网络思维-2
连通性，协议栈

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提纲

- 网络思维概述
- 名词术语
- 网页编程

- 连通性
  - 名字空间
  - 网络拓扑
- 协议栈
  - 分组交换
  - Web over Internet

- 网络效应与职业素养

课件中包含教科书未包括的素材引用，特此致谢

Acu-Exams-CP

计算机科学导论的三位教师
孙晓明 徐志伟 张家琳 有什么合作关系？

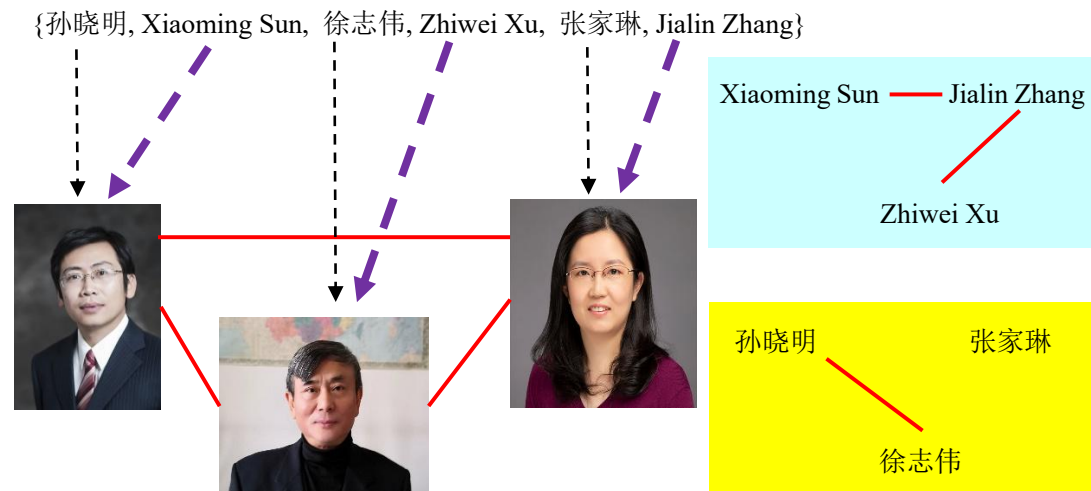# 提纲

- 连通性
  - 名字空间
  - 网络拓扑
- 协议栈
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  - Web over Internet

Acu-Exams-CP

计算机科学导论的三位教师
孙晓明 徐志伟 张家琳 有什么合作关系？
他们如何合作？如何通信？

{孙晓明, Xiaoming Sun, 徐志伟, Zhiwei Xu, 张家琳, Jialin Zhang}

Xiaoming Sun —— Jialin Zhang

Zhiwei Xu

孙晓明   张家琳

徐志伟

三位老师的合著关系网：
实体网（左）
英文网（右上）、中文网（右下）

1. Connectivity (连通性，互联互通)

- 连通性往往用一个图表示
  - Often expressed as a graph $G = <V, E>$ of two sets
    - Set of nodes (vertices): $V = \{v_1, v_2, \ldots, v_n\}$
    - Set of edges (links): $E = \{e_1, e_2, \ldots, e_m\}$

- Connectivity studies *naming* and *topology* problems
  - Naming: How to name the nodes of a network? How to find a specific node? How to refer to a specific node? 如何命名网络的节点、发现节点、指向节点？
  - How are the nodes interconnected? Does the network structure change over time?

