CS120: Computer Networks

Lecture 12. Other Topics in IP Layer

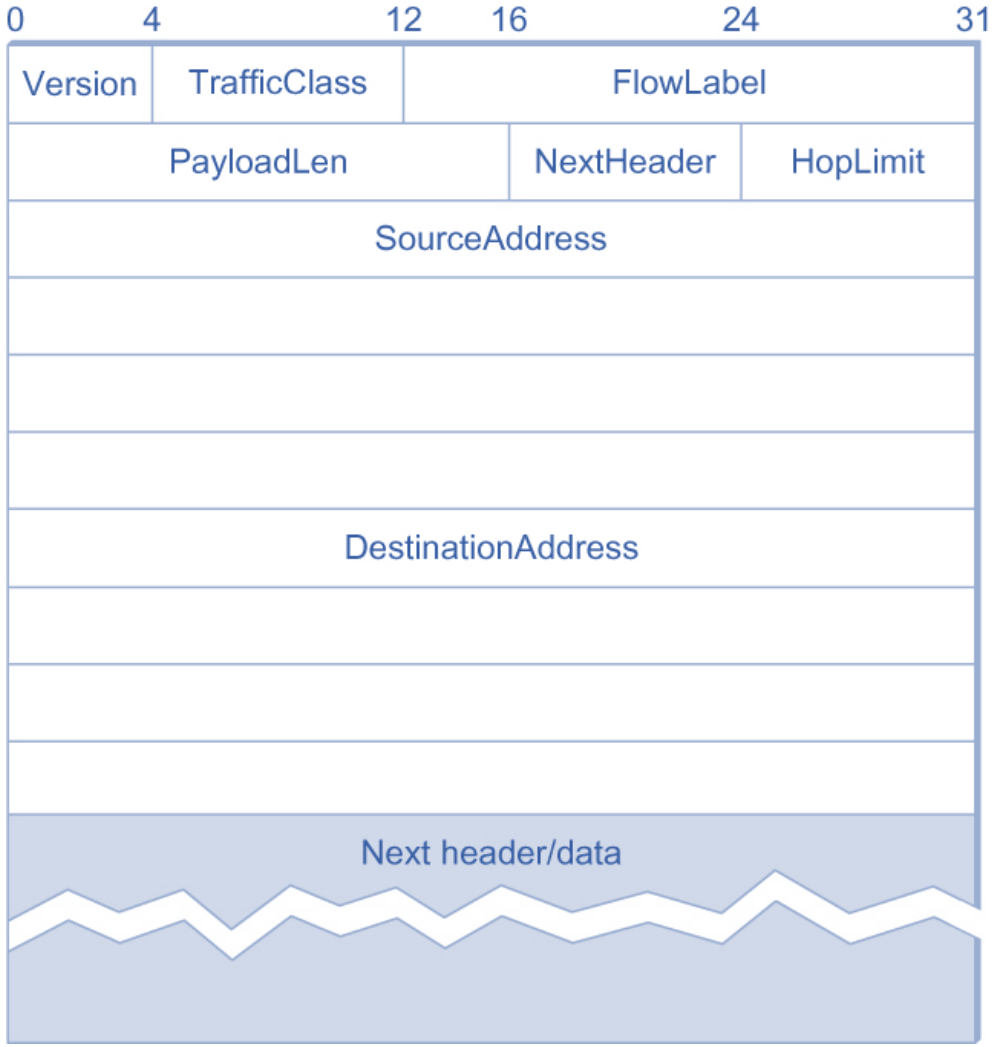
Zhice Yang

Outline

- IPv6
- NAT
- Router Implementation

IP Version 6 (IPv6)

- Motivation
  - 32 bits IPv4 Address is not enough
  - Other Features
    - Stateless auto configuration
    - Source routing
- Launched around 2000
- IPv6 “base” Header
  - 40 bytes “base” header
  - 16 bytes addresses
- Extension headers
  - Fragmentation
  - Source routing
  - etc.



IPv6 Address

- 16 bytes
  - 1500 addresses per square foot (Earth's surface)
- Classless addressing/routing (similar to CIDR)
  - Notation: x:x:x:x:x:x:x:x/y (x = 16-bit hex number, y = netmask)
  - Contiguous 0s are compressed: 47CD::A456:0124
  - IPv4-mapped IPv6 address: ::FFFF:123.45.67.8
- Address assignment

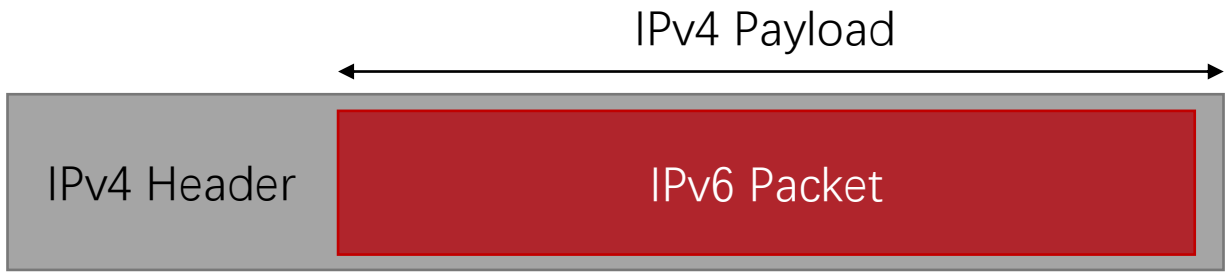
Transition from IPv4 to IPv6

- IETF began looking at the problem of IPv4 address space in 1991
- Not all routers can be upgraded simultaneously

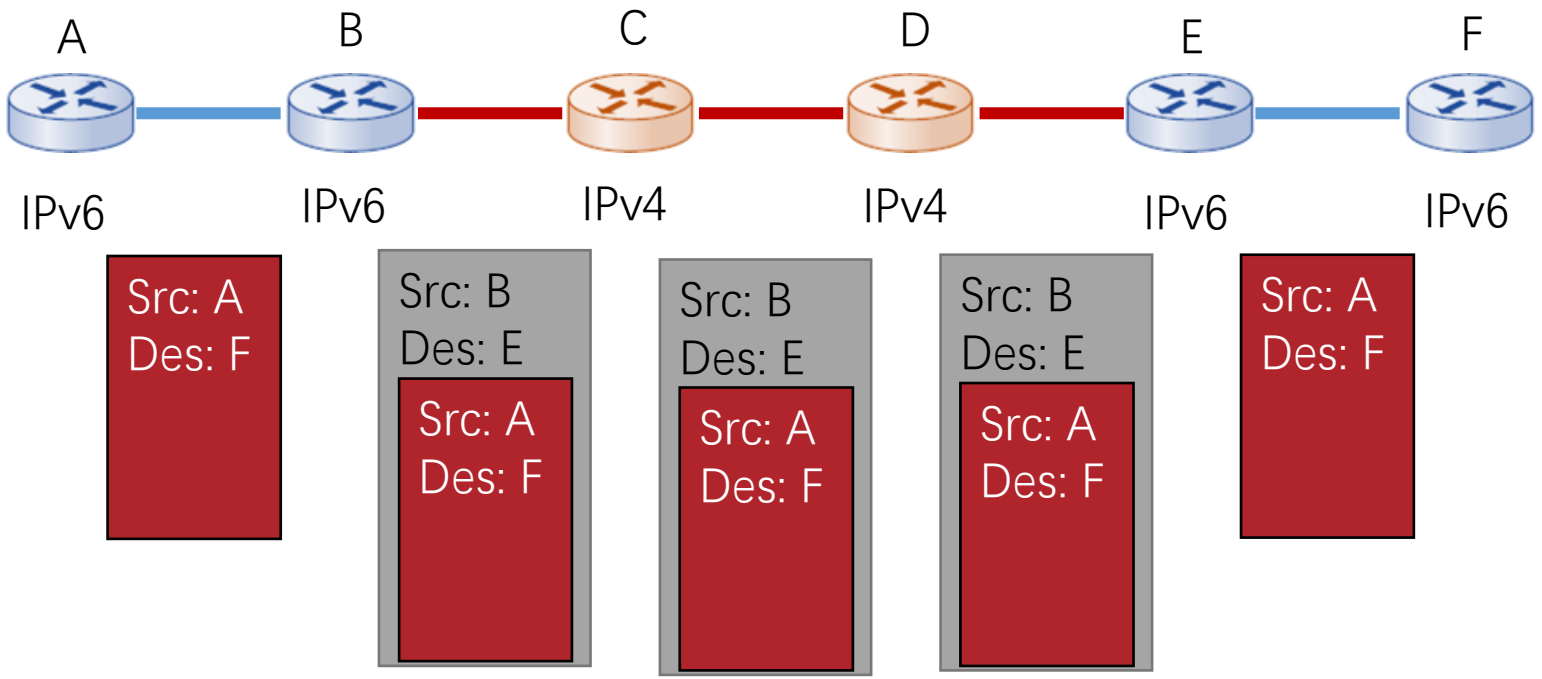
How will network operate with mixed IPv4 and IPv6 routers?

Transition from IPv4 to IPv6

- Tunneling: IPv6 datagram carried as payload in IPv4 datagram among IPv4 routers



