CS120: Computer Networks

Lecture 13. Other Topics in IP 2

Zhice Yang

Outline

- IPv6
- NAT
- MPLS
- Router Implementation

Longest Prefix Matching

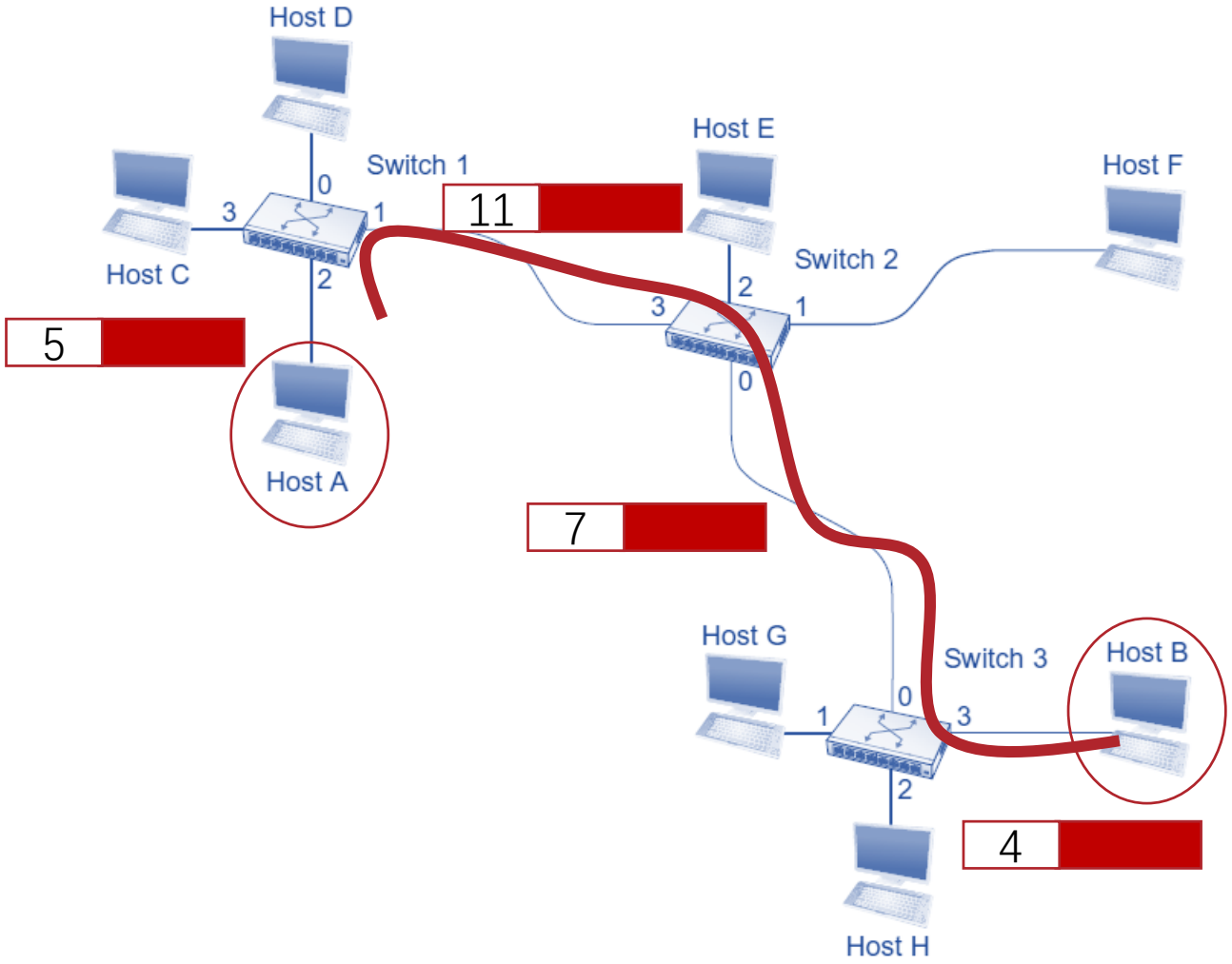
- When looking for forwarding table entry for given destination address, use longest address prefix that matches destination address.

SubnetNum	NextHop	
197.168.0.0/22	R4	11000101.10101000.000000**.********
197.168.3.0/24	R7	11000101.10101000.00000011.********
197.168.4.0/22	R9	11000101.10101000.000001**.********

How to Accelerate Prefix Matching in Backbone Routers ?

11000101.10101000.00000111.11010111 → R9

Virtual Circuit

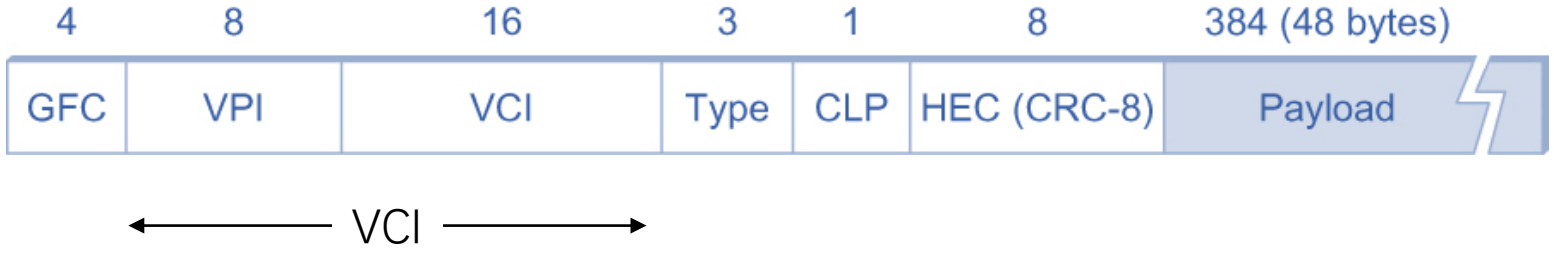


Virtual Circuit Table

Switch1			
Incoming Interface	Incoming VCI	Outgoing Interface	Incoming VCI
2	5	1	11
Switch2			
Incoming Interface	Incoming VCI	Outgoing Interface	Incoming VCI
3	11	0	7
Switch3			
Incoming Interface	Incoming VCI	Outgoing Interface	Incoming VCI
0	7	3	4

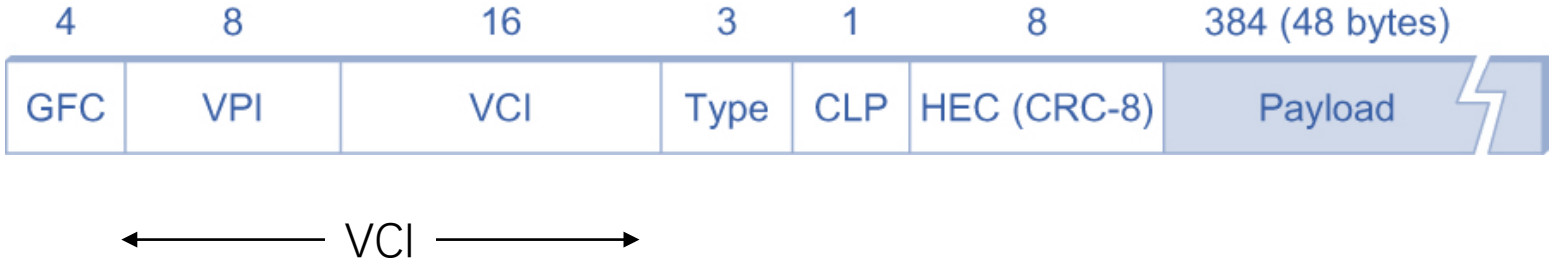
Asynchronous Transfer Mode (ATM)

- Basic properties
  - Connection-oriented packet-switched network
  - Guaranteed Service: strict timing, reliability, etc.
- Packets are called cells
  - Use VPI+VCI as switching label



ATM Switch

- Packet Length is Fixed
  - Easier to switch in hardware
- VCI Length is Fixed
  - VCI looking up complexity is O(1)
  - High throughput

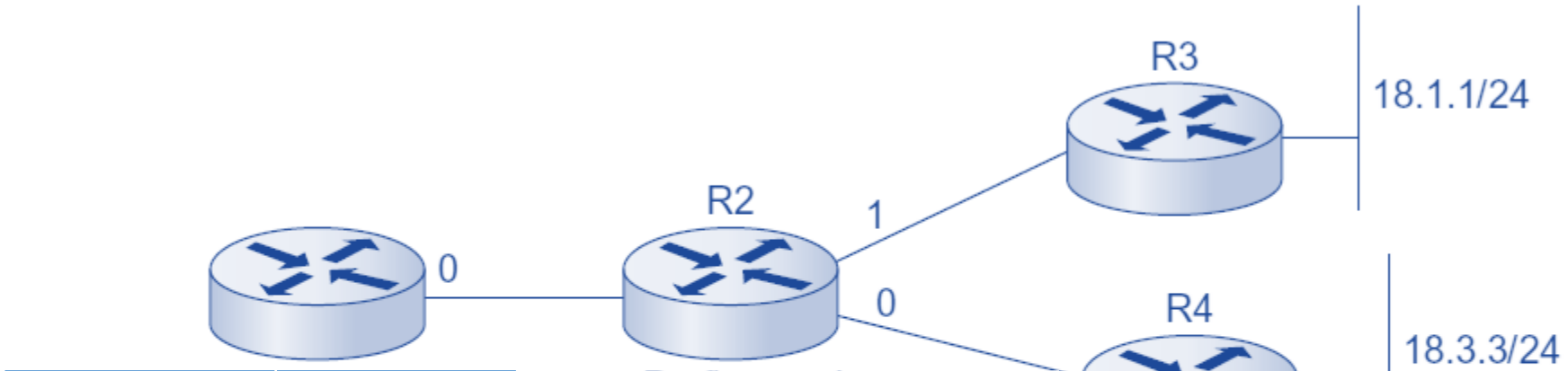


Multiprotocol Label Switching (MPLS)

- Original Motivation
  - Improve IP forwarding throughput
    - Leverage ATM switch for IP forwarding
- Benefit
  - Destination-Based Forwarding
    - Enable IP forwarding on devices that do not have IP forwarding ability (i.e., ATM Switches)
      - Capability (Support IP in ATM)
      - Throughput
  - Traffic Engineering
  - Tunneling
    - VPN

