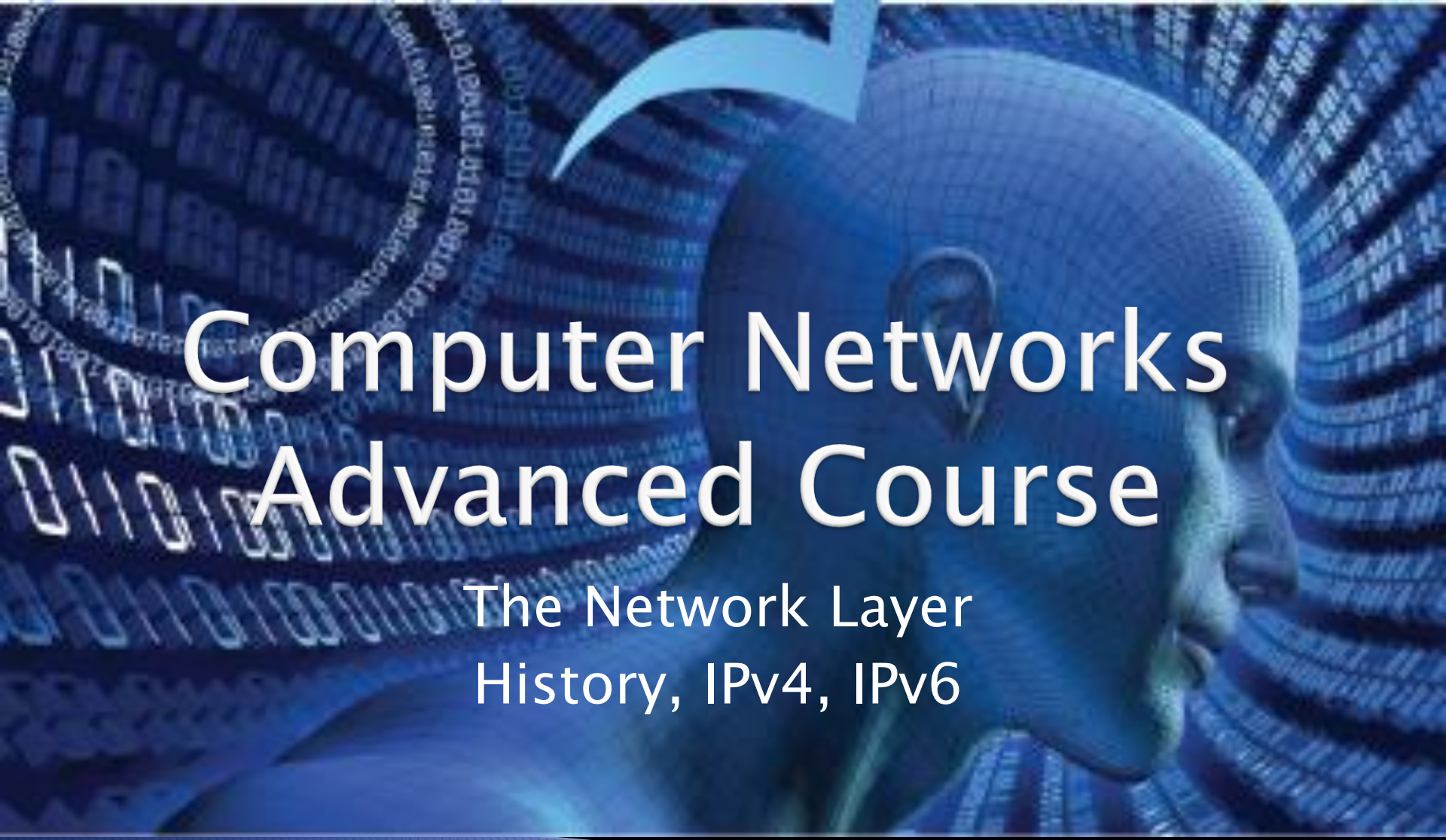


Computer Networks Advanced Course

The Network Layer
History, IPv4, IPv6

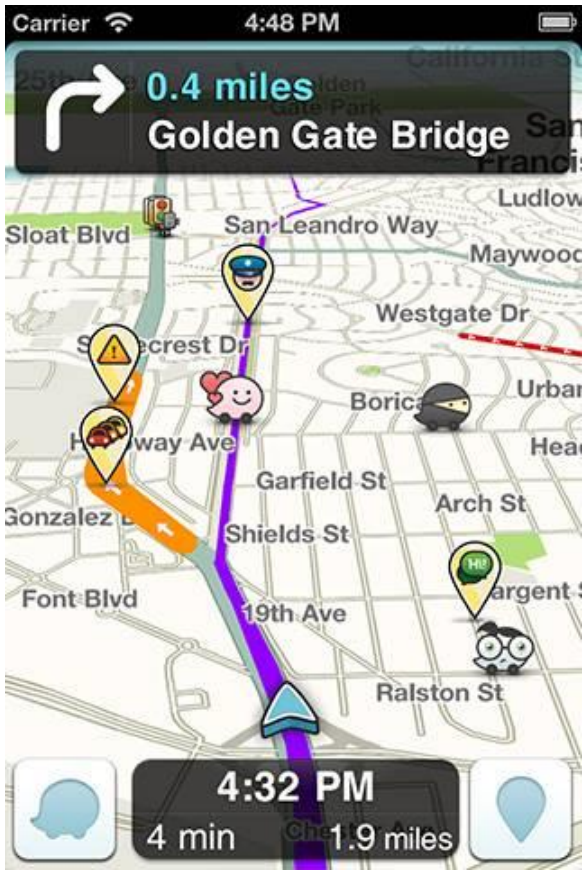
Barak Gonen

Network Layer Topics

- Routing
- Router
- IPv4, IPv6
- NAT
- ICMP
- DHCP
- Routing protocols – OSPF

Routing

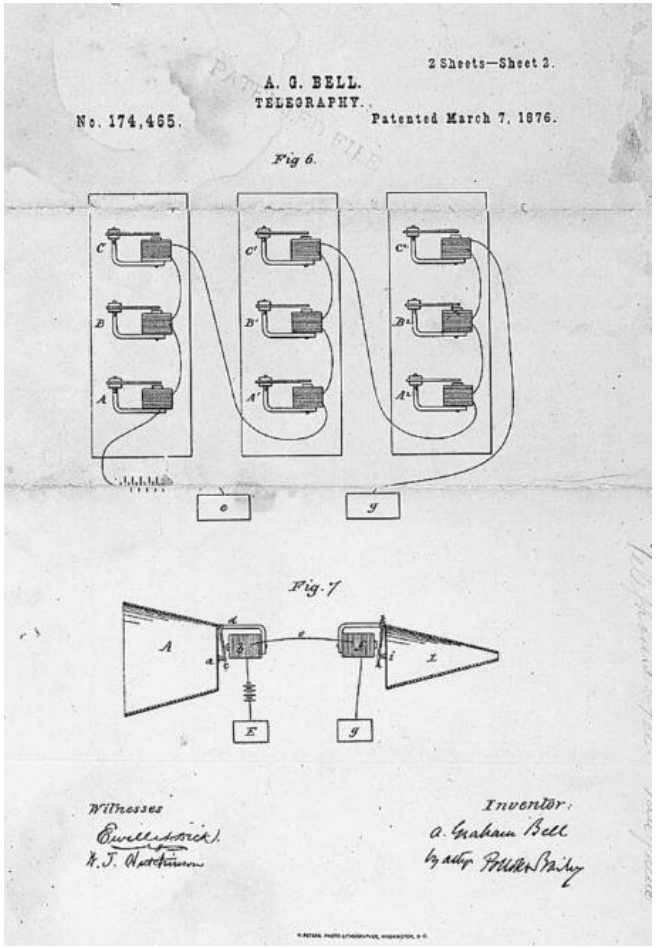
- Choose path for packet from A to B
- Possible criteria:
  - Shortest time
  - Minimal hops
  - Cheapest
- Path has to be dynamic



Routing

- Historical review – why things are as they?
- Evolution:
  - Simple telephony network
  - PSTN and Telephony Exchange
  - Arpanet

Invention of Telephone



2 Sheets—Sheet 2.

A. G. BELL.

TELEGRAPHY.

No. 174,465. Patented March 7, 1876.

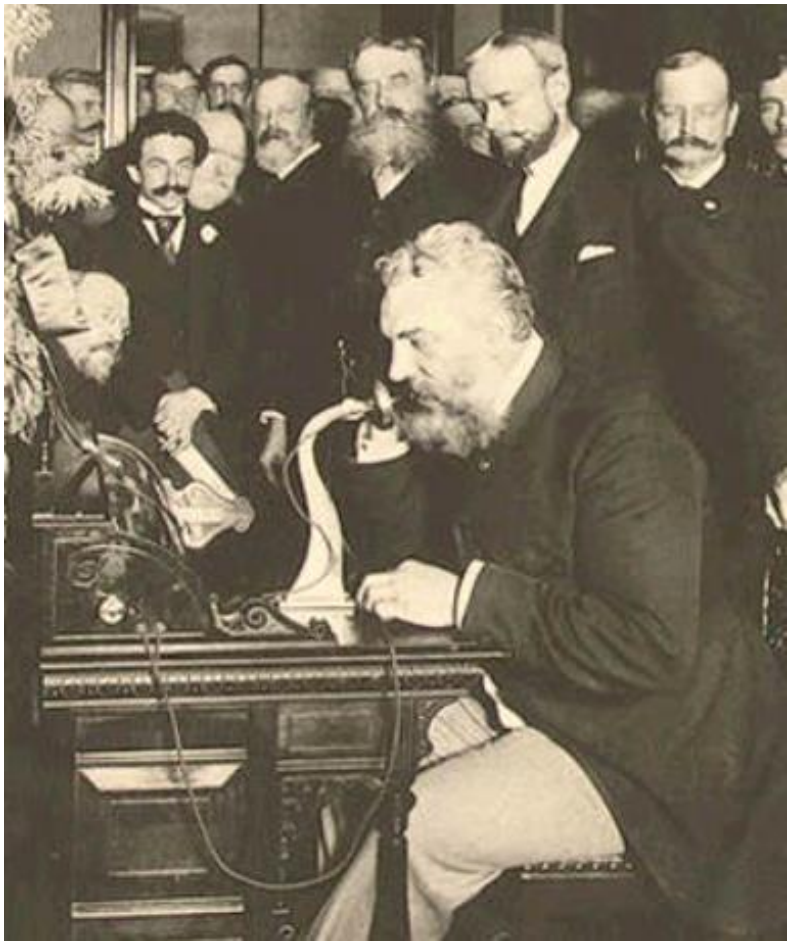
Fig 6.