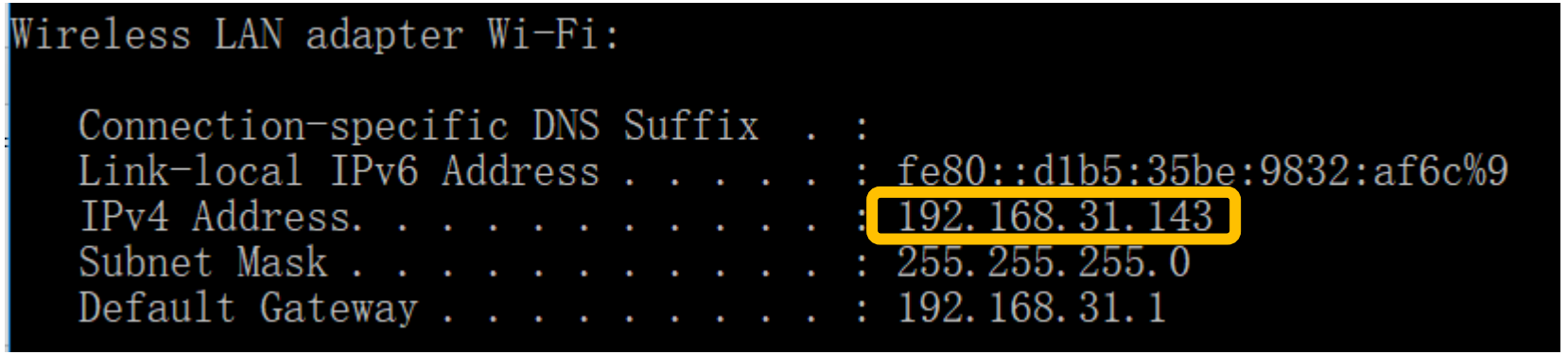
Transition from IPv4 to IPv6



Outline

- IPv6
  - NAT
- Router Implementation

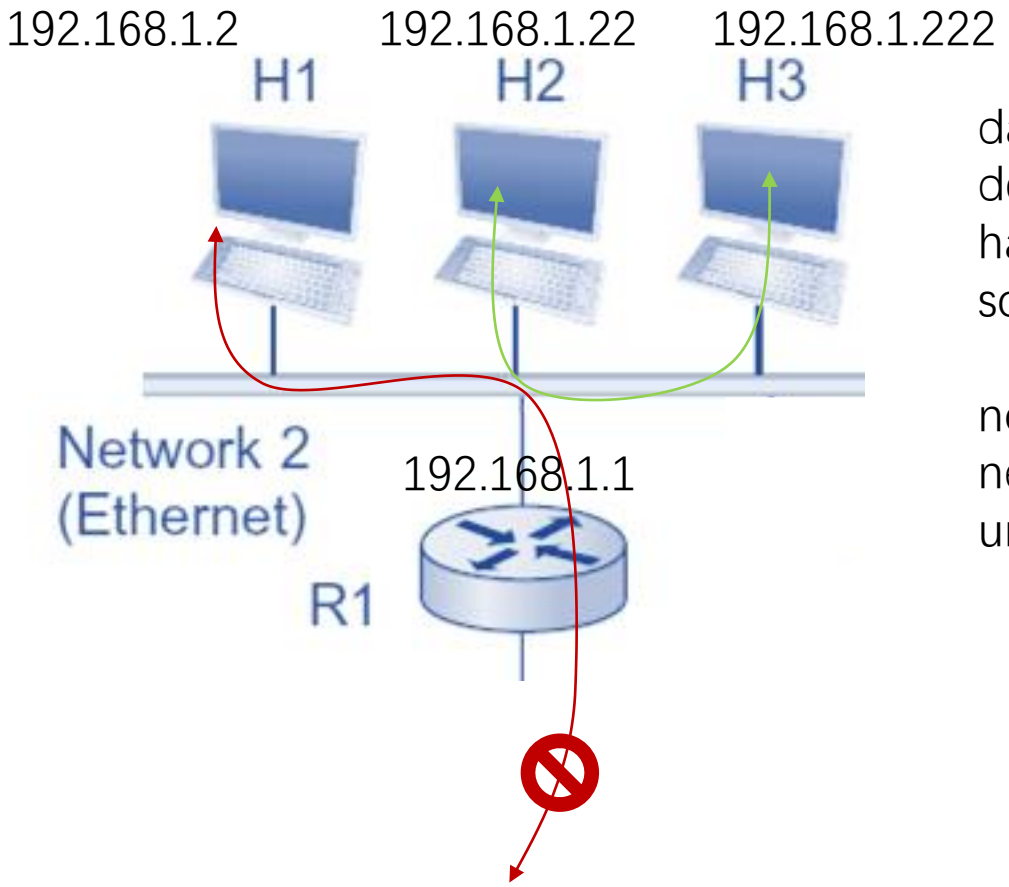
LAN Address



LAN address: not routable on the public network and are used only within a local network.

LAN Addresses	Subnet mask	Provides	Addresses per LAN
10.0.0.0 - 10.255.255.255	255.0.0.0	1 class A LAN	16,777,216
172.16.0.0 - 172.31.255.255	255.255.0.0	16 class B LANs	65,536
192.168.0.0 - 192.168.255.255	255.255.255.0	256 class C LANs	256

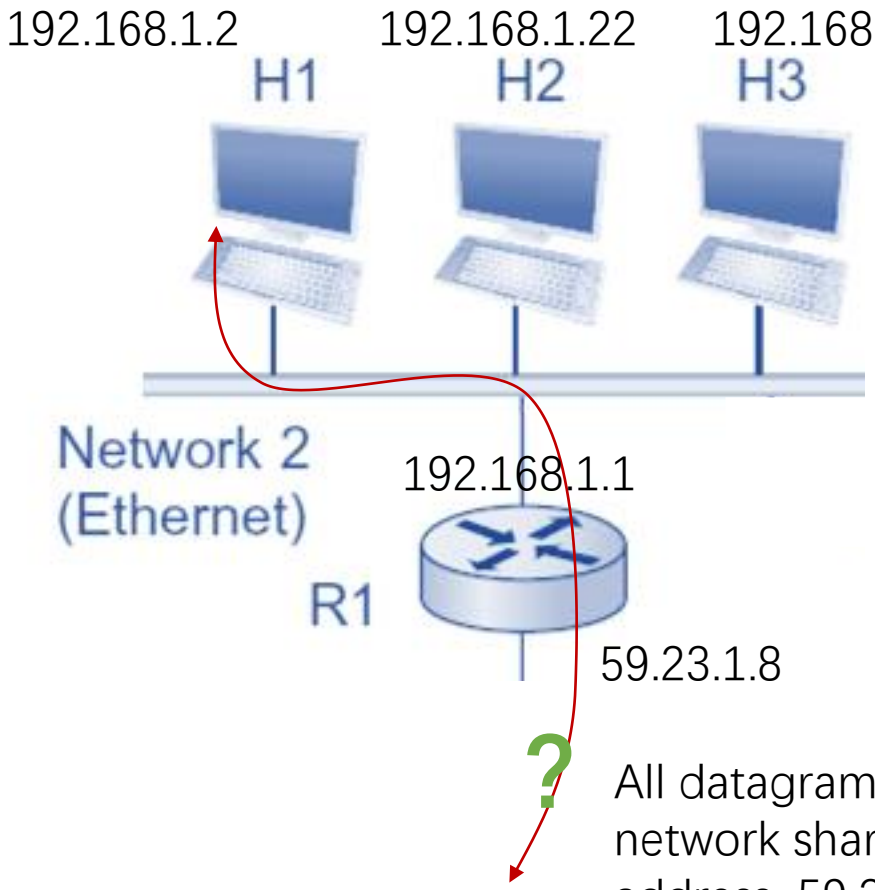
LAN Address



datagrams with source or destination in this network have 192.168.1.0/24 address for source, destination

not routable on the public network (LAN addresses are not unique)

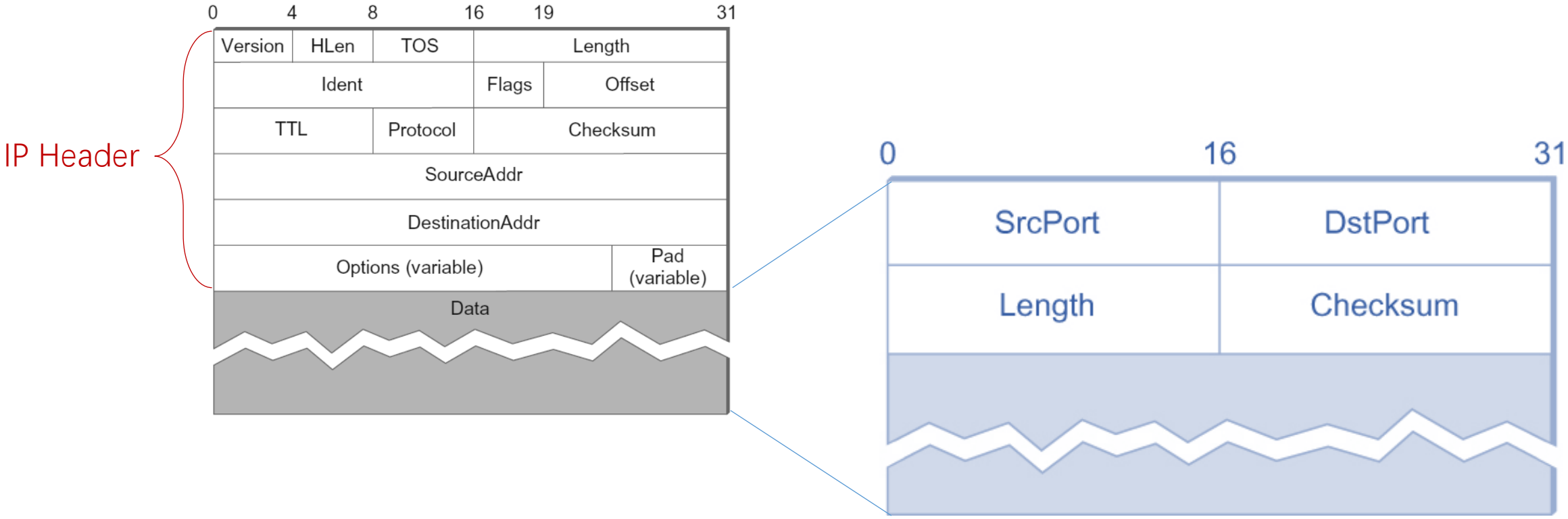
NAT: Network Address Translation



datagrams with source or destination in this network have 192.168.1.0/24 address for source, destination

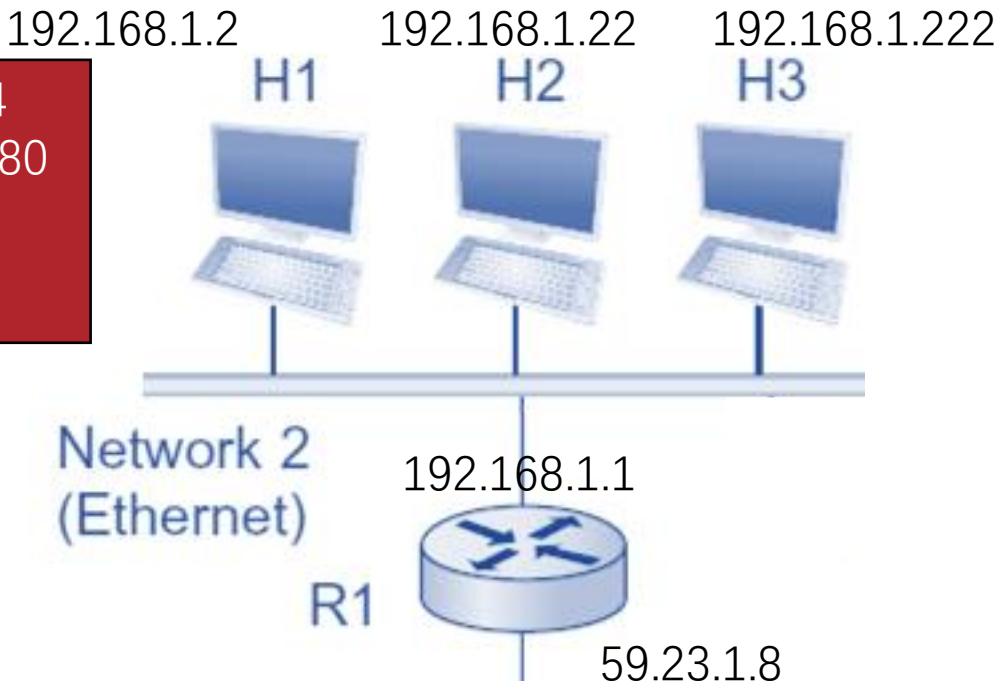
All datagrams leaving the local network share the same source IP address: 59.23.1.8 of the gateway router ?