    网络拓扑如何变化？

- Undirected
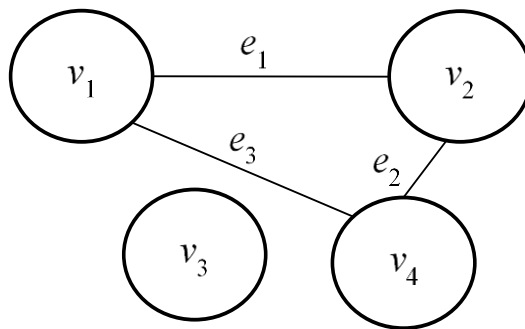- $V = \{v_1, v_2, v_3, v_4\}$
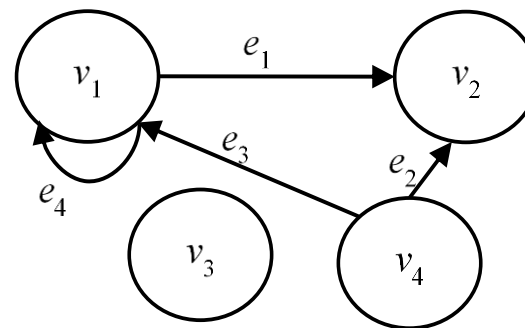- $E = \{e_1, e_2, e_3\}$
- Directed
- $V = \{v_1, v_2, v_3, v_4\}$
- $E = \{e_1, e_2, e_3, e_4\}$

undirected graph

directed graph

1.1 Naming 命名与名字空间

- Every network has one or more **namespaces**
  - Consisting of all names specified by a naming scheme
    - Naming scheme: a function mapping a legitimate string to a node or an edge
    - 一个名字是一个合规字符串

1.1 Naming 命名与名字空间

- Every network has one or more **namespaces**
  - Consisting of all names specified by a naming scheme
    - Naming scheme: a function mapping a legitimate string to a node or an edge
  - Specified by a standards body 命名方法往往由志愿者社区标准确定
    - Institute of Electrical and Electronics Engineers (IEEE)　　国际电气与电子工程师协会
    - Internet Engineering Task Force (IETF)　　　　　　　　国际互联网工程任务组
    - World Wide Web Consortium (W3C)　　　　　　　　　万维网联盟

Namespace	Instance	Remark on naming schemes
Personal name	Joan Smith	Personal names in a country
WeChat user	中关村民	Any legitimate string per WeChat standard
URL	cs101.ucas.edu.cn/中文/	Universal Resource Locator of a webpage
Internet site	www.ict.ac.cn	Any domain name by IETF standards
Email address	zxu@ict.ac.cn	userName@domainName
IP address	159.226.97.84	Internet Protocol address per IETF standards
Phone number	189-6666-8888	11 decimal digits by Telcom provider standards
MAC address	00-1E-C9-43-24-42	12 hexadecimal digits per IEEE standards

命名涉及的三个概念

- **名字**（name）是最广的概念，指代某个实体（entity）
  - 实体往往是网络中的节点，也可以是边
  - 例如，同学们用Go语言编程时使用的变量名 studentGender := 0

- **地址**（address）是可直接用于访问所指代实体的名字
  - 例如，采用地址运算符获得的地址 &studentRank
  - 例如，汇编语言程序看见的内存地址
  - 不是地址的名字需要转换出地址才能直接访问实体

- **标识符**（identifier，ID）是可唯一标识所指代实体的名字
  - 在某个范围内唯一
  - 例如，一个自然人的身份证号
  - 例如，万维网网址 URL

Naming issues and considerations

- *Uniqueness*. Does a name map to a unique node? 唯一性
  - The email address namespace enjoys uniqueness, but the namespace of personal names of a country's population does not have uniqueness. There may be multiple persons named Joan Smith, causing *name conflicts*, which in turn may lead to wrong connections.

- 可与身份证号比较（教科书242页）

Namespace	Name (a legitimate string)	Uniqueness
Personal name 自然人姓名	Joan Smith	?
WeChat user 微信用户名	中关村民	?
URL 万维网网址	cs101.ucas.edu.cn/中文/	?
Internet site 因特网域名	www.ict.ac.cn	?
Email address 电子邮件地址	zxu@ict.ac.cn	?
IP address IP地址	159.226.97.84	?
Phone number 手机号码	189-6666-8888	?
MAC address MAC地址	00-1E-C9-43-24-42	?

