Software Defined Network

Course Introduction

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Spring 2024

About Me

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About the Course

- Software Defined Network (软件定义网络)
- Content
  - Introducing some necessary knowledge of network
  - Introducing the basic concept of SDN
  - Experiments with SDN

About the Course

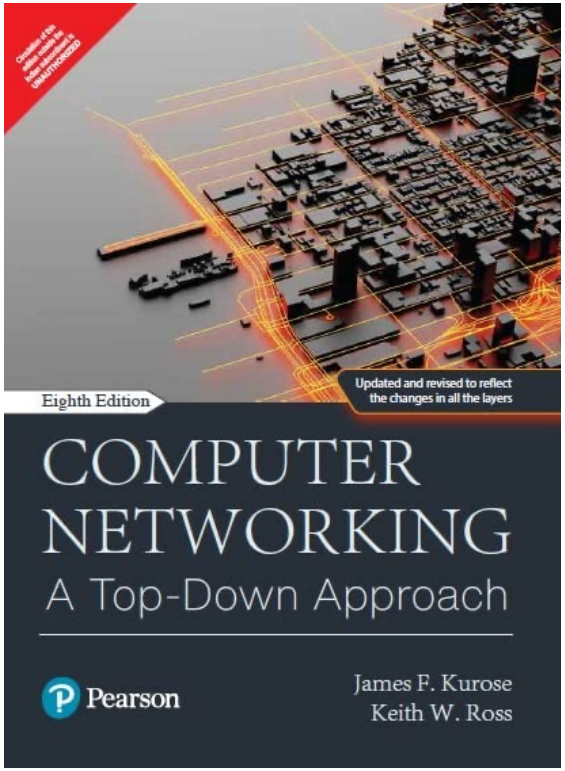
- Chinese + English
  - Slides in *English*, Presentation in *Chinese*
  - Why? The awkward story about "What is switch?"

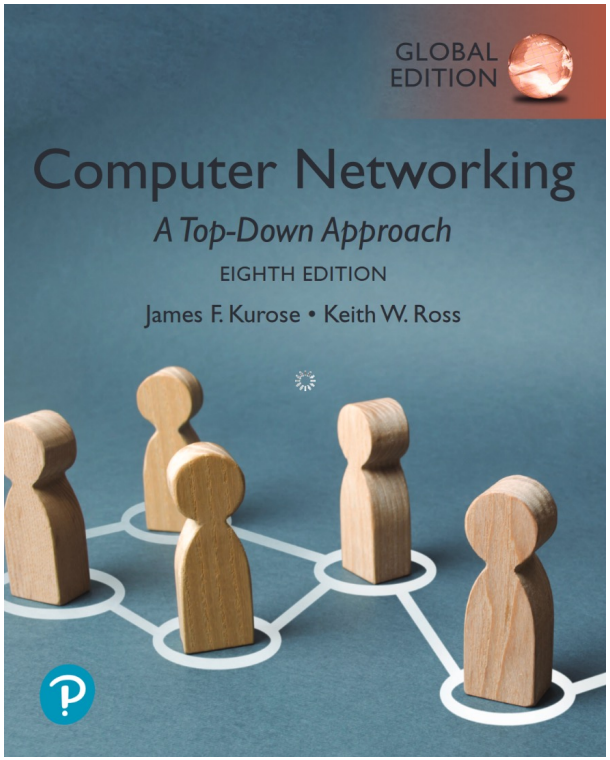
- Why >> How
  - **"How"** is not the most important thing
  - Always push yourself to think **"Why"**

Books

Computer Networking: A Top-Down Approach

by James F. Kurose and Keith W. Ross





Online Course: https://gaia.cs.umass.edu/kurose_ross/online_lectures.htm

Reference Course

Communication Networks @ ETH

https://comm-net.ethz.ch

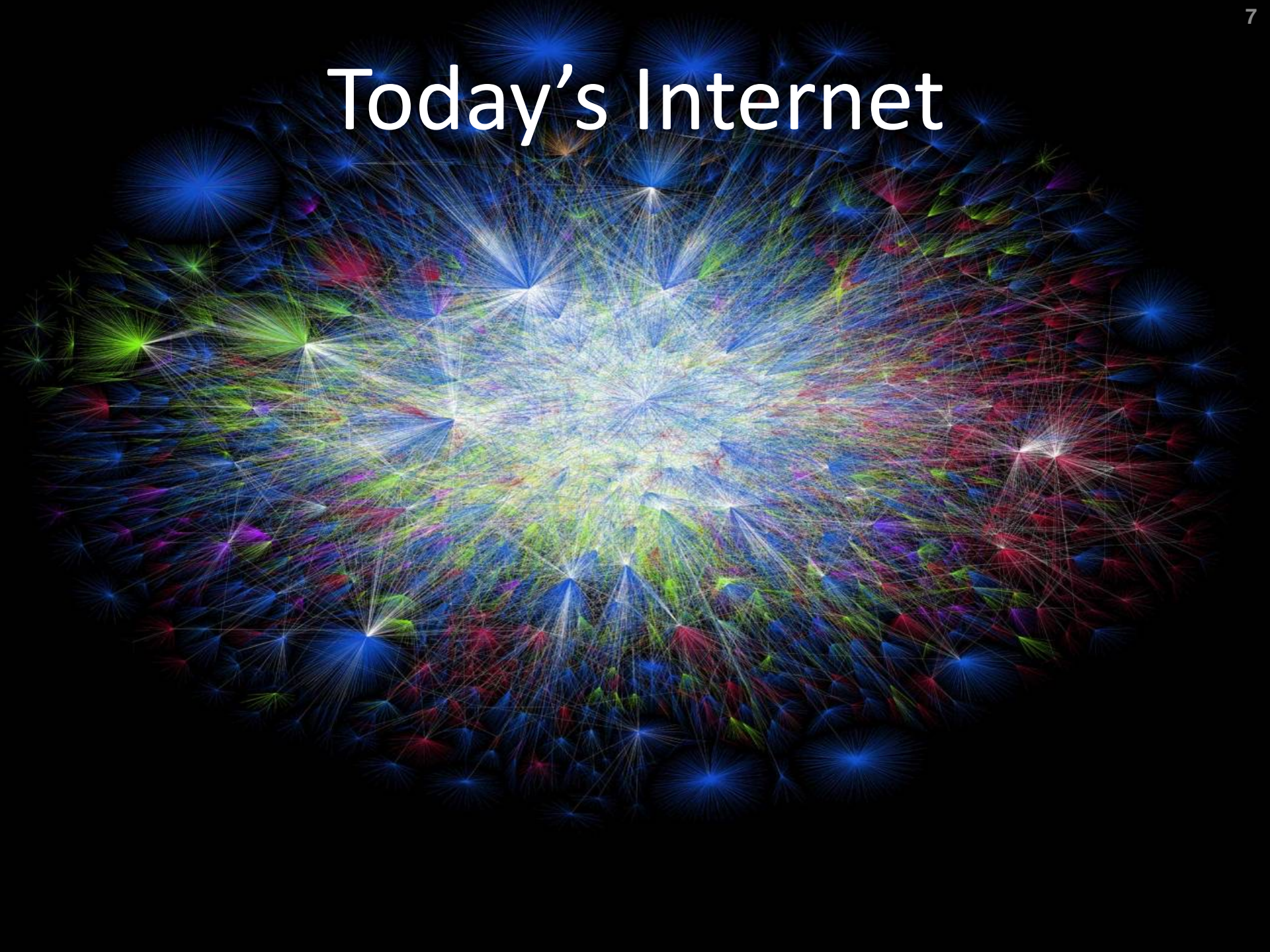
Communication Networks

Lecturer: Laurent Vanbever

Semester: Spring

In this introductory lecture, students learn about “how does the Internet work”. Starting from the fundamentals, the lecture builds up the mechanisms underpinning any Internet-based communication and illustrates them with (many) real-world examples. The lecture is hands-on and includes two projects, including the mini-Internet in which the entire classroom builds and operates its very own Internet infrastructure.

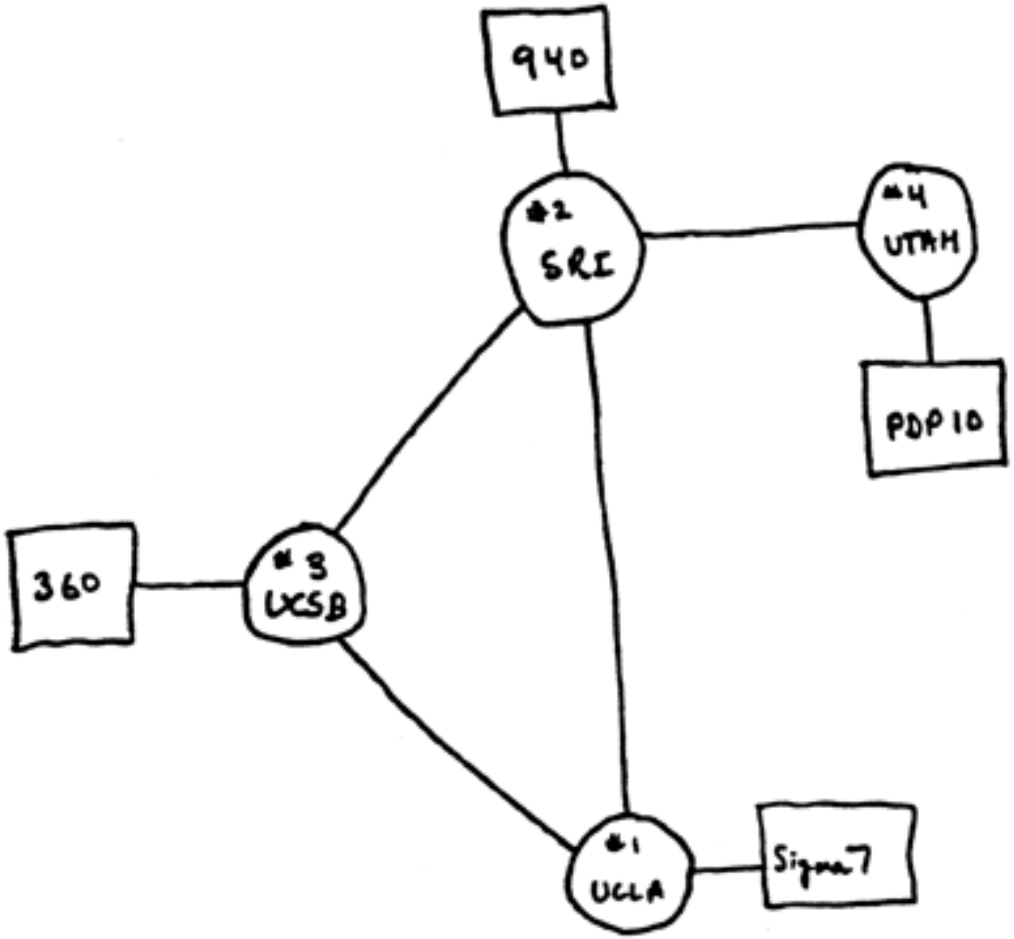
Today's Internet



History of the Internet

Birth of Internet

- 1969: ARPANET, 4 nodes, 50kbps



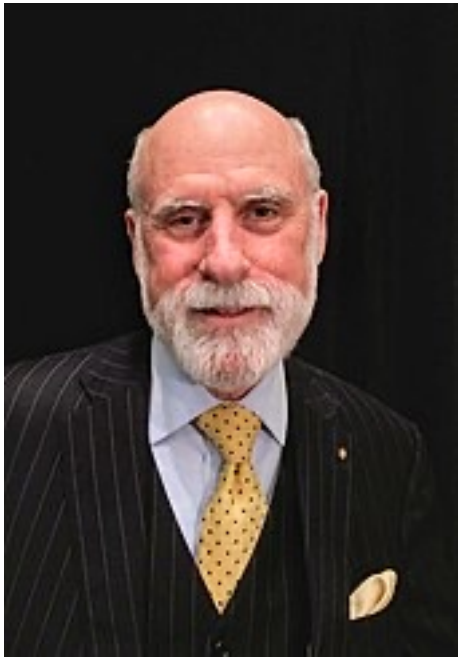
History: Ethernet

- 1973: Robert Metcalfe developed Ethernet
  - Turing Award 2023

An Ethernet port on a laptop computer connected to a twisted pair cable with an 8P8C modular connector