The Port Field



NAT: Network Address Translation

Src: 192.168.1.2:1234
Des: 220.181.57.216:80



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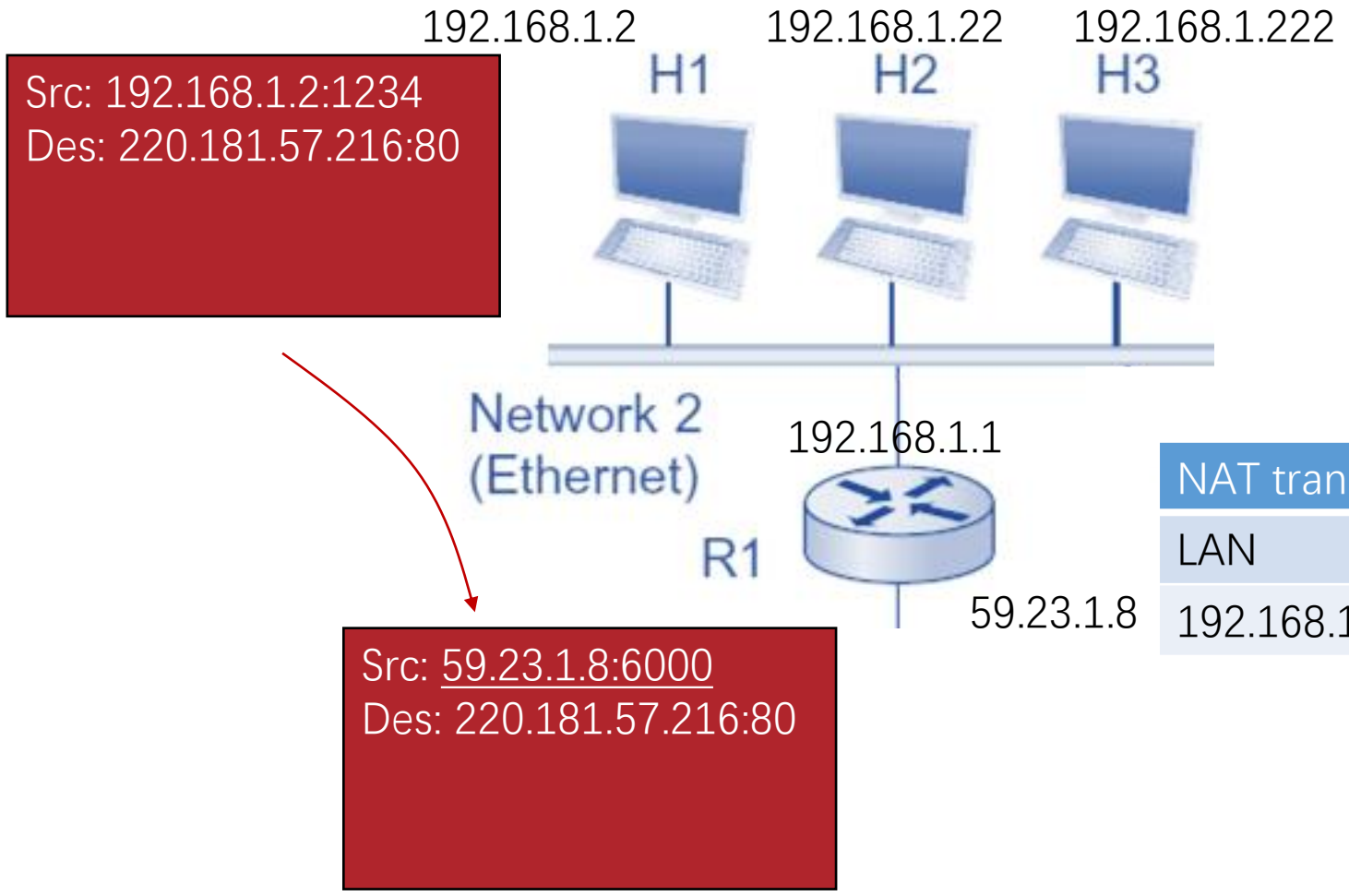
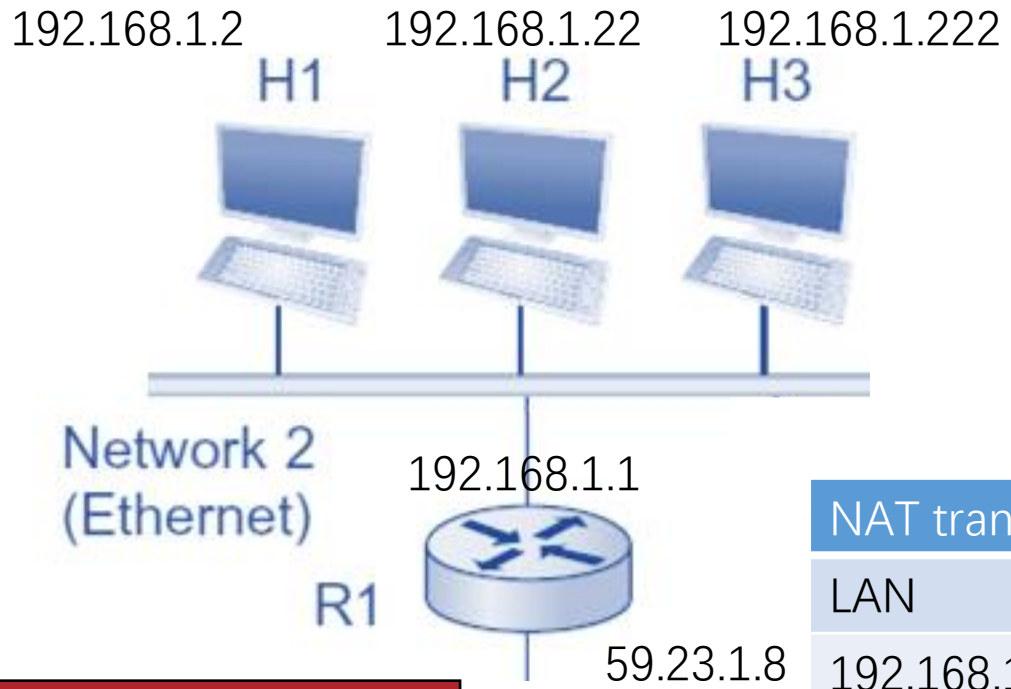


NAT translation table	
LAN	WAN
192.168.1.2:1234	59.23.1.8:6000

NAT: Network Address Translation



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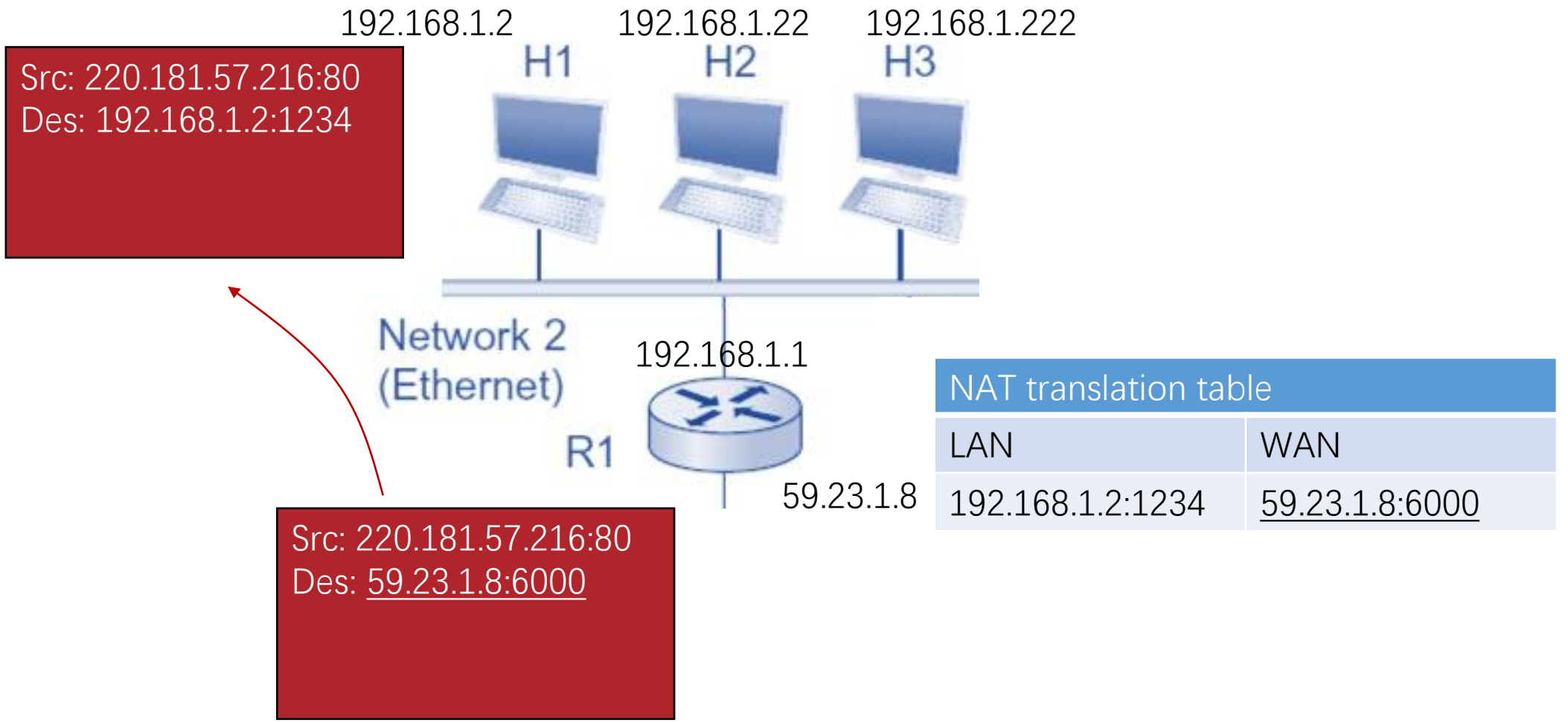
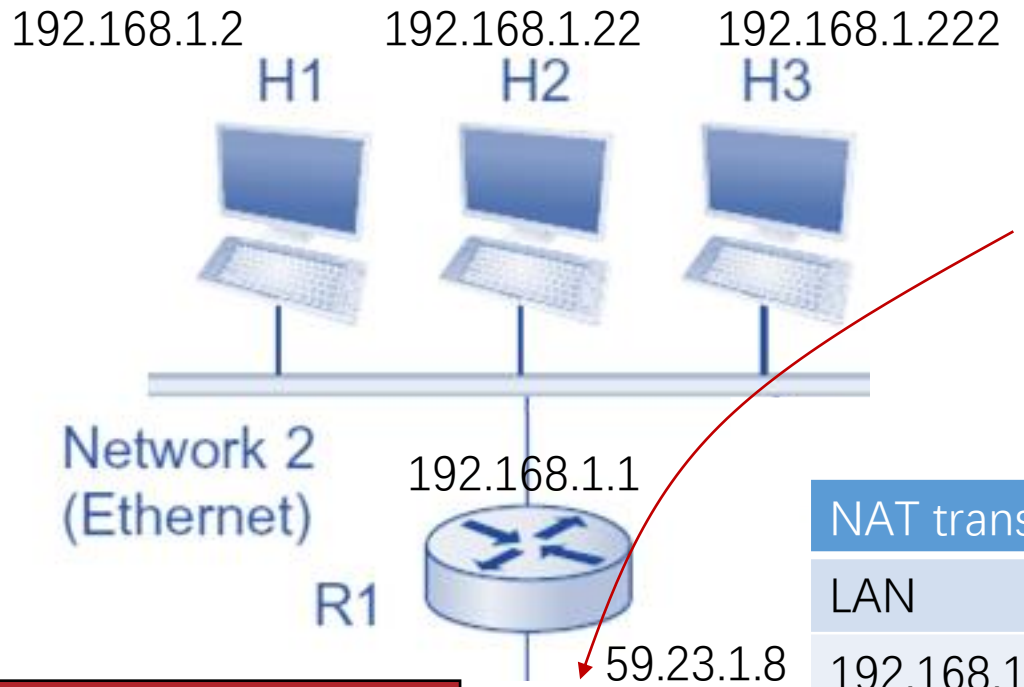