MPLS: Destination-Based Forwarding

- IP Forwarding with Normal Routers

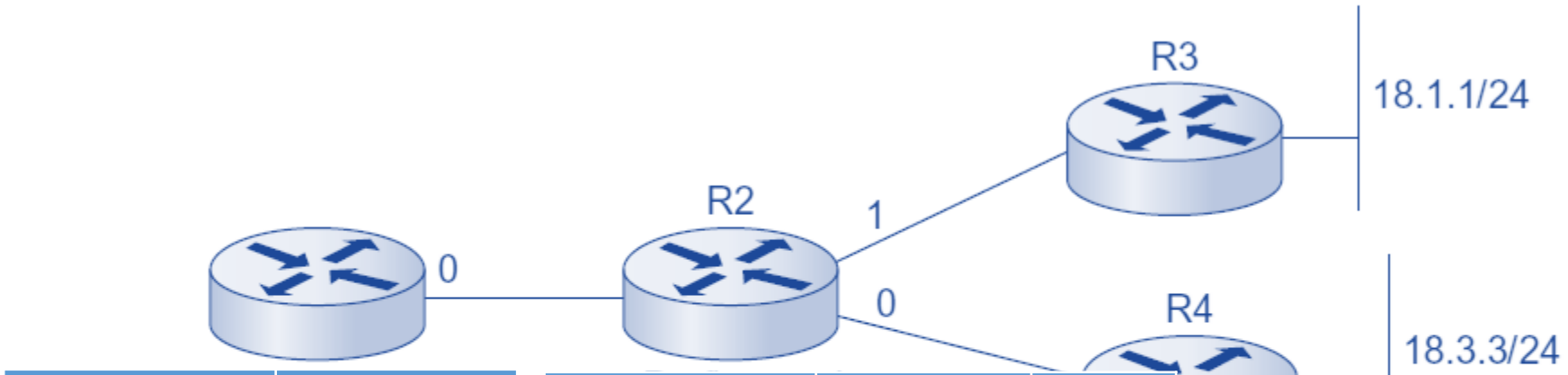


SubnetNum	Interface
18.1.1/24	0
18.3.3/24	0

SubnetNum	Interface
18.1.1/24	1
18.3.3/24	0

MPLS: Destination-Based Forwarding

- IP Forwarding with Labels



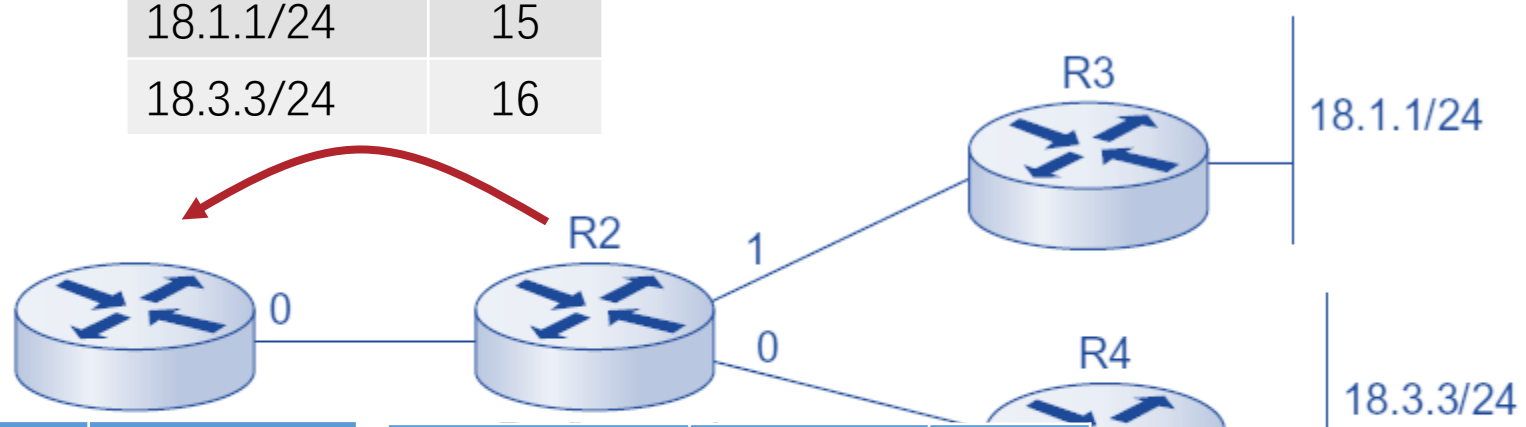
SubnetNum	Interface
18.1.1/24	0
18.3.3/24	0

SubnetNum	Interface	Label
18.1.1/24	1	15
18.3.3/24	0	16

MPLS: Destination-Based Forwarding

- IP Forwarding with Labels

SubnetNum	Label
18.1.1/24	15
18.3.3/24	16



SubnetNum	Interface
18.1.1/24	0
18.3.3/24	0

SubnetNum	Interface	Label
18.1.1/24	1	15
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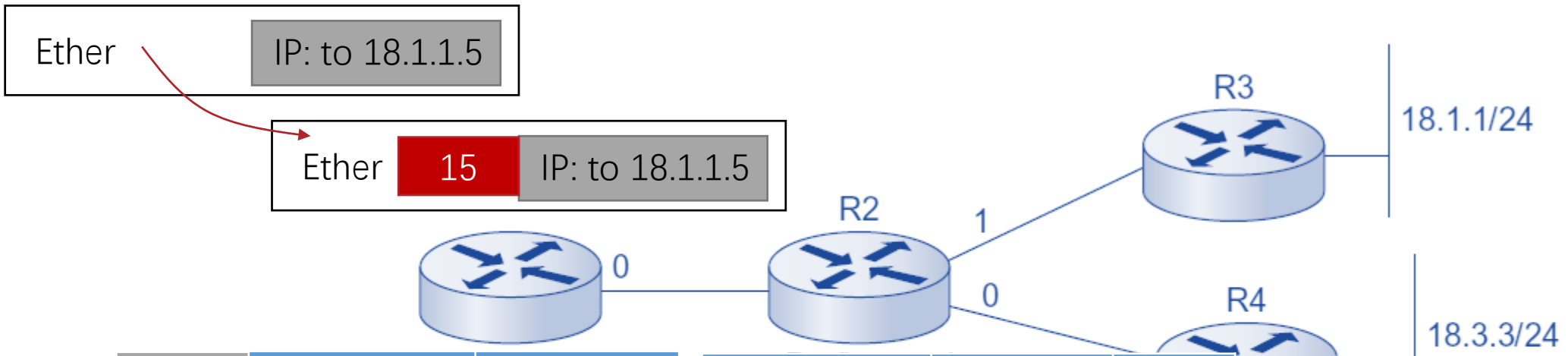
MPLS: Destination-Based Forwarding

- IP Forwarding with Labels



Label	SubnetNum	Interface
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MPLS: Destination-Based Forwarding

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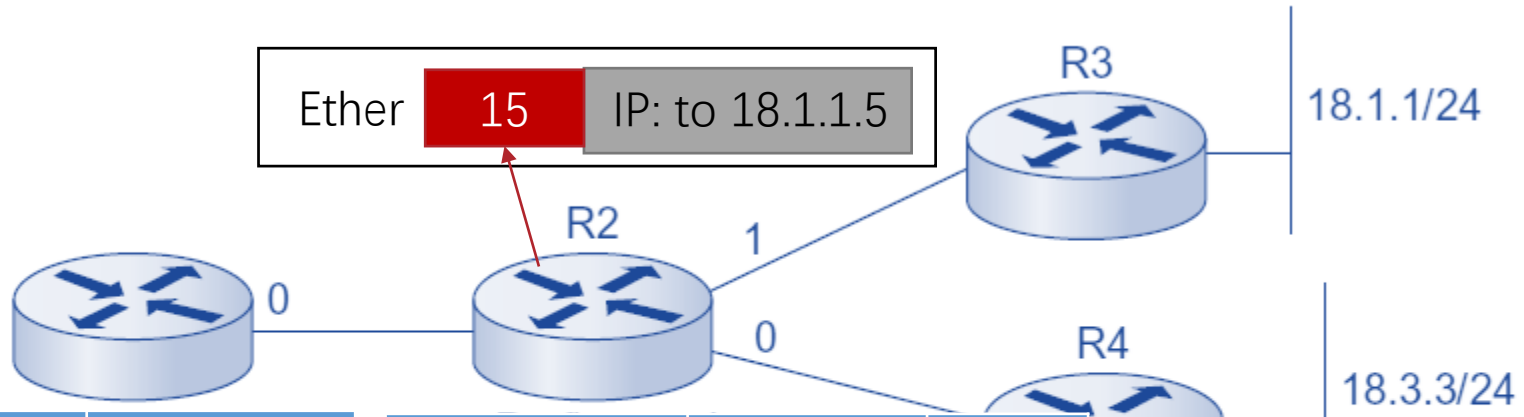

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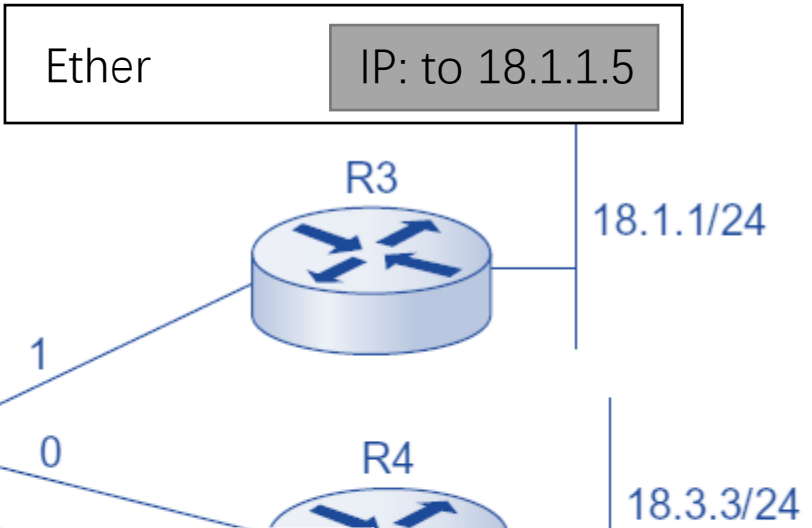
- IP Forwarding with Labels



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SubnetNum	Interface	Label
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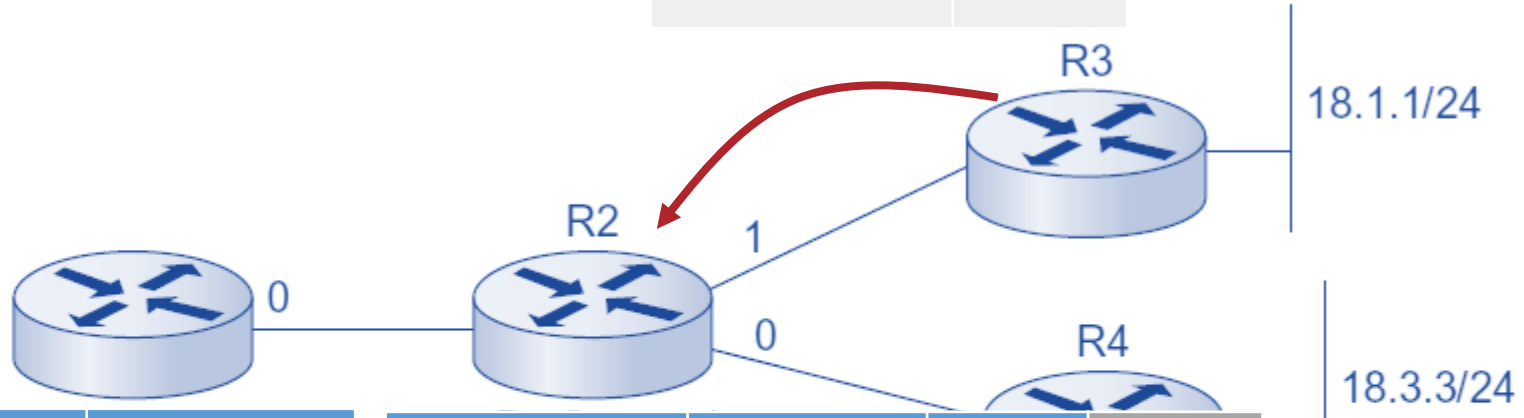
MPLS: Destination-Based Forwarding

- IP Forwarding with Labels
  - Use labels along the path

SubnetNum	Label
18.1.1/24	24



Label	SubnetNum	Interface
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SubnetNum	Interface	Label	Label
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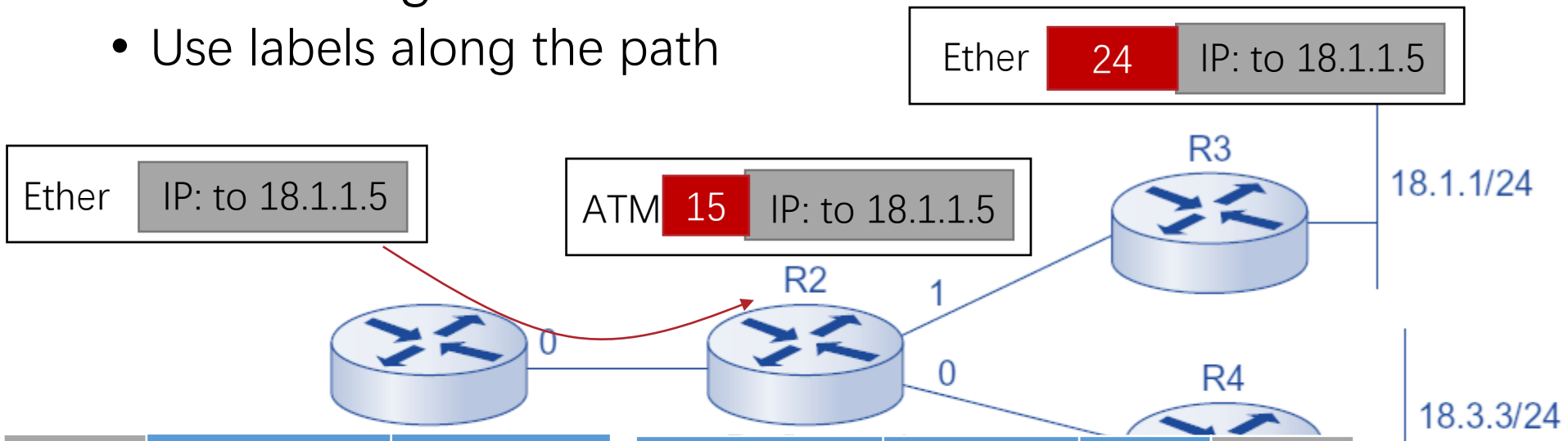