History: TCP/IP

- 1974: Bob Kahn and Vint Cerf published TCP/IP
  - Turing Award 2004



History: WWW

- 1989: Tim Berners-Lee invented the World Wide Web (WWW)
  - Turing Award 2016

Tim Berners-Lee acknowledging the huge cheers received at the London 2012 Olympic Opening Ceremony

History: Birth of SDN

- *2008: the OpenFlow paper was published*

OpenFlow: enabling innovation in campus networks

N McKeown, T Anderson, H Balakrishnan… - ACM SIGCOMM …, 2008 - dl.acm.org

… -front — most experiments in **OpenFlow networks** are yet to be thought of. Here, for illustration, we offer some examples of how **OpenFlowenabled networks** could be used to experiment …

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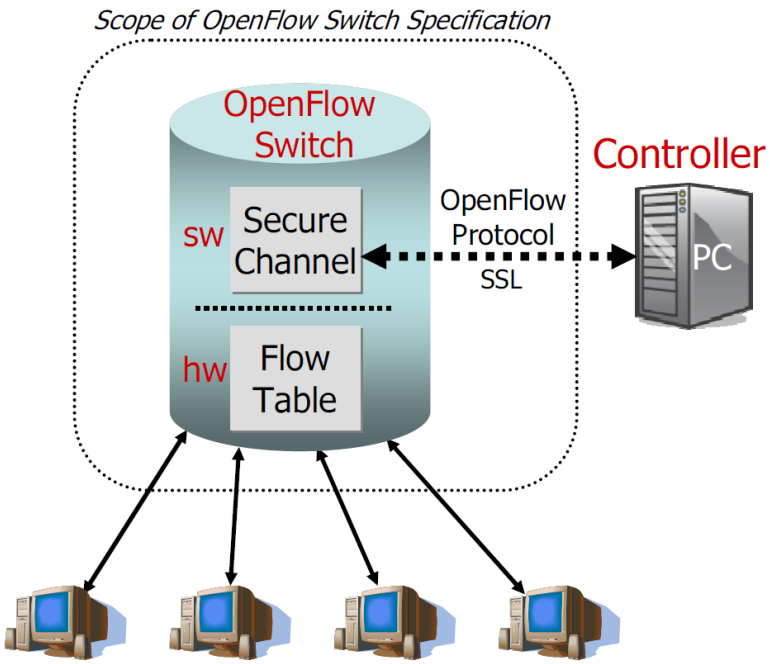
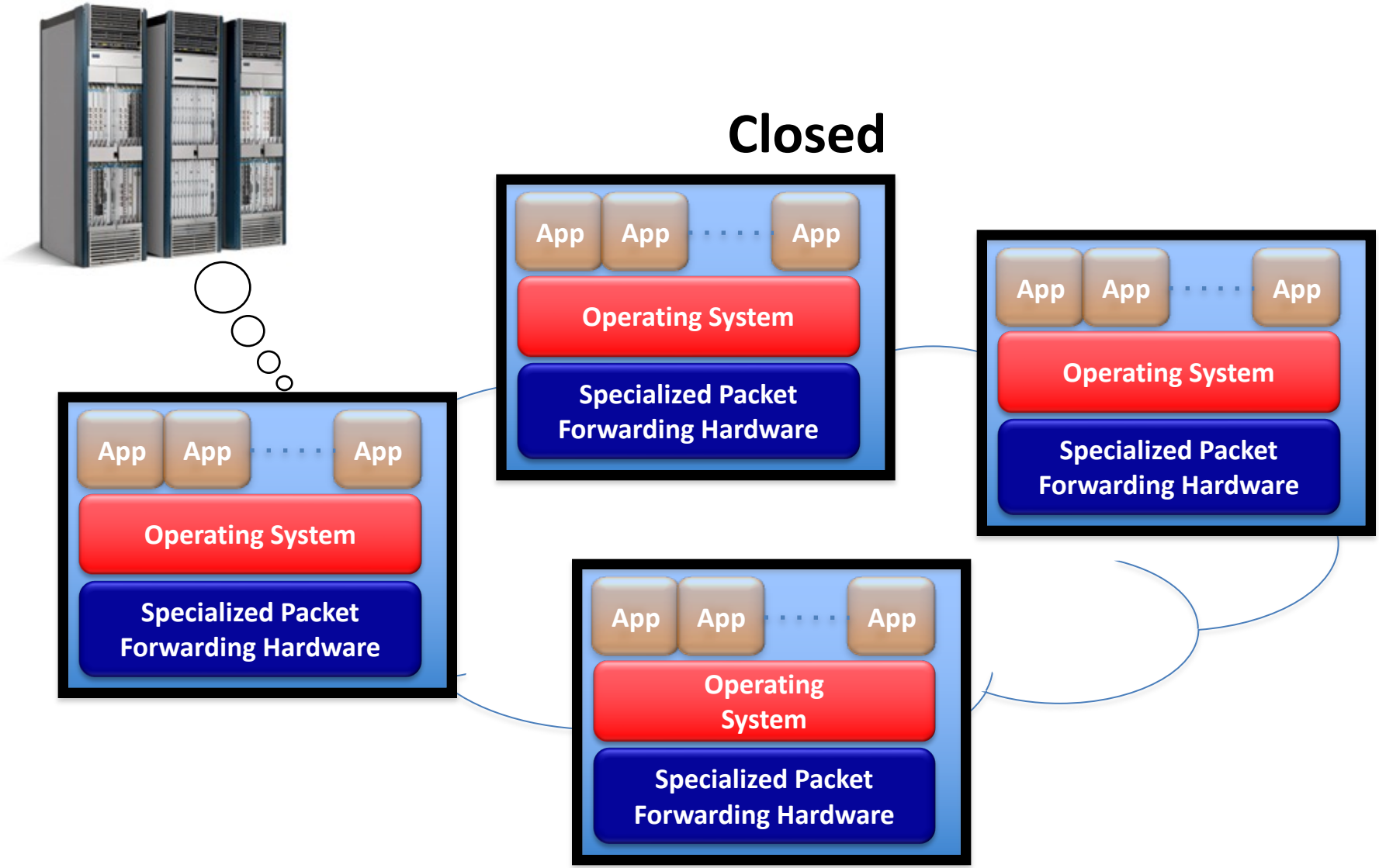
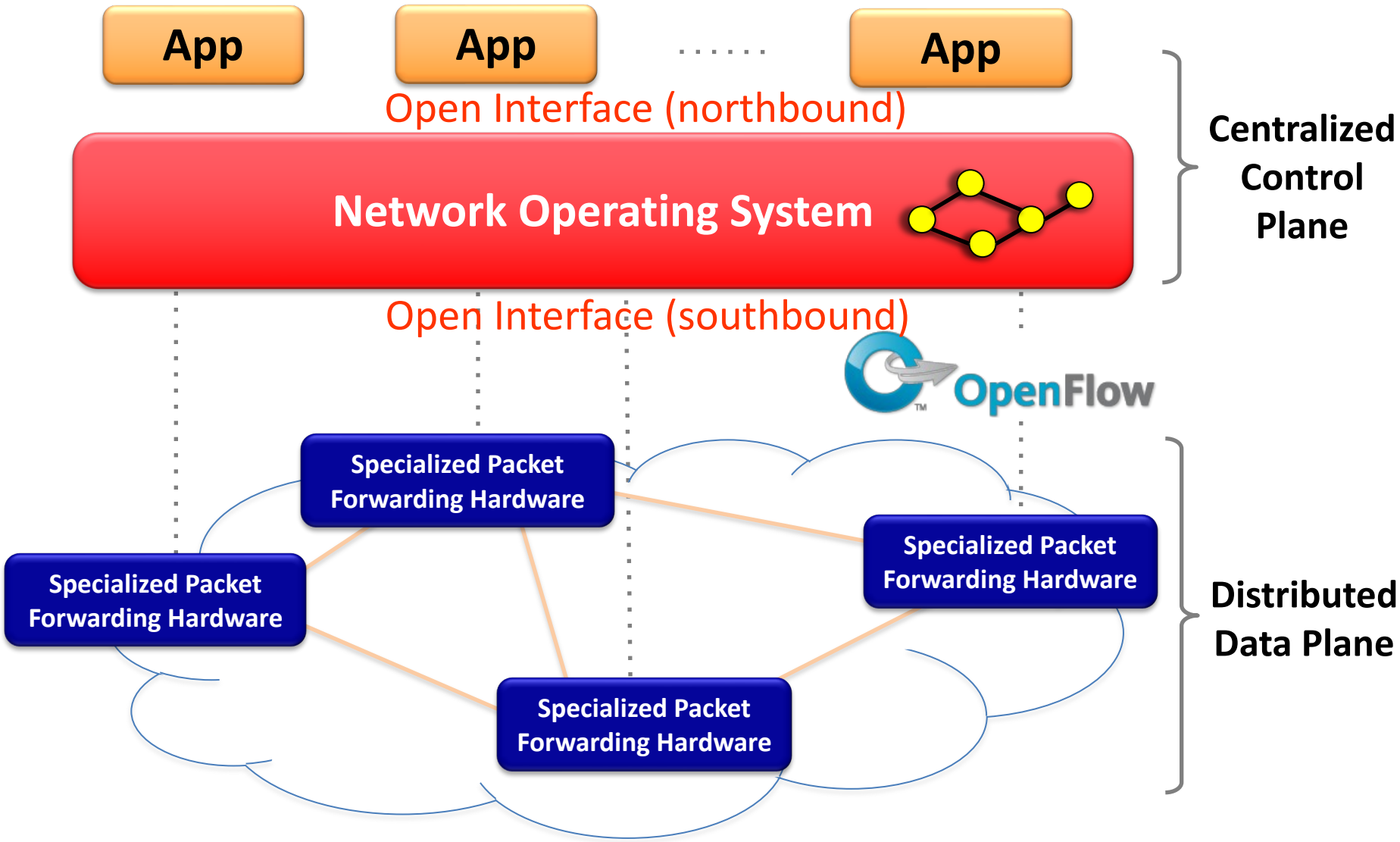


Traditional Computer Networks



Software Defined Network



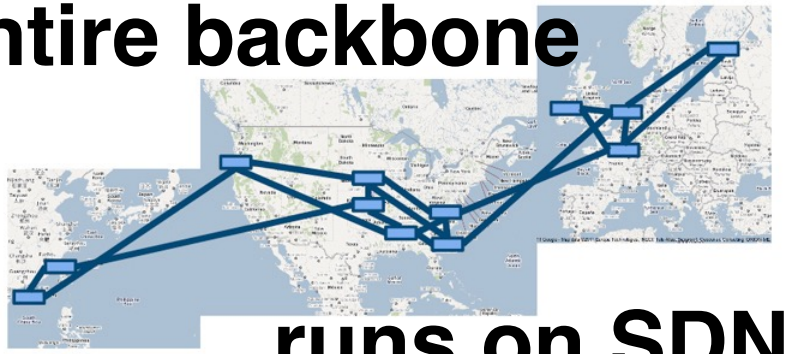
SDN: A Major Trend in Networking

OPEN NETWORKING FOUNDATION

Deutsche Telekom · facebook · Goldman Sachs · Google · Microsoft · NTT Communications · verizon · YAHOO!