NAT translation table	
LAN	WAN
192.168.1.2:1234	59.23.1.8:6000

NAT: Network Address Translation

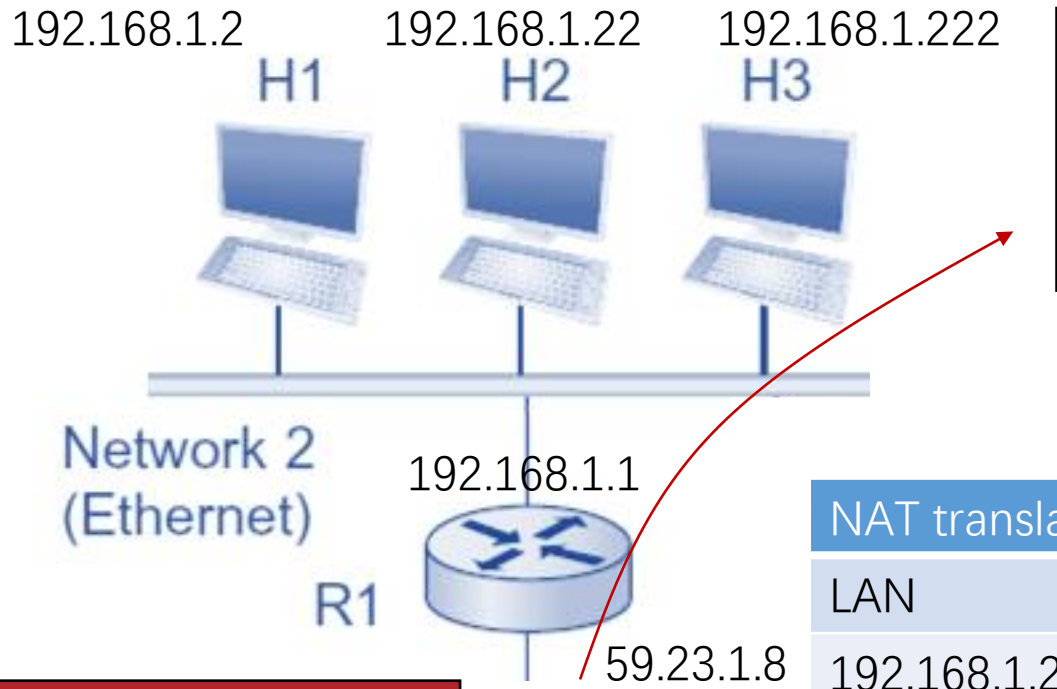


Src: 192.168.1.222:1234
Des: 220.181.57.216:80

Src: 59.23.1.8:5000
Des: 220.181.57.216:80

NAT translation table	
LAN	WAN
192.168.1.2:1234	59.23.1.8:6000
192.168.1.222:1234	59.23.1.8:5000

NAT: Network Address Translation



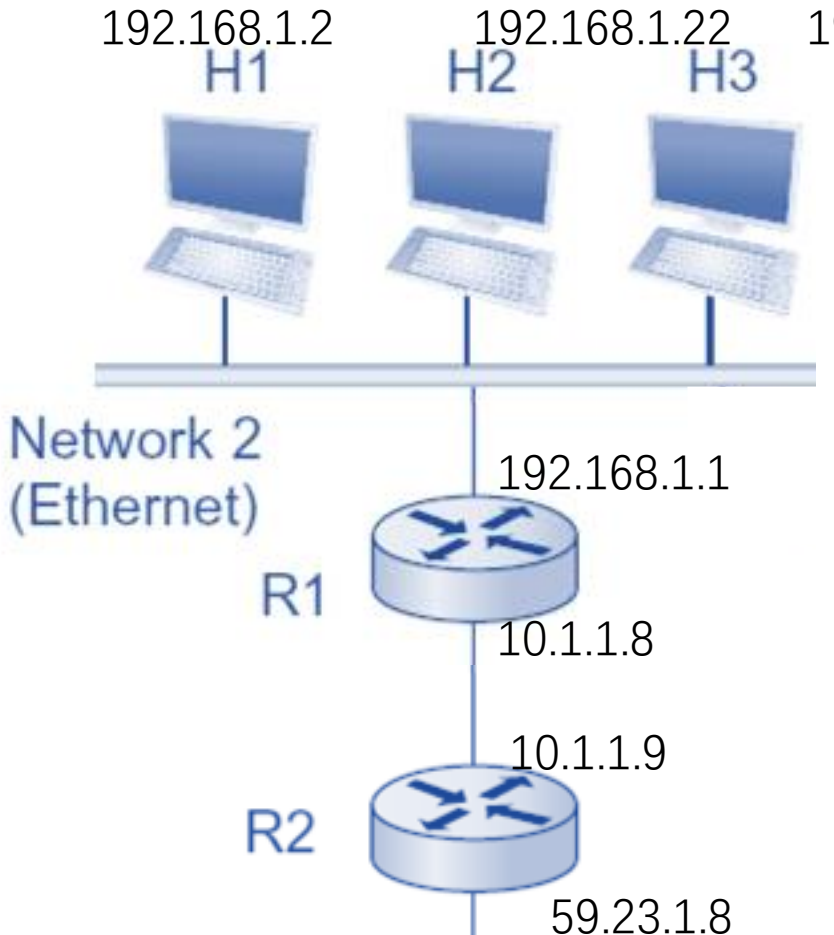
Src: 192.168.1.222:1234
Des: 220.181.57.216:80

Src: 220.181.57.216:80
Des: 59.23.1.8:5000

NAT translation table	
LAN	WAN
192.168.1.2:1234	59.23.1.8:6000
192.168.1.222:1234	59.23.1.8:5000

NAT: Network Address Translation

- Multi-Layer NAT



NAT translation table R1	
LAN	WAN
192.168.1.2:1234	10.1.1.8:6321

NAT translation table R2	
LAN	WAN
10.1.1.8:6321	59.23.1.8:6000

NAT: Network Address Translation

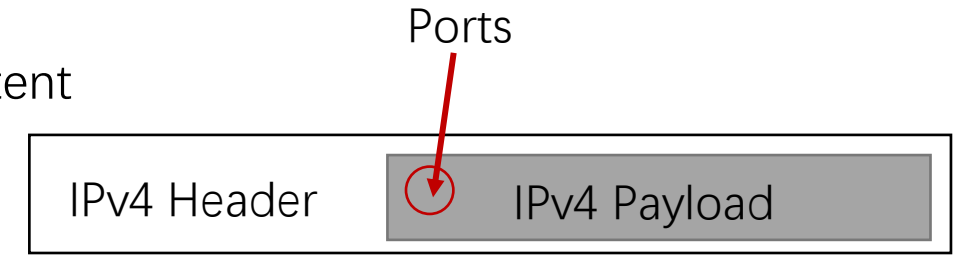
- Demo

```
Tracing route to baidu.com [111.13.101.208]
over a maximum of 30 hops:

  1     5 ms     2 ms    <1 ms  XiaoQiang [192.168.31.1]
  2     2 ms     2 ms     3 ms  10.19.14.1
  3    11 ms     1 ms     2 ms  10.13.7.25
  4     *        *        *     Request timed out.
```

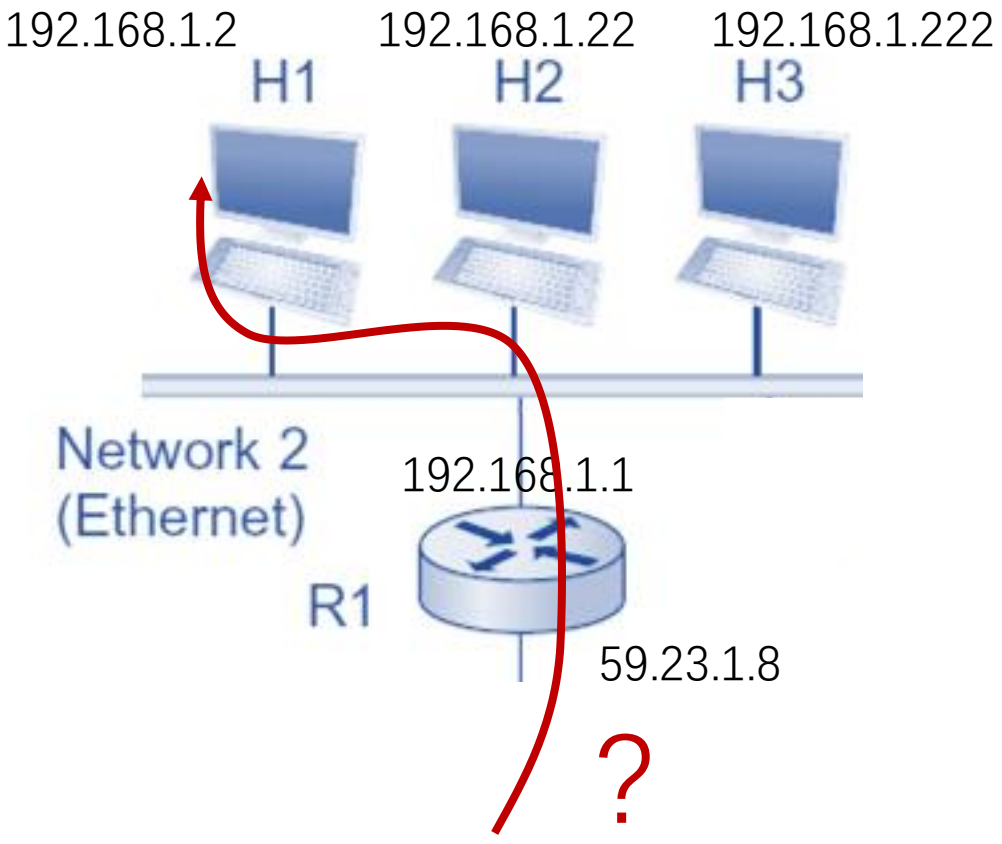
NAT: Network Address Translation

- 16-bit port-number field (covered in later lectures)
  - ~60,000 simultaneous connections with a single IPv4 address
  - Hosts can uses LAN addresses to communicate with the public network
    - 192.168.0.0/16
    - 10.0.0.0/8
    - 172.16.0.0/12
    - etc.
- Criticisms
  - NAT is “impure”
    - Routers should not touch higher layers content
  - Efficiency
  - Traversal Connections