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SubnetNum	Interface	Label	Label
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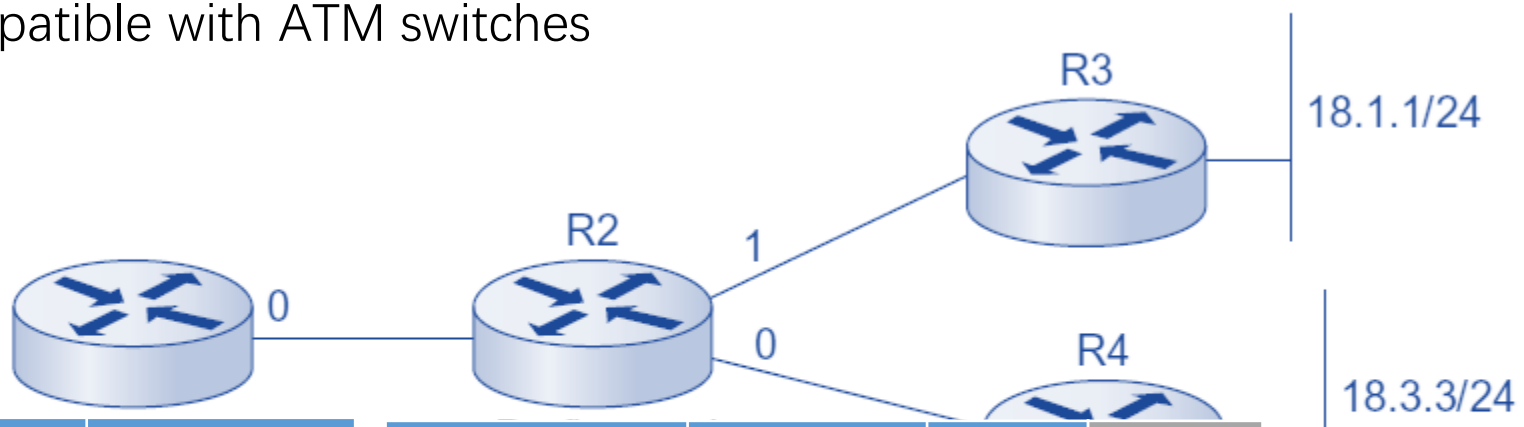
MPLS: Destination-Based Forwarding

- IP Forwarding with Labels
  - The forwarding hardware is based on label
    - Compatible with ATM switches



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SubnetNum	Interface	Label	Label
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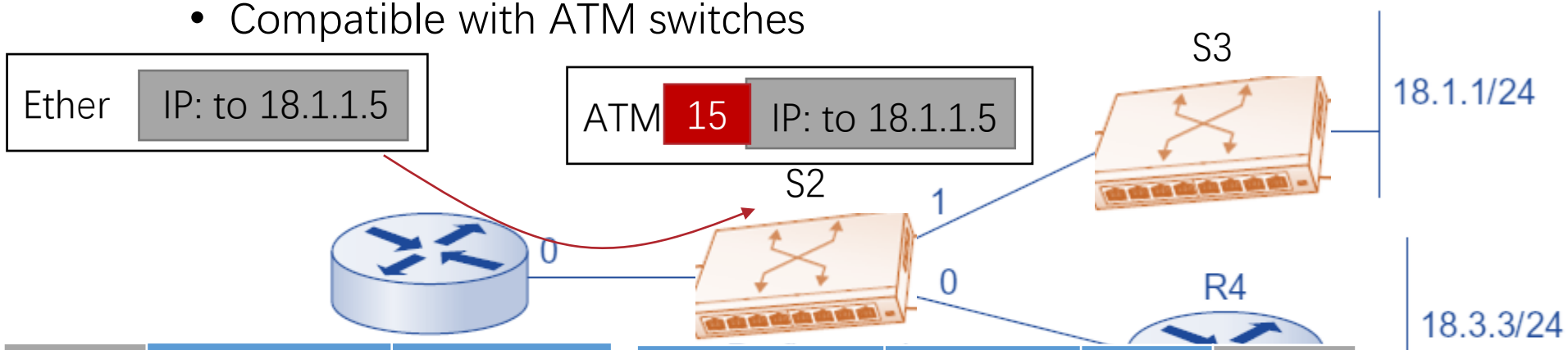

Label	SubnetNum	Interface
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SubnetNum	Interface	Label	Label
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MPLS: Destination-Based Forwarding

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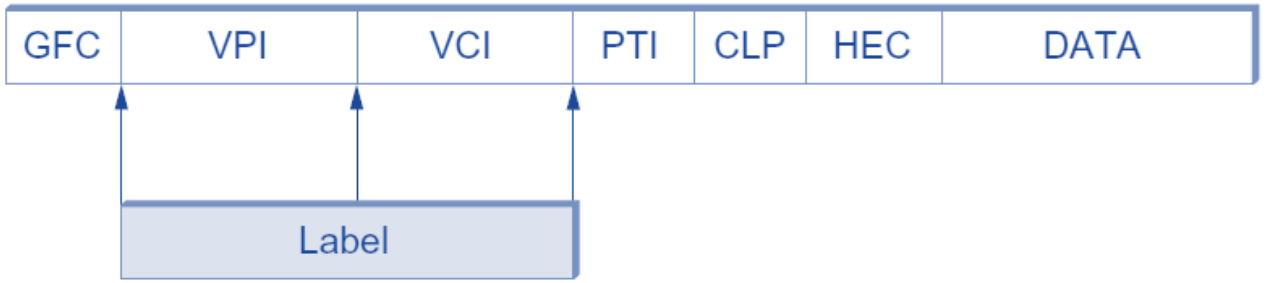
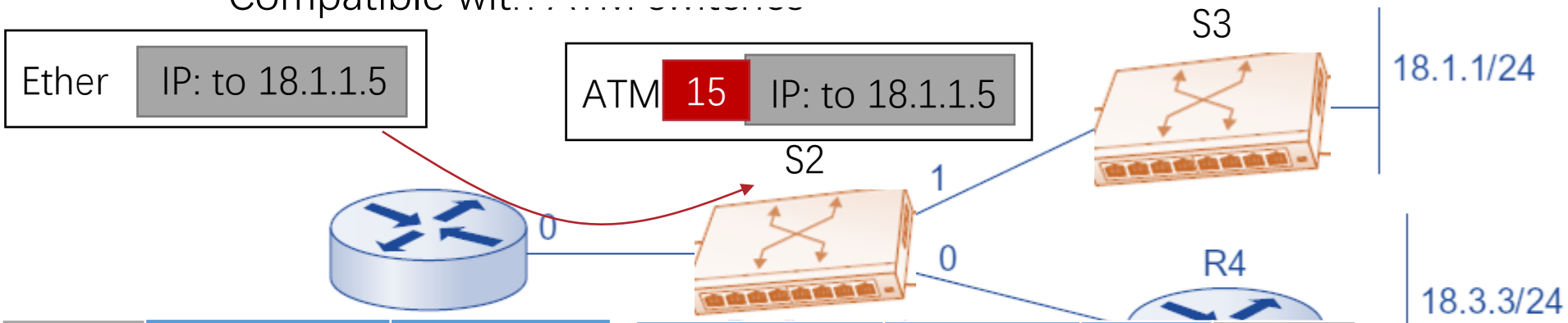
  - The forwarding
    - Compatible wit





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SubnetNum	Interface	Label	Label
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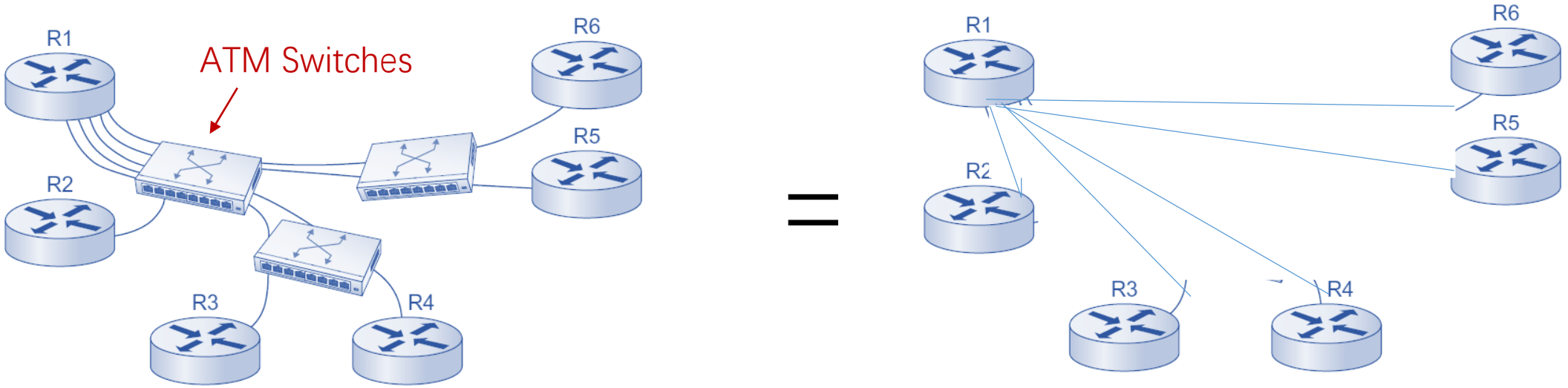
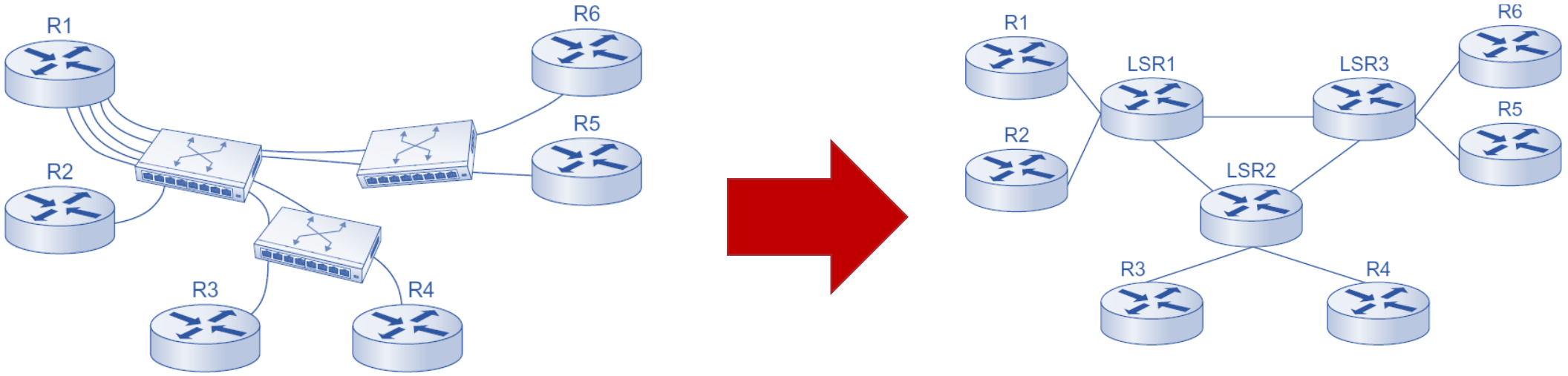
MPLS: Destination-Based Forwarding

- IP Network with ATM Backbone



MPLS: Destination-Based Forwarding

- Transform ATM switches into IP routers
  - Only software changes are needed
  - IP routers connected by ATM network are able to see better network topology