Google

Entire backbone



runs on SDN

nicira

Bought for $1.2 x 10^9 (mostly cash)

SDN in Google

Washington
Montana
Minnesota
Ontario
Quebec
Wisconsin
Michigan
New York
Pennsylvania
Ohio
Nevada
California
Arizona
New Mexico
Texas
Louisiana
Florida
Mexico
Shanghai
Hangzhou
Fuzhou
Guangzhou
Changsha
Philippines
Philippine Sea
South China Sea
Norge
Polska
France
España
Portugal
Italia
Ελλάς
Latvija
Lietuva
Eesti
Belarus
Moldova
Ukraine
Slovenska
Magyarország
Romania
Hrvatska
Slovenija
Österreich
Deutschland
Czech Rep.
Cymru
Ireland
Danmark
Sverige
Suomi
Island
Cyprus
Türkiye
Bulgaria
Ελλάς
Tyrrhenian Sea
North Sea
Baltic Sea
Gulf of Bothnia
Gulf of Mexico
North Atlantic Ocean
Caribbean Sea
Cuba
Dominican Republic
Haiti
Jamaica
Belize
Guatemala
Honduras
Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Saskatchewan
Newfoundland and Labrador
Nova Scotia
New Brunswick
Maine
Vermont
New Hampshire
Massachusetts
North Dakota
South Dakota
Nebraska
Kansas
Oklahoma
Arkansas
Tennessee
Kentucky
Indiana
Illinois
Iowa
Missouri
Alabama
Georgia
Mississippi
Virginia
West Virginia
Delaware
Maryland
Nuevo Leon
Tamaulipas
Sonora
Chihuahua
Coahuila
Durango
Zacatecas
Sinaloa
Baja California
Baja California Sur
Nayarit
Jalisco
Guerrero
Oaxaca
Tabasco
Yucatan
Quintana Roo
Campeche
Chiapas
Veracruz
Puebla
Hidalgo
Tlaxcala
Morelos
Michoacan
Guanajuato
San Luis Potosi
Aguascalientes
Tamaulipas
Hebei
Shanxi
Shandong
Henan
Jiangsu
Anhui
Hubei
Sichuan
Guangxi
Guangdong
Hunan
Jiangxi
Zhejiang
Fujian
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Tianjin
Beijing
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Jilin
Heilongjiang
Inner Mongolia
Gansu
Shaanxi
Ningxia
Qinghai
Xinjiang
Tibet
Yunnan
Guizhou
Hong Kong
Macao
Korea
Japan
Kyushu
Shikoku
Chugoku
Kansai
Chubu
Kanto
Tohoku
Hokkaido
Okinawa
Taipei
Kaohsiung
Taichung
Tainan
Hualien
Taitung
Nagoya
Osaka
Fukuoka
Sapporo
Tokyo
Yokohama
Kyoto
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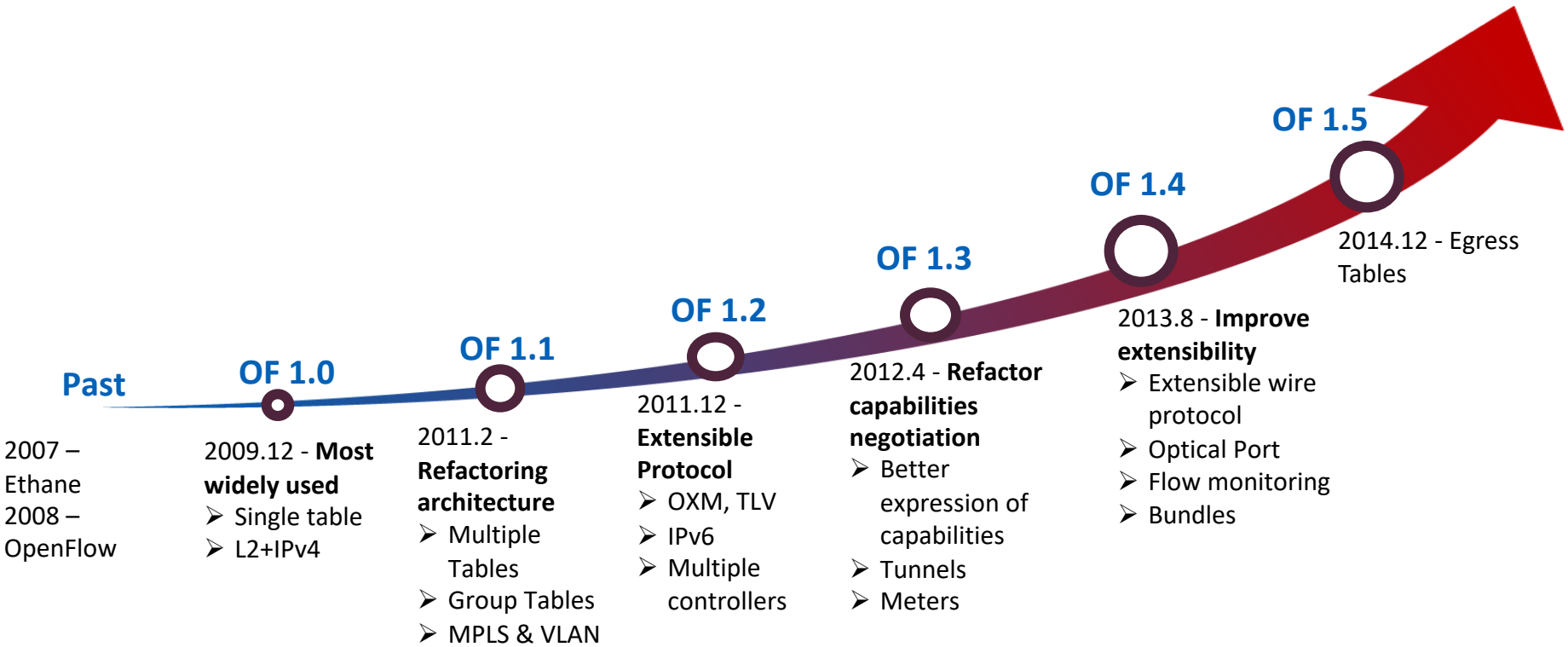
Sendai
Niigata
Kanazawa
Matsuyama
Kagoshima
Naha
Pusan
Taegu
Kwangju
Taejon
Inchon
Seoul
Pyongyang
Kaesong
Nampo
Wonsan
Hamhung
Chongjin
Sinuiju
Shenyang
Dalian
Changchun
Harbin
Qingdao
Jinan
Zhengzhou
Wuhan
Nanjing
Hefei
Changsha
Nanchang
Kunming
Chengdu
Chongqing
Lhasa
Urumqi
Lanzhou
Xi'an
Taiyuan
Shijiazhuang
Tianjin
Beijing
Hong Kong
Macao
Taipei
Kaohsiung
Taichung
Tainan
Hualien
Taitung

OpenFlow Versions

Version	Date	Statistics	Matches	Actions	Instructions	Ports
OF 1.0	Dec 2009	Per table/flow/port/queue	**12/**	13/	1	8
OF 1.1	Feb 2011	Group/Action bucket	**15/**	32/	0	8
OF 1.2	Dec 2011	--	**36/**	51/	5	8
OF 1.3	Jun 2012	Per flow meter	**40/**	58/	6	8
OF 1.4	Oct 2013	Optical port properties	**41/**	59/	6	8



Roadmap

- Introduction (1 lecture)
- Network Fundaments (2 lectures, 1 homework)
  - Components, layering, routing, switching
- Modern Networks (3 lectures, 1 homework)
  - Internet, virtualization, Mininet
- Software Defined Network (3 lectures, 3 labs)
  - OpenFlow data plane, SDN controller, P4
- Network Verification (2 lectures, 1 lab)
  - Data plane verification, Control plane verification
- Conclusion (1 lecture)

Grading

- Attendance (10%)
- Homework (20%)
  - 2 homework, each accounting for 10%
- Lab (70%)
  - 3-4 labs, including a final project (30%)
  - Grading based on lab report and **live demo for TA**
  - Be prepared for a heavy workload say 5-10 hours for each lab