NAT Traversal Problem

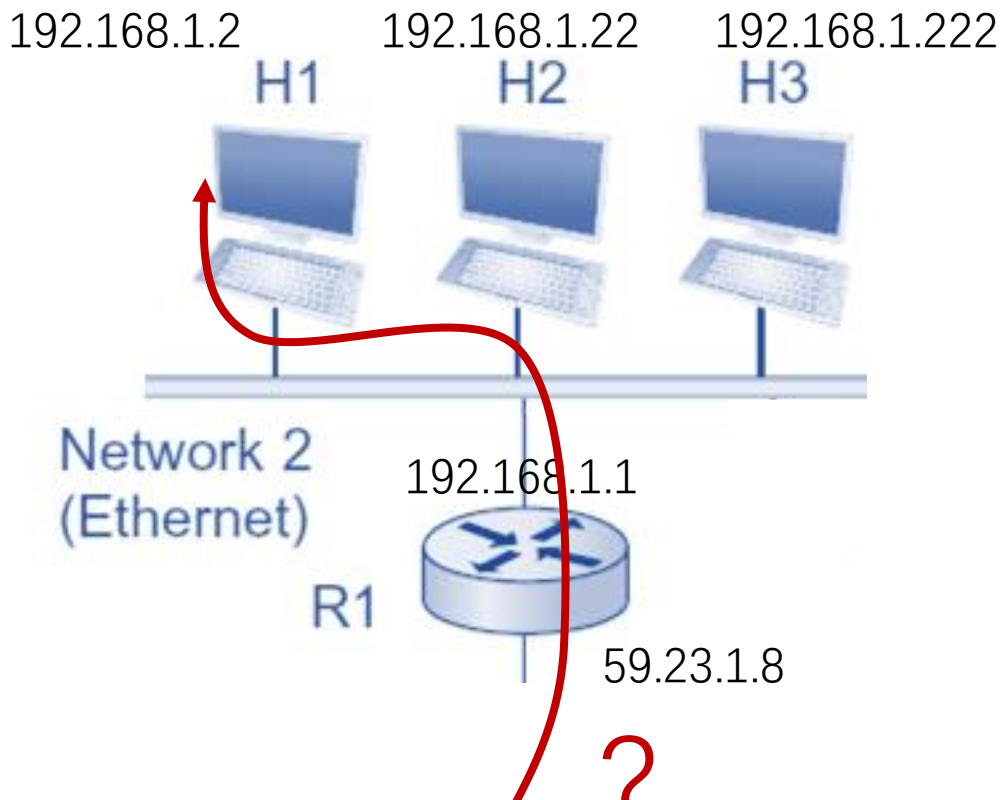
- How to initiate connections to Host 1 from the external network?
  - e.g., VoIP (Voice Call)



NAT Traversal Problem

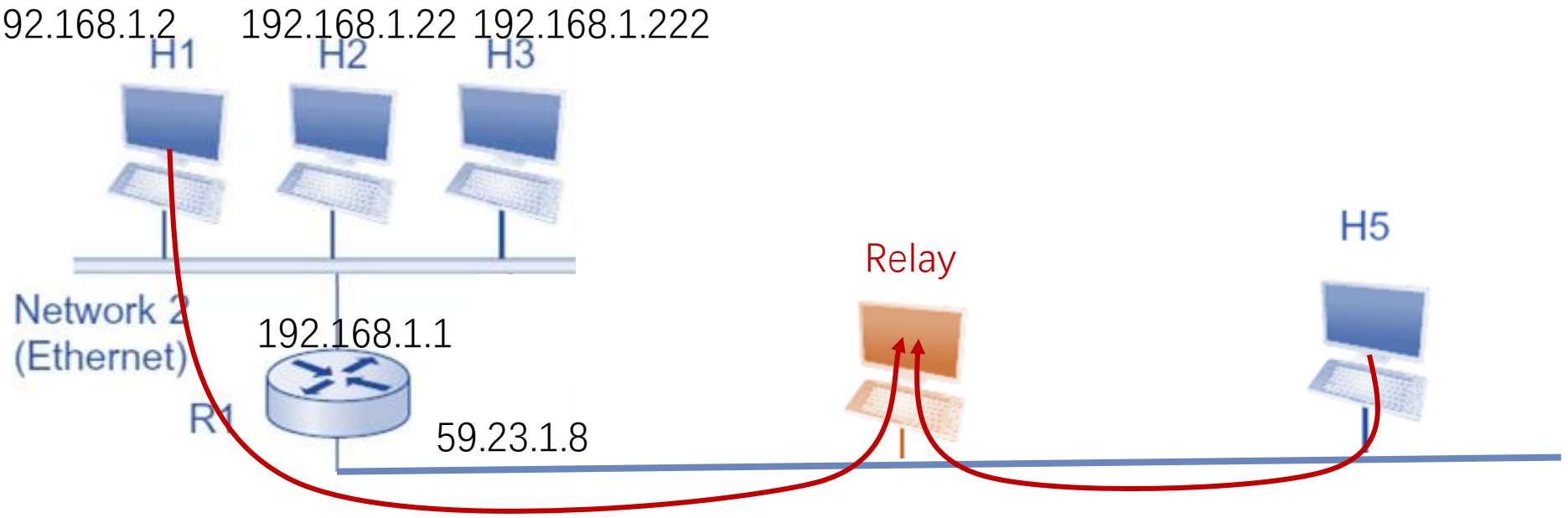
- Solution 1: Static Configure
  - Configure NAT to forward incoming connection requests at given port to the host's given port
  - Preshare the port number to the connector

NAT translation table	
LAN	WAN
192.168.1.2:80	59.23.1.8:6000



NAT Traversal Problem

- Solution 2: Relay
  - NATed host keeps connection to a relay host
  - External host connects to the relay
  - Relay bridges packets between two hosts

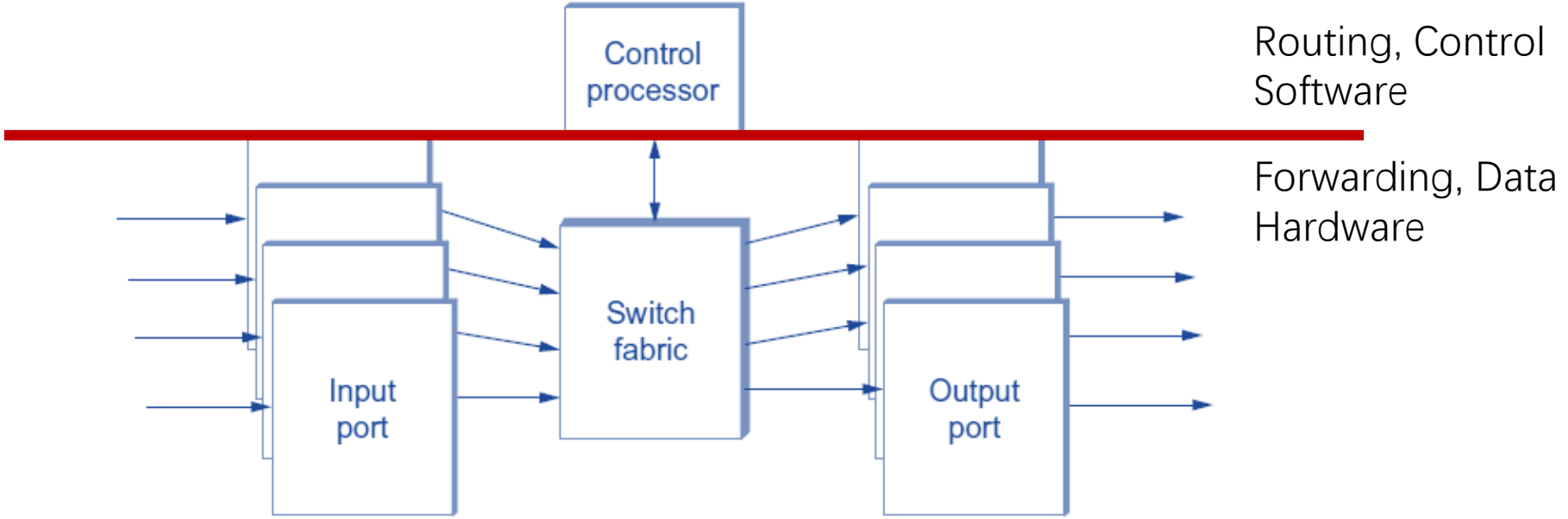


Outline

- IPv6
- NAT
- ➢Router Implementation

Router Architecture

- Two Key Functions:
  - Routing protocols (e.g., RIP, OSPF, BGP, etc.)
  - Forwarding packets from input to output ports
- Performance metrics: packet per second (PPS)