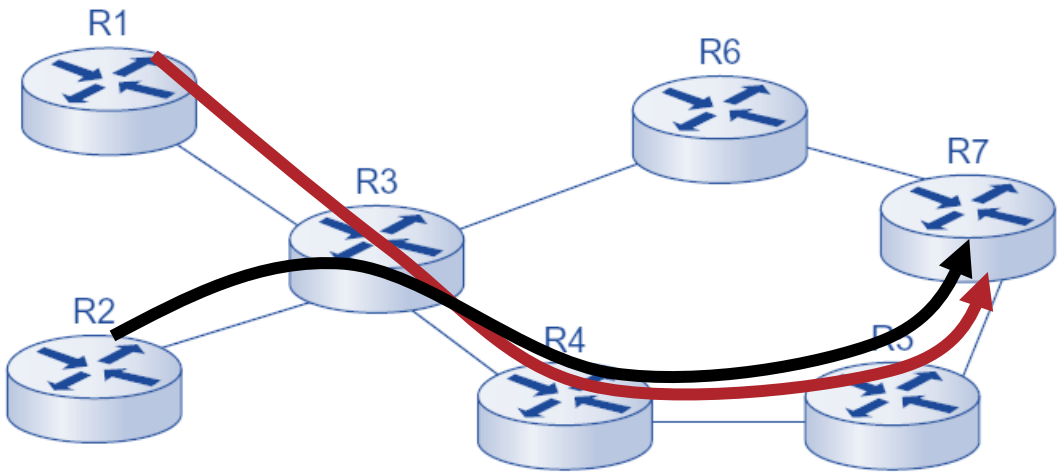


MPLS: Traffic Engineering

- MPLS Forwarding Decisions
  - Can follow IP routing algorithm
    - Same path as IP forwarding
  - Can differ from IP routing algorithm
- Application
  - Traffic engineering
    - Use destination and source addresses to route flows to same destination differently
  - Fast reroute
    - pre-computed backup paths

MPLS: Traffic Engineering

- IP Routing: path to destination determined by destination address alone
  - Contains no information about the traffic of certain path



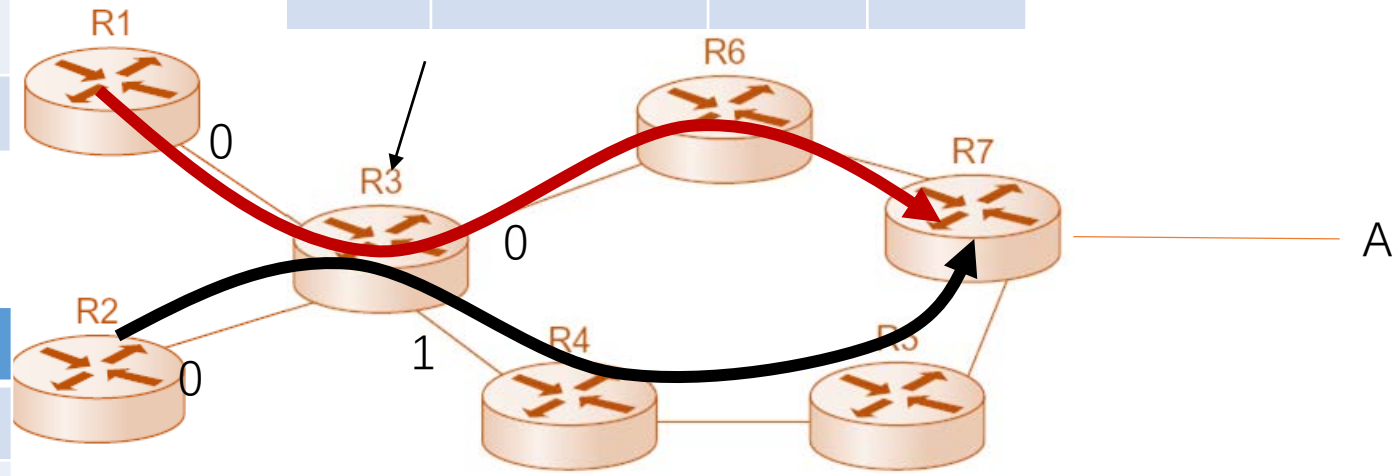
MPLS: Traffic Engineering

- MPLS routing: path to destination can be based on source and destination address

Dest	Interface	L_IN	L_OUT
A	0	/	25

Dest	Interface	L_IN	L_OUT
A	0	25	3
A	1	12	4

Dest	Interface	L_IN	L_OUT
A	0	/	12



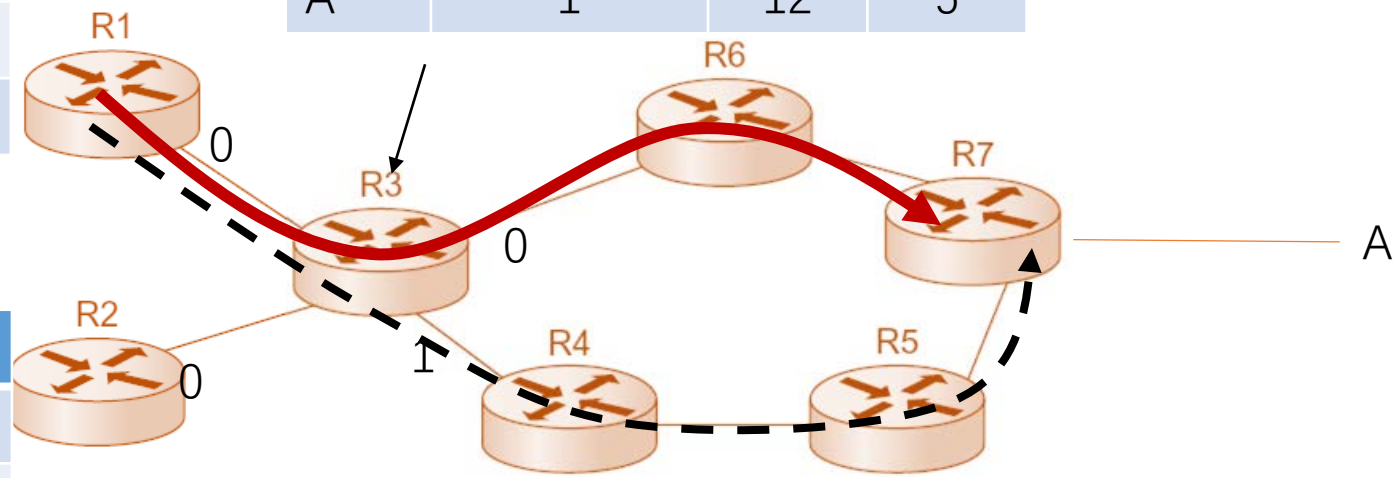
MPLS: Traffic Engineering

- MPLS routing: path to destination can be based on source and destination address

Dest	Interface	L_IN	L_OUT
A	0	/	25
A	0	/	26	

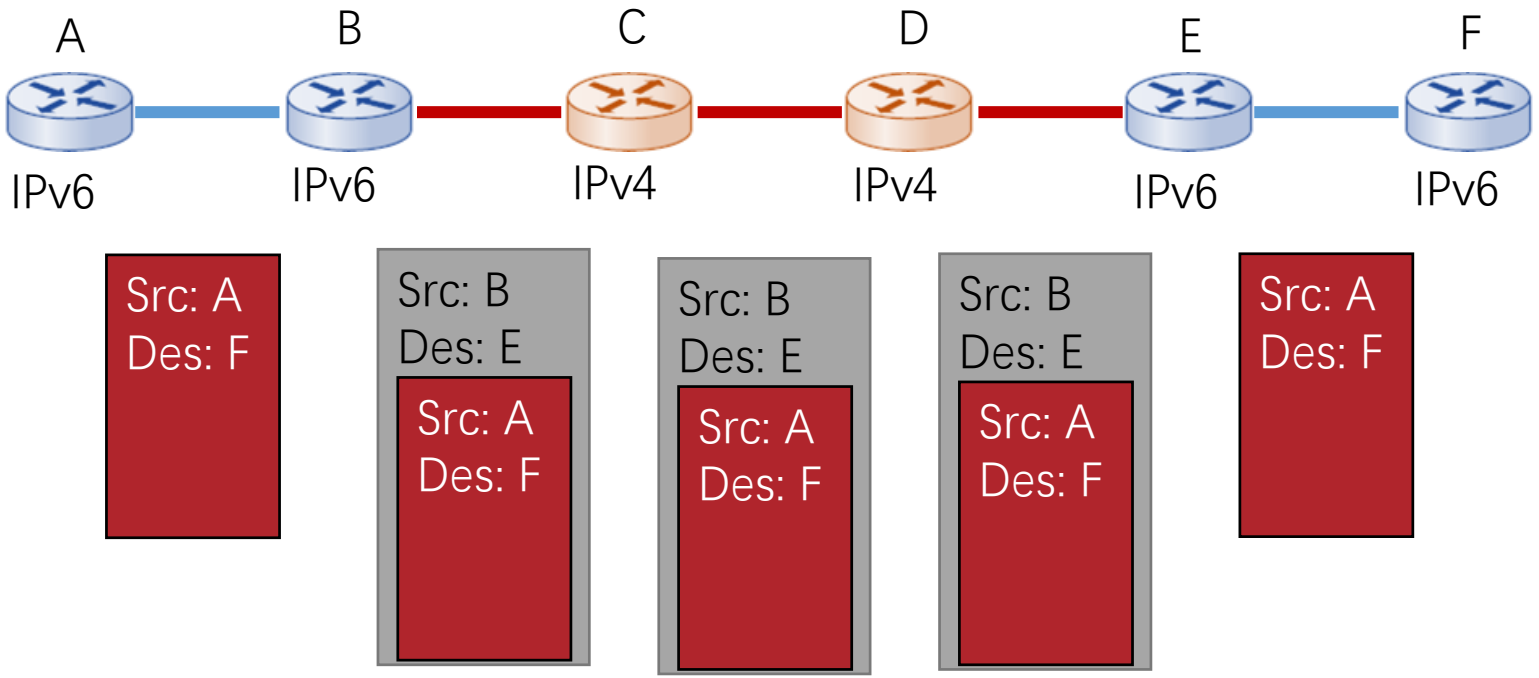
Dest	Interface	L_IN	L_OUT
A	0	25	3
A	1	26	4
A	1	12	5

Dest	Interface	L_IN	L_OUT
A	0	/	12	



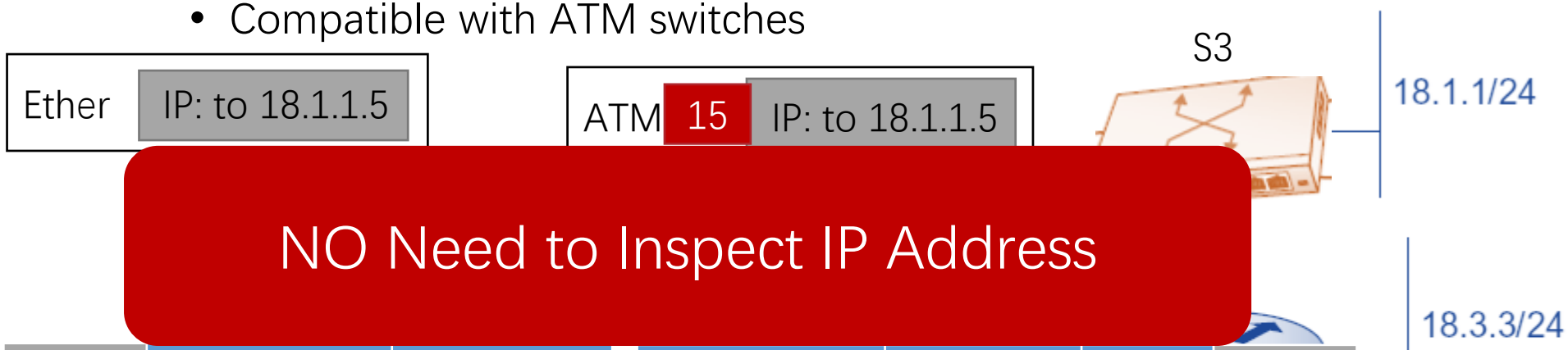
MPLS: Tunneling

- IPv4 Tunneling



MPLS: Destination-Based Forwarding

- IP Forwarding with Labels
  - The forwarding hardware is based on label
    - Compatible with ATM switches