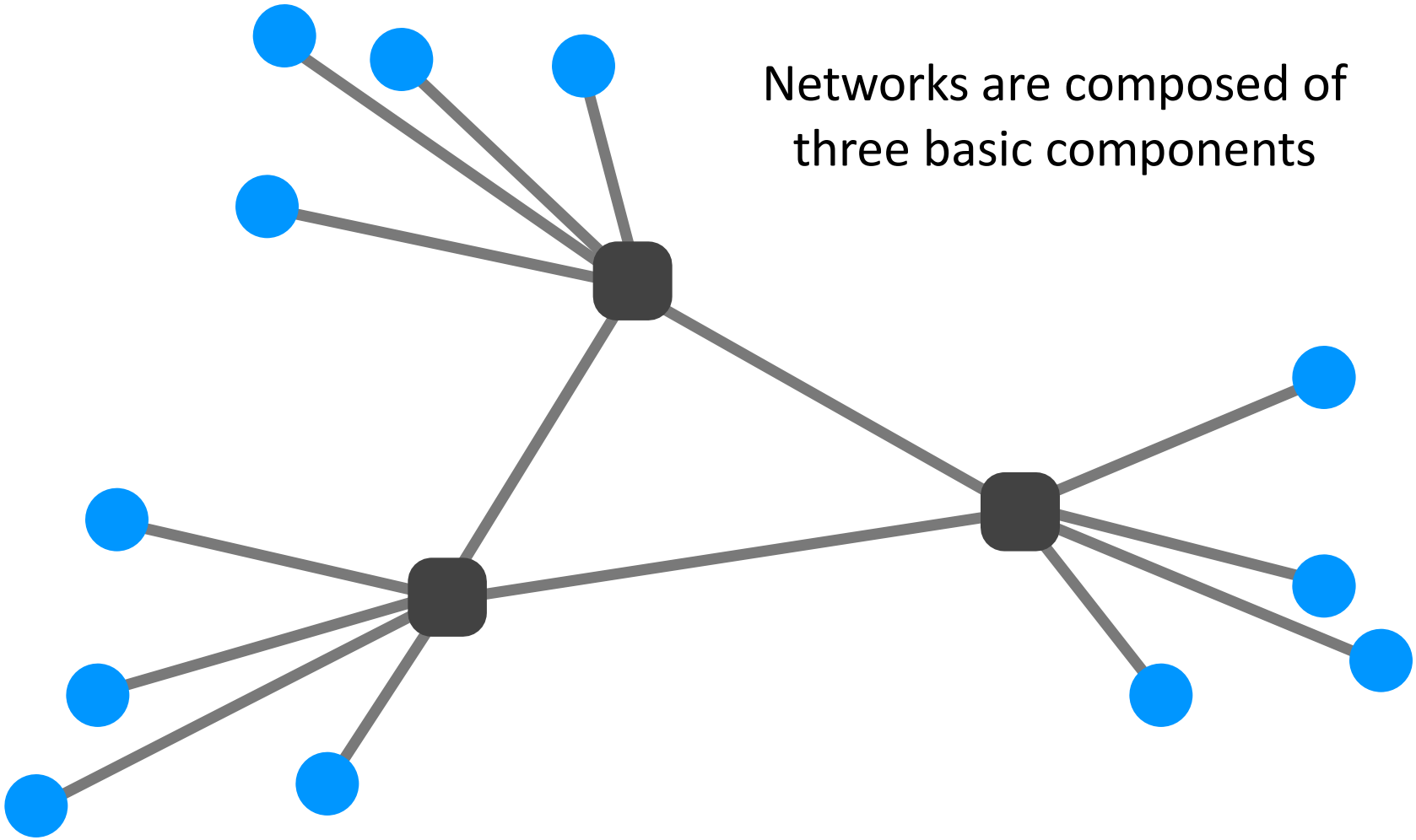
Network Fundamentals

Peng Zhang
School of Computer Science and Technology
Xi'an Jiaotong University

Spring 2024

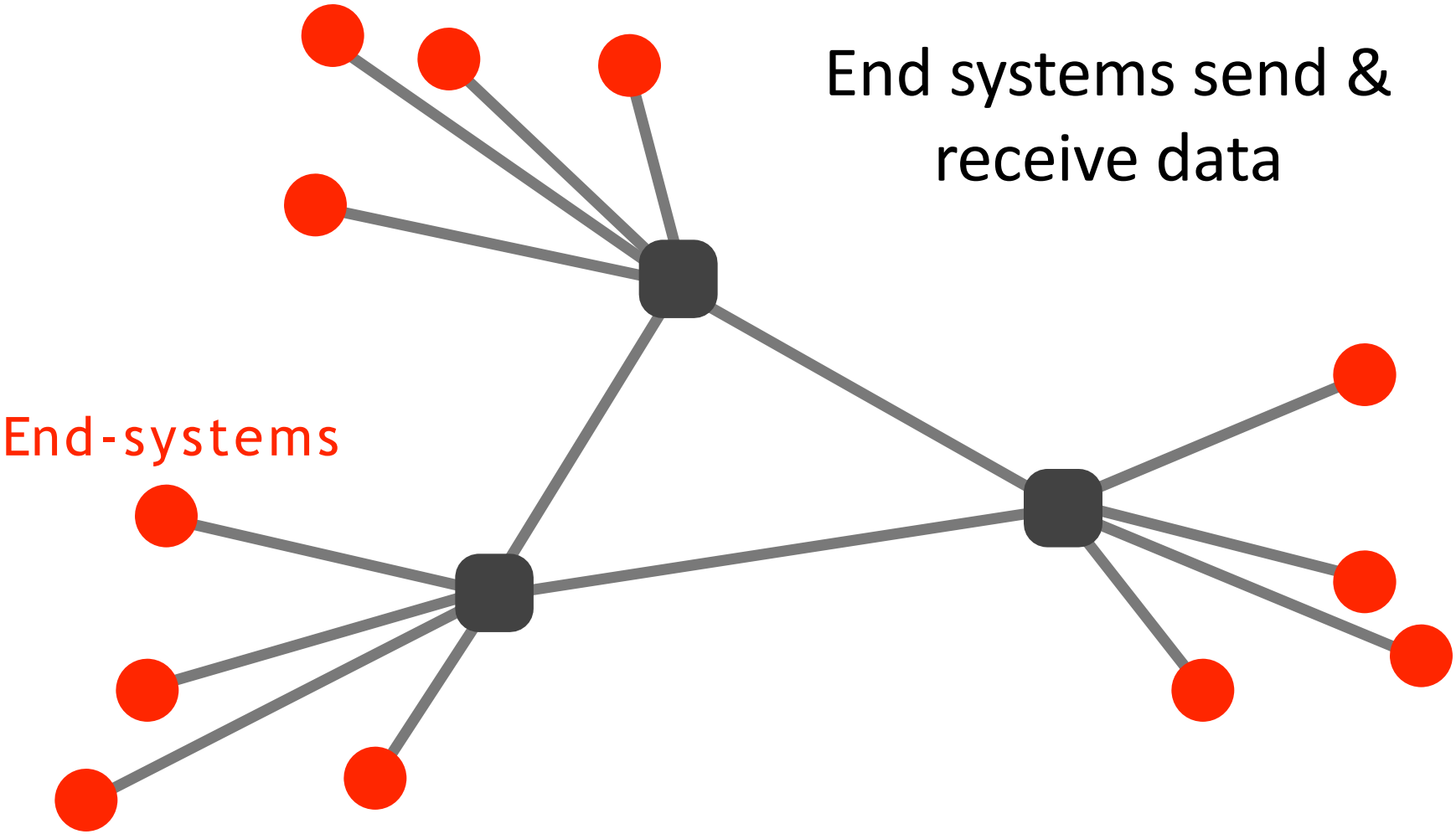
1. What is the Network Made of?

What is the Network Made of?



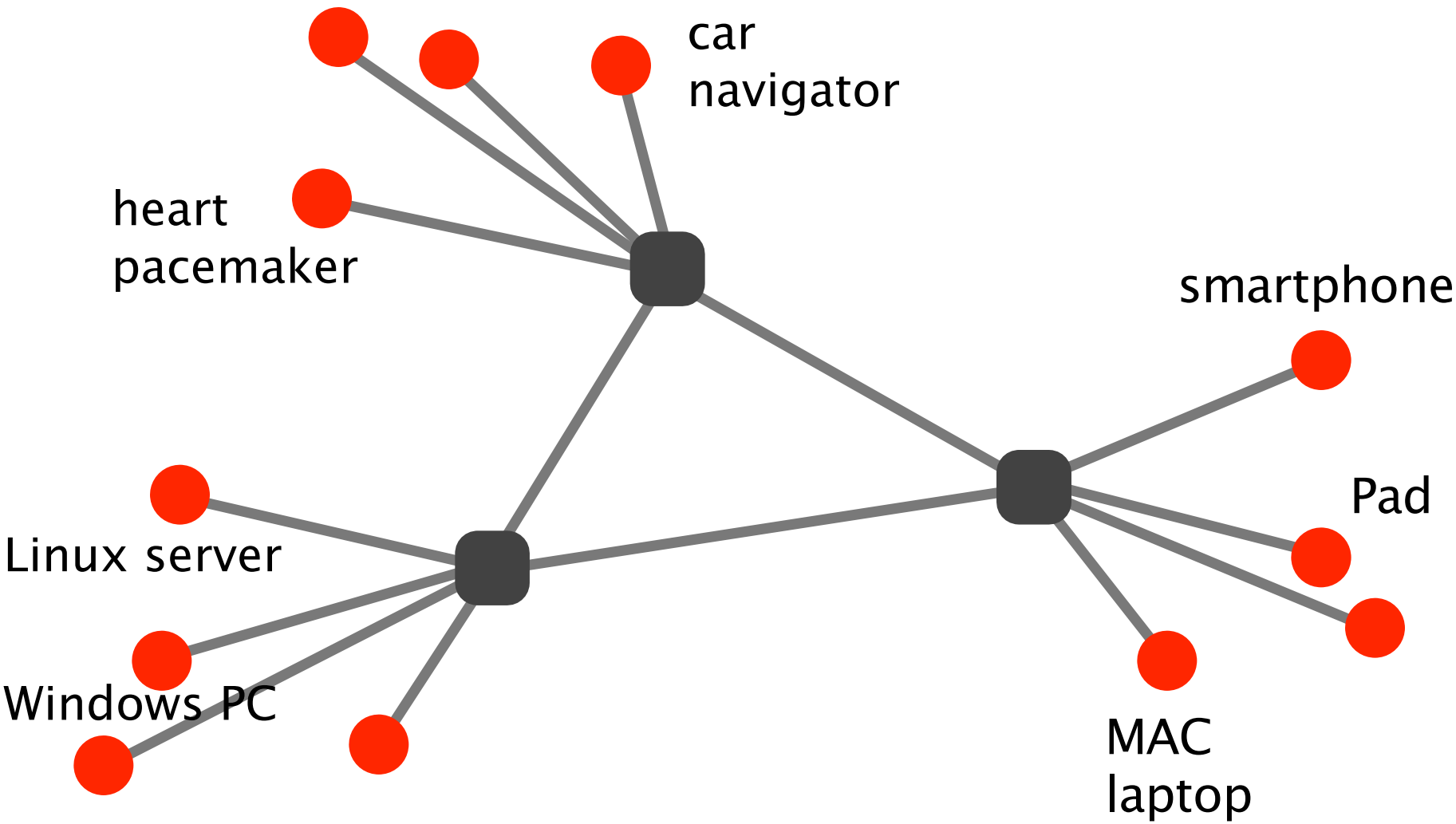
Networks are composed of three basic components

What is the Network Made of?



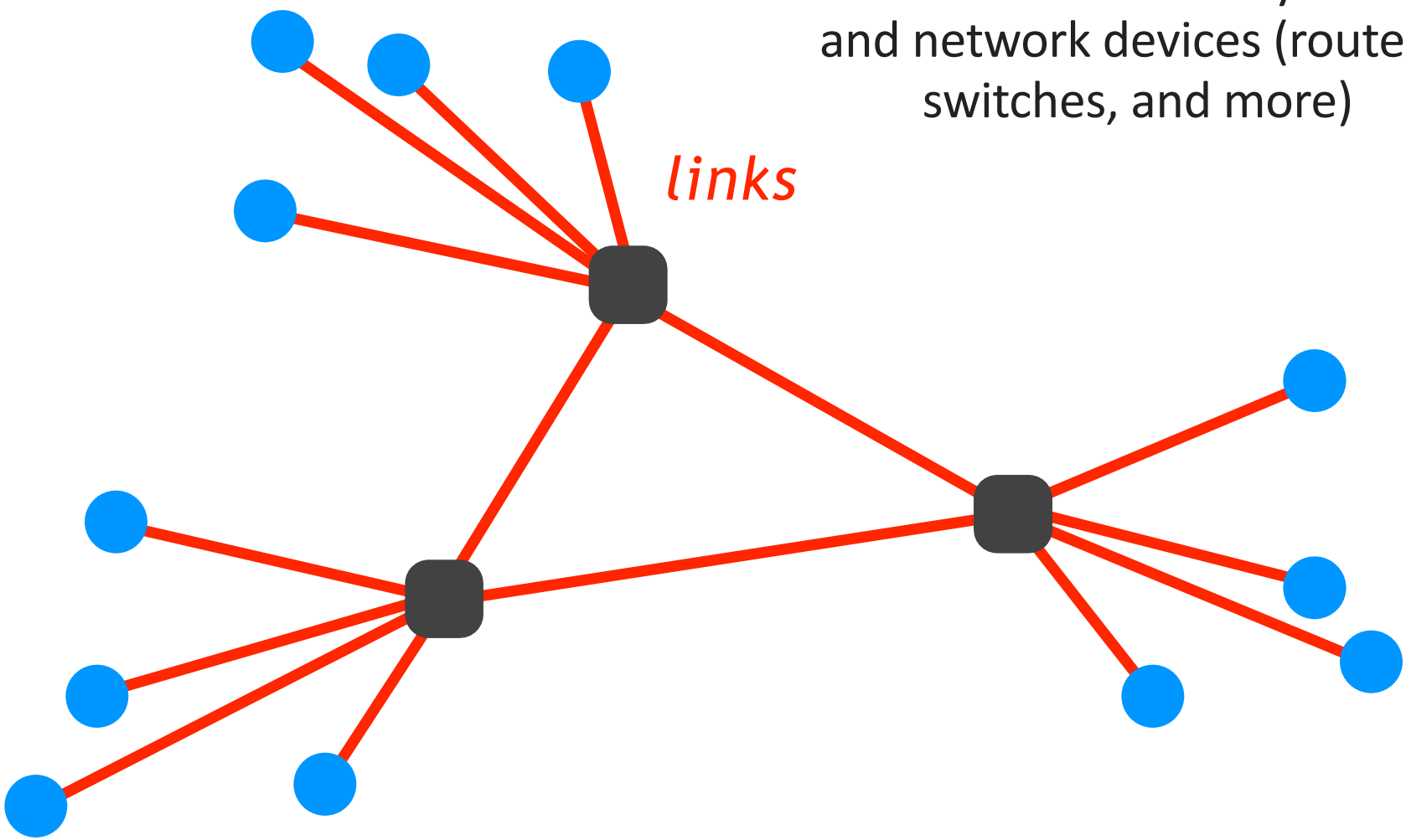
What is the Network Made of?

End-systems come in a wide-variety



What is the Network Made of?

Links connect end-systems and network devices (routers, switches, and more)

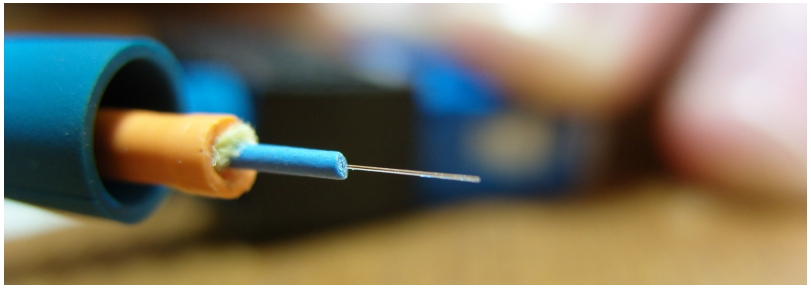


What is the Network Made of?

