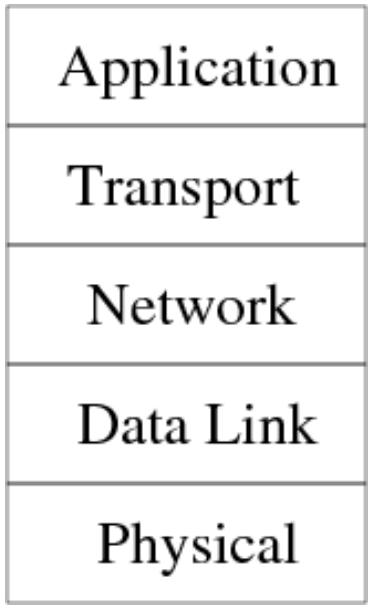
Layered Architecture



Shortest Path Routing Algorithms

- Bellman-Ford algorithm (Distance Vector Routing)
- Dijkstra's algorithm (Link State Routing)

Routing Algorithms

Distance Vector Routing

- Distributed algorithm
- Each node uses local information

Link State Routing

- Distributed algorithm
- Each node needs global information

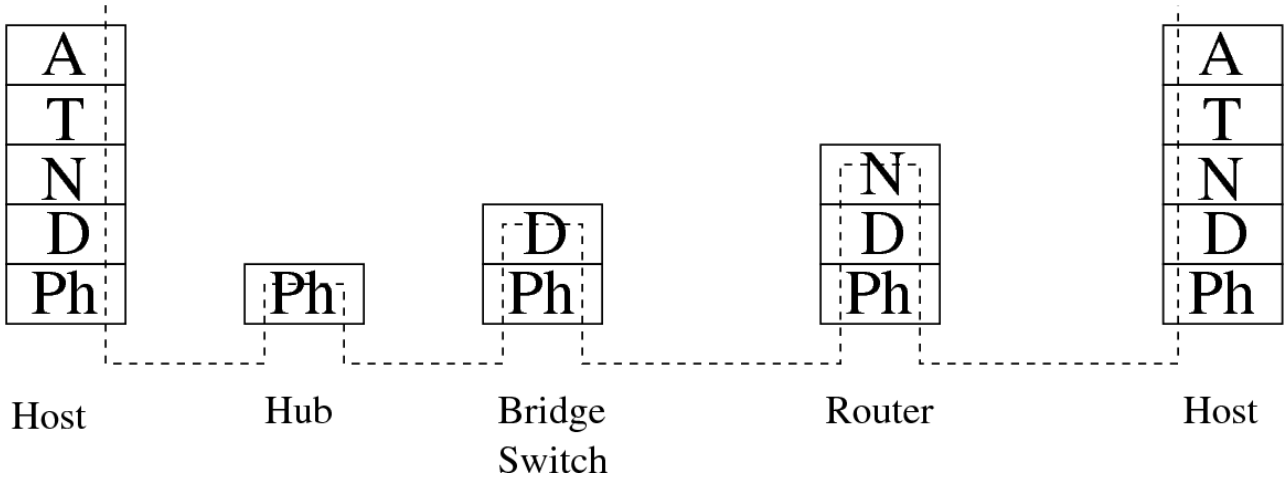
Routing in Practice

- Large Network (of Networks)
- Autonomous Systems
- Addressing

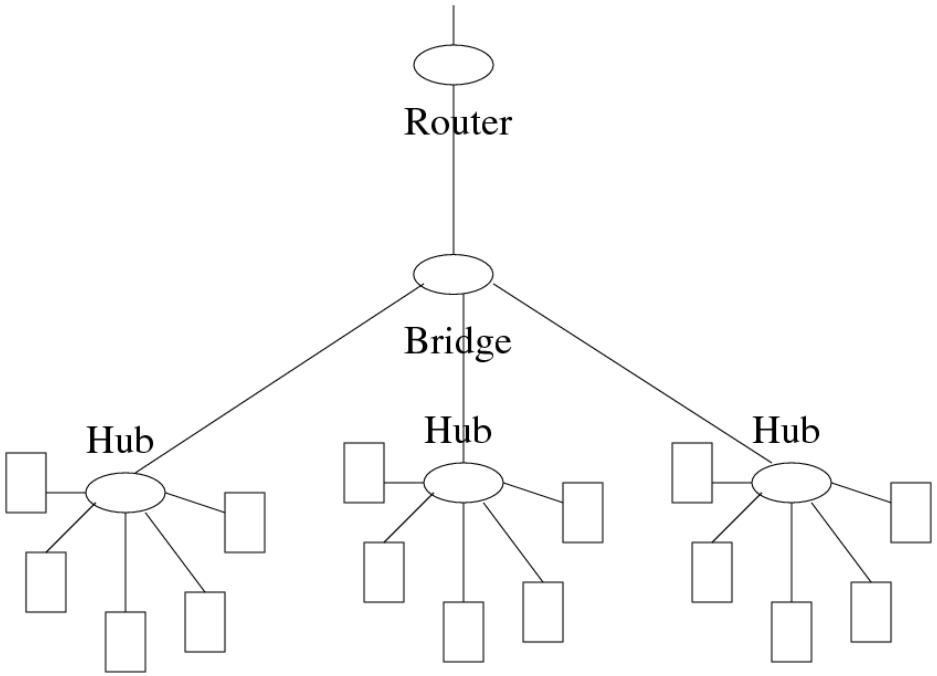
Goal

- Understand network layer issues that are important in practice
- Understand components of the Internet network layer

