routing table contains a list of destination networks and the next hop for each destination.
- A routing table is kept small by listing destination networks instead of hosts.
- A routing table can be further reduced by using a **default route**—that is, a route to use if a destination is not explicitly listed.
Actual Routing Tables

- The destination is stored as a network address.
- The next hop is stored as the IP address of the router.
- Each entry also has an address mask or a subnet mask.
Address Masks

- address mask - a 32-bit value that specifies which bits of an IP address correspond to a network and a subnet.

- An address mask is used to identify the destination network.

- Example address masks:
  - Class A: 255.0.0.0
  - Class B: 255.255.0.0
  - Class C: 255.255.255.0
How It Works

• Apply the address mask to the destination address.

• Look up the resulting destination network address in the routing table.

• Forward the datagram as indicated in the table.

• The computation can be done with the bitwise Boolean and operator & as follows:
How It Works

if ((Mask\[i\] & D) == Destination\[i\]) {
    Forward to NextHop\[i\];
}

**Here, D = destination address,**
**Mask\[i\] = i^{th} address mask,**
**Destination\[i\] = i^{th} network address,**
**NextHop\[i\] = i^{th} next hop.**

- **Example:** Consider 128.1.15.26.

  255.255.0.0 & 128.1.15.26
  = 11111111 11111111 00000000 00000000 &
  10000000 00000001 00001111 00001110
  = 10000000 00000001 00000000 00000000
  = 128.1.0.0
Destination & Next Hop

• The destination address in an IP datagram is always the final destination.

• A router looks up the next-hop address and forwards the datagram.

• The next-hop address never appears in the IP datagram header.

• After computing the next-hop address, IP software uses address binding as described in Chapter 17 to translate the next-hop address to an equivalent hardware address for transmission.

• More on this in the next chapter.
Best-Effort Delivery

• IP provides a delivery service similar to a LAN.

• IP does NOT guarantee against
  - duplicate datagrams,
  - delayed or out-of-order delivery,
  - data corruption,
  - datagram loss.

• The network layer (IP) can detect and report errors, but it doesn’t fix them. It is focused on datagram delivery.

• Reliable delivery is provided by higher transport layer software (such as TCP).