Software

Hardware

Routing Table

SubnetNum	NextHop
197.168.0.0/22	100.11.12.5

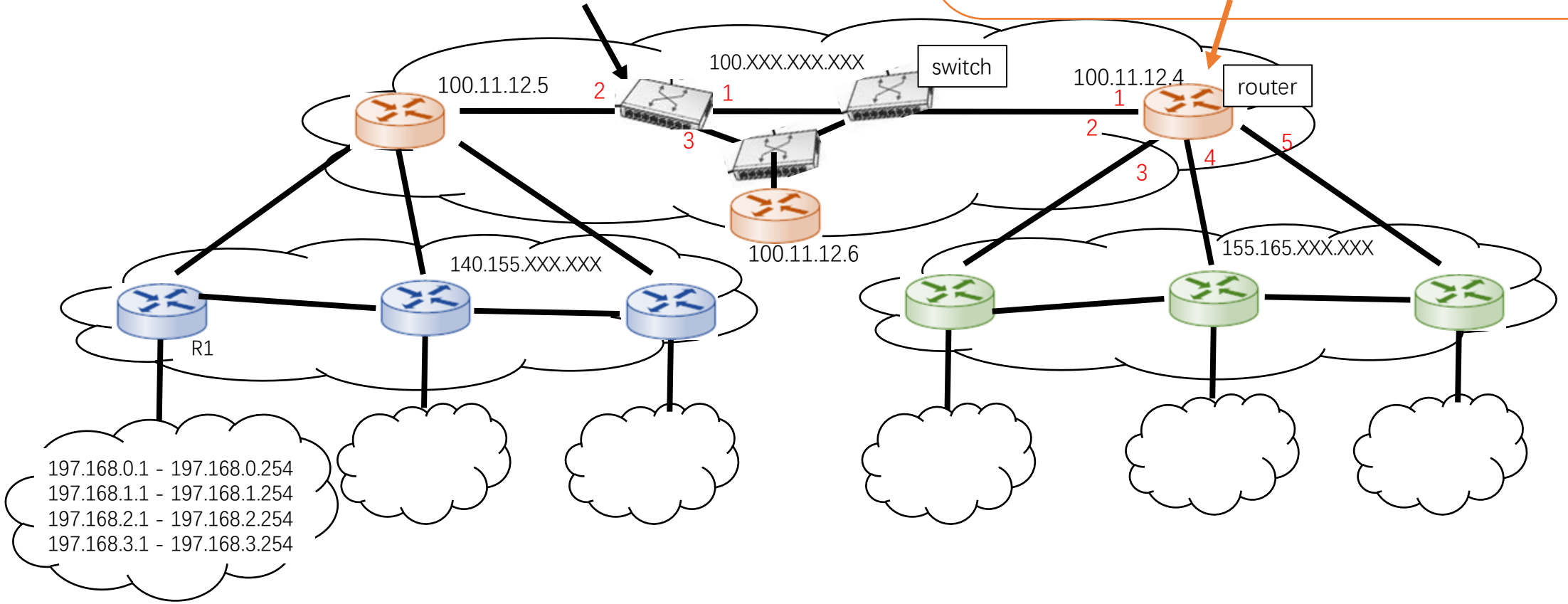
ARP

Forwarding Table

SubnetNum	Interface	Next-Hop MAC
197.168.0.0/22	1	AB.CD.EF.12.34.56

Forwarding Table

Dest MAC	Port
AB.CD.EF.12.34.56	2



Router Architecture

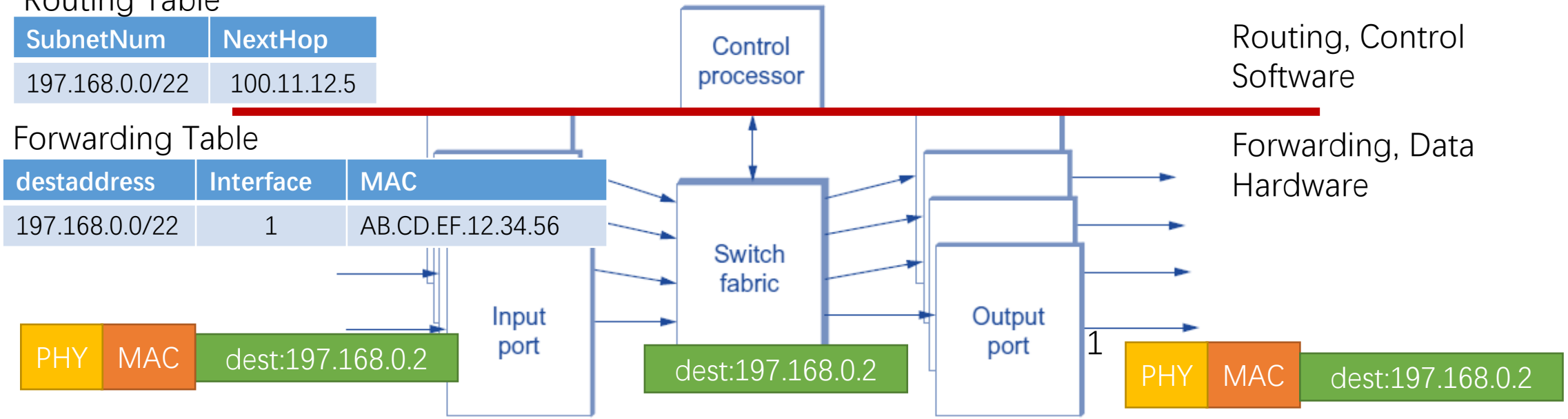
- Two Key Functions:
  - Routing algorithms (e.g, RIP, OSPF, BGP, etc.)
  - Forwarding packets from input to output ports
- Performance metrics: packet per second (PPS)

Routing Table

SubnetNum	NextHop
197.168.0.0/22	100.11.12.5

Forwarding Table

destaddress	Interface	MAC
197.168.0.0/22	1	AB.CD.EF.12.34.56

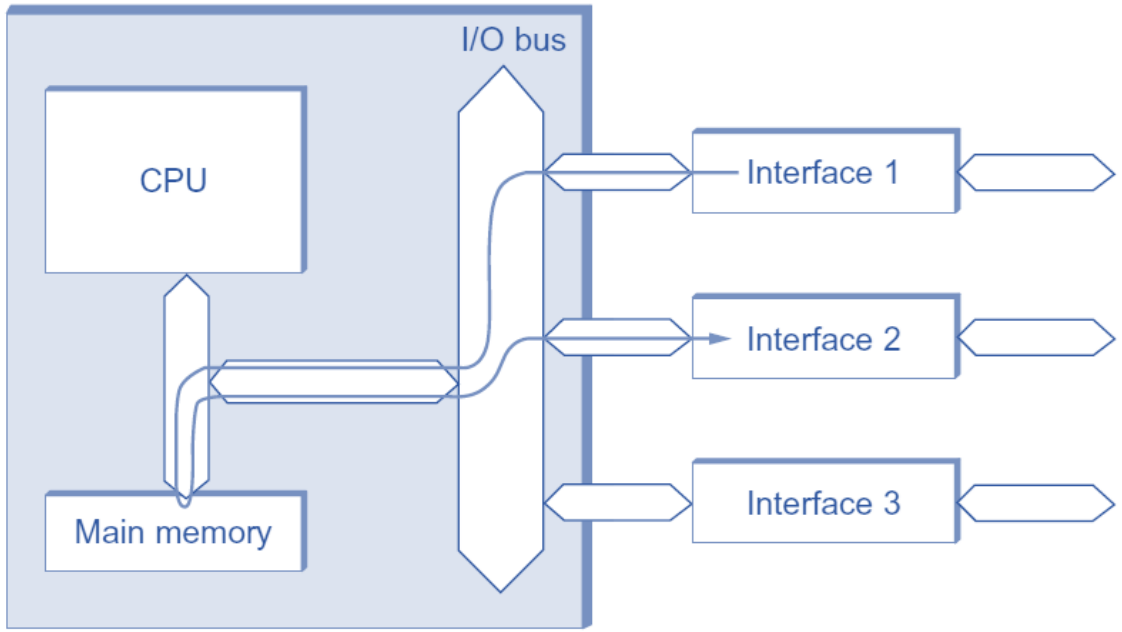


Key Components

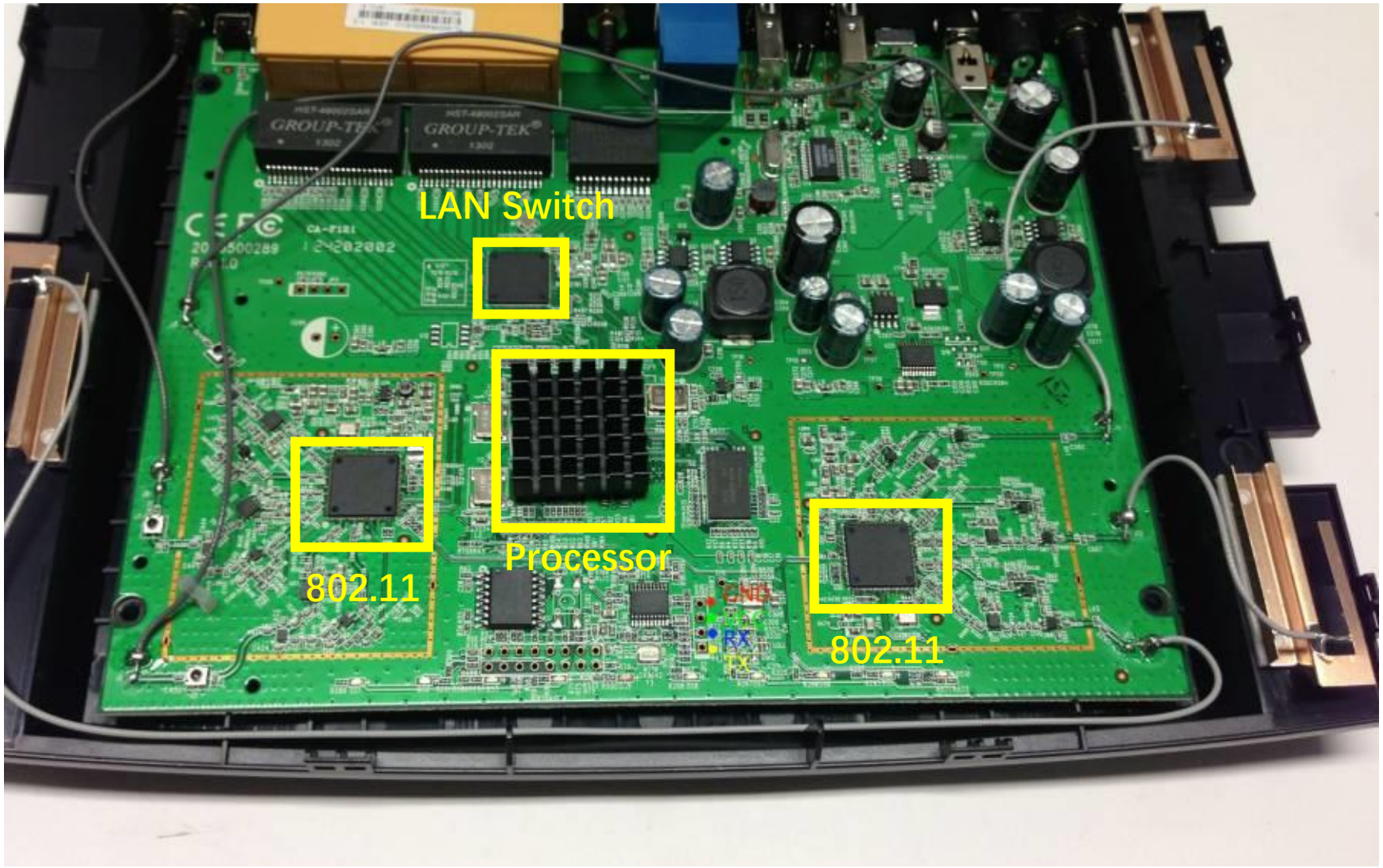
- Control Processor
  - Control and configuration
    - Ports and switch fabrics
  - Calculation
    - Routing Algorithm
    - Push forwarding tables into ports
- Port
  - Handle PHY and MAC Protocols
  - Output Port Looking Up
  - Deliver Packet to Switch Fabric
  - Buffer
- Switching Fabrics
  - Transfer packets from input buffer to appropriate output buffer
  - Types
    - Shared Bus/memory
    - Crossbar
    - Self-routing