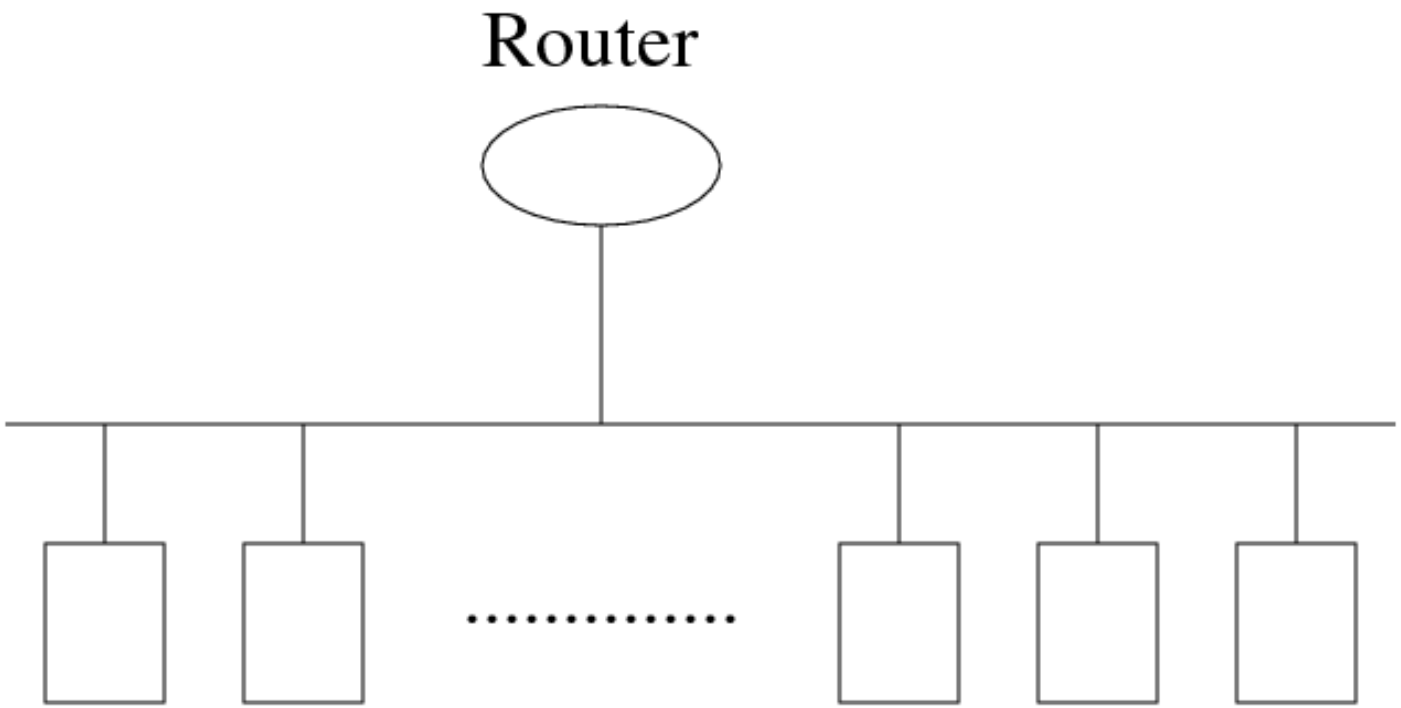
Boxes in a Network



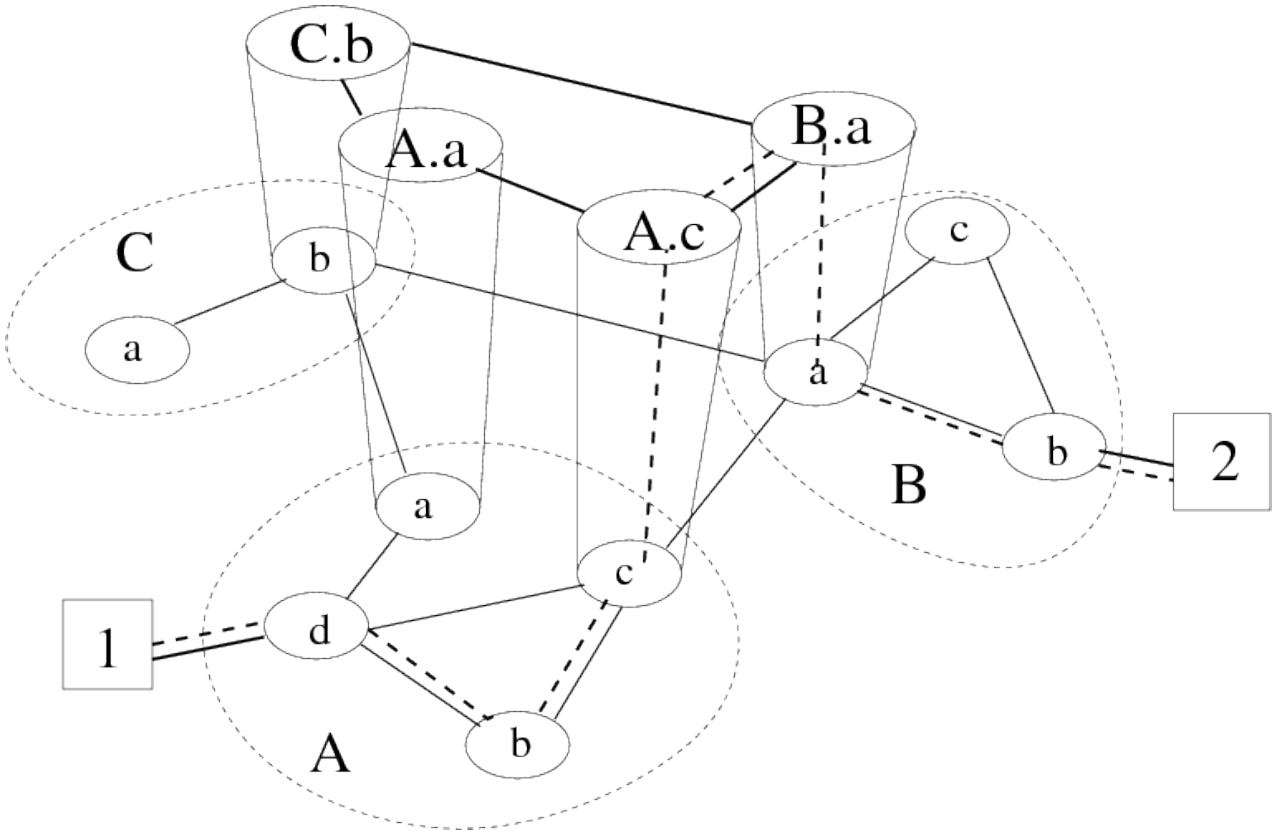
Network Topology



Network Topology seen by Network Layer



Hierarchical Routing



Hierarchical Routing

- Intra-Autonomous System (Intra-AS) Routing Protocol
- Inter-Autonomous System (Inter-AS) Routing Protocol