Fig. 7

Witnesses

Inventor:
A. Graham Bell

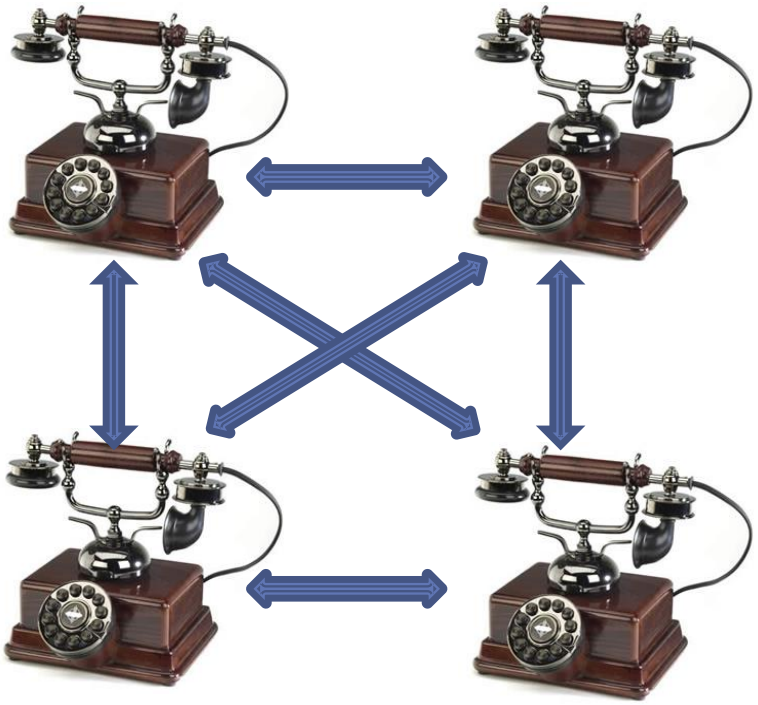
Patent March 1876



Alexander Graham Bell Opening New-York to Chicago line, 1892

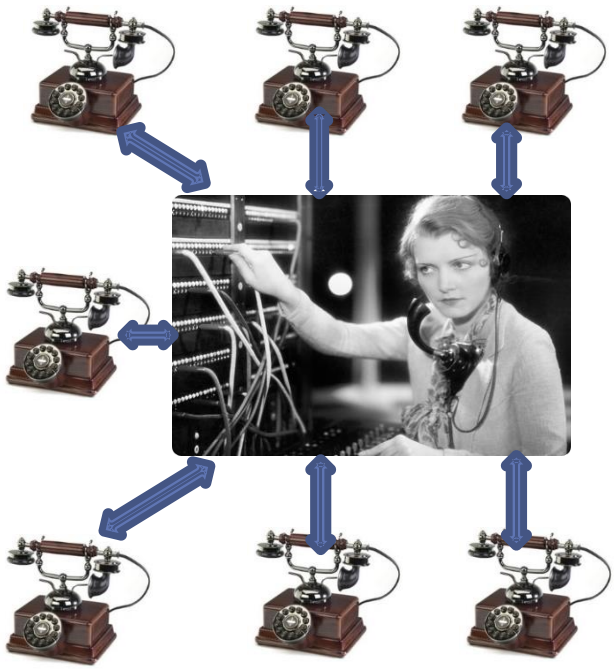
Telephony Network

- Assume we built the first telephony network
- Each device is physically connected via cable to others
  - Connection is called **Physical Circuit**
  - Network topology is **Mesh Network**
- Easy deployment
- Impossible to scale up



Telephony Exchange

- To reduce cables, routing element is required
- The telephony exchange is linked to all phones
- The operator connects two phones
  - **Virtual Circuit** – the endpoints are not aware that their link is ad-hoc, not Physical Circuit
  - Topology is **Star Network**
- Can one telephony exchange serve a country?

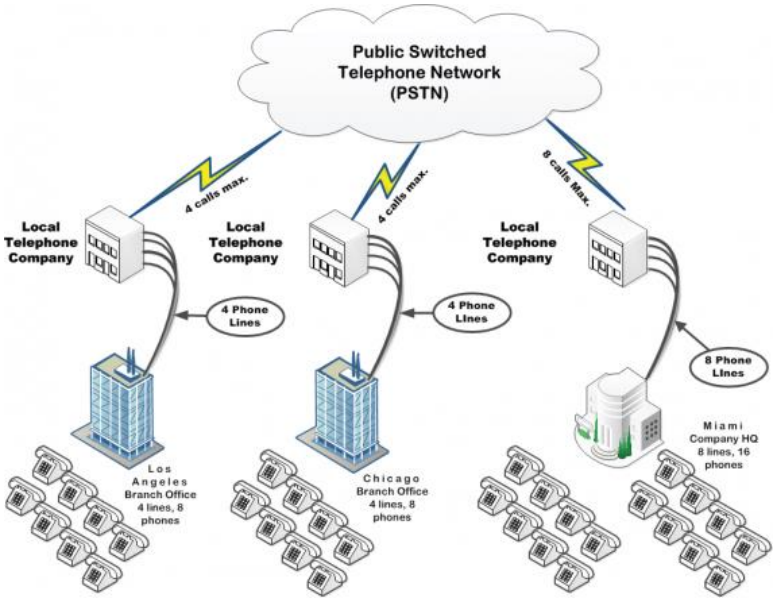


Local Telephony Exchanges

- Divide a country to several regions, each covered by a local telephone exchange
  - Name as much area codes in Israel as possible
  - https://www.youtube.com/watch?v=0jUsVX-gb7o ☺
- A new element is required – national telephony exchange

PSTN

- Public Switched Telephone Network
- If both endpoints belong to same local exchange, it will connect them
- Calls outside of local exchange are “long distance”
- Hierarchy of exchanges:
  - Class 1 – Regional Center
  - Class 2 – Sectional Center
  - Class 3 – Primary Center
  - Class 4 – Toll Center
  - Class 5 – Local Exchange
- A telephony exchange with higher hierarchy will transfer the call



www.voicenewengland.com

PSTN Example

- Up to 1970's establishment of virtual circuit was manual
- The national telephony exchange instructs the local operator how to route the call
  - Note how it begins with routing instructions
  - Afterwards, the operator "connects the dots" to establish connection
- https://data.cyber.org.il/networks/links/long_distance_call.mp3
  - Credit: Wikipedia, Long distance calls

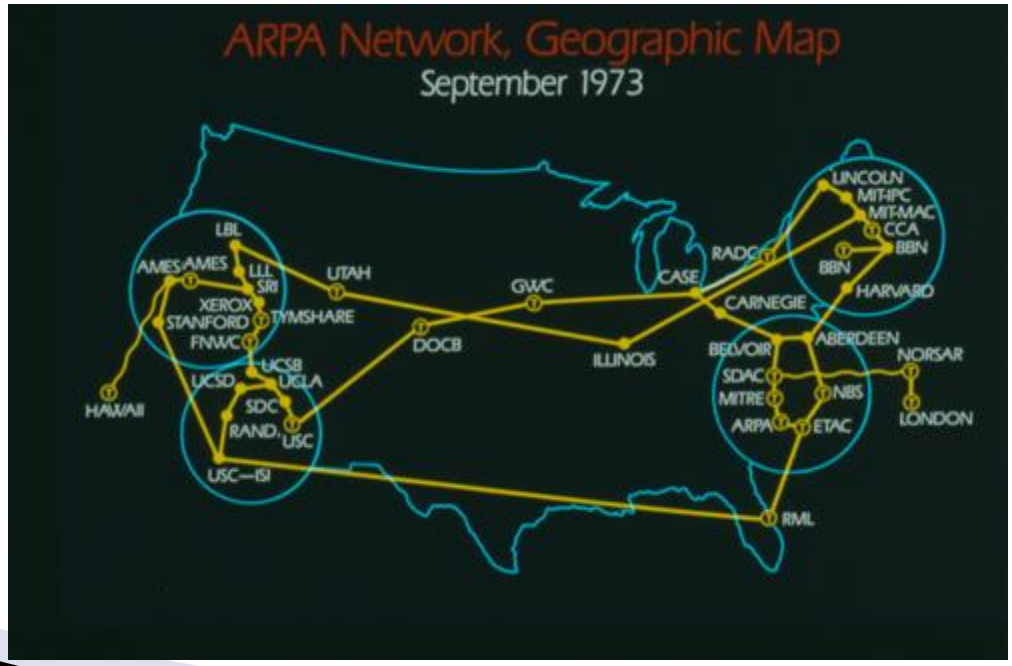
The Cold War

1945-1989

- The PSTN model is problematic
  - If the higher class exchanges are hit…
- US MoD sets new network requirements