Naming issues and considerations

- *Uniqueness*. Does a name map to a unique node?
  - The email address namespace enjoys uniqueness, but the namespace of personal names of a country's population does not have uniqueness. There may be multiple persons named Joan Smith, causing *name conflicts*, which in turn may lead to wrong connections.

Namespace	Name (a legitimate string)	Uniqueness
Personal name	Joan Smith	No
WeChat user	中关村民	No
URL	cs101.ucas.edu.cn/中文/	Yes
Internet site	www.ict.ac.cn	Yes
Email address	zxu@ict.ac.cn	Yes
IP address	159.226.97.84	Yes
Phone number	189-6666-8888	Yes
MAC address	00-1E-C9-43-24-42	Yes

Naming issues and considerations

- *Friendliness*. Are the names user-friendly, i.e., understandable by humans?
  用户友好性：是否对人（用户）友好，便于用户理解？
  - The eight name schemes in Table have roughly decreasing user friendliness
  - "Joan Smith" is much more understandable than "00-1E-C9-43-24-42", which is the name of the network interface circuitry in a computer, also called MAC address

Namespace	Name (a legitimate string)	User Friendliness
Personal name	Joan Smith	Yes
WeChat user	中关村民	Mostly Yes
URL	cs101.ucas.edu.cn/中文/	Somewhat friendly
Internet site	www.ict.ac.cn	Somewhat friendly
Email address	zxu@ict.ac.cn	Somewhat friendly
IP address	159.226.97.84	No
Phone number	189-6666-8888	No
MAC address	00-1E-C9-43-24-42	No

Naming issues and considerations

- *Autonomy*. Can a user create or change a name on his own? 自主性
  - Autonomy has the advantage of convenience, but may lead to chaos
  - One may change a URL, but Web links to the old URL become invalid
  - Creating or modifying a name may need to go through a centralized process
    - Involving an authority of name registry

Namespace	Name (a legitimate string)	Autonomy
Personal name	Joan Smith	?
WeChat user	中关村民	?
URL	cs101.ucas.edu.cn/中文/	?
Internet site	www.ict.ac.cn	?
Email address	zxu@ict.ac.cn	?
IP address	159.226.97.84	?
Phone number	189-6666-8888	?
MAC address	00-1E-C9-43-24-42	?

Naming issues and considerations

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Namespace	Name (a legitimate string)	Autonomy
Personal name	Joan Smith	Yes
WeChat user	中关村民	Mostly Yes
URL	cs101.ucas.edu.cn/中文/	Hierarchically Centralized
Internet site	www.ict.ac.cn	Hierarchically Centralized
Email address	zxu@ict.ac.cn	Hierarchically Centralized
IP address	159.226.97.84	Hierarchically Centralized
Phone number	189-6666-8888	Choose from a centralized pool
MAC address	00-1E-C9-43-24-42	Hierarchically Centralized

Naming issues and considerations

- *Name conversion*. An entity can have two namespaces.
  - The Internet site with domain name www.ict.ac.cn and IP address 159.226.97.84
  - The Domain Name System (**DNS**) converts a domain name to its IP address
    DNS将互联网域名转换为IP地址
    - **http://www.ict.ac.cn ➔ http://159.226.97.84**

- Two types of IP addresses are used today 两类**IP**地址
  - **IPv4 addresses** use **32 bits** and can generate 2^{32} different IP addresses
    - Each IPv4 address is organized as a 4-field format xxx.xxx.xxx.xxx such as 159.226.97.84
      IPv4地址通常写成"."区分开的4个字段，每个从0到255
    - Each field is a decimal number from 0 to 255   159.266.97.84是非法的