Internet Network Layer

Datagram (Connectionless) Service

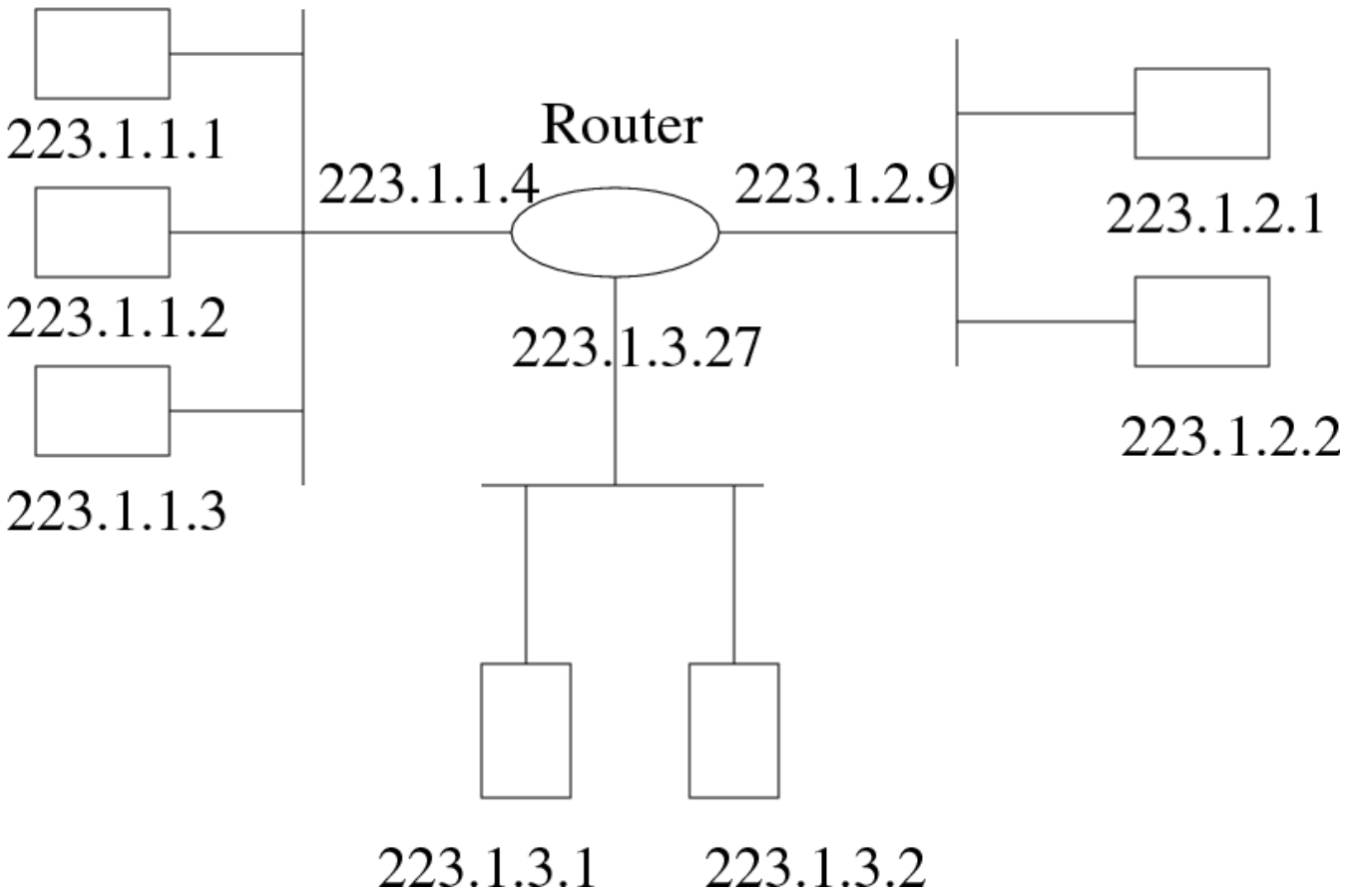
- Internet Protocol (IP)
  - Addressing
  - Definition of Datagram
- Routing Protocol
  - Intra-AS: RIP (Routing Information Protocol), OSPF (Open Shortest Path First), EIGRP (Enhanced Interior Gateway Routing Protocol) by Cisco.
  - Inter-AS: BGP (Border Gateway Protocol)
- ICMP (Internet Control Message Protocol)

