Chapter 4
Network Layer

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Computer Networking:
A Top Down Approach
Featuring the Internet,
3rd edition.
Jim Kurose, Keith Ross
Addison-Wesley, July 2004.
Chapter 4: Network Layer

Chapter goals:

- understand principles behind network layer services:
  - routing (path selection)
  - dealing with scale
  - how a router works
  - advanced topics: IPv6, mobility
- instantiation and implementation in the Internet
Chapter 4: Network Layer

4.1 Introduction

4.2 Virtual circuit and datagram networks

4.3 What’s inside a router

4.4 IP: Internet Protocol
   - Datagram format
   - IPv4 addressing
   - ICMP
   - IPv6

4.5 Routing algorithms
   - Link state
   - Distance Vector
   - Hierarchical routing

4.6 Routing in the Internet
   - RIP
   - OSPF
   - BGP

4.7 Broadcast and multicast routing
Network layer

- transport segment from sending to receiving host
- on sending side, encapsulates segments into datagrams
- on receiving side, delivers segments to transport layer
- network layer protocols in every host, router
- Router examines header fields in all IP datagrams passing through it
Key Network-Layer Functions

- **forwarding**: move packets from router's input to appropriate router output

- **routing**: determine route taken by packets from source to dest.

Routing algorithms

**analogy:**

- **routing**: process of planning trip from source to dest
- **forwarding**: process of getting through single interchange
Interplay between routing and forwarding

Routing algorithm

<table>
<thead>
<tr>
<th>header value</th>
<th>output link</th>
</tr>
</thead>
<tbody>
<tr>
<td>0100</td>
<td>3</td>
</tr>
<tr>
<td>0101</td>
<td>2</td>
</tr>
<tr>
<td>0111</td>
<td>2</td>
</tr>
<tr>
<td>1001</td>
<td>1</td>
</tr>
</tbody>
</table>

Value in arriving packet's header: 0111

Network Layer 4-20
Datagram networks

- no call setup at network layer
- routers: no state about end-to-end connections
  - no network-level concept of "connection"
- packets forwarded using destination host address
  - packets between same source-dest pair may take different paths
## Forwarding Table

<table>
<thead>
<tr>
<th>Destination Address Range</th>
<th>Link Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>11001000 00010111 00010000 00000000 through 11001000 00010111 00010111 11111111</td>
<td>0</td>
</tr>
<tr>
<td>11001000 00010111 00011000 00000000 through 11001000 00010111 00011000 11111111</td>
<td>1</td>
</tr>
<tr>
<td>11001000 00010111 00011111 11111111 otherwise 11001000 00010111 00011111 11111111</td>
<td>2</td>
</tr>
<tr>
<td>otherwise</td>
<td>3</td>
</tr>
</tbody>
</table>

4 billion possible entries
**Longest prefix matching**

<table>
<thead>
<tr>
<th>Prefix Match</th>
<th>Link Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>11001000 00010111 00010</td>
<td>0</td>
</tr>
<tr>
<td>11001000 00010111 00011000</td>
<td>1</td>
</tr>
<tr>
<td>11001000 00010111 00011</td>
<td>2</td>
</tr>
<tr>
<td>otherwise</td>
<td>3</td>
</tr>
</tbody>
</table>

**Examples**

**DA: 11001000 00010111 00010110 10100001** Which interface?

**DA: 11001000 00010111 00011000 10101010** Which interface?
IP Addressing: introduction

- **IP address**: 32-bit identifier for host, router interface
- **interface**: connection between host/router and physical link
  - router’s typically have multiple interfaces
  - host may have multiple interfaces
  - IP addresses associated with each interface

```
223.1.1.1 = 11011111 00000001 00000001 00000001
```

223 1 1 1 1
Subnets

IP address:
- subnet part (high order bits)
- host part (low order bits)

What's a subnet?
- device interfaces with same subnet part of IP address
- can physically reach each other without intervening router

network consisting of 3 subnets
## Subnets

### Recipe

- To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Each isolated network is called a **subnet**.

**Subnet mask: /24**
Subnets

How many?

