Chapter-1: Networking and Network Routing: an introduction

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http://www.NetworkRouting.net
(Note: Chapter-1 assumes that the audience has some knowledge of networking from an introductory course; thus other material may be added as appropriate)

What's routing

- Simply stated, how to go from point-A to point-B
  - There might be multiple ways to go: Which one to choose?
    - Take the perspective from the user (reach there as fast as possible)
    - From the perspective of the network (not letting some suffer by giving benefit to others)
  - Addressing
    - How addressing might be useful in routing

Postal System

- Address has essentially three parts:
  - Name ("User")
  - Street Address ("House address")
  - City/Zip code ("City")
- If we consider routing to a person, the origination point doesn't really need all three pieces of information, just the destination zip code is sufficient
- Re-arranging, we look at address as follows:
  - City | House Address | User
  - Least specific part at the beginning, and more specific at the end
- Note: for postal address, the postman doesn't need to know the Name at all: her job is to drop at the House address, and let the residents of the house "route" to the actual person

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Network-based System

- Addressing is important as it can be useful in routing, and routing efficiently
  - Routers do not need to store detailed address information (means: less memory)
- Two ways to look at address:
  - Hierarchical
  - Flat

  (also, a mixed mode is possible)

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Hierarchical addressing

- Postal code (in most countries)

  US zip code: five digit number

  The first two digits represent a geographical area, such as "64" in "64110" which signifies the Kansas City area

  Secondly, there's a bit of structure to it, going from East cost to the west coast as the first two digits change from "01" to "94"
- Telephone number in most countries:
  - Geographic code (area/city code) followed by a local number

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Flat addressing

- Doesn't say anything about address proximity
  - IP address prefix ("net-id")
    - 134.193.0.0 identifies the address block assigned to the University of Missouri-Kansas City
    - 134.192.0.0 identifies the University of Maryland at Baltimore
    - <address doesn't show any geographic proximity>

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Why structure of addressing matter?

- In network routing, structure of the addressing can influence what can be accomplished (and what might be hard to do)

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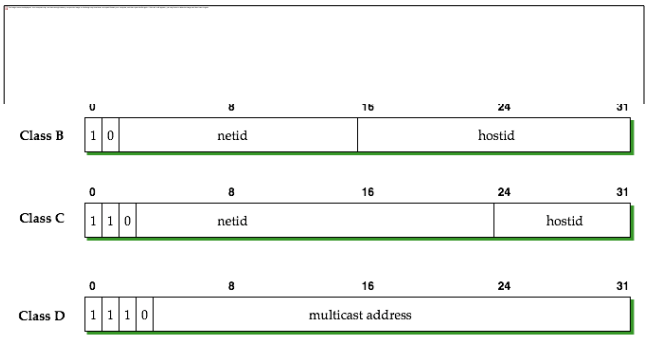
IP addressing: overview

- 32-bit addressing originally defined (known as IPv4 address)
  - Originally *classful*: based on bit boundary (class A: 2^7, Class-B: 2^{14}, Class-C: 2^{21})



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IP address

- It is used for identifying devices
  - Common terminology: “host”
  - Computers, routers …

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IPv6 addressing

- 128-bit address scheme
  - Divided by provider and country

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Subnetting/Mask in IPv4

- The idea is identify if an IP address below to a "network" (subnet)
  - Classful: easy, because of bit boundary: for example 10.0.0.0 belongs to class-A and so on
  - Class*less*: not implicitly defined by a class boundary
    - Known as CIDR (classless inter-domain routing) notation

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CIDR notation: illustration

- Bit-wise AND operation of an address with its subnet mask 255.255.255.0, also written as /24 since (first 24-bits of the mask are all 1's)
- Bit-wise AND operation with mask /24:

```
      11000000 10101000 00101000 00000011   → 192.168.40.3
AND   11111111 11111111 11111111 00000000   → netmask (/24)
      11000000 10101000 00101000 00000000   → 192.168.40.0
```

- While the outcome looks the same, clear they represent different subnets, one with /24 and the other with /21.

```
      11000000 10101000 00101000 00000011   → 192.168.40.3
AND   11111111 11111111 11111000 00000000   → netmask (/21)
      11000000 10101000 00101000 00000000   → 192.168.40.0
```

  - Explicitly mention the mask
    - 192.168.40.0/24, 192.168.40.0/21
  - Note the difference with implicit mask as with classful address

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Why CIDR

- Routing in IP is based on flat addressing, i.e., need an entry for each netid at the core of the Internet
- Classful address for Class C creates a large number of addresses (2^21): CIDR allows aggregation
- CIDR is used for routing purpose in the Internet (started with BGP version 4)
- (More as we discuss routing later)

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On Architectures

- Used in many different ways:
  - Service Architecture
  - Protocol Stack Architecture
  - Router Architecture
  - Network Topology Architecture
  - Network Management Architecture

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Service Architecture

- A service model gives the basic framework for the type of services a network offers
  - IP networks
    - Best-Effort Services
    - Integrated Services
    - Differentiated Serivces
- Note: a service architecture can be supplemented by proper traffic engineering to provide a high quality of service