IPv4 Addressing

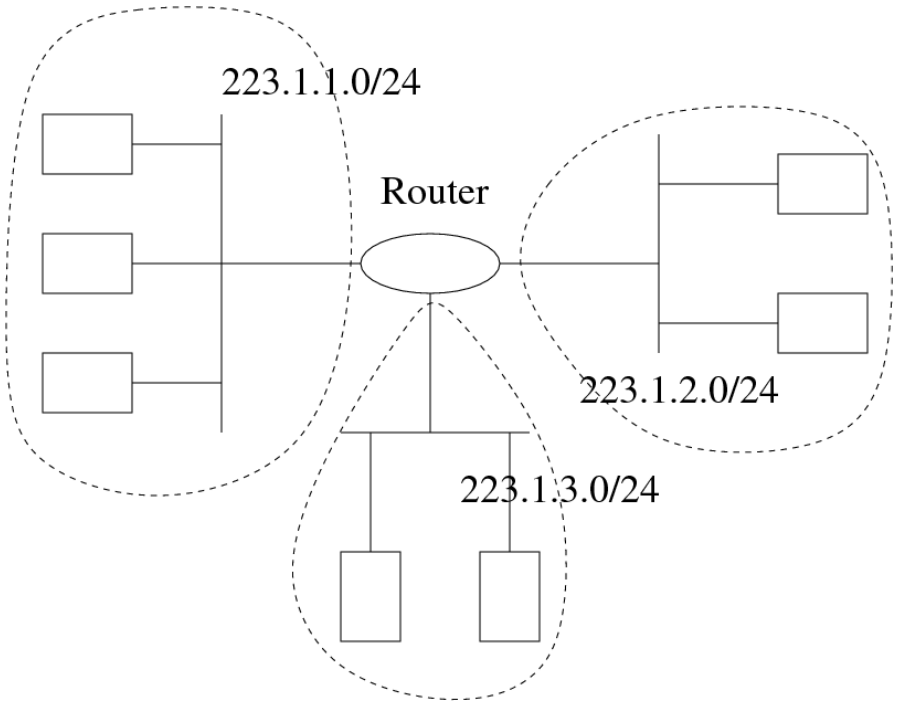
- 32 bits long (4 bytes)
- 2^{32} possible addresses
- dotted-decimal notation: each byte of the address is written in its decimal form and is separated by a period (“dot”) from other bytes in the address.