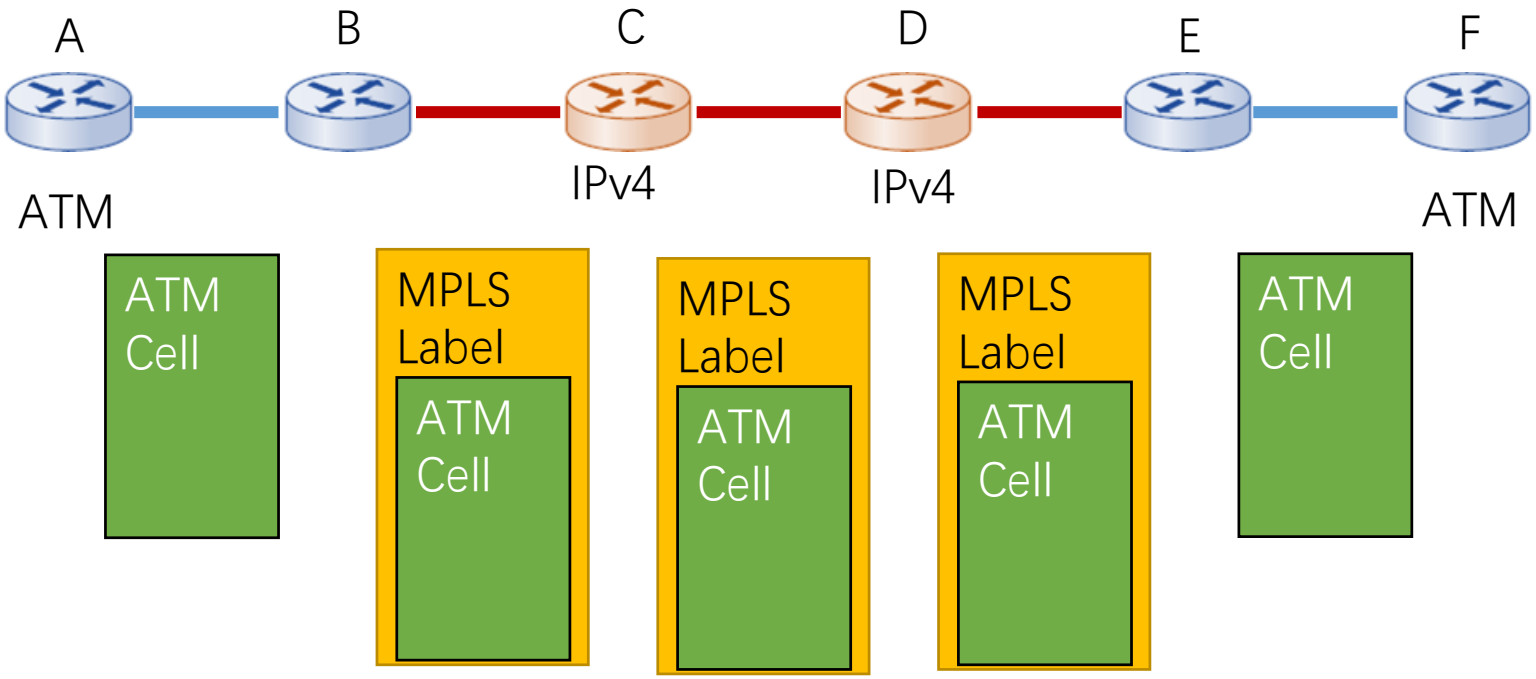
NO Need to Inspect IP Address

Label	SubnetNum	Interface
15	18.1.1/24	0
16	18.3.3/24	0

SubnetNum	Interface	Label	Label
18.1.1/24	1	15	24
18.3.3/24	0	16	

MPLS: Tunneling

- MPLS Tunneling

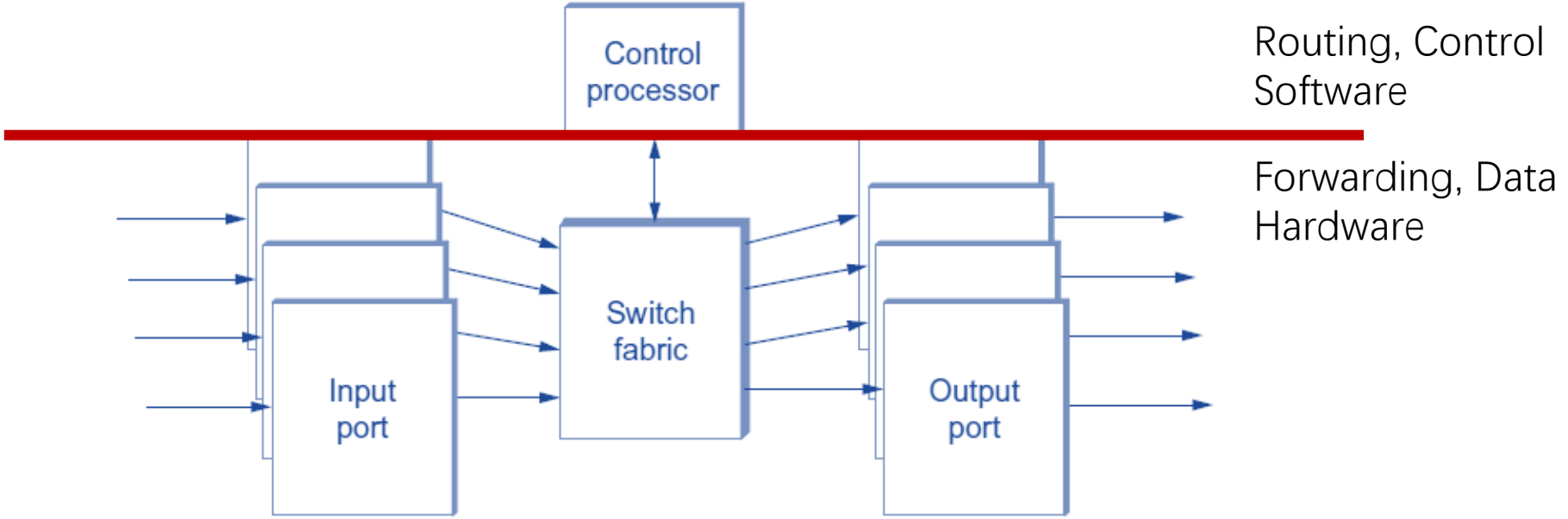


Centralize or Decentralize ?

- That is the question

Router Architecture

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



Router Architecture

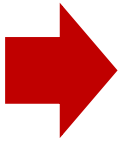
- Two Key Functions:
  - Routing algorithms (e.g, RIP, OSPF, etc.)
  - Forwarding packets from input to output ports
- Performance: packet per second
  - e.g.: line rate 640Gbps for a core router
  - Packets arrival order
  - Packets destination
  - Packets size

Control Processor

- Functions
  - Control and Configure Hardware
    - Ports and switch fabrics
  - Calculation
    - Routing algorithm
      - RIP, OSPF
      - Translate routing Information into forwarding table for input ports

Routing Table

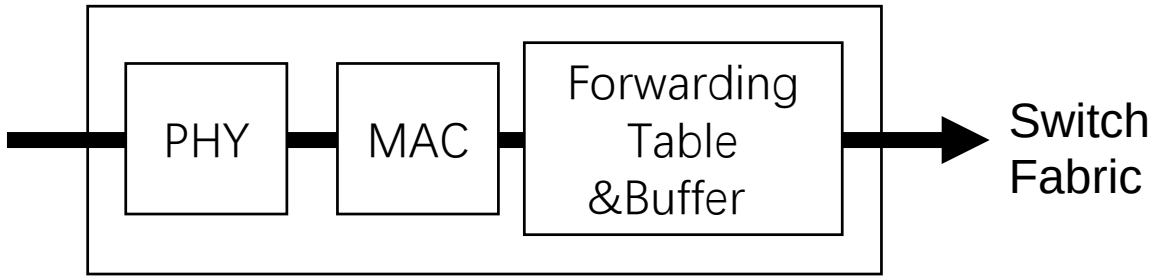
SubnetNum	NextHop
197.168.0.0/22	100.11.12.5



Forwarding Table

Sourcaddress	Destaddress	Interface	MAC
197.168.0.0/22	100.11.12.5	1	AB.CD.EF.12.34.56

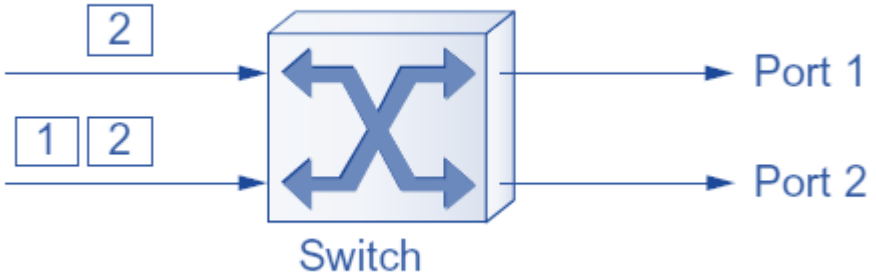
Input Port



- Function
  - Handle low level protocols
    - MAC, PHY
  - Deliver “clean” packets to switch fabric
    - Destination Port + Payload
- Processing workload: output port looking up
  - Given packet destination lookup output port
    - Ethernet
      - Using table: destination MAC ⇔ port
    - ATM
      - Using table: VCI ⇔ port
  - Goal: complete processing at “line speed”
- Buffer

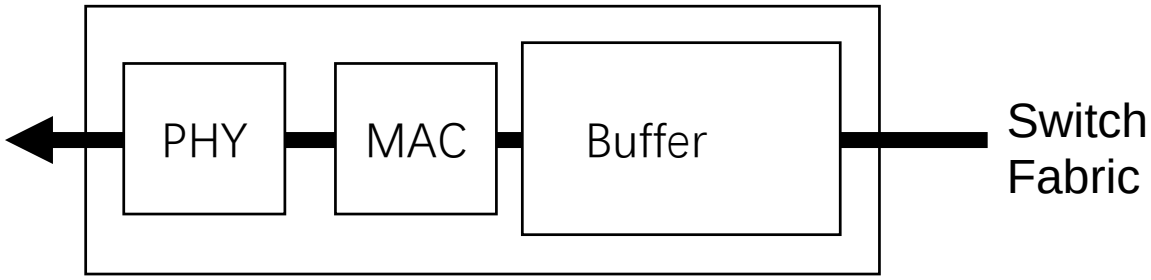
Input Port

- Buffer: Head-of-line Blocking



Output Port

- Function
  - Buffer packets from switch fabric
  - Deliver packets to network

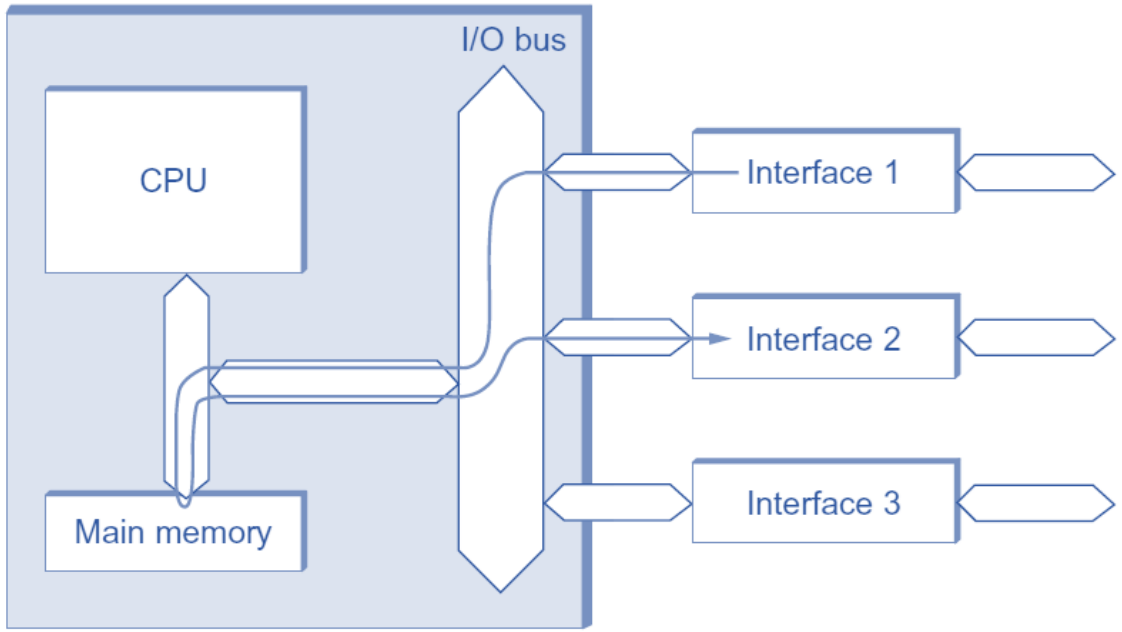


Switch Fabrics

- Function
  - Transfer packet from input port buffer to appropriate output port buffer
- Switching Throughput
  - Rate at which packets can be transfer from inputs to outputs
    - N inputs: switching throughput N times line rate desirable
- Design Goal
  - Throughput
  - Scalability
- Types
  - Shared bus
  - Shared memory
  - Crossbar
  - Self-routing