Shared Bus/Memory

- Datagram from input port to output port via a shared bus
  - 2 bus crossings per datagram
  - Bus and memory bandwidth determines switch throughput

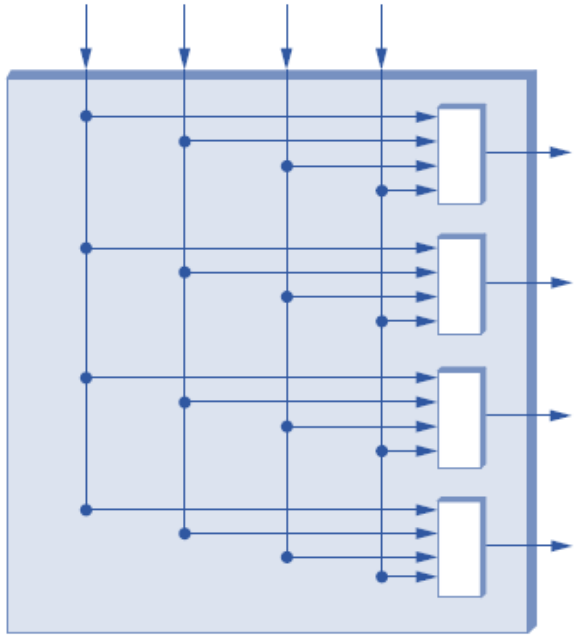


Inside Wireless Routers



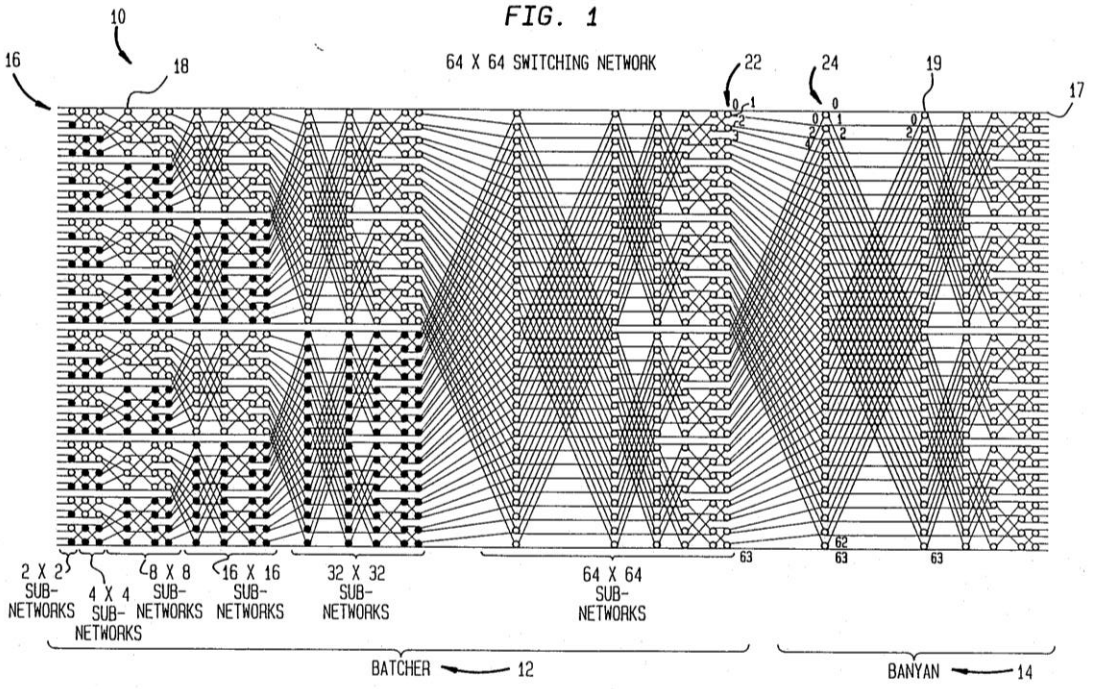
Crossbar

- A crossbar switch is a matrix of pathways that can be configured to connect any input port to any output port
  - number of port-to-port connections => complexity and cost



Self-routing

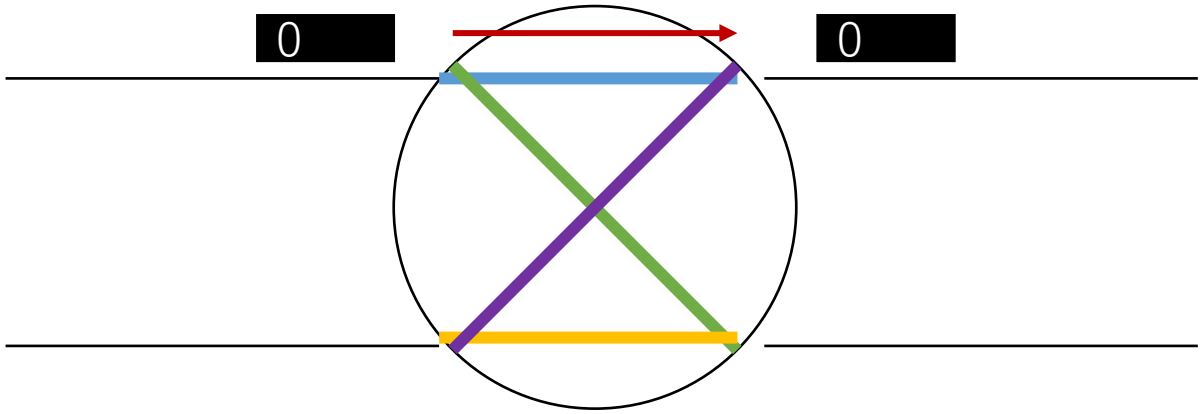
- Insight: increase the number of port-to-port hops but decrease the number of port-to-port connections



U.S. Patent Mar. 20, 1990 Sheet 1 of 28 4,910,730

Self-routing

- Switching Element
  - 0=> up
  - 1=> down



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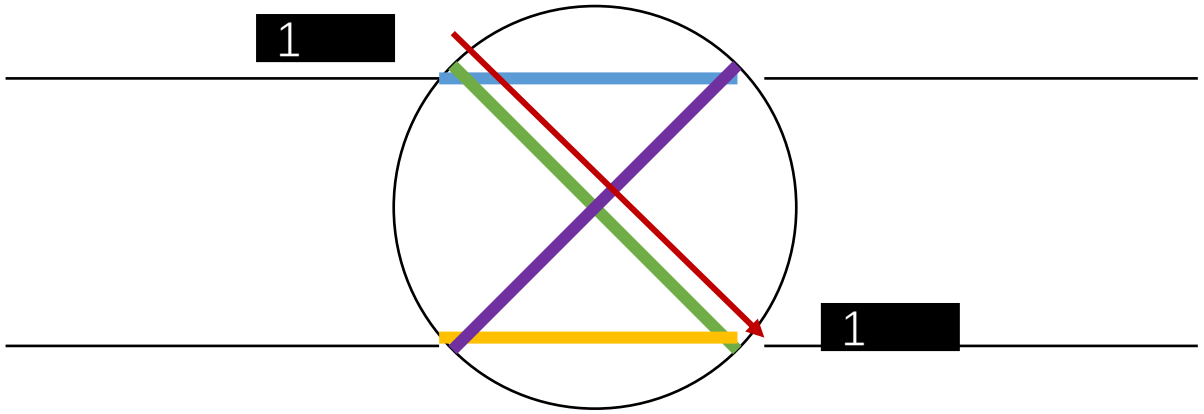

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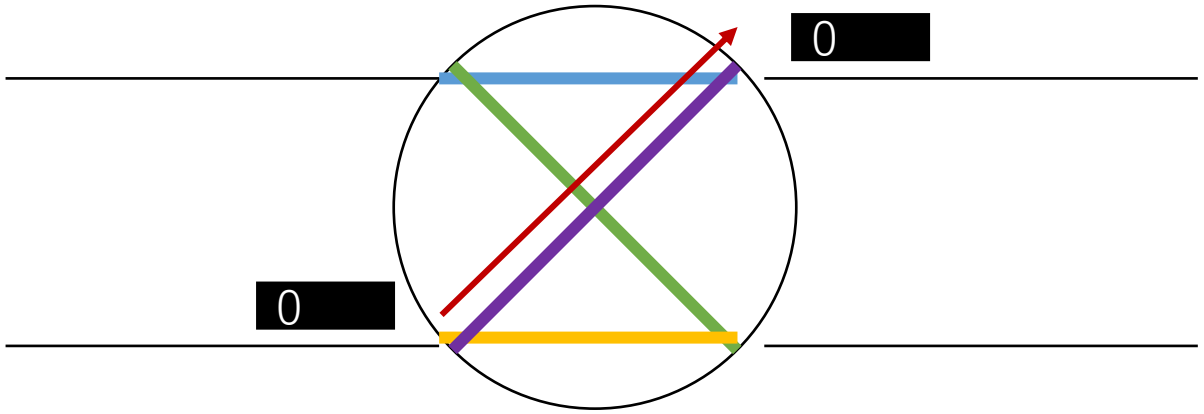

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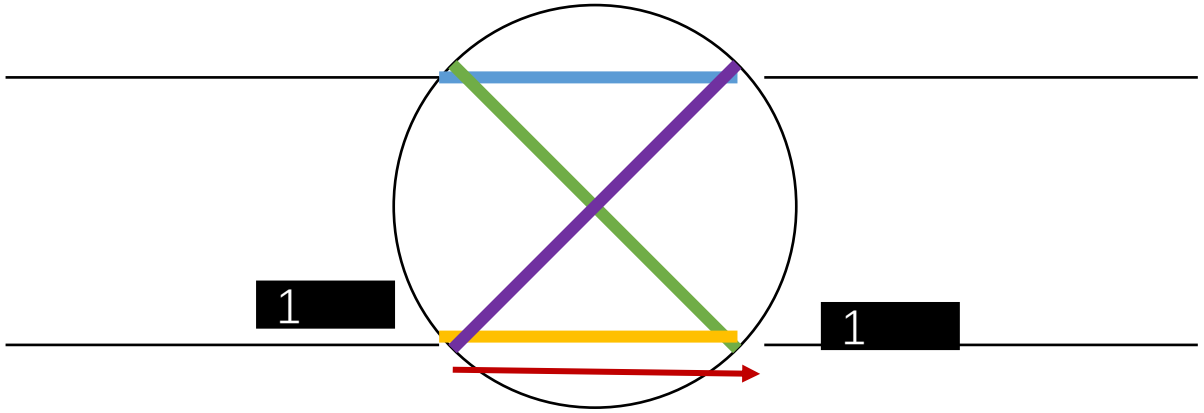
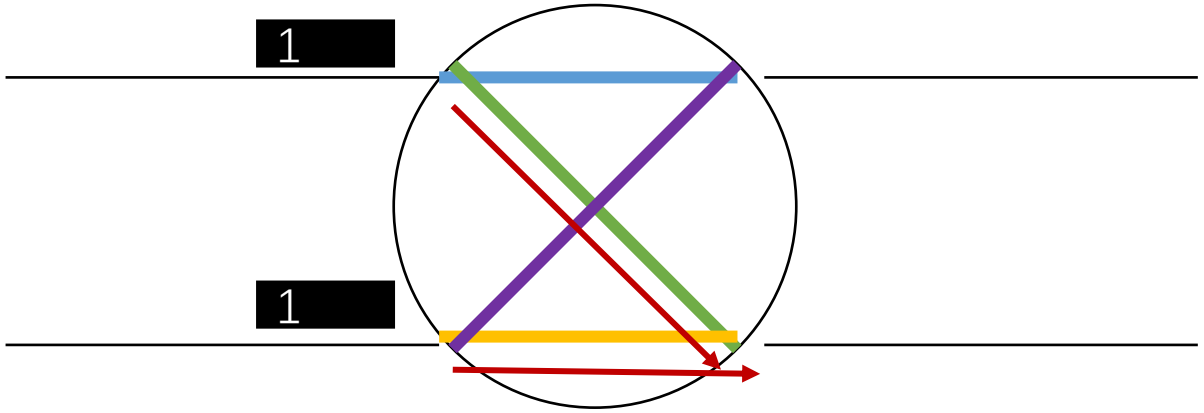