ARPANET

- US MoD network
- Technological break-throughs:
  - No specific element controls routing
  - Packet switched network



Packet Switched Network

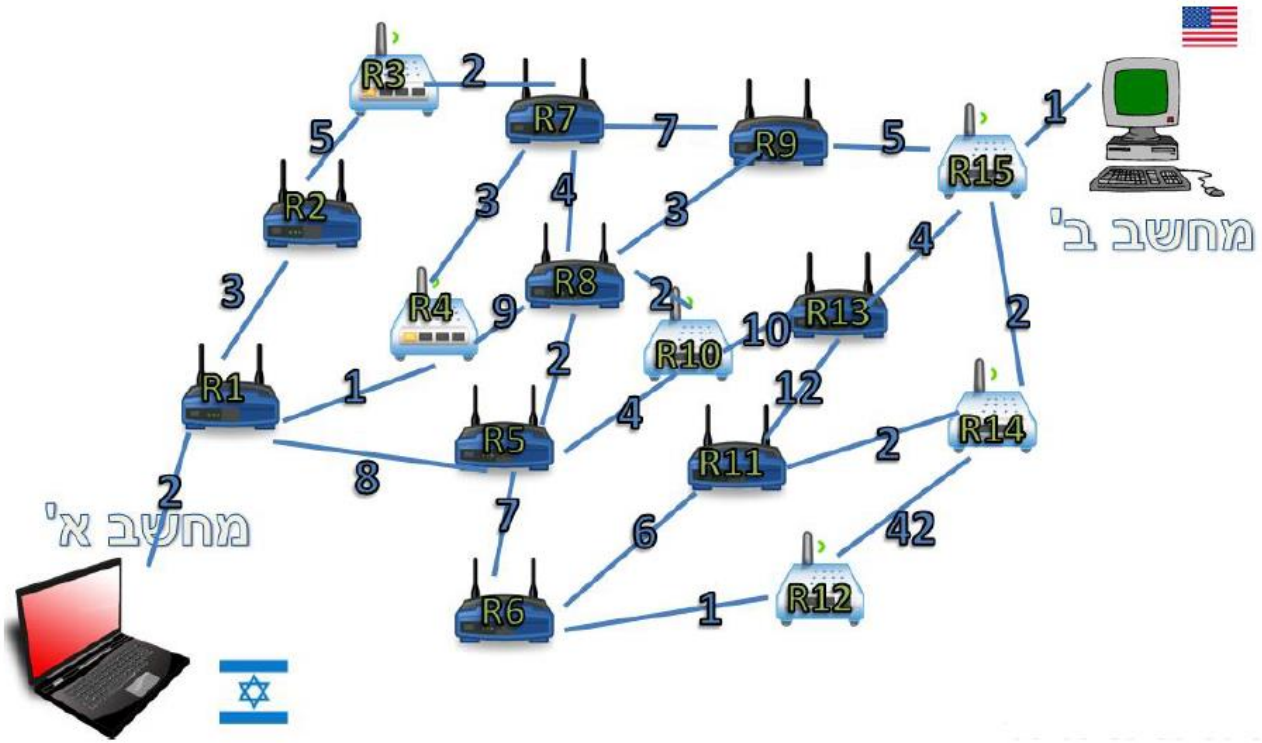
- Circuit switched network:
  - Routing is predetermined, fixed
  - Physical medium (cables etc.) is temporarily owned by the endpoints
- Packet switched network:
  - Communication is divided to packets
    - Reassembled in destination
  - Packets may have different routes
  - Physical medium is shared between users

Arpanet

- More resilient to attacks
  - No critical location
  - Many routes, alternatives
  - More suitable to digital communication
  - If a packet is lost – retransmit