Naming issues and considerations

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      IPv4地址通常写成".""区分开的4个字段
    - Each field is a decimal number from 0 to 255   159.266.97.84是非法的
  - **IPv6 addresses** use **128 bits** and can generate 2^{128} different IP addresses
  - *** Each IPv6 address is an 8-field format (colon-hexadecimal form)
    xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
    such as 2001:0db8:85a3:0000:0000:8a2e:0370:7334
  - ***IPv6地址通常写成":""区分开的8个字段，每个包含4个Hex数

Naming issues and considerations

- *Name conversion*. An entity can have two namespaces.
  - The Internet site with domain name www.ict.ac.cn has an IP address 159.226.97.84
  - The Domain Name System (**DNS**) converts a domain name to its IP address
  DNS将互联网域名转换为IP地址
    - **http://www.ict.ac.cn** → **http://159.226.97.84**

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    IPv4地址通常写成"."区分开的4个字段
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  - **IPv6 addresses** use **128 bits** and can generate 2^{128} different IP addresses
    - *** such as 2001:0db8:85a3:0000:0000:8a2e:0370:7334
- IPv4 addresses exhaustion occurred as of November 2019
  - There are $2^{128-32} = 2^{96}$ times as many IPv6 addresses as IPv4 addresses
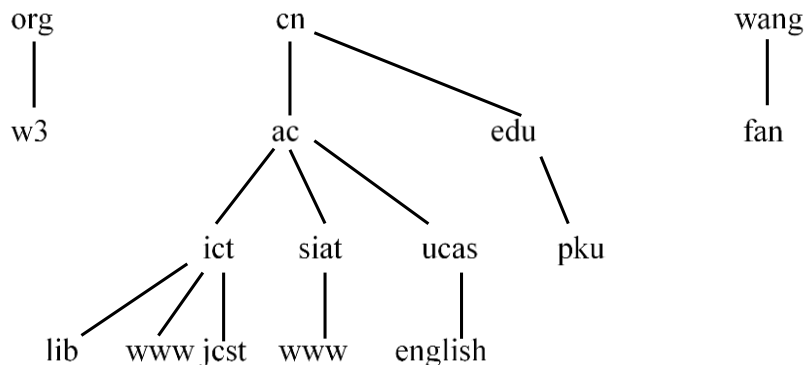 - 2019年11月，全球IPv4地址已穷尽

万维网网址 URL

● Uniform Resource Locator 入门知识

http   ://   cs101.ucas.edu.cn   /中文/

协议   网站（域名或IP地址）   路径

● 其他协议：
  ● file：访问本计算机的文件
  ● ftp：访问互联网上任意计算机的文件
  ● https：安全地访问Web资源
  ● mailto：访问电子邮件地址

# Domain name hierarchy and URL

- 给定域名树，What is the URL of the homepage 首页 of the following institutions?
  - Fan Wang
  - Journal of Computer Science and Technology
  - Peking University
  - Shenzhen Institute of Advanced Technology
  - The World Wide Web Consortium
  - The University of Chinese Academy of Sciences
- Check your answers by accessing the URLs

http **://** **www.ict.ac.cn** **/** **cs101**

Scheme	Host	Path
Protocol Name	Domain Name	A File Path Name
	IP Address	

http   ://   159.226.97.84   /   cs101
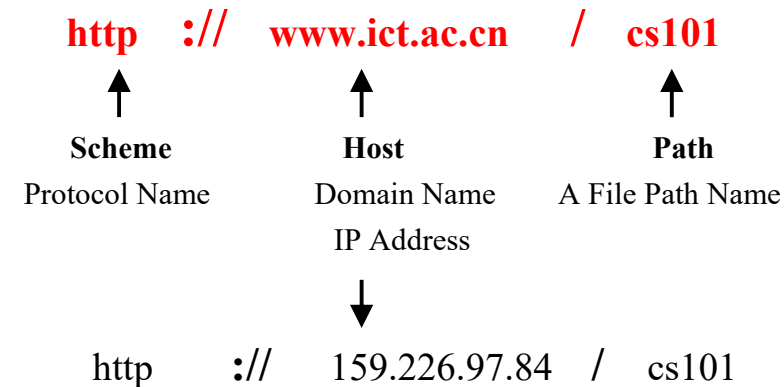
Domain name hierarchy and URL

- What is the URL of the homepage of each of the following institutions? What is the top-level domain?