Links, too, vary in size and usage

Copper

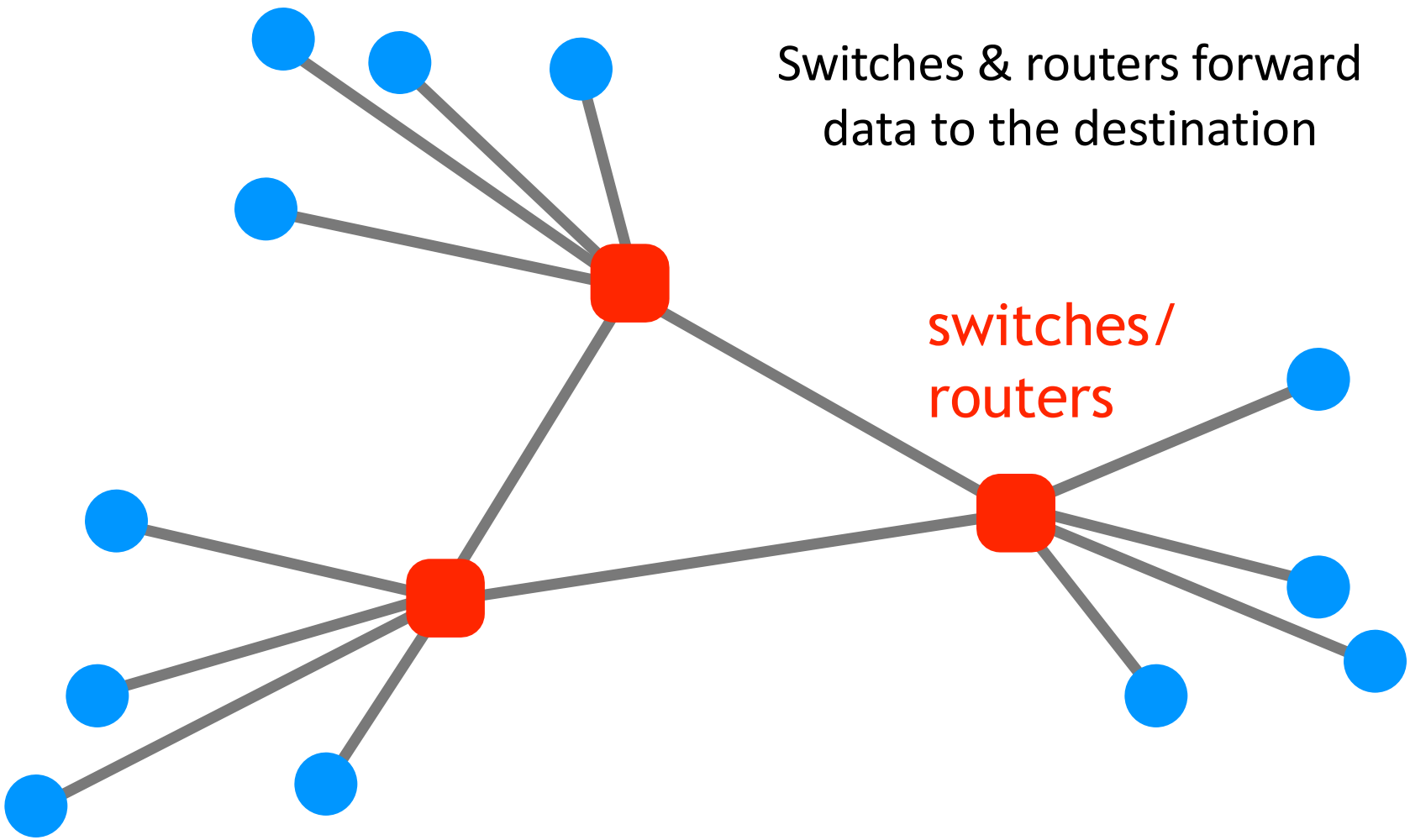
ADSL, RJ-45…



Optical fibers

Wireless link

What is the Network Made of?



Switches & routers forward data to the destination

What is the Network Made of?

Routers/switches vary in size and usage

Home router

~20 cm

0,5 kg

1 Gbps

Internet core router

>200cm

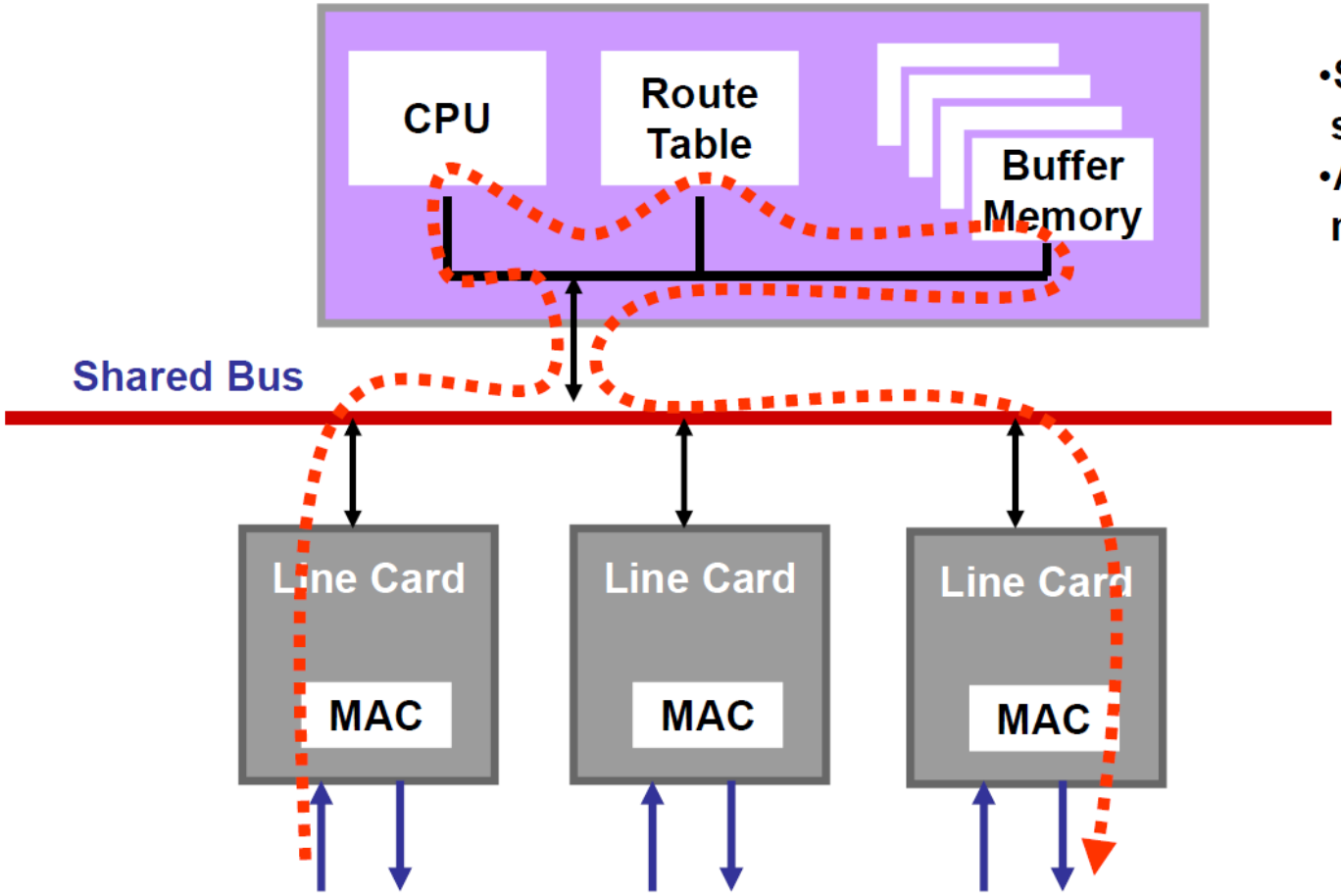
700kg

>12 Tbps

(>920 Tbps in multi-chassis*)

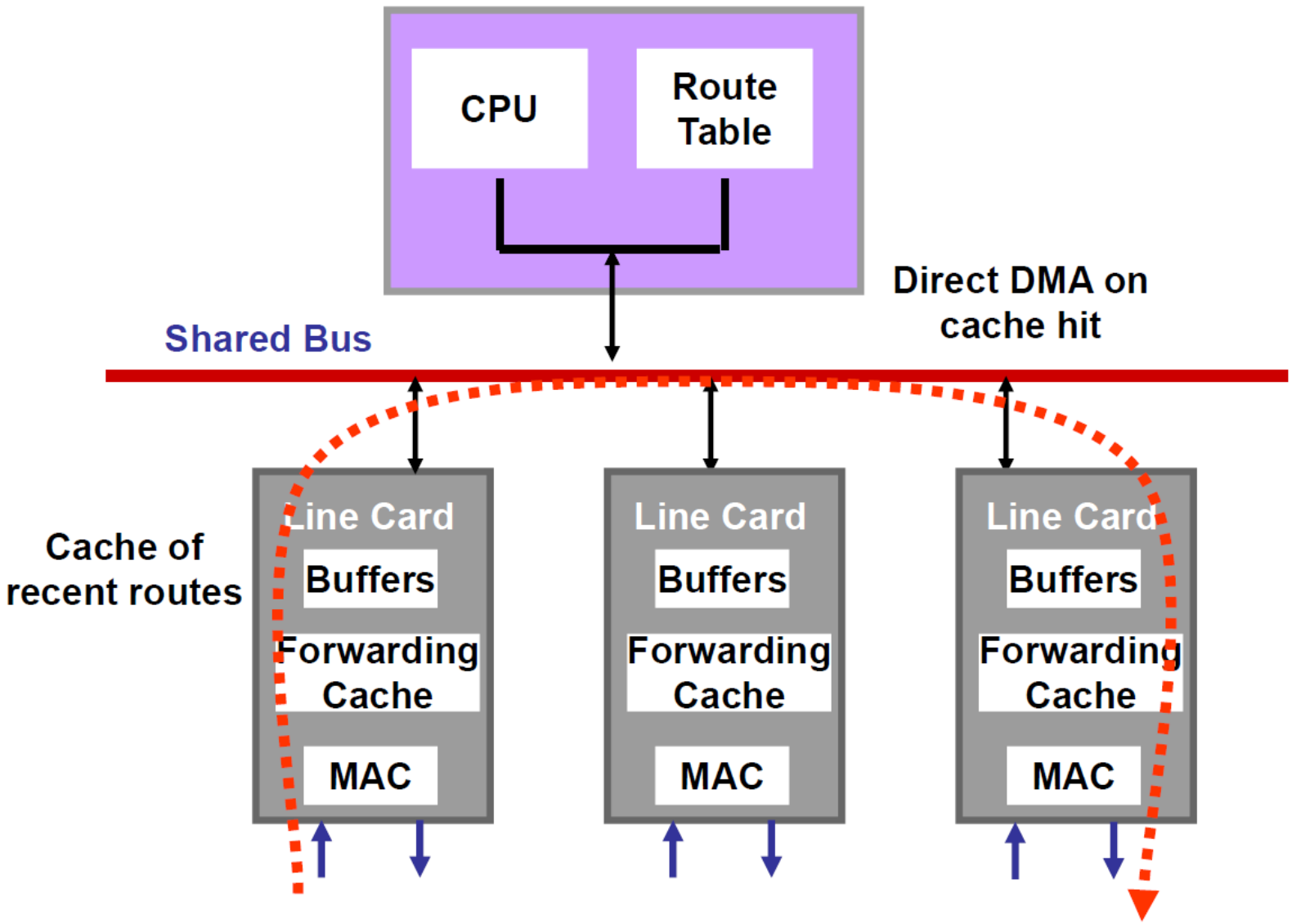
2. What’s Inside a Router?

