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).