Network Layer 4-30
**IP addressing: CIDR**

**CIDR:** Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: `a.b.c.d/x`, where `x` is # bits in subnet portion of address

```
11001000  00010111 00010000  00000000
```

```
200.23.16.0/23
```
**IP addresses: how to get one?**

**Q:** How does host get IP address?

- hard-coded by system admin in a file
  - Wintel: control-panel->network->configuration->tcp/ip->properties
  - UNIX: /etc/rc.config
- **DHCP:** Dynamic Host Configuration Protocol: dynamically get address from as server
  - “plug-and-play”
  (more in next chapter)
**IP addresses: how to get one?**

**Q:** How does network get subnet part of IP addr?

**A:** gets allocated portion of its provider ISP’s address space

<table>
<thead>
<tr>
<th>ISP's block</th>
<th>11001000 00010111 00010000 00000000</th>
<th>200.23.16.0/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization 0</td>
<td>11001000 00010111 00010000 00000000</td>
<td>200.23.16.0/23</td>
</tr>
<tr>
<td>Organization 1</td>
<td>11001000 00010111 00010010 00000000</td>
<td>200.23.18.0/23</td>
</tr>
<tr>
<td>Organization 2</td>
<td>11001000 00010111 00010100 00000000</td>
<td>200.23.20.0/23</td>
</tr>
<tr>
<td>...</td>
<td>.....</td>
<td>.....</td>
</tr>
<tr>
<td>Organization 7</td>
<td>11001000 00010111 00011110 00000000</td>
<td>200.23.30.0/23</td>
</tr>
</tbody>
</table>
Hierarchical addressing: route aggregation

Hierarchical addressing allows efficient advertisement of routing information:

Organization 0
- 200.23.16.0/23

Organization 1
- 200.23.18.0/23

Organization 2
- 200.23.20.0/23

Organization 7
- 200.23.30.0/23

Fly-By-Night-ISP

ISPs-R-Us

Internet

"Send me anything with addresses beginning 200.23.16.0/20"

"Send me anything with addresses beginning 199.31.0.0/16"
Hierarchical addressing: more specific routes

ISPs-R-Us has a more specific route to Organization 1

Organization 0
200.23.16.0/23

Organization 2
200.23.20.0/23

Organization 7
200.23.30.0/23

Organization 1
200.23.18.0/23

Fly-By-Night-ISP

“Send me anything with addresses beginning 200.23.16.0/20”

ISPs-R-Us

“Send me anything with addresses beginning 199.31.0.0/16 or 200.23.18.0/23”

Internet
IP addressing: the last word...

**Q:** How does an ISP get block of addresses?

**A:** ICANN: Internet Corporation for Assigned Names and Numbers

- allocates addresses
- manages DNS
- assigns domain names, resolves disputes
The following slides about DHCP are from the 2nd edition of Kurose and Ross - omitted from the 3rd edition?
**DHCP: Dynamic Host Configuration Protocol**

**Goal:** allow host to dynamically obtain its IP address from network server when it joins network
- Can renew its lease on address in use
- Allows reuse of addresses (only hold address while connected and “on”)
- Support for mobile users who want to join network (more shortly)

**DHCP overview:**
- Host broadcasts “DHCP discover” msg
- DHCP server responds with “DHCP offer” msg
- Host requests IP addr.: “DHCP request” msg
- DHCP server sends addr.: “DHCP ack” msg
DHCP client-server scenario

arriving DHCP client needs address in this network
DHCP client-server scenario

DHCP discover

DHCP server: 223.1.2.5

src: 0.0.0.0, 68
dest.: 255.255.255.255, 67
yiaddr: 0.0.0.0
transaction ID: 654

DHCP offer

src: 0.0.0.0, 68
dest.: 255.255.255.255, 67
yiaddr: 223.1.2.4
transaction ID: 654
Lifetime: 3600 secs

DHCP request

src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddr: 223.1.2.4
transaction ID: 655
Lifetime: 3600 secs

DHCP ACK

src: 223.1.2.5, 67
dest: 255.255.255.255, 68
yiaddr: 223.1.2.4
transaction ID: 655
Lifetime: 3600 secs

67 = IP protocol number for DHCP servers
68 = IP protocol number for DHCP clients
yiaddr = your internet address