First Generation Routers

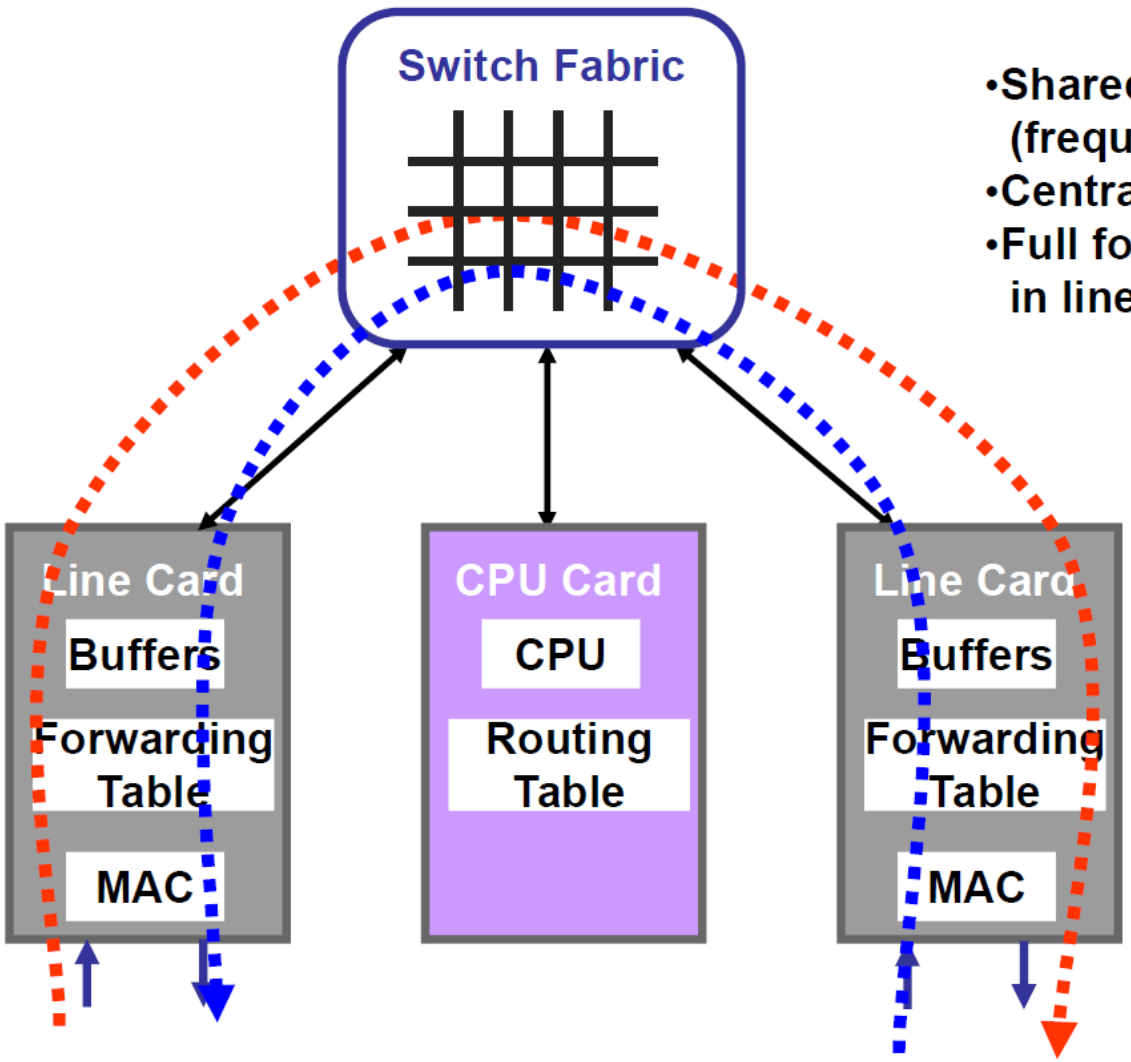


- Single CPU and shared memory;
- All classification by main CPU

Second Generation Routers



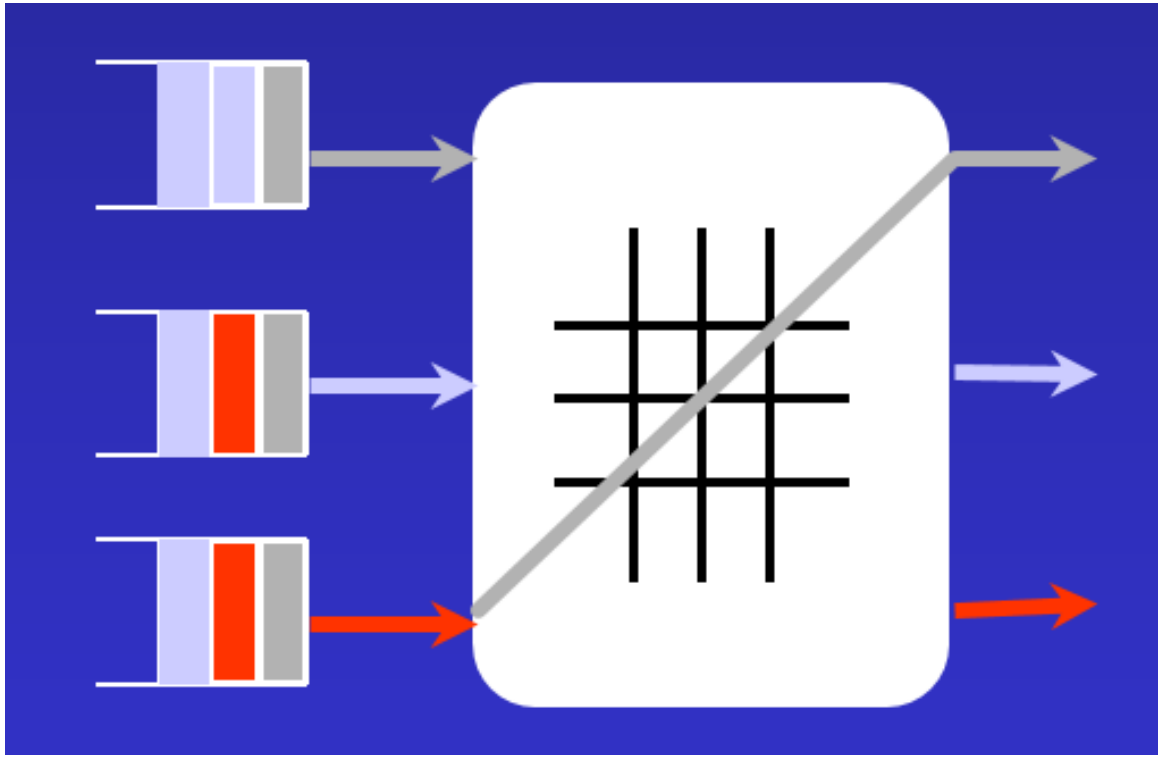
Third Generation Routers



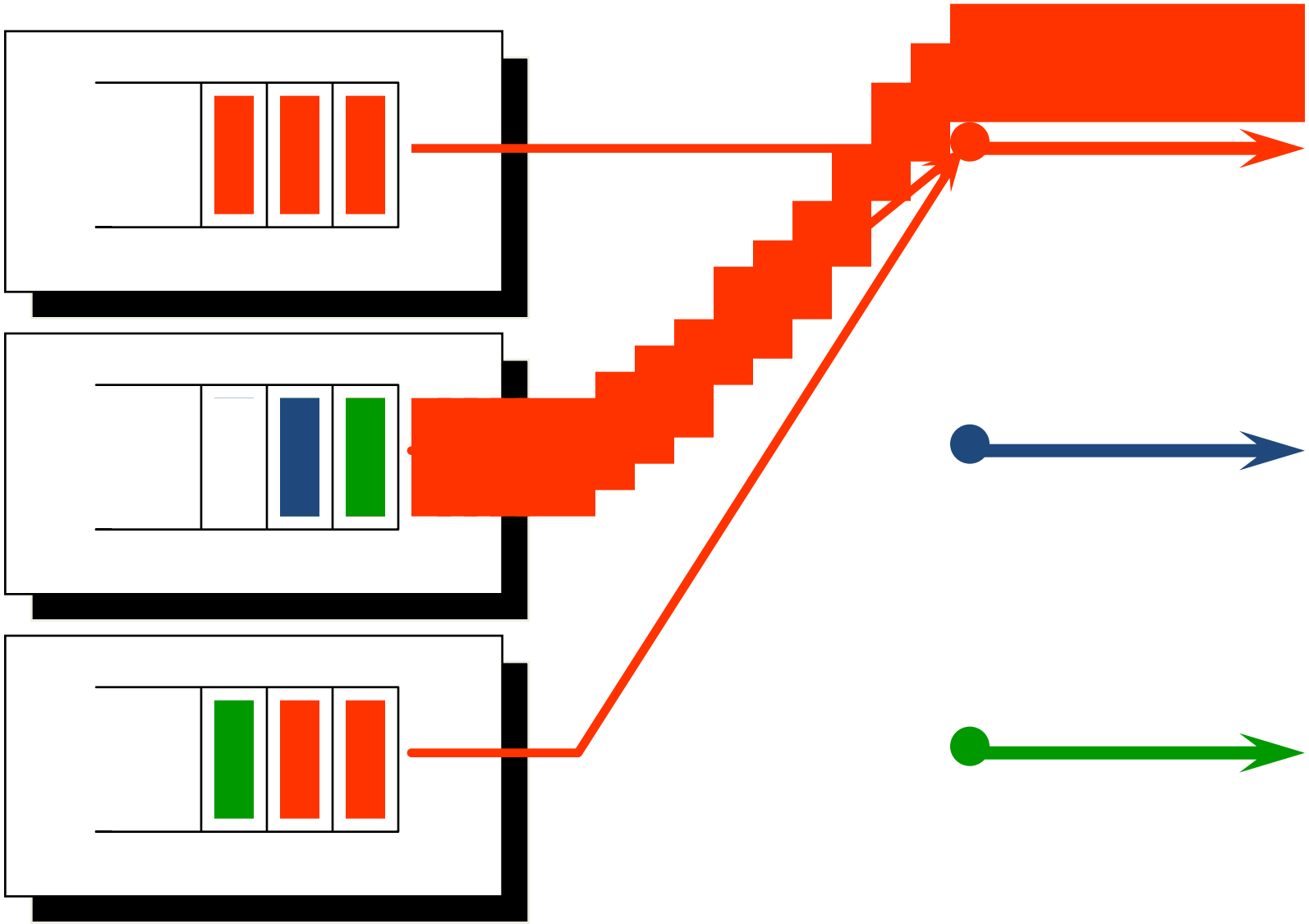
- Shared interconnect (frequently crossbar)
- Centralized scheduler
- Full forwarding table in line card

Contention

- What if packets from different input ports contend for the same output port?