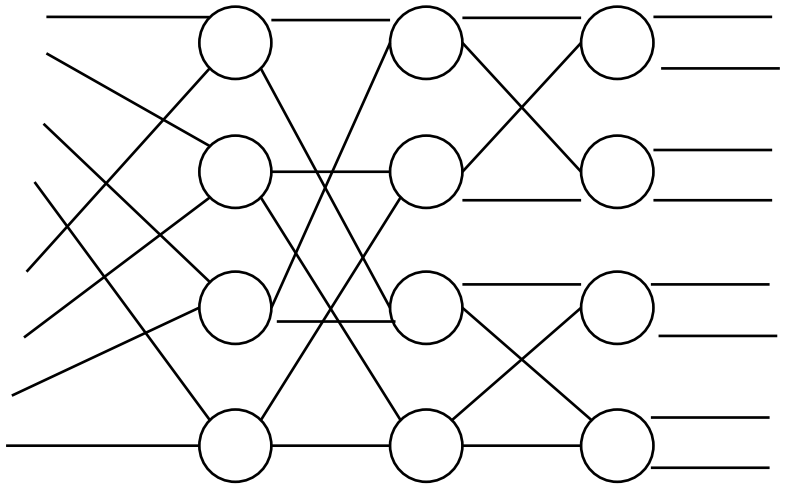
Self-routing

- Switching Element
  - Collision: Two packets with same output ports



Self-routing

- Banyan Network
  - Collision Free
    - Assumption: input Packets are sorted according to routing header



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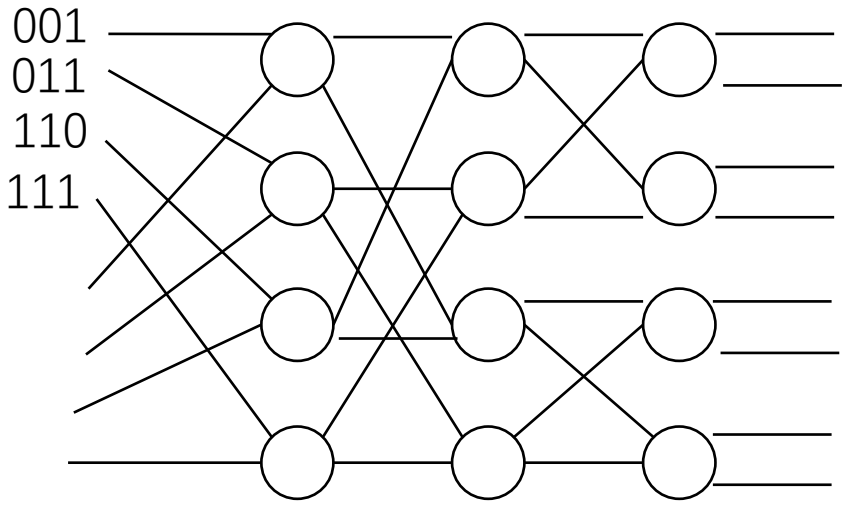

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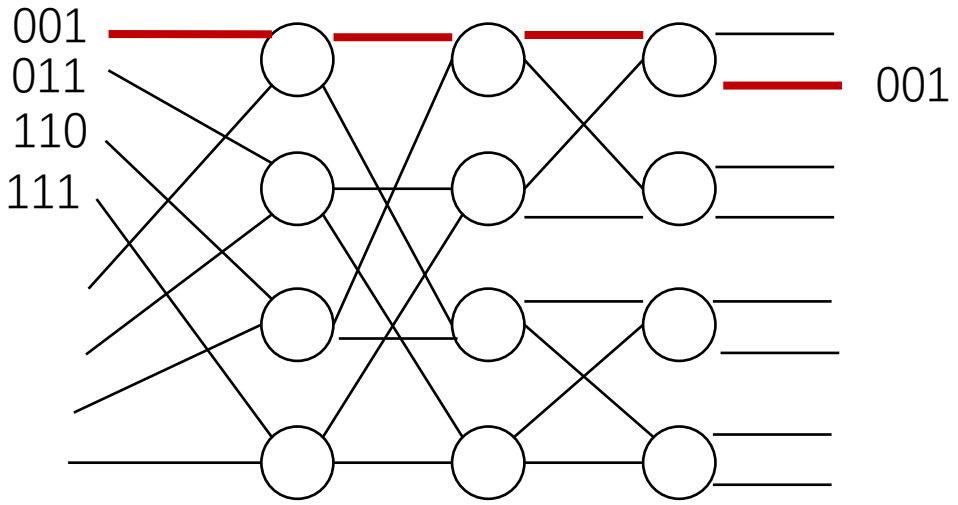

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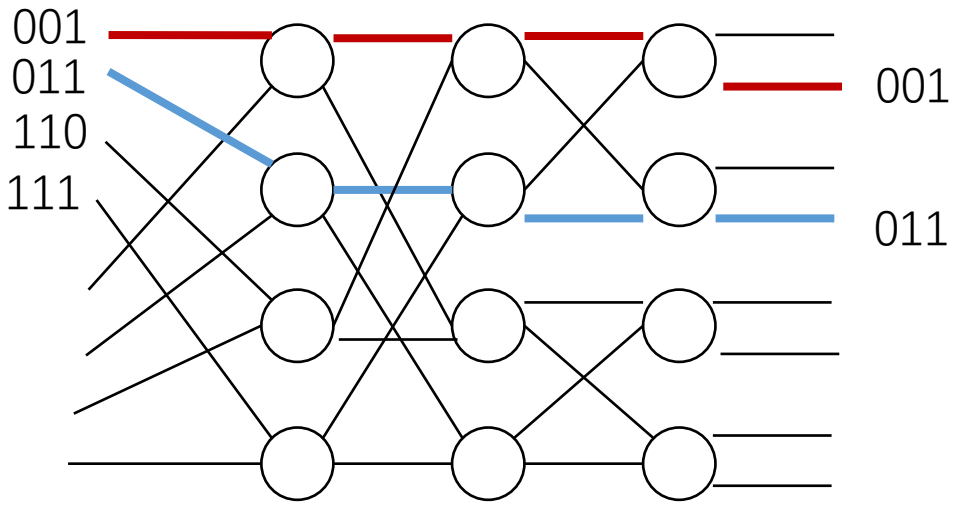

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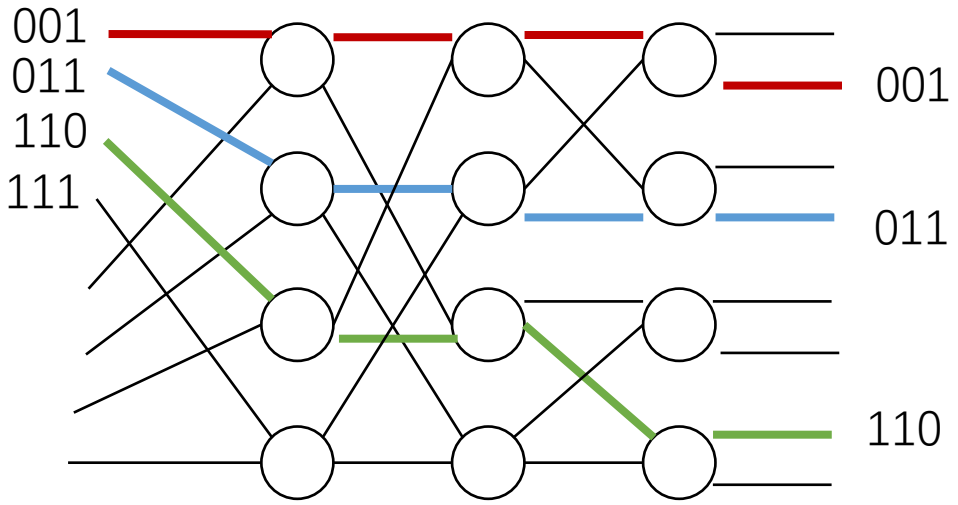

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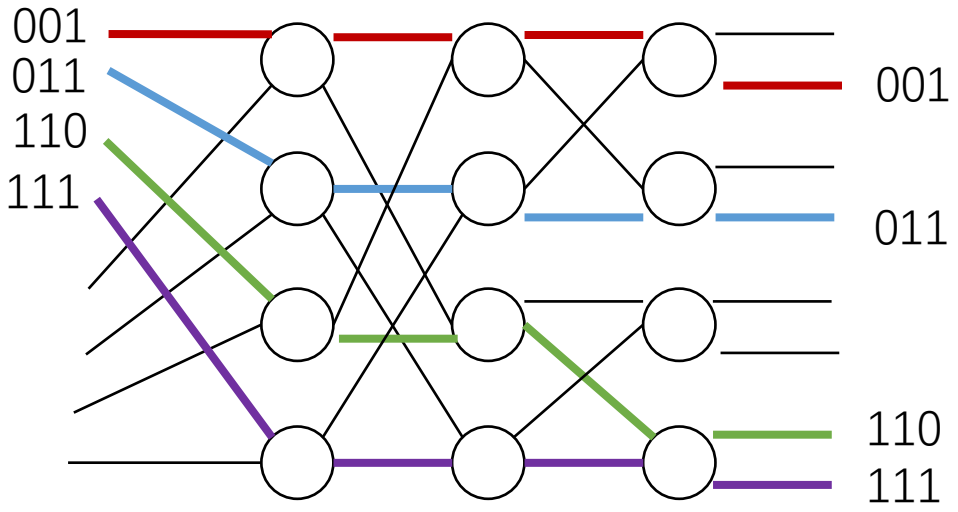

Reference

- Textbook 4.1
- Textbook 4.3
- Textbook 3.4