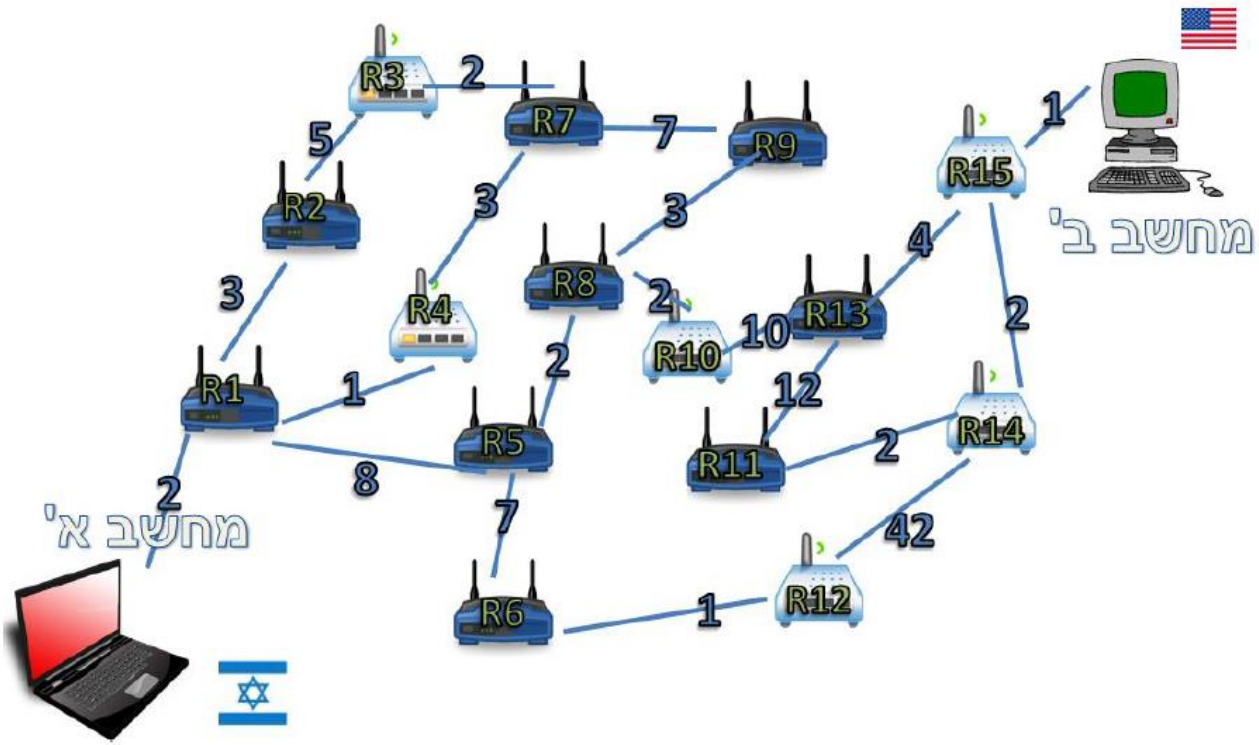
Routing

- What is needed for routing?
- To find that, first find the shortest path:



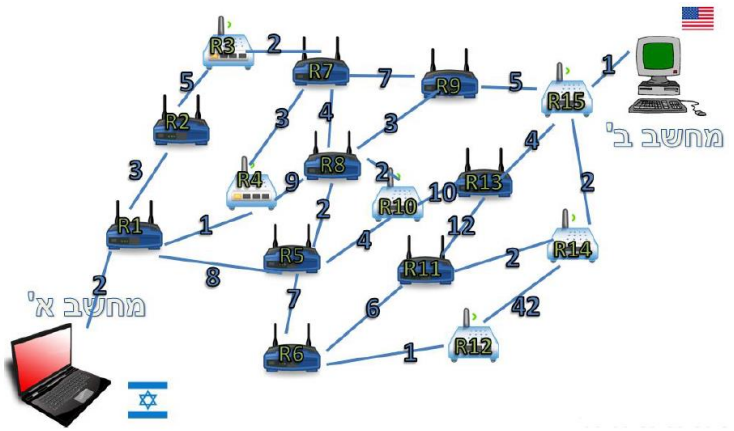
Routing

- Find the shortest path again
- What is the conclusion?



Routing in the Internet

- Endpoint addresses
- Routing devices
- Routing protocol
  - Dynamic
- We shall cover each




IP

Topics

- IP addresses
  - Network / host ID
- IPv4 header
- IPv6 addresses
  - Network / subnet /host ID
  - Global
  - Unique local
  - Link local
  - Localhost
- IPv6 header
- IPv6 tunnelling over IPv4

IPv4

- Designed in 1980
- 32 bits = 4 Giga addresses
- Network ID – the network
- Host ID – the network interface
- Example:
  - Assume office has Network ID 200.100
  - Assume PC in office has host ID 0.1
  - Full IP address : 200.100.0.1

Network ID

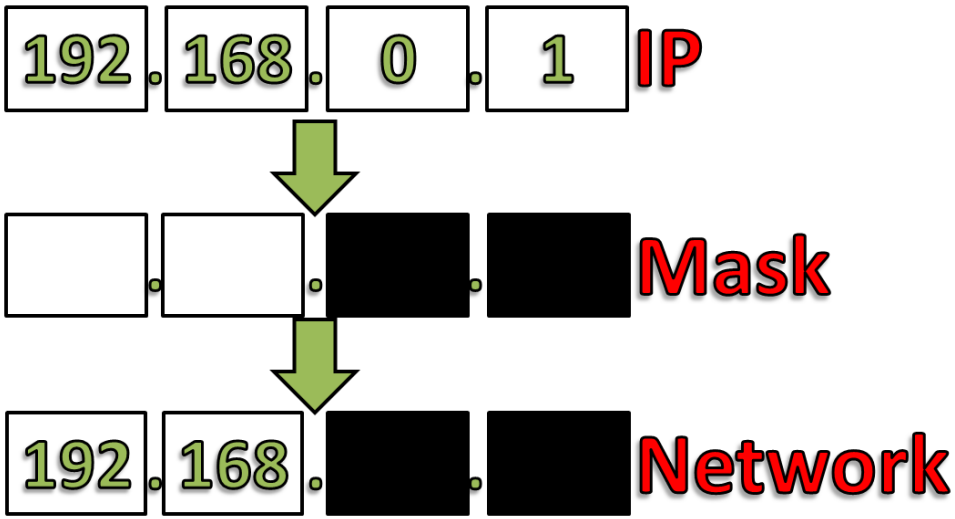
- Assume our IP is 192.168.0.5
- Is 192.168.10.3 also on the same network?

Subnet Mask

- To tell if two IP addresses are in the same network, we need to know how many bits represent the Network ID
- Example– or IP is 192.168.0.5
- Binary – 11000000 10101000 00000000 00000101
- If the Network ID is…:
  - 8 bits – all IP starts with 11000000 has same network
  - 16 bits – all IP starts with 11000000 10101000 has same network
  - 18 bits – all IP starts with 11000000 10101000 00 has same network
  - Network ID does not have to be multiple of 8 bits

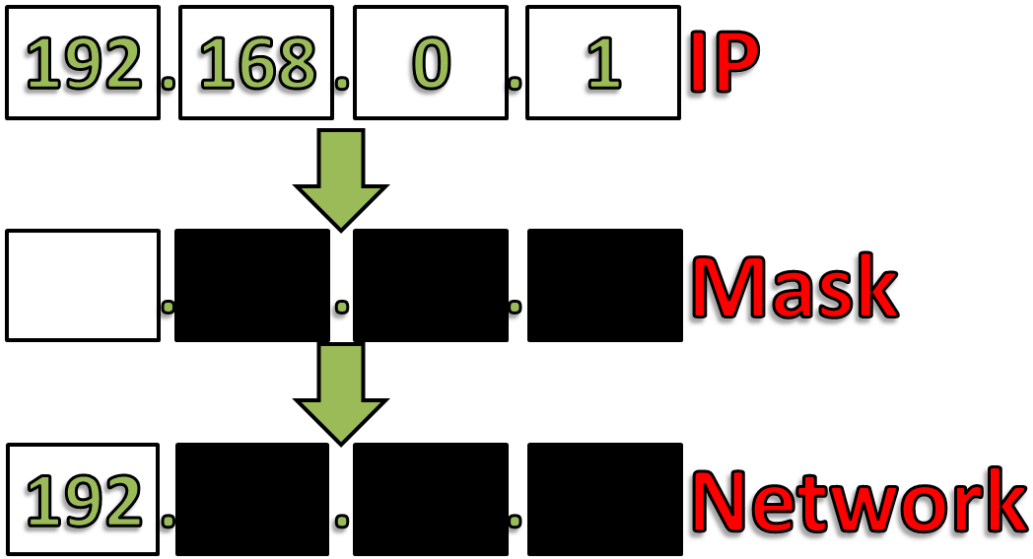
Subnet Mask

- The number of bits in Network ID is noted by:
  - Slash and number, as 192.168.0.5/16 indicates first 16 bits are Network ID
  - Subnet mask, as 255.255.0.0 indicates first 16 bits are “up” and part of the Network ID