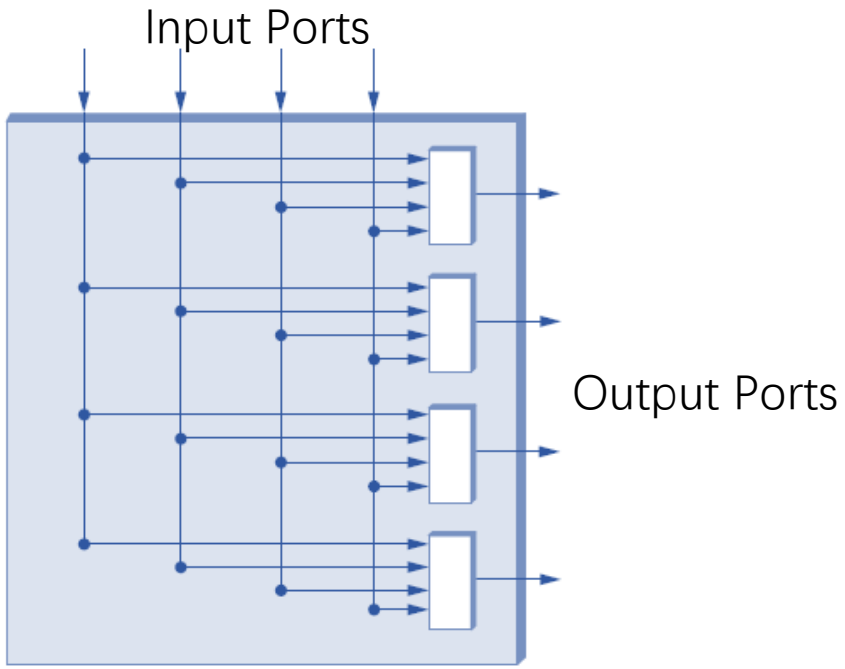
Shared Bus/Memory

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



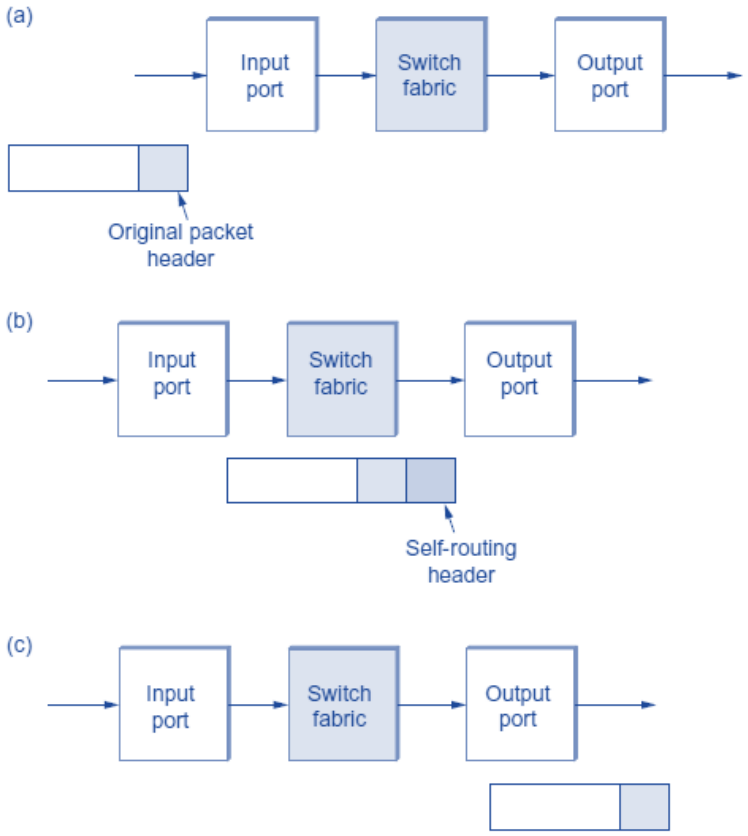
Crossbar

- Input ports are connected any output port
  - High bus rate is required for output ports



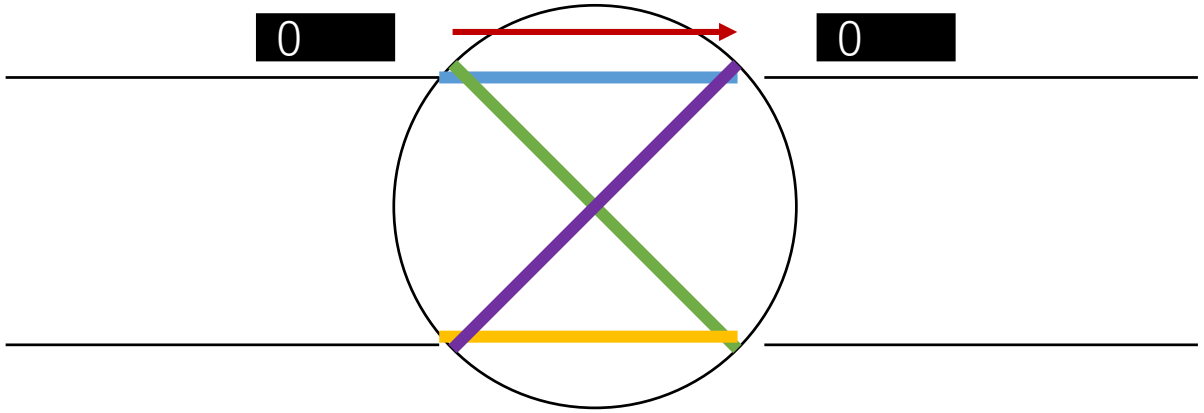
Self-routing

- Switching information is carried in the self-routing header:
  - Self-routing header is responsible for directing packets in the switching fabric



Self-routing

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



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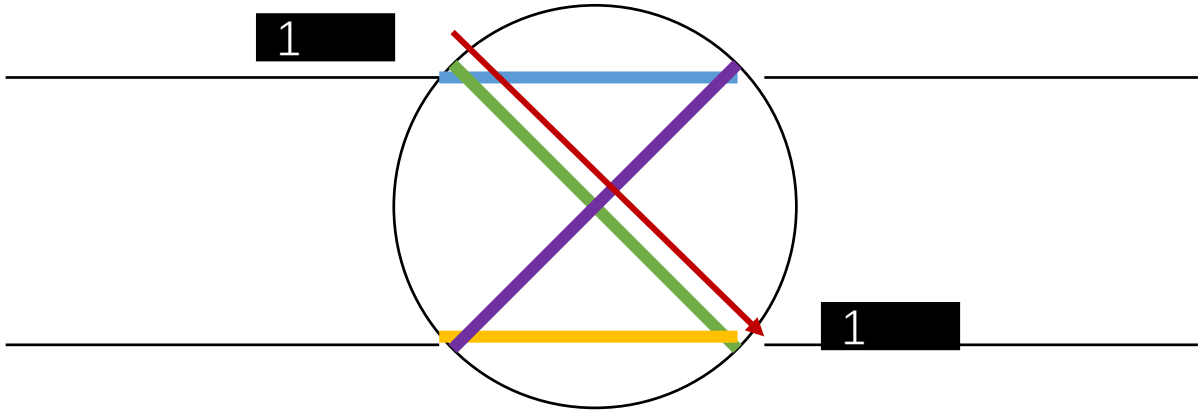

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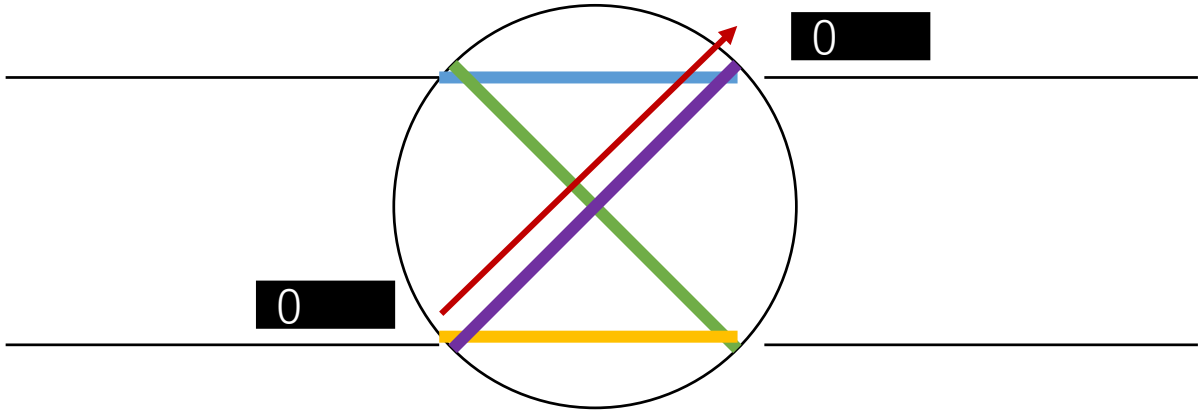
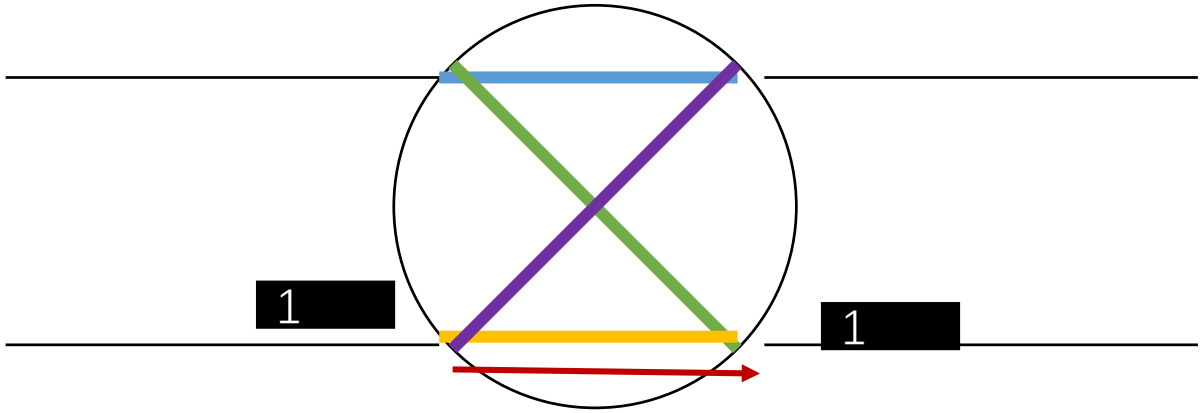
  - 0=> up
  - 1=> down