  - http://fan.wang/   wang   .wang
  - http://jcst.ict.ac.cn/   cn   .cn
  - http://pku.edu.cn/   cn   .cn
  - http://www.siat.ac.cn/   cn   .cn
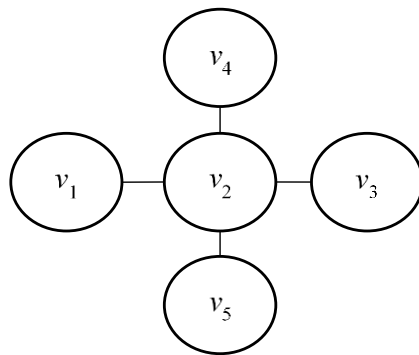 - http://w3.org/   org   .org
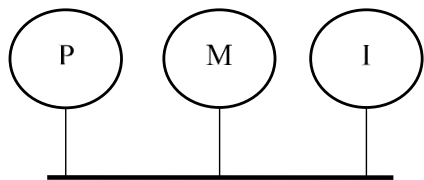 - http://English.ucas.ac.cn   cn   .cn

顶级域名

18
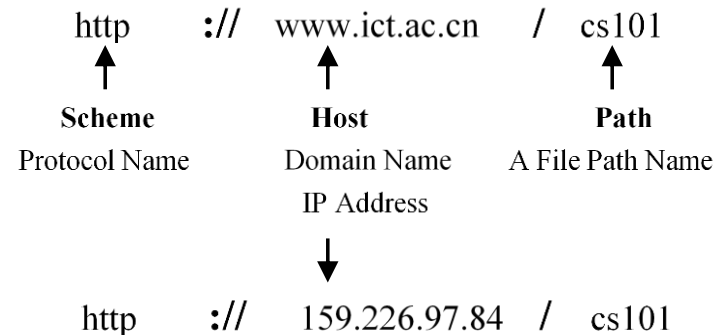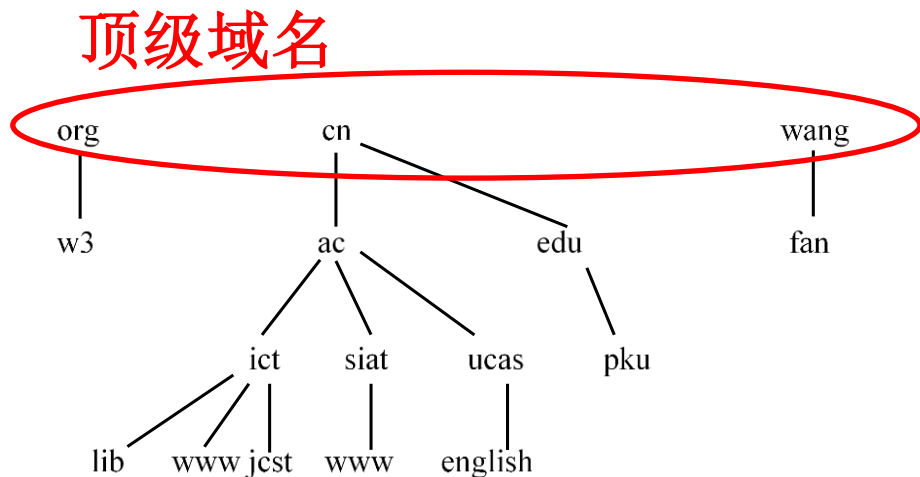
1.2 Topology 网络拓扑——有三类网络

