4 The Network Layer

4.1 Introduction

- The primary purpose of the network layer: to interconnect nodes, possibly at a distance.
- Interconnecting networks to make internetworks.

4.1.1 Forwarding and Routing

- Forwarding is based on the destination address next-hop forwarding.
- The destination network is given by the highest (left-most) bits in an address (like a phone number).
- Forwarding tables are used to look up next hops based on desired destinations.
- Routing is the process of building forwarding tables.

4.1.2 Network Service Models

- Internet: Best Effort

4.2 Virtual Circuit and Datagram Networks

- Virtual circuit (VC) networks provide connections.
- Datagram networks provide connectionless service.

4.2.1 Virtual Circuit Networks

- Virtual circuit tables, virtual circuit identifiers
- Connection setup time
- Smaller headers than datagram services
- complexity inside network

4.2.2 Datagram Networks

- Forwarding tables
- No connection, so no connection setup time
- Larger headers than VC networks
- packets forwarded using destination host address
- simple inside network, complexity at “edge”

4.3 What’s Inside a Router?

- run routing algorithms/protocols
- forwarding datagrams from incoming to outgoing link

4.4 IP: Forwarding and Addressing on the Internet

IP service model:

- Makes very few assumptions about underlying link layer(s)
- Provides no timing assurances
- Best effort

4.4.1 Datagram Format (IPv4)

IPv4 Header

- Version
- TTL (time to live—called hop limit in IPv6)
- protocol (called next header in IPv6)
- checksum
- source & destination addresses (32b each; 128b each in IPv6)

Payload

- Theoretical maximum size of the IP datagram is based on 16 bits; 65,535 bytes
- Usually much smaller to avoid fragmentation
- Payload contents identified by the payload header field (usually TCP or UDP)
- fragmentation and reassembly
- "reassembled" only at final destination

4.4.2 IPv4 Addressing

- 32-bit identifier for host, router *interface*
- subnet part (high order bits)
- host part (low order bits)
- single prefix to advertise multiple networks, referred as address/route aggregation
- *longest* address prefix matching

• A field of n bits has 2^n different values.

– So how many bits are needed to enumerate n subnets?

– How many subnets are supported by n bits?

– How many bits are needed for n addresses per subnet?

– How many addresses are provided by an n-bit host portion?

Dynamic Host Configuration Protocol (DHCP):

- Hosts need:
  - IP address
  - Subnet mask
  - IP address of default router
  - IP address of one or more DNS servers
- Prefer to distribute these things automatically, not manually.
- In IPv4, the request is broadcast, and the response is unicast.
- 255.255.255.255 is broadcast.

Network Address Translation (NAT):

- There are no IPv4 addresses left, so we share.
- Private address blocks: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16 etc.
- A NAT router shares its IP address with clients.
- A NAT router rewrites IP addresses and port numbers as datagrams enter and leave a network.

Peer-to-peer and NAT Traversal Problem:

- Universal Plug and Play (UPnP) Internet Gateway Device (IGD) Protocol.
- What's a Skype relay?
- Why does Skype need these things?

4.4.3 ICMP

The Internet Control Message Protocol provides diagnostics and other information.

4.4.4 IPv6

- Why is IPv6 needed?
- 128bit addresses
- fixed-length 40 byte header
- no fragmentation allowed
- checksum: removed entirely to reduce processing time at each hop
- Flow labels—traffic management, load balancing, and simulated virtual circuits.
- Subnetting is fundamentally the same as in IPv4
- No broadcast: use multicast
- Routers do not do fragmentation: they discard. Reassembly may still be needed on the receiving end.

Transition from IPv4

- IPv4 addresses can be expressed in IPv6 (but not vice-versa)

- Tunneling
- Why is it more important to tunnel IPv6 over IPv4 than vice-versa?