Subnet Mask

- Example: 255.0.0.0 indicates first 8 bits are network ID

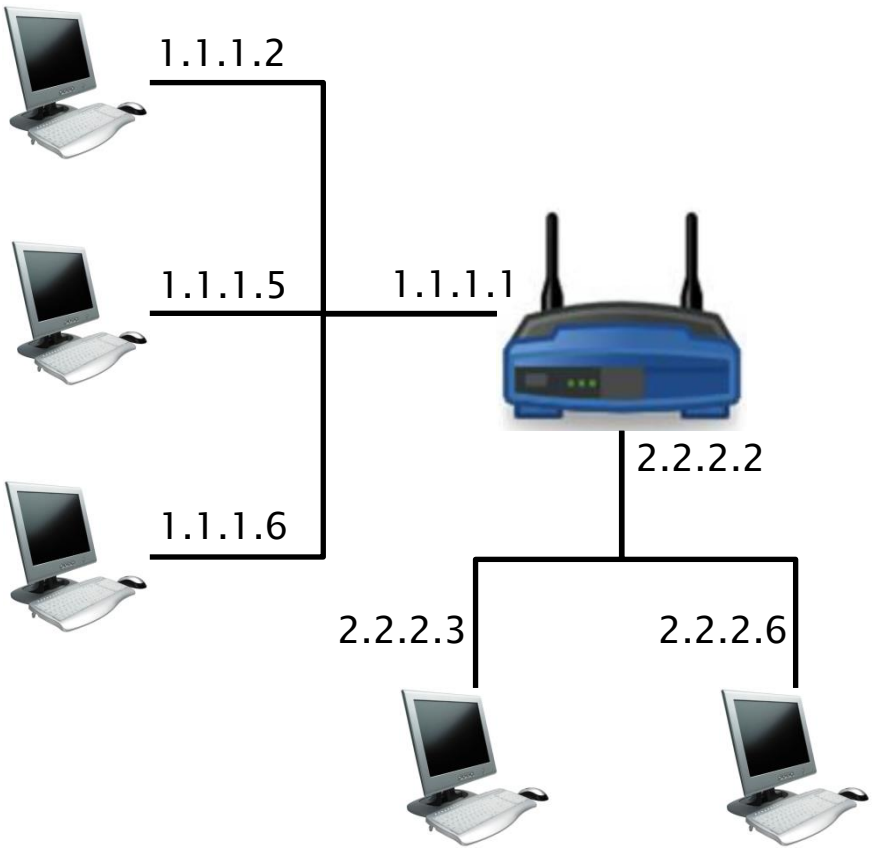


Subnet Mask

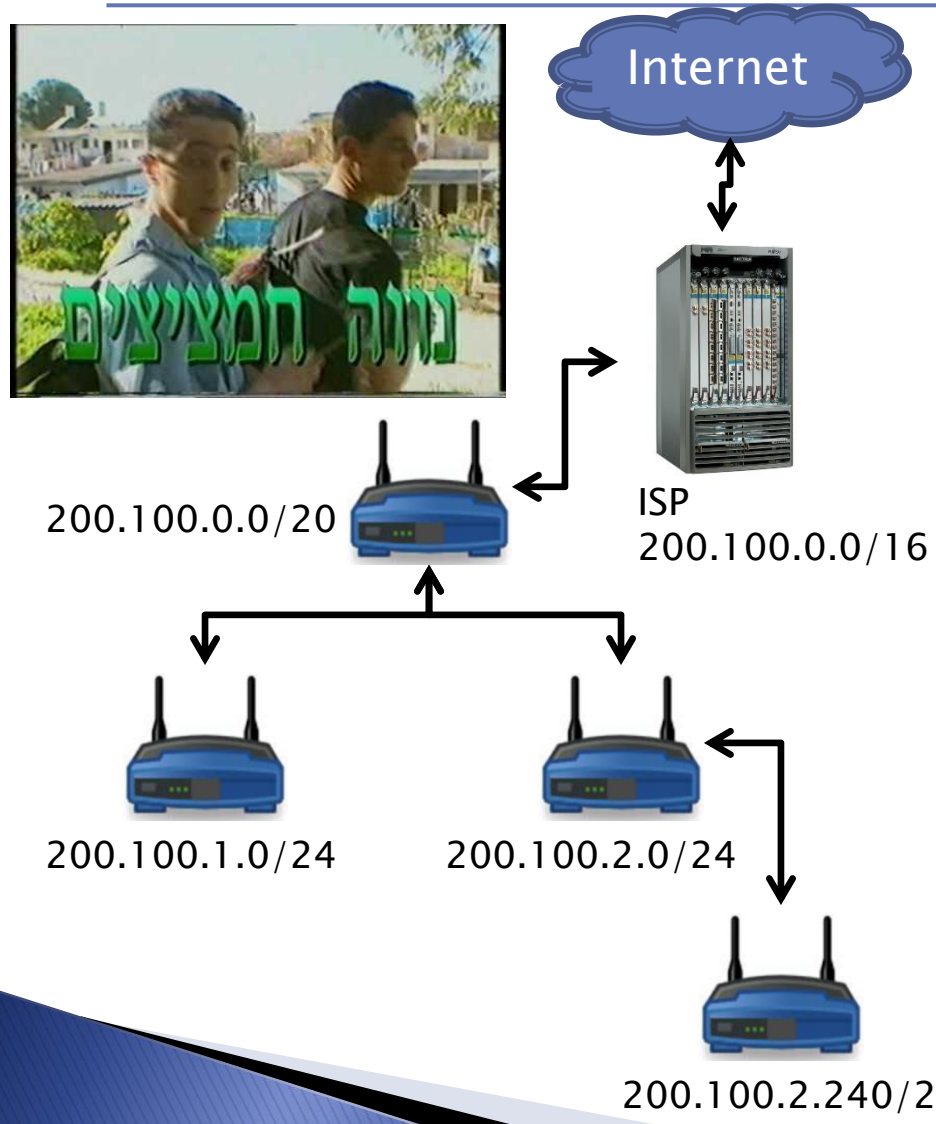
- Use ipconfig to find your subnet mask
- Make sure you and the default gateway belong to the same network