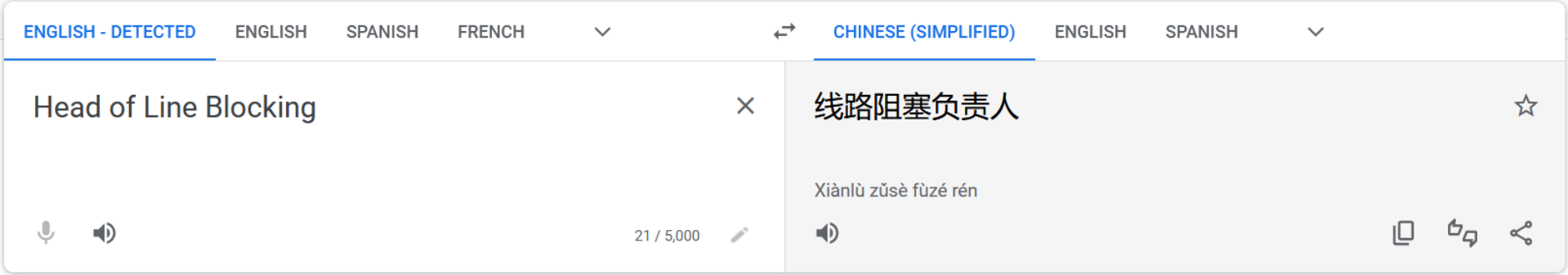


Head of Line Blocking（HOLB）

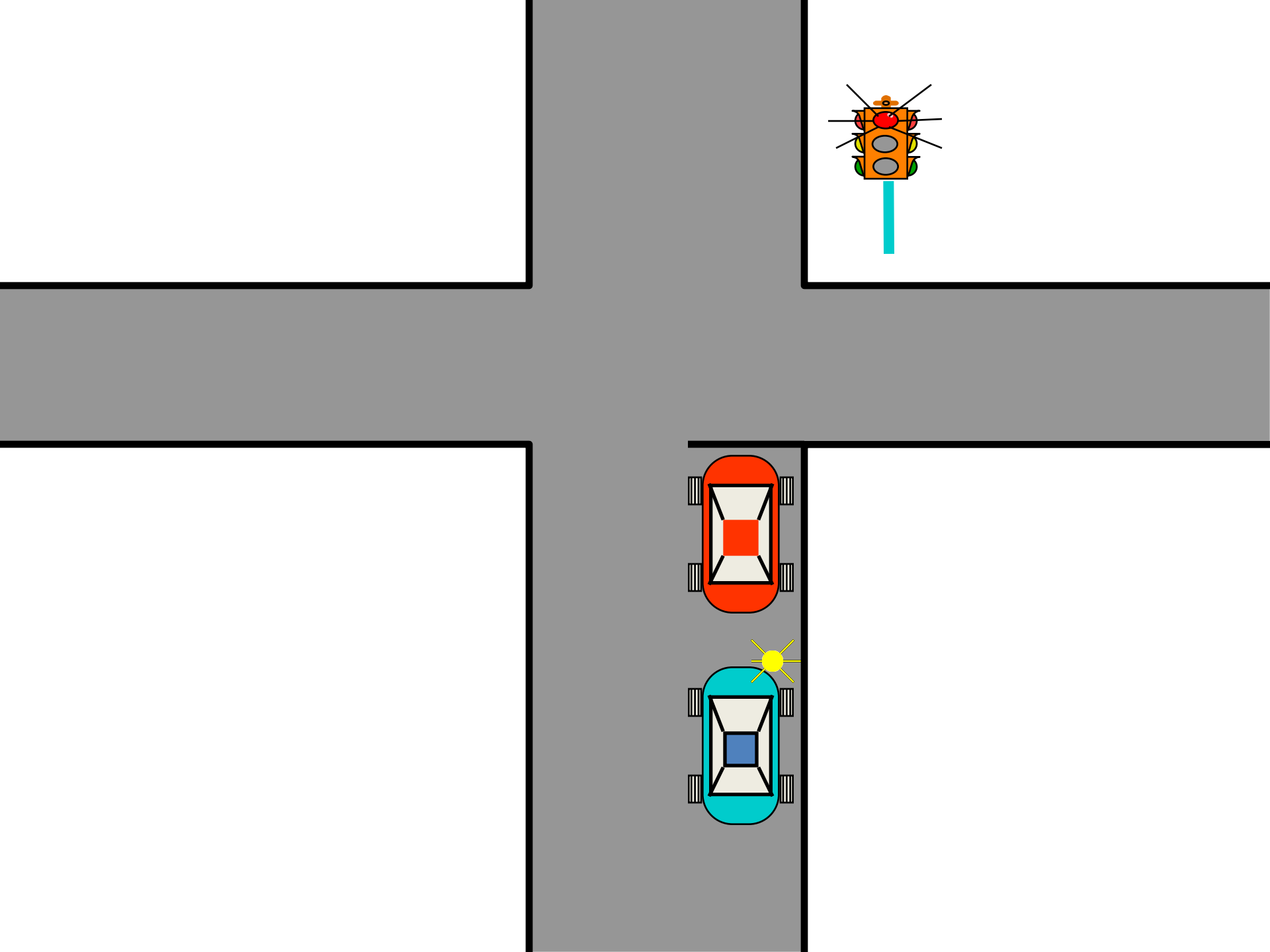


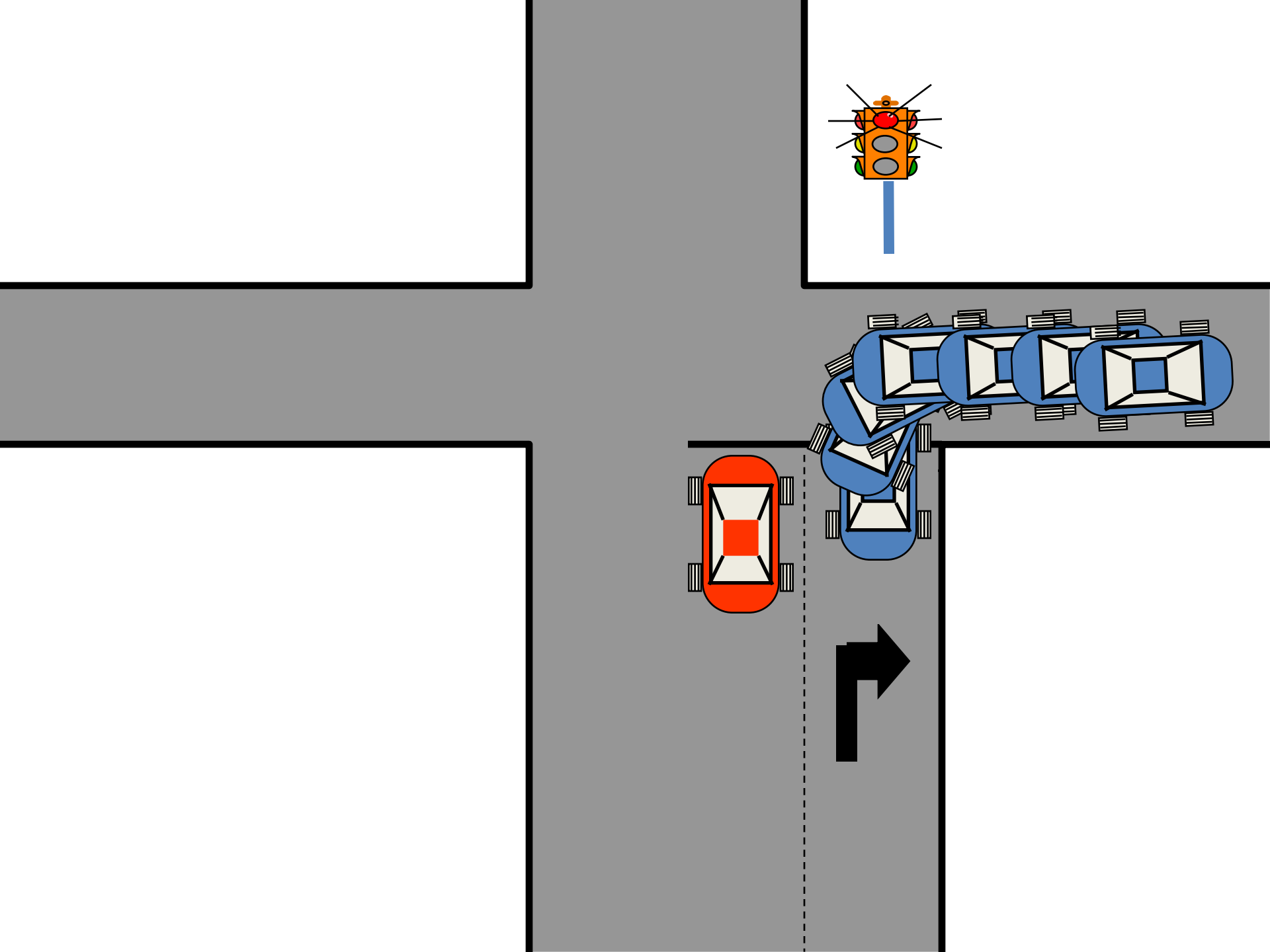
Head of Line Blocking（HOLB）

- Translate: 队列头阻塞
- From Google Translate:

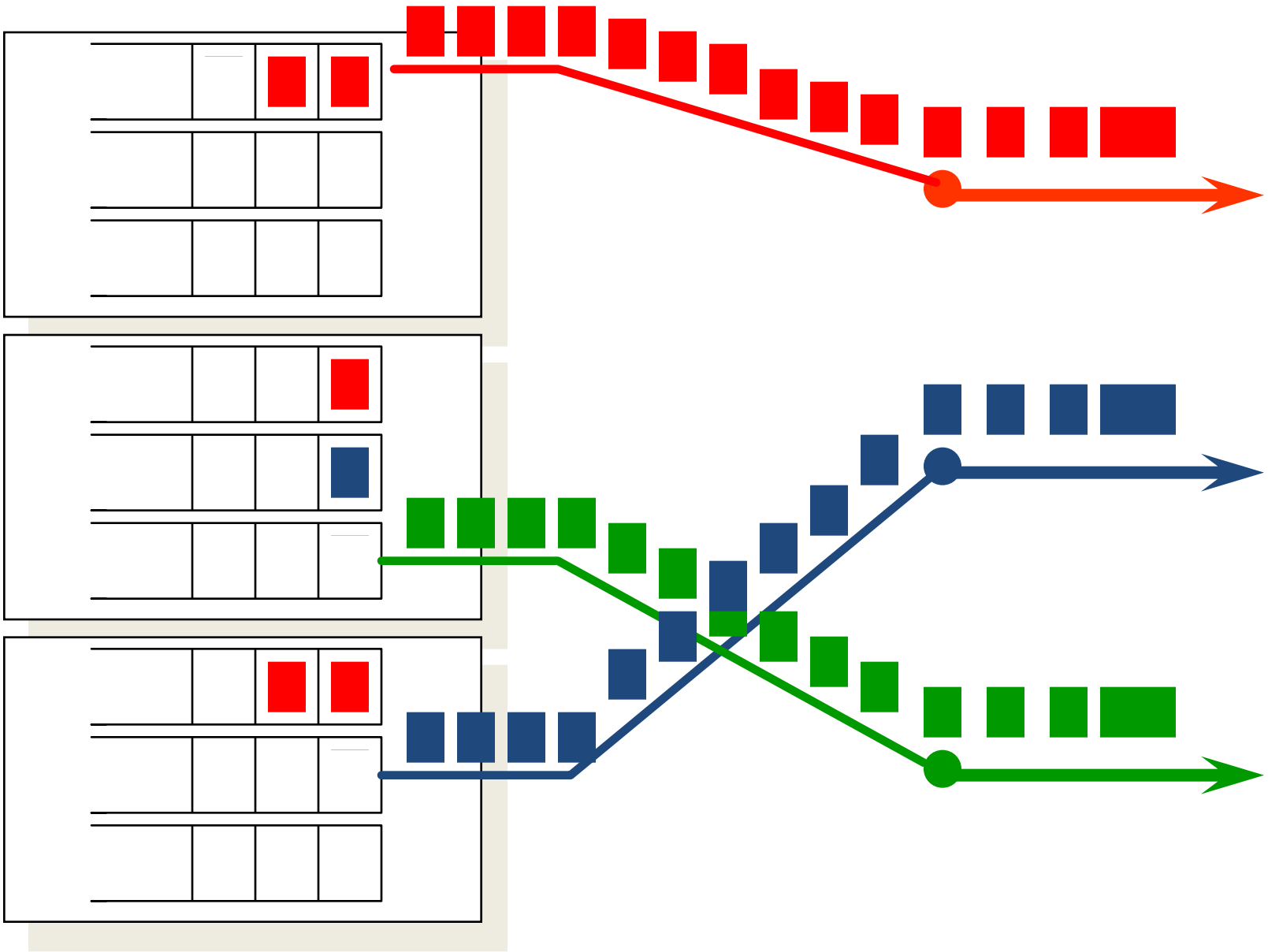


Any Solutions?