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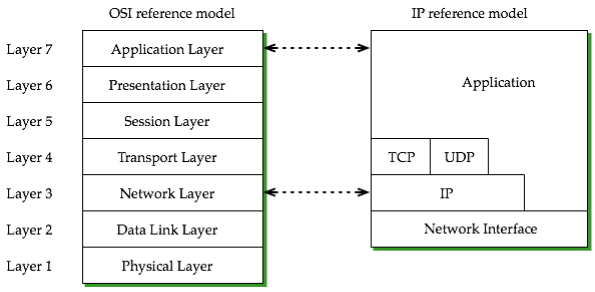
Protocol Stack Architecture

- OSI Reference Model
- TCP/IP Protocol Stack Model



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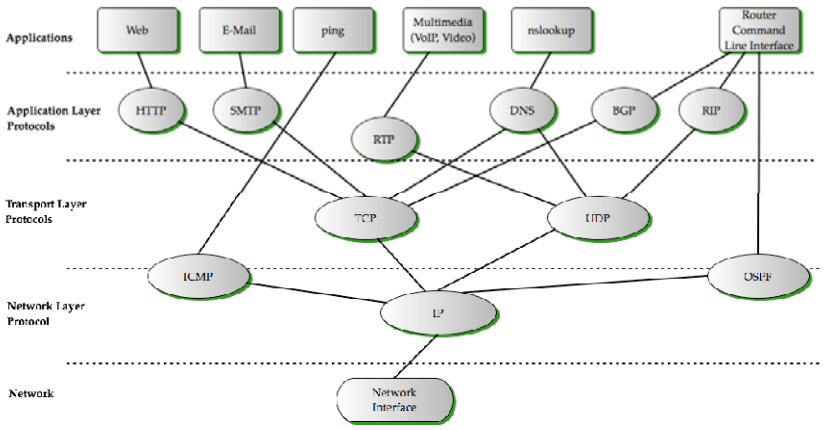
Where do routing protocols fit in?

- It's a mixed bag: OSPF: directly over IP; BGP & RIP: transport layer



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- Important to note:
  - To do network layer function, upper layer mechanisms are needed to *communicate* routing information
  - Important to distinguish between routing information and the function of a network layer

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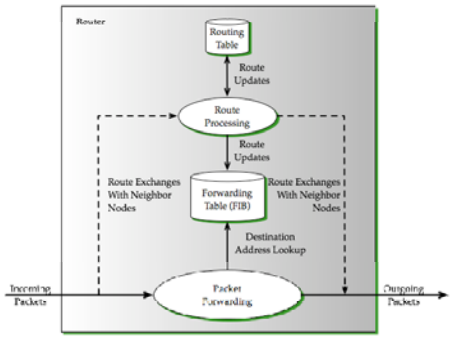
Router Architecture

- Routers provider several important functions
  - Packet Forwarding
  - Routing protocol message processing
  - Specialized services (for example, for monitoring and management)



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Network Topology Architecture

- Encompasses how a network is to be architected in an operational environment
  - Topology of the network
  - Bandwidth for carrying traffic volume
  - Operational considerations
- Sometimes, simply referred to as 'Network Architecture'

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Network Management Architecture

- Functional architecture for being able to monitor and manage the network
- Different planes:
  - Management plane
    - Routing configuration, collection of various statistics
  - Control plane
    - Control information between routers for management of various functions, such as setup a virtual link
  - Data plane
    - User application traffic
- Note that at IP layer, no distinction between packets due to these three planes

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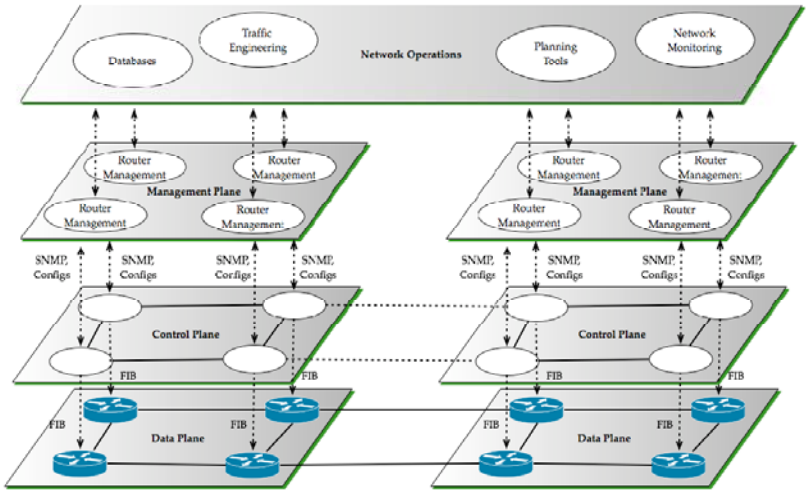
NM Architecture: Pictorial View



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Public Switched Telephone Network

- In short, PSTN; also known as GSTN (Global Switched Telephone Network)
- Architecturally and technologically different than IP networks
  - Unit of information: a call
  - Uses circuit switching to set up a call on demand
  - End device ("phone") is dumb, intelligence starts from the end office switch
  - Control information carried on a separate signaling network (known as SS7)
  - Its own addressing mechanism, known as E.164

(More details in later chapter)

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Communication Technologies

- Different technologies, link speeds are used for communicating information

TABLE 1.2 Modular data rates.