Subnet

- A collection of network interfaces with the same Network ID are called “subnet”
- It is possible to have a subnet within a subnet
  - Like a family tree
- Subnets are linked by routers
  - Router is a networking device which has an IP in more than one network



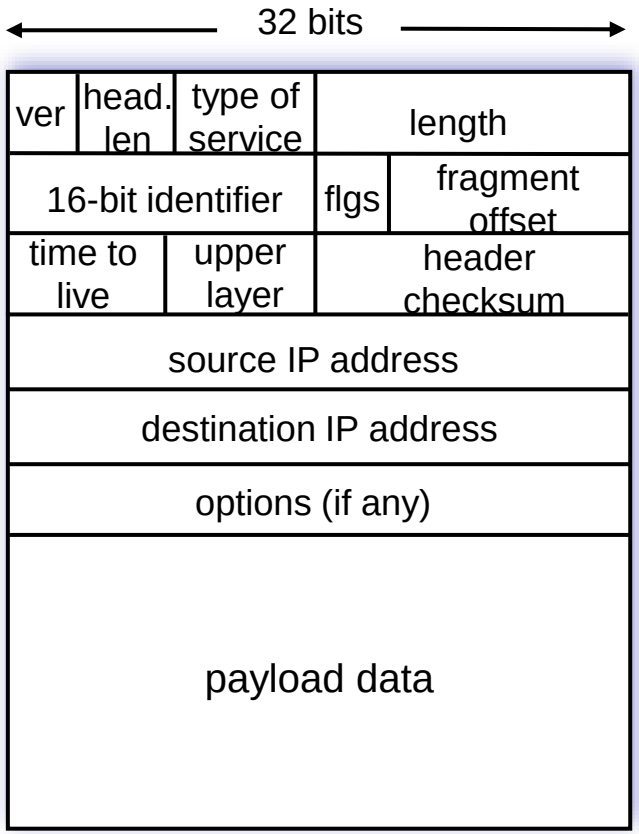
Subnets



- School network is 200.100.0.0/20
- Lab A has network 200.100.1.0/24
- Lab B has network 200.100.2.0/24
- Lab C has network 200.100.2.240/28
- How many computers each subnet may contain?

IP Header

- Header length may change
  - Not good for speedy processing
- IP packet length is 16 bit = 64KB
  - Typically 1500 bytes or less
- Upper layer – TCP, UDP, ICMP
- TTL – prevent infinite loops

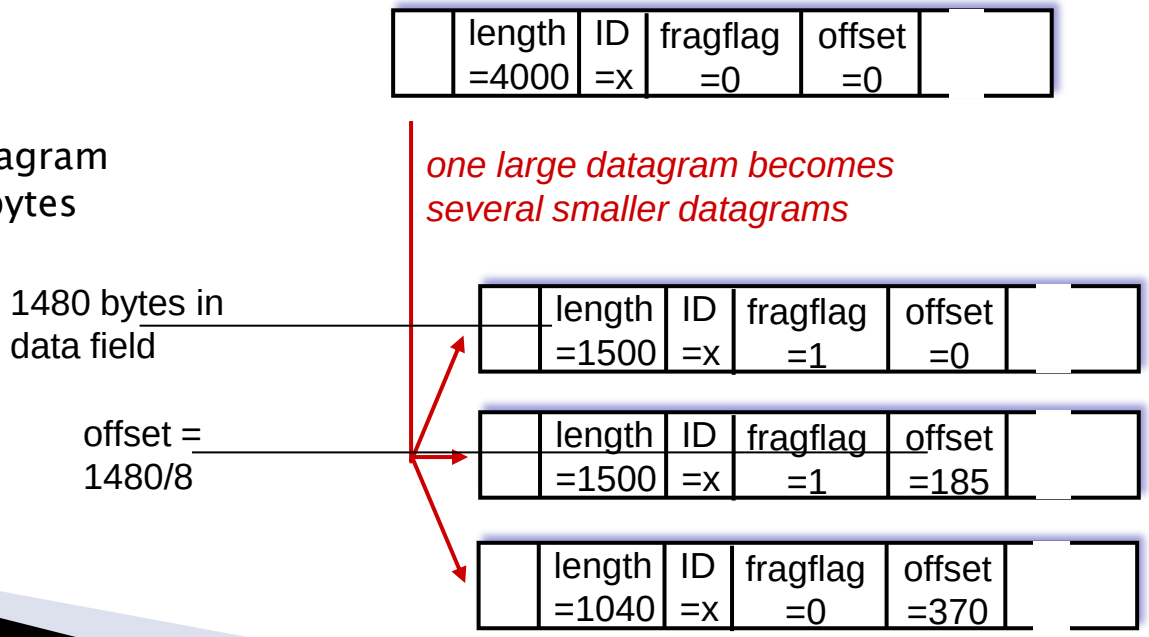


IP Fragmentation

- Data link connection have MTU – Maximum Transmission Unit
- If the IP packet size is bigger, need to fragment
- IP header bits indicates fragmentation and put back in order at destination

example:

- 4000 byte datagram
- MTU = 1500 bytes

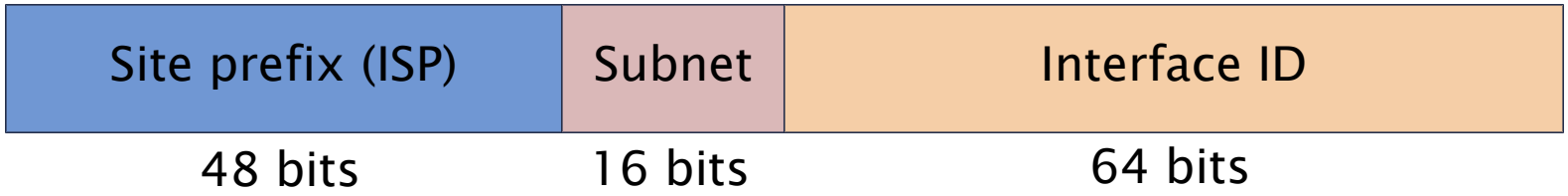


Credit: Kurose

IPv6 Addresses

- 128 bit
- Each nibble (4 bit) is one hex digit
- Each 4 nibbles separated with “:”
- Example:
  - 2a0d:6fc2:131c:0000:0000:b653:34de:624b
- Zeroes are omitted, using “::”
  - 2a0d:6fc2:131c:: b653:34de:624b
  - “::” may be used only once