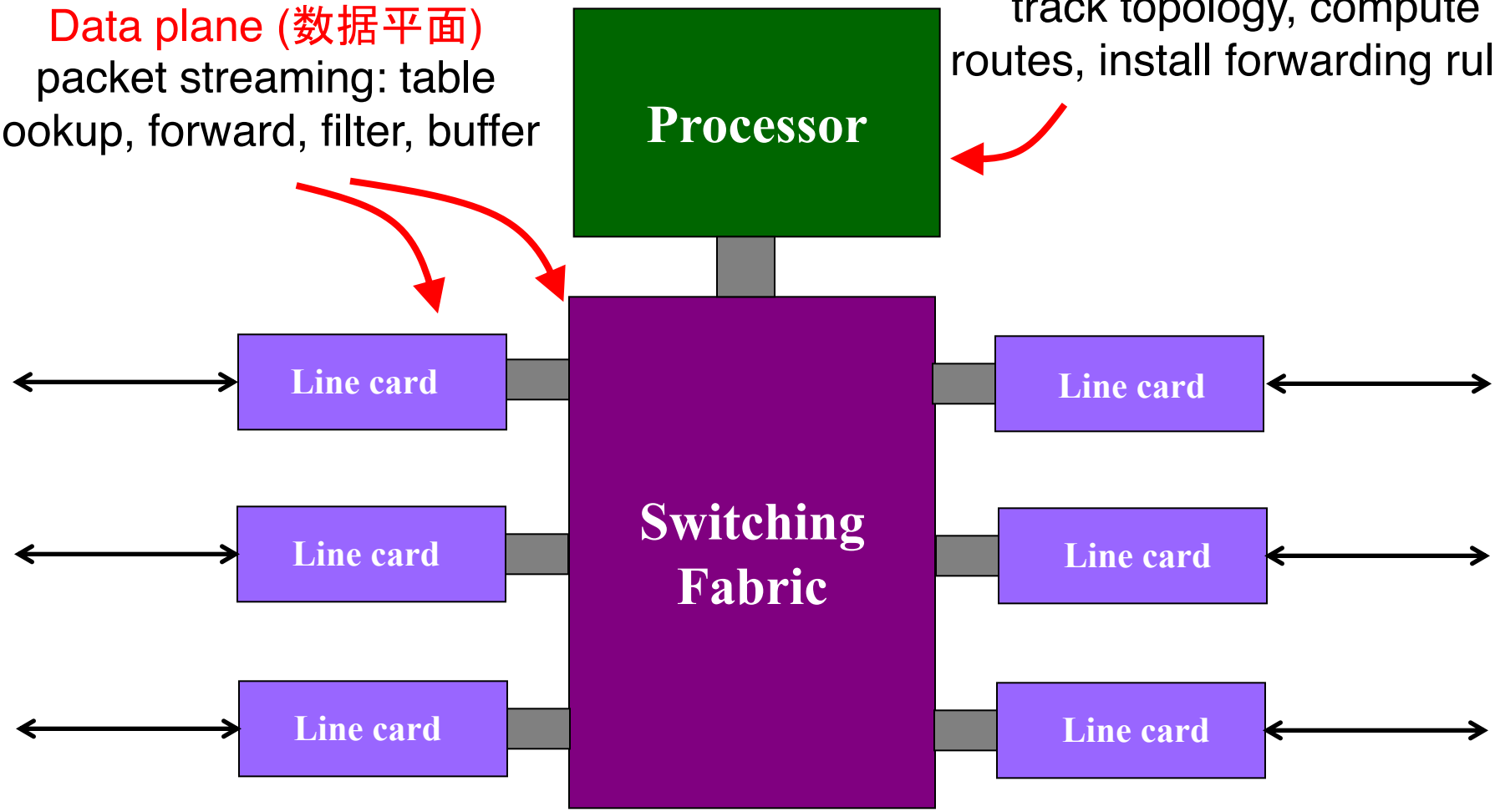
Virtual output queues (VOQs)



Control Plane vs. Data Plane

Control plane（控制平面）:
distributed algorithms:
track topology, compute
routes, install forwarding rules

Data plane (数据平面)
packet streaming: table
lookup, forward, filter, buffer



3. How Router and Switch Work?

Layering

The classical 5 layers

	layer	service provided:
L5	Application	network access
L4	Transport	end-to-end delivery (reliable or not)
L3	Network	global best-effort delivery
L2	Link	local best-effort delivery
L1	Physical	physical transfer of bits

Layering

Each layer communicates with a unit of data

	layer	role
L5	Application	exchanges messages between processes
L4	Transport	transports segments between end systems
L3	Network	moves packets around the network
L2	Link	moves frames across a link
L1	Physical	moves bits across a physical medium

Layering

Each layer has some protocols

	layer	protocol
L5	Application	HTTP, SMTP, FTP, SIP, …
L4	Transport	TCP, UDP, SCTP
L3	Network	IP
L2	Link	Ethernet, Wifi, (A/V)DSL, WiMAX, LTE, …
L1	Physical	Twisted pair, fiber, coaxial cable, …

Layering

Each layer provide service to the layer above using the service provided by the layer directly below it

Applications

...built on...

Reliable (or unreliable) transport

...built on...

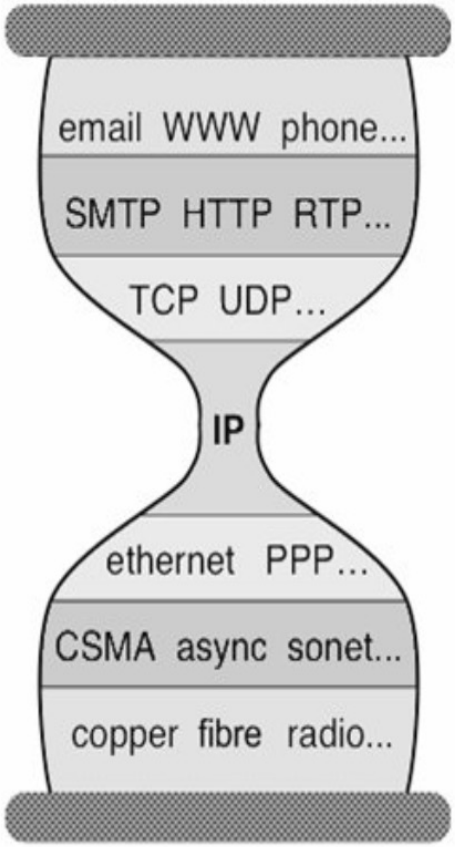
Best-effort global packet delivery

...built on...

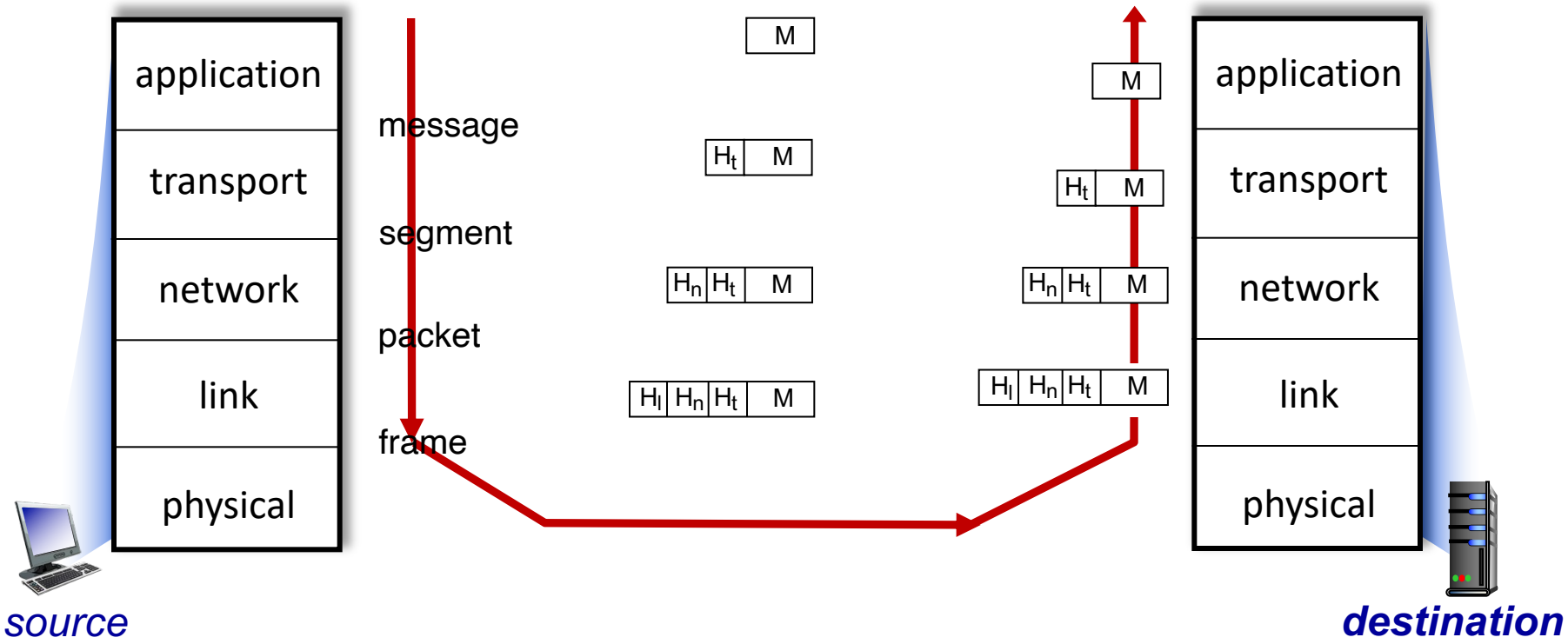
Best-effort local packet delivery

...built on...

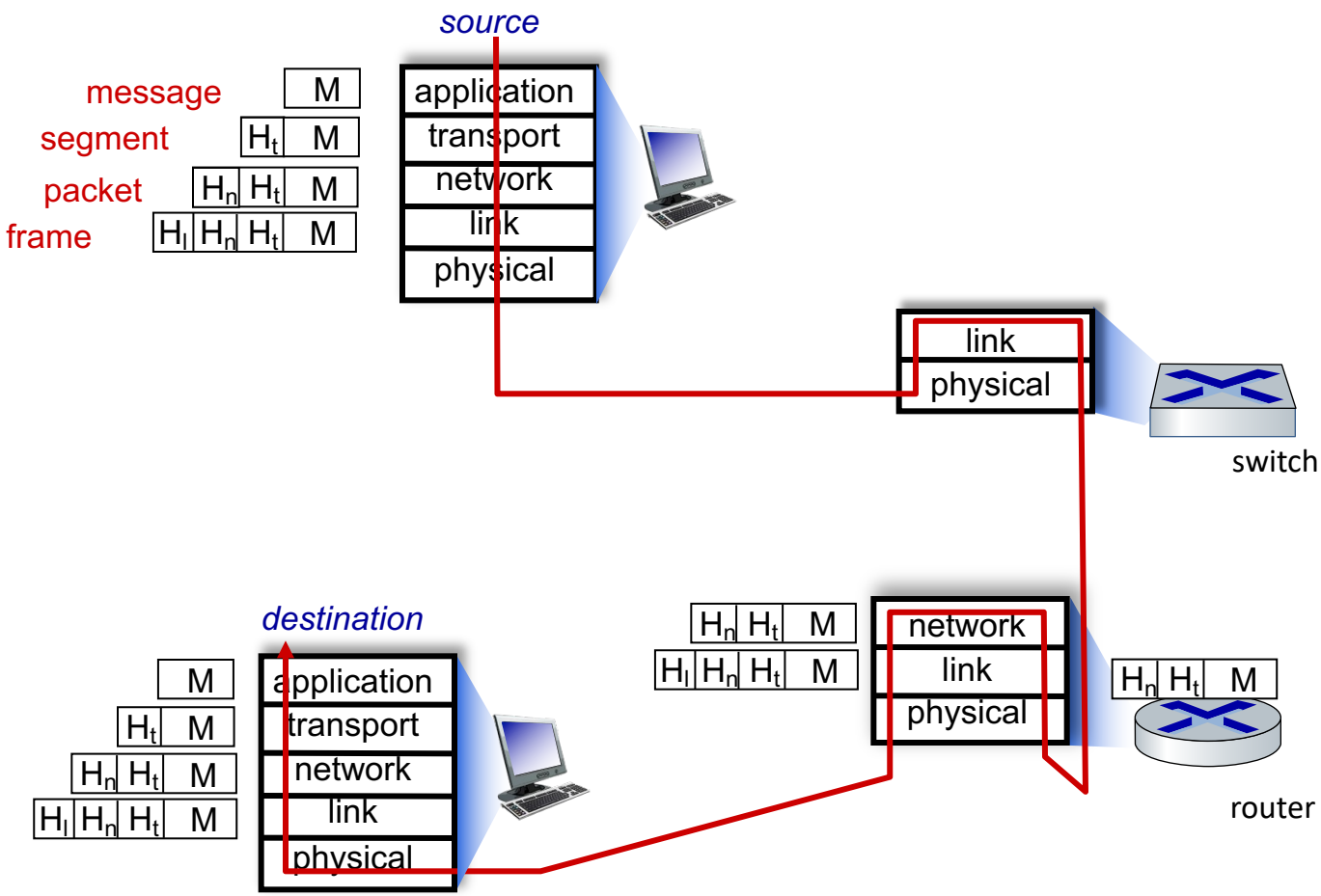
Physical transfer of bits



Layering


application
transport
network
link
physical
message
segment
packet
frame
M
H_t M
H_n H_t M
H_l H_n H_t M
M
H_t M
H_n H_t M
H_l H_n H_t M
application
transport
network
link
physical
source
destination

Encapsulation: an end-end view



软件定义网络2024

群号: 703495959

Password: xjtusdn24