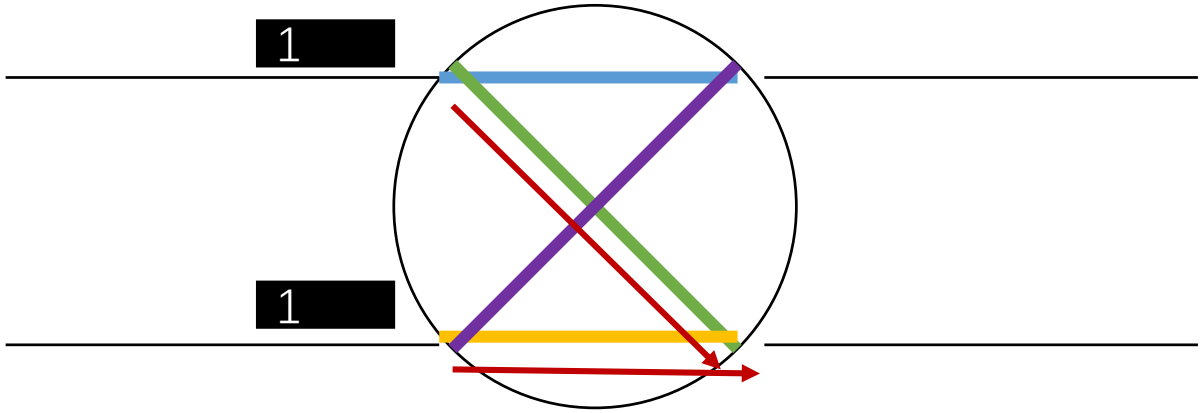
Self-routing

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



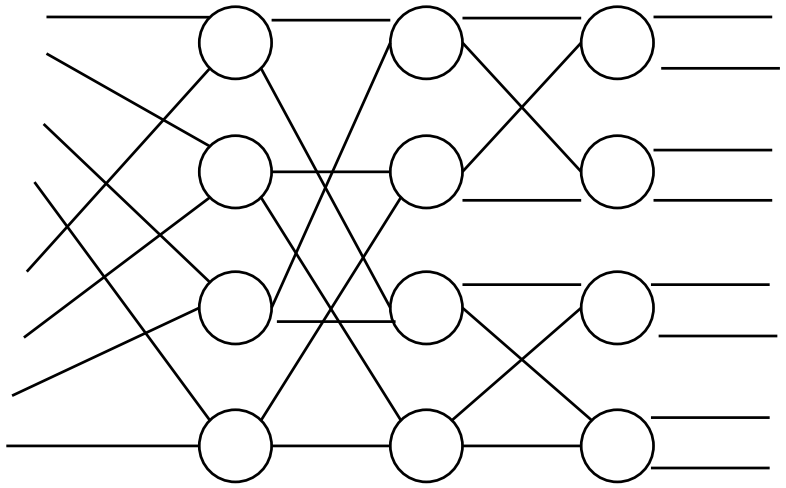
Self-routing

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



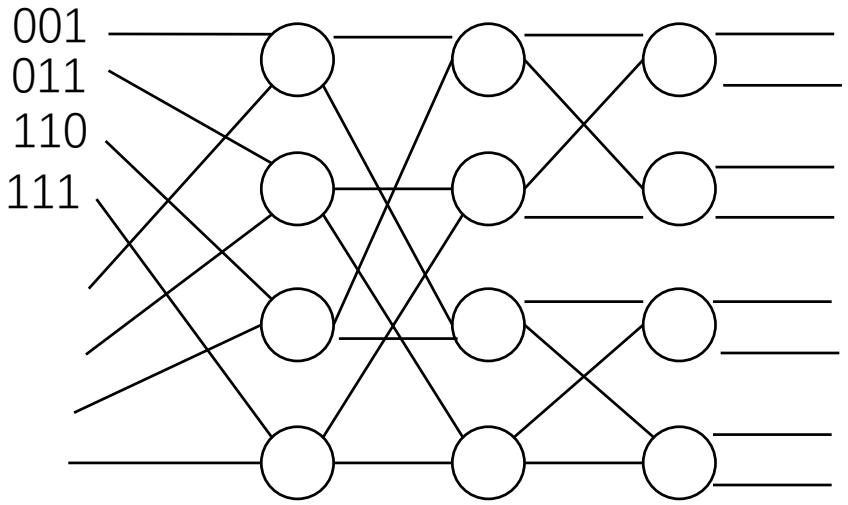
Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header



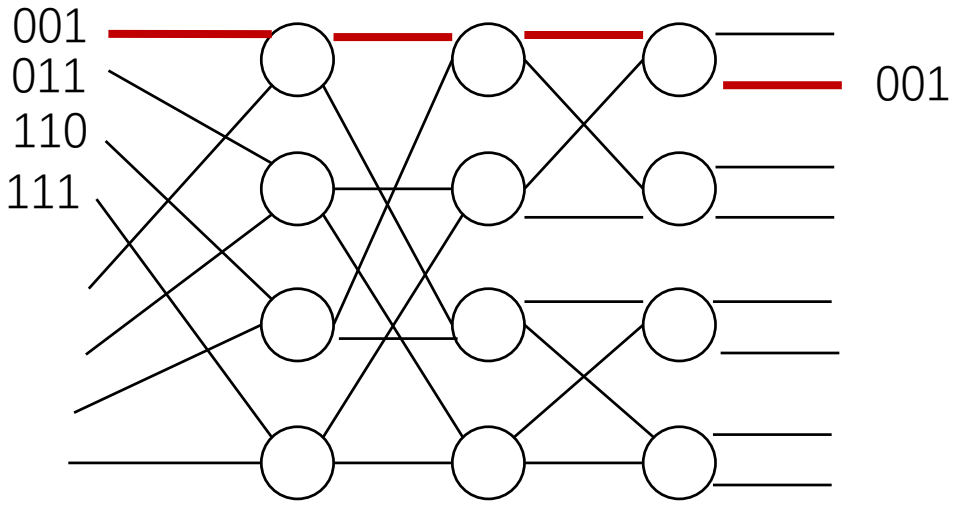
Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header



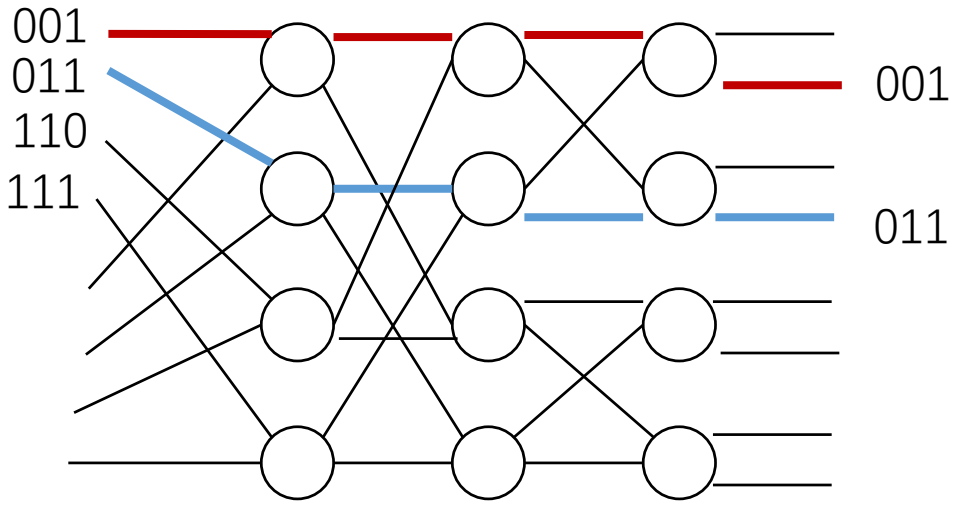
Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header
    - Forwarding packets with well connected basic switching elements



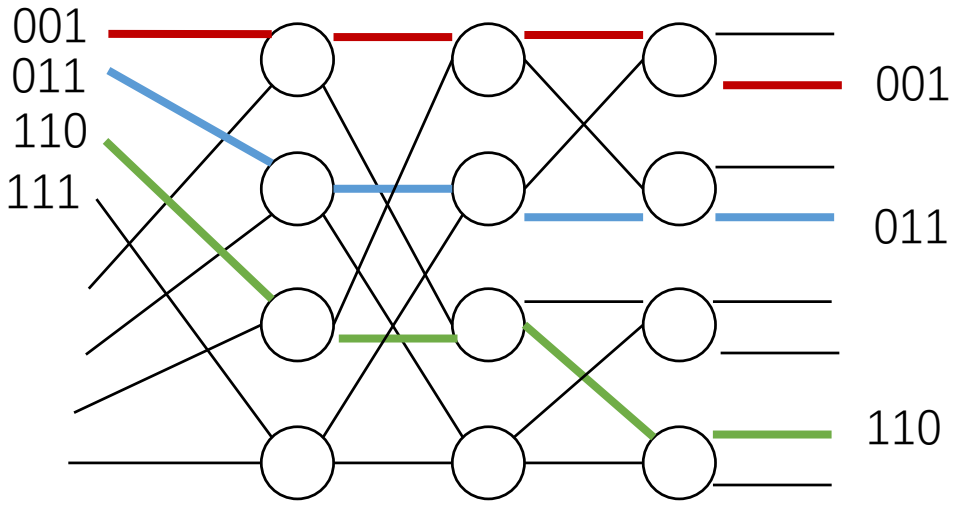
Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header
    - Forwarding packets with well connected basic switching elements



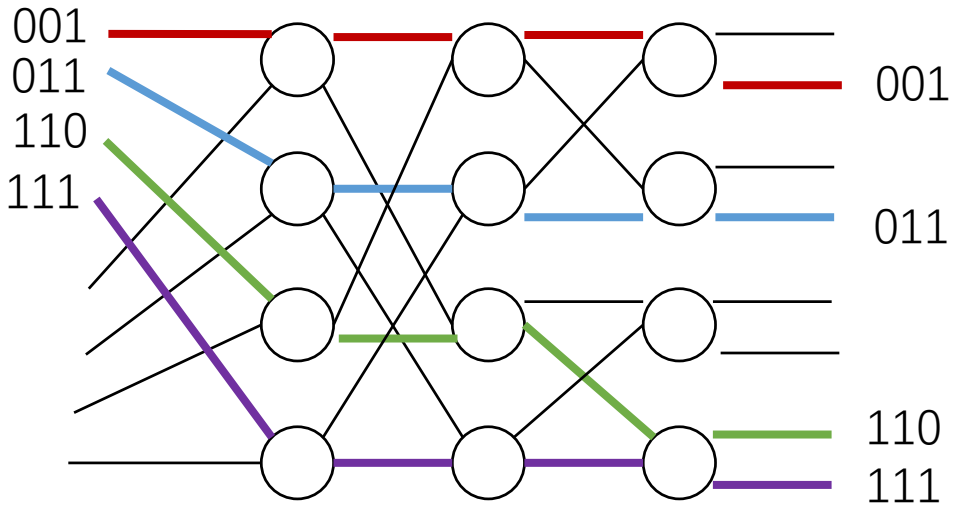
Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header
    - Forwarding packets with well connected basic switching elements



Self-routing

- Banyan Network
  - Collision Free
    - Input packets are sorted according to routing header
    - Forwarding packets with well connected basic switching elements