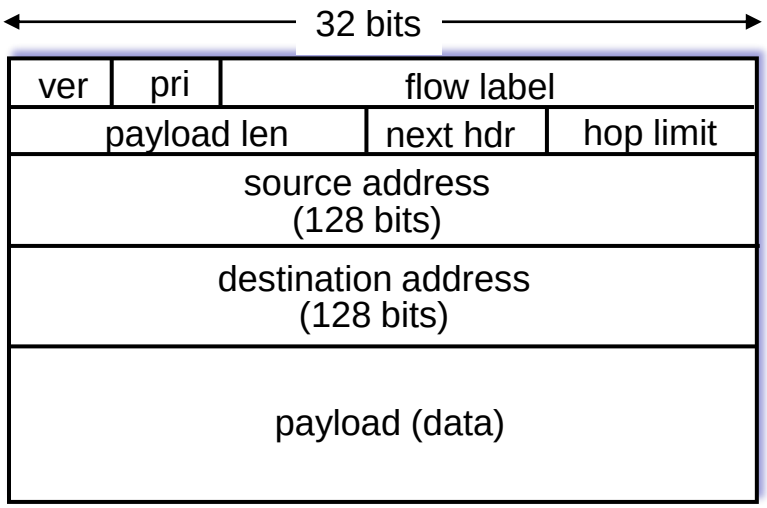
IPv6 Addresses



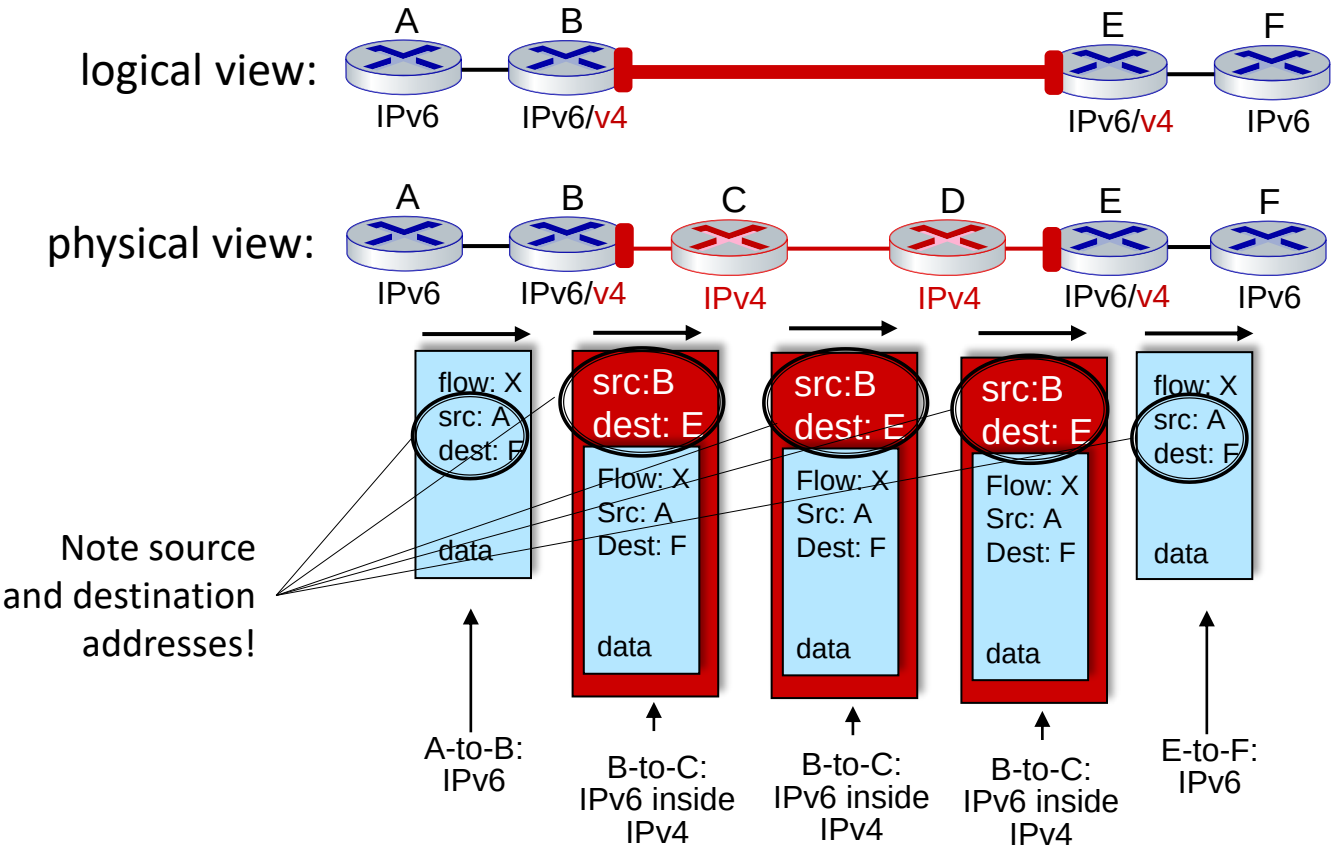
- Global – can route through internet
  - 2000::/3 – starts with 001
- Unique local – can route in organization network
  - FC00::/7 – starts with 1111 110
- Link local – can not route, used only in LAN
  - FE80::/10 – starts with 1111 1110 10
- Localhost
  - ::1/128 – 0000 ... 0001
- Sender shall always use the IPv6 address with less possible routing

IPv6 Header

- Fixed size
- Flow label – indicate packets belong to the same flow, like file or stream
  - Helps middleboxes make decisions
- Next header – transport layer protocol
- Hop limit – TTL



IPv6 Tunnelling Over IPv4



Credit: Kurose