193.32.216.9

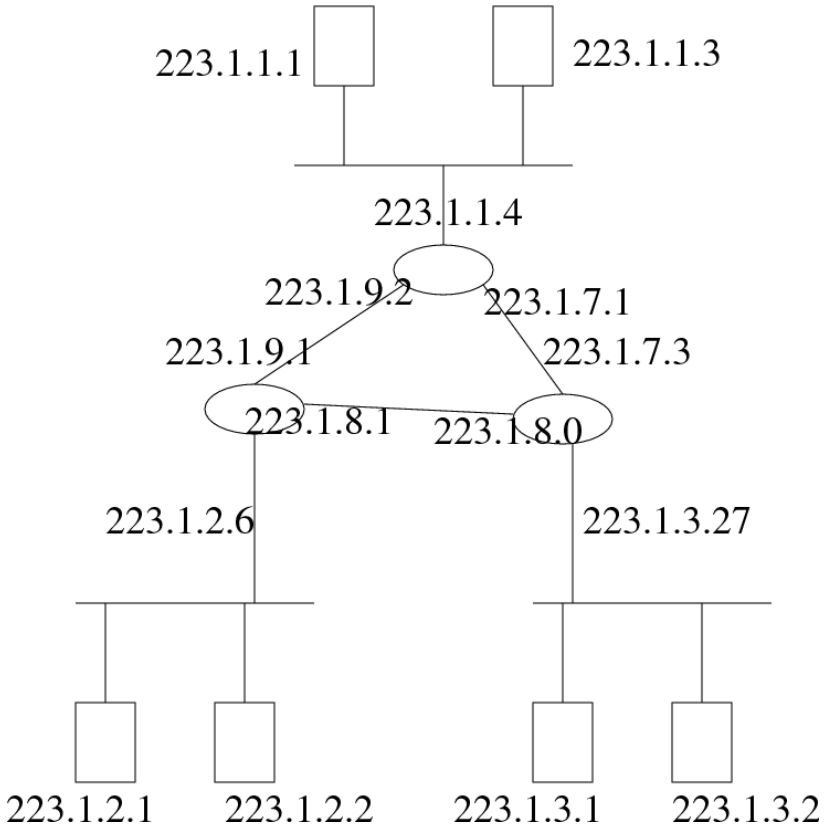
IPv4 Addressing: Interface Addresses



IPv4 Addressing: Network Addresses



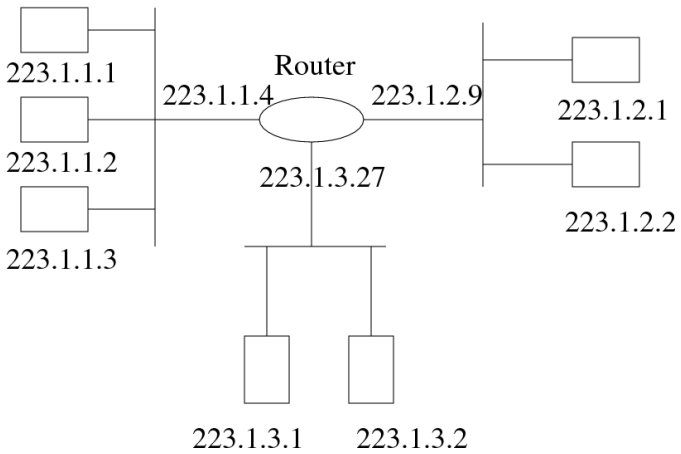
IPv4 Addressing: Network Addresses




Misc.
Source
Dest
Data

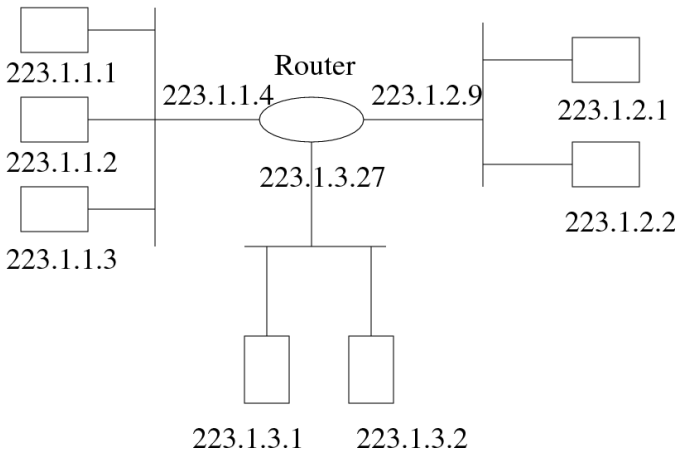
Routing Table in A:

Dest. Network	Next router	Nhops
223.1.1.0/24		1
223.1.2.0/24	223.1.1.4	2
223.1.3.0/24	223.1.1.4	2



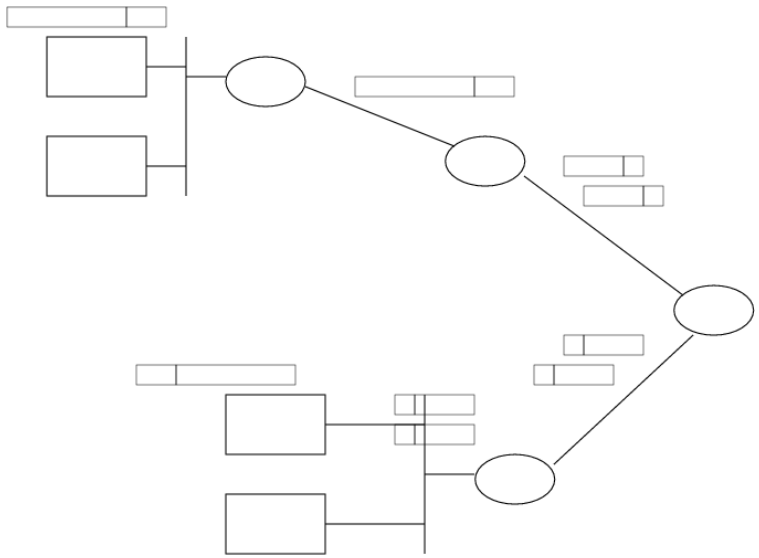
Routing Table in Router:

Dest. Network	Next router	Nhops	Interface
223.1.1.0/24		1	223.1.1.4
223.1.2.0/24		1	223.1.2.9
223.1.3.0/24		1	223.1.3.27



IP Fragmentation and Reassembly

- IPv4 Datagrams can be up to 65,353 bytes long
- Ethernet frames can carry up to 1,500 bytes of data



Routing in the Internet

Intra-AS Routing:

- RIP: Routing Information Protocol
  - Distance Vector Protocol
  - Min-Hop Routing
- OSPF: Open Shortest Path First
  - Link State Protocol
  - Supports Several Cost Metrics
- EIGRP: Enhanced Interior Gateway Routing Protocol
  - Distance Vector Protocol
  - Supports Several Cost Metrics

Routing in the Internet

Inter-AS Routing:

- BGP: Border Gateway Protocol
  - Distance Vector Protocol
  - No Cost Metric
  - Indicates Path Vector
  - De Facto Standard in public Internet
  - Allows to Define Routing Policies
- Example: To get from a node in AS X to a destination in AS Z, use AS's
  - X_1, X_2, or
  - X_1, X_3, X_4

Network Layer

- Introduction
- Routing Algorithms
  - Bellman-Ford
  - Dijkstra's
- Hierarchical Routing
- Internet Network Layer
  - IP
  - Routing Protocols