- 静态网络 A **static network** does not change nodes and edges
- 动态网络 A **dynamic network** does not change nodes; may change edges
  - At one moment, the bus connects the processor (P) and the memory (M)
  - At the next moment, the bus connects the memory (M) and an input device (I)
    - The bus supports a *shared-media network*, while the crossbar supports a *switching network*
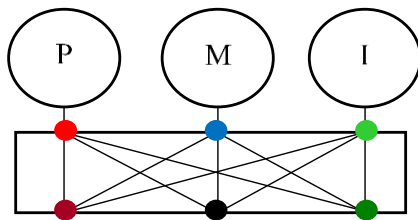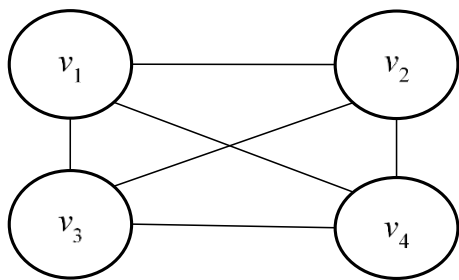   总线：一对一、一对多（广播）；交叉开关：多对多
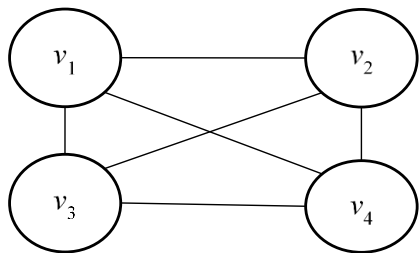
(a) A fully connected graph
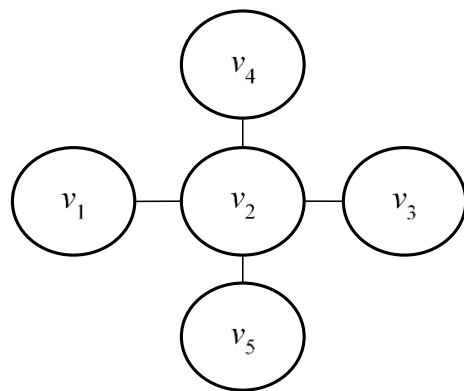
(b) A star network

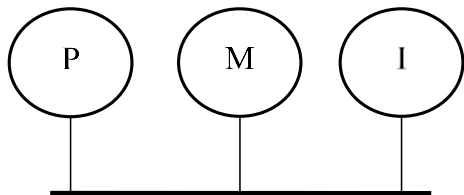Nodes connected by (c) a bus

(d) a crossbar switch

三类网络

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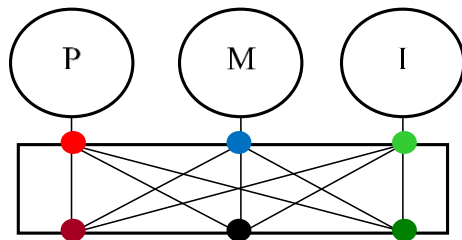- 演化网络 An **Evolutionary network** change both nodes and edges over time
  - Internet, WWW

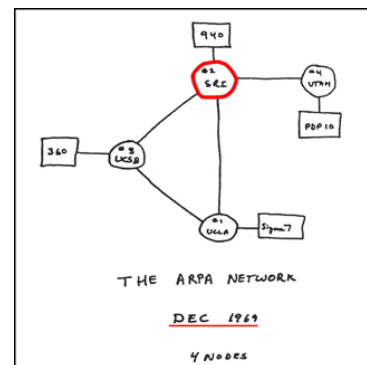(a) A fully connected graph

(b) A star network

Nodes connected by (c) a bus

(d) a crossbar switch

互联网
的演化

THE ARPA NETWORK

DEC 1969

4 NODES

1969年：4个节点

联网设备
交换机、路由器

服务端宿主机
服务器、超级计算机

客户端宿主机
智能手机、PC、Pad

IoT设备

2025年：数十亿节点

三类网络

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