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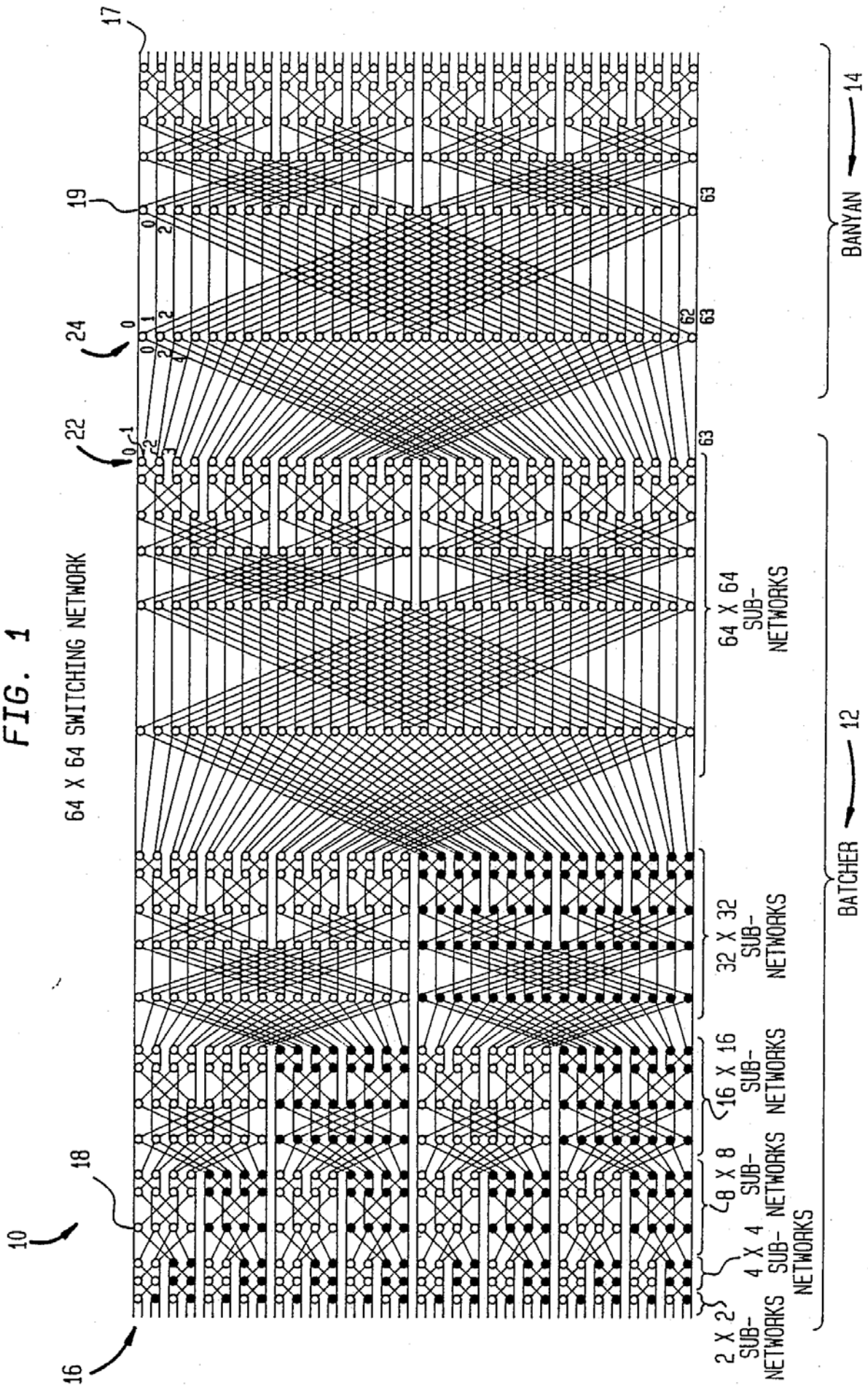
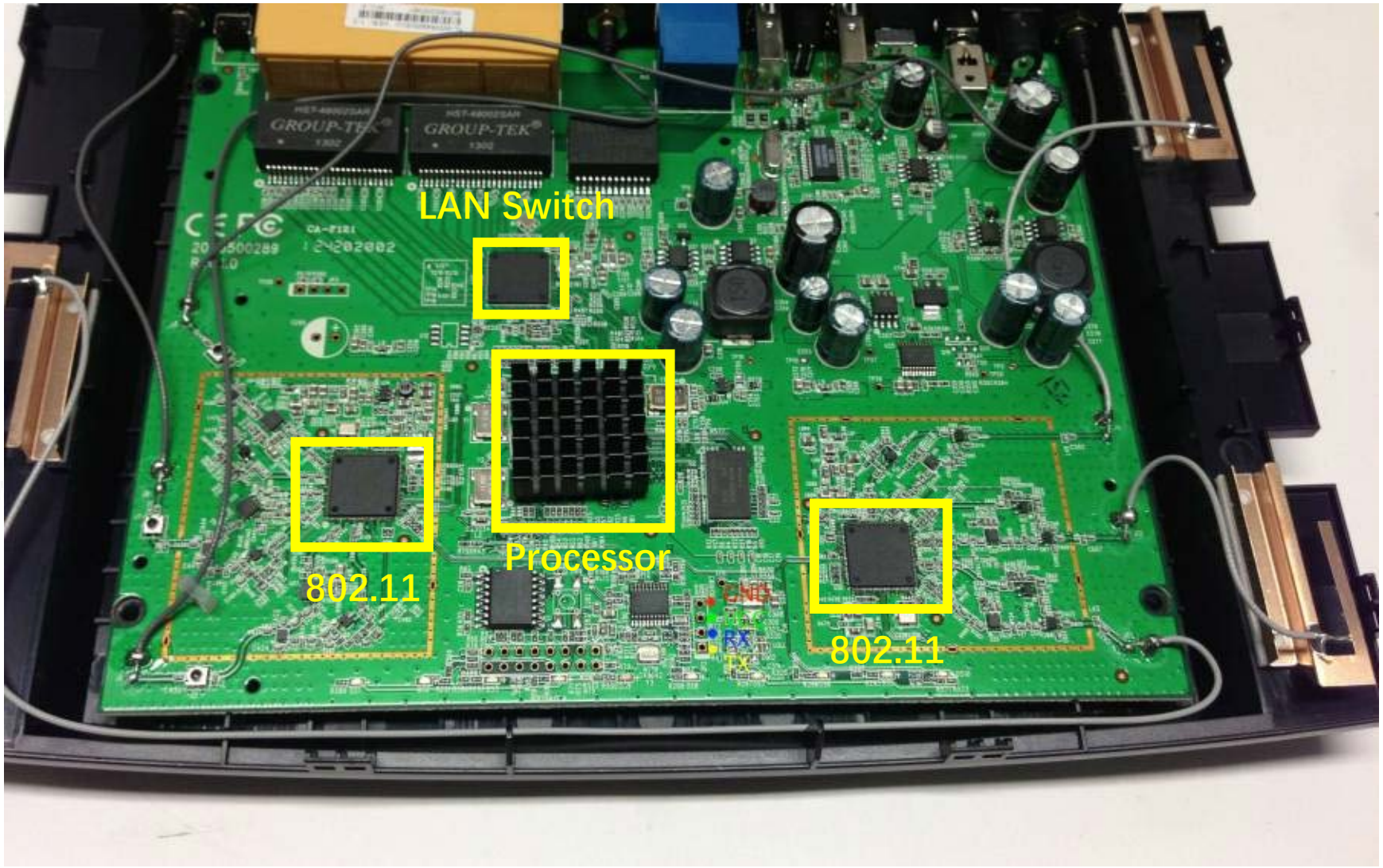


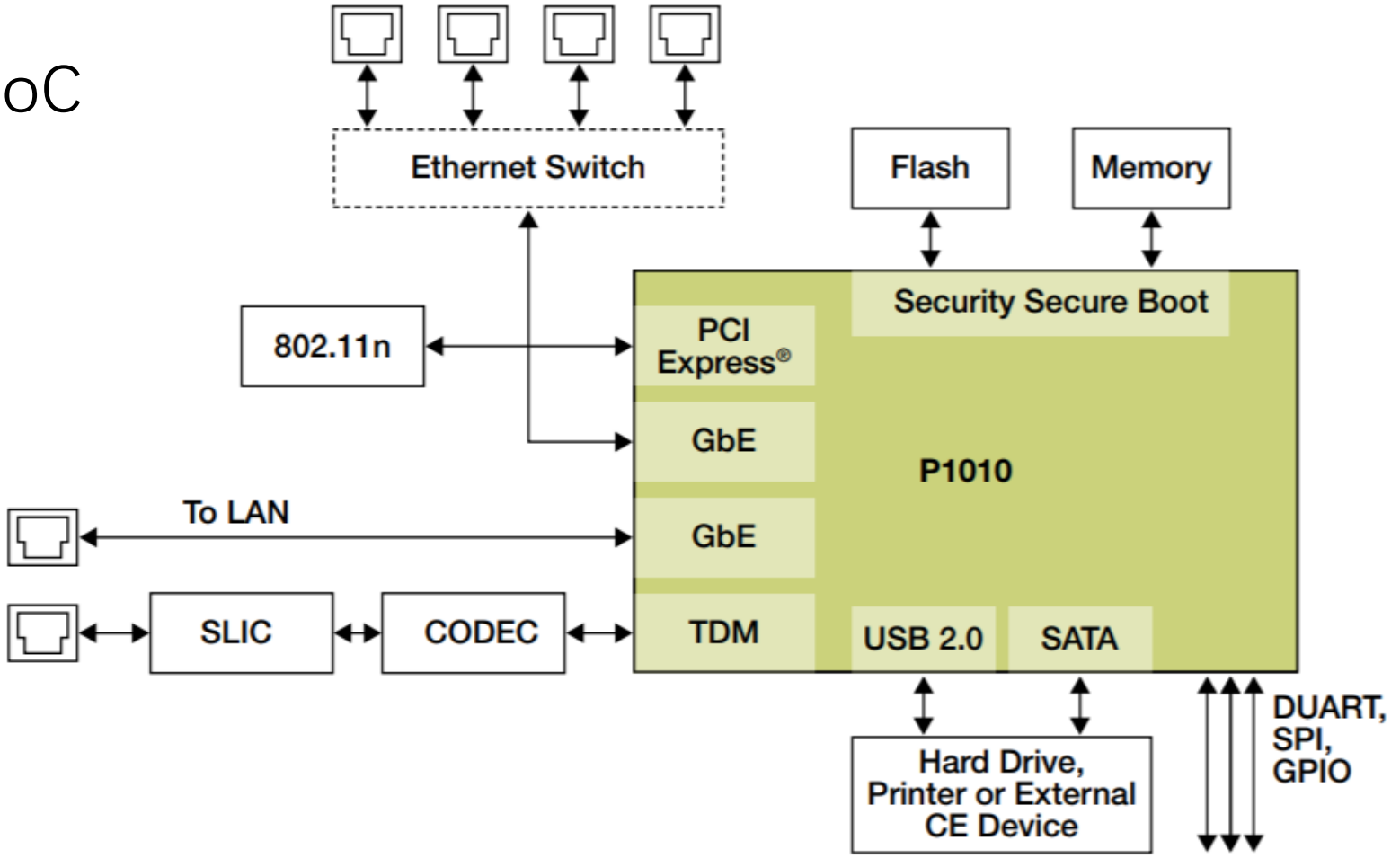
FIG. 1

Inside Routers



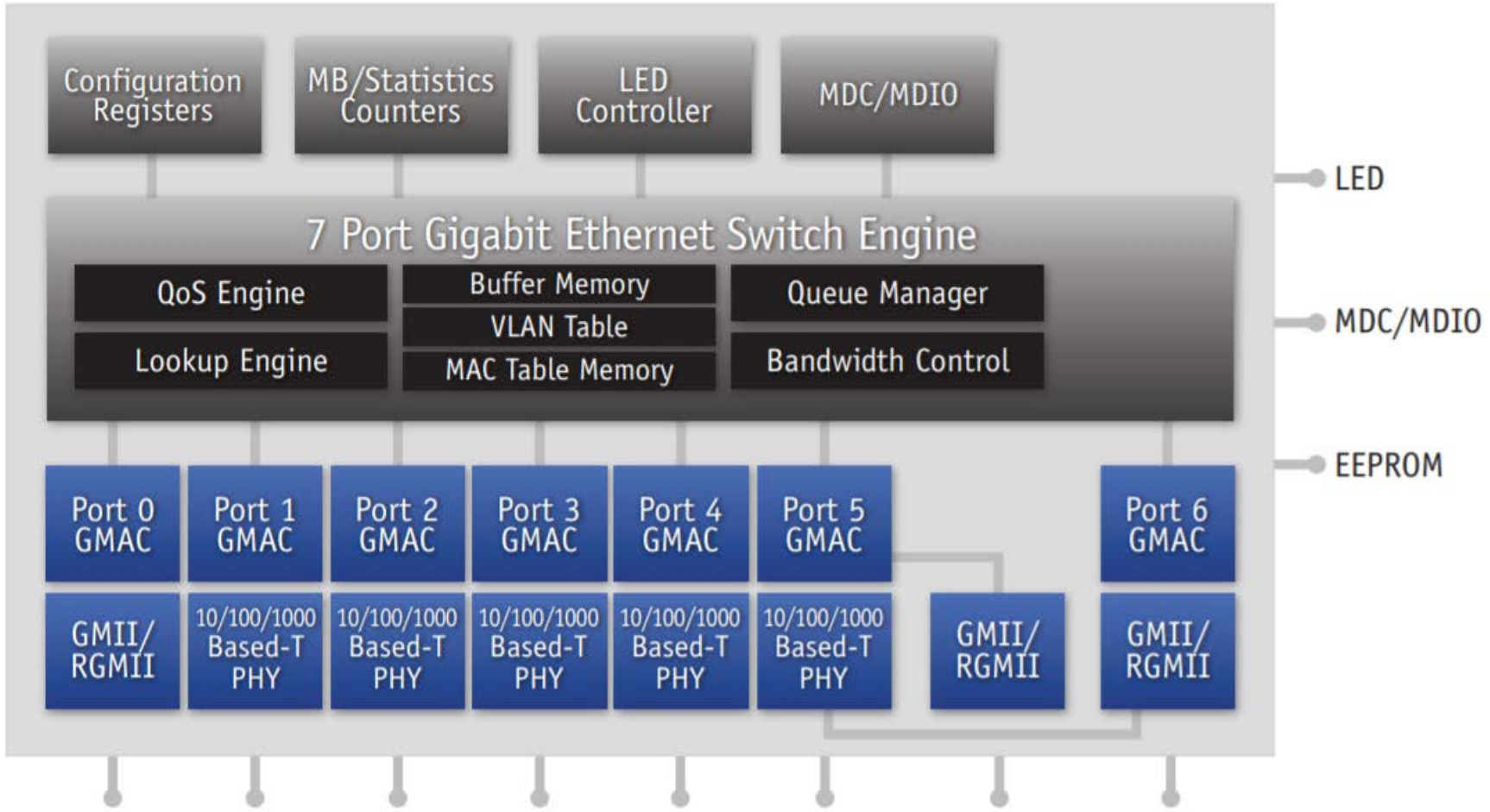
Inside Routers

- Freescale P1010 SoC



Inside Routers

- AR8327 Switch



Open Sourced Wireless Router

- Linksys WRT54G

OpenWrt
Wireless Freedom

Reference

- Textbook 4.1
- Textbook 4.3
- Textbook 3.4