Drivers

- CPU ↑
- Link Rates ↑
- # Users ↑
- Economic Policy

- Value of Net ↑
Issues in Networking

Sharing
Protocols
Distributed Network Elements (NE)
Imperfect Knowledge
“Real time”
Cooperation among competing entities (network of networks)

Components

Transmission
- TDM, TDMA, TDD
- FDM, FDMA, FDD
- Statistical multiplexing

Switching
Signaling: Mechanism to control the network
Structure of the Internet
- Tier i
- ISP
- NAP
Network Evolution, Standards, and Layered Architectures

Standards
- IETF
- IEEE
- ITU
- The good and bad of standards

Layers provide a way to
- Describe networks
- Organize functionality
- Enable flexibility

Layered Architecture (OSI)
- PHY, DLC, Network, Transport, Session, Presentation, Application

Internet Architecture
- PHY, Access Network, Internetwork, Transport, Application
Network Evolution, Standards, and Layered Architectures

Role of packet headers
- Add headers (containing protocol information) as data goes from upper-to-lower layers
- Consume headers as data goes from lower-to-upper layers

Role of encapsulation

Common Protocol Functions

Network Evolution, Standards, and Layered Architectures

Common Protocol Functions
- Encapsulation
- Fragmentation and reassembly
- Connection control
- Ordered delivery
- Flow control
- Error control
- Addressing
- Multiplexing
Network Switching Technologies, Impairments, and Metrics

Circuit Switching
Packet Switching
  Statistical multiplexing
Virtual circuit packet switching
Datagram
Connection oriented

Trade-offs and attributes

Impairments
- Delay
  - # bits in RTT
  - # packets in RTT
  - LAN, MAN, WAN, Satellite
- Errors
  - Random
  - Bursty
  - Time between errors
Network Switching Technologies, Impairments, and Metrics

Metrics
- Response Time
- Throughput
- Normalized Throughput = $S$
- $S_{\text{Max}}$
- Utilization
- Channel Efficiency
- Loss/blocking
- Reliability
- Fairness

Network Performance Guarantees
- QoS
- CoS

Internet Protocols

IPv4 – packet header
- Source/Destination Address-32 bits
- TTL
- ToS
- Header check
- Fragmentation/reassembly
Internet Protocols

Addressing IPv4

- Net_Id, Host_Id
- a.b.c.d format
- /X
  - Subnetwork mask
  - Address range/network
  - # hosts/network
- Subnetworks

Internet Protocols

Header check sum Not equal 0 → drop packet
TTL=1 and when decrement TTL= 0 then → drop packet & send ICMP packet to source
Forwarding → Router actions upon arriving packet
Using the forwarding table: Longest Prefix Match

<table>
<thead>
<tr>
<th>Dest Network</th>
<th>Next Hop</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.1.1.0/24</td>
<td>Router 7</td>
<td>Fiber1</td>
</tr>
<tr>
<td>237.5.0.0/16</td>
<td>Router 9</td>
<td>Eth3</td>
</tr>
<tr>
<td>Default</td>
<td>Router 8</td>
<td>Fiber2</td>
</tr>
</tbody>
</table>
Internet Protocols

ICMP
DHCP
DNS
ARP (PHY/Layer 2/MAC and IP Addresses)
Tunneling
NAT

Routing

• gather information and build the forwarding tables
• Issues
  - How to learn the network topology?
  - How to share information?
  - How to define “distance”?
  - What shortest path algorithm to use?
  - How to respond to failures?
  - How to respond to congestion?

Exhaustive Search
Internet Protocols

Routing hierarchy
- AS & between AS’s
  - Within one AS uses IGP, example OSPF
  - Between AS’s uses EGP, example BGP
- ASN (32 bits)
- EGP’s need to consider cooperation among competing entities, BGP policies are based on business relationships

Source Routing

Internet Protocols

IPv6
- Addresses → 128 bits
- Header
  - TTL becomes a Hop Limit
  - No header checksum
  - No Fragmentation
  - Flow label
  - Traffic Class
- Transition IPv4 to IPv6
  - Dual stacks
  - Tunneling
At the conclusion of this class the students are expected to:

- Understand the basics of multiplexing
- Understand the layered structure of protocols
- Understand the importance of standards and who sets them
- Understand the basics of network protocols, including,
  - Datagram/virtual circuit switching,
  - Statistical multiplexing
  - Forwarding,
  - IP & supporting protocols
  - Routing,
- Be fluent in the language of communication networks, i.e., understand the meaning of networking terms and abbreviations
- Use network analysis tools, e.g., traceroute and ping