Signal/data rate name	Bit rate (Mbps)
DS0 (voice circuit)	0.064
T1 (DS-1)	1.54
E1	2.04
Ethernet	10.00
T3 (DS-3)	45.00
E3	34.36
STS-1	51.84
Fast Ethernet	100.00
OC-3/STS-3/STM-1	155.52
OC-12/STS-12/STM-4	622.08
Gigabit Ethernet	1,000.00
OC-48/STS-48/STM-16	2,488.32
OTU1 (Optical Transport Unit-1)	2,666.06
OC-192/STS-192/STM-64	9,953.28
OTU2 (Optical Transport Unit-2)	10,709.22
OC-768/STS-768/STM-256	39,813.12
OTU3 (Optical Transport Unit-3)	43,018.41

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Standards: a few words

- Standards are important
  - Allows a common way to do something
  - Different vendors can build product which can "talk" in the language specified through standards
  - Market competition, drives to cost down

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IETF

- Internet Engineering Task Force (http://www.ietf.org)
  - Standardizes anything related to Internet
    - Published as *Request for Comments (RFC)*
      - Not all RFCs are standards document
      - They aren't 'request' any more; name is historical, stuck on
  - Traditionally, didn't do much below layer-3
  - In recent years, Layer-2.5 and below functions such as Multi-protocol label switching (MPLS)
  - Note: anything related to web is standarded by WWW consortium (http://www.w3.org/)
- Assignment: study how IETF works

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ITU-T

- International Telecommunications Union-Telecommunication Standardization Sector (http://www.itu.int)
  - A United Nations specialized agency
  - Develops standards referred to as *Recommendations*

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Many other standardization bodies

- MFA Forum
  - MPLS and Frame Relay Forum,
    - http://www.mfaforum.org/
- OIF
  - Optical Interworking Forum
    - http://www.oiforum.com/
- ANSI
  - American National Standards Institute
    - http://www.ansi.org/

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Summary

- An overview of addressing and routing
  - Comparison to other "routing" systems such as the postal system, the road transportation network
- Overview of TCP/IP protocol architecture
- A walk through the notion of architecture
- Standards

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Extras

- Packet formats for IPv4, IPv6, TCP, and UDP enclosed

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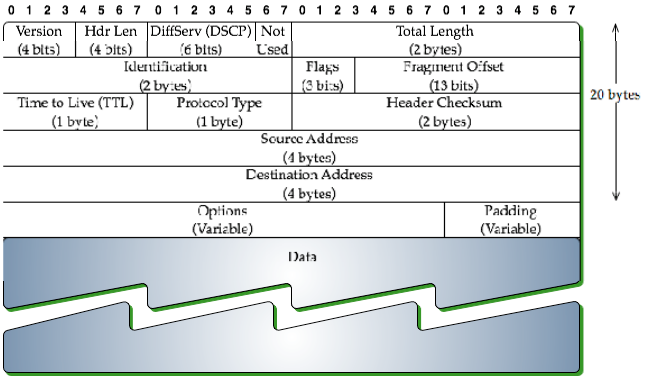
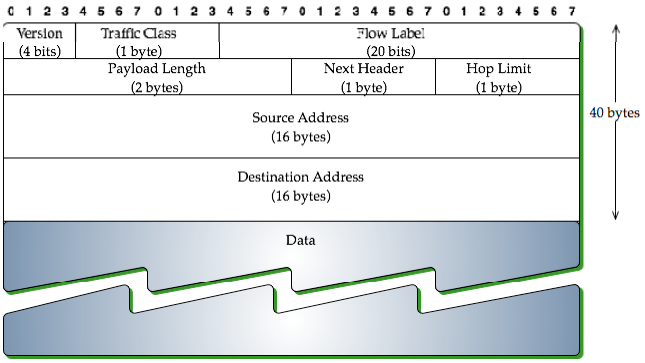
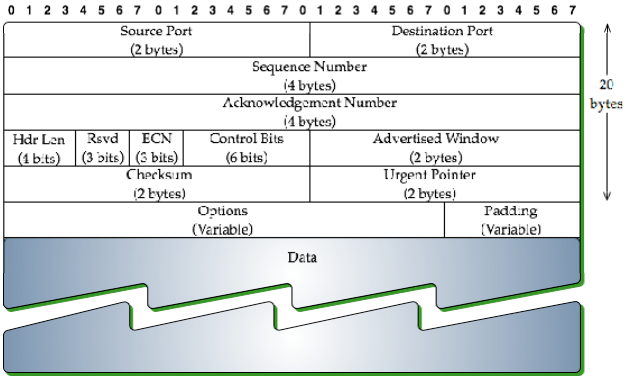
IPv4 packet format



IPv6 packet format



TCP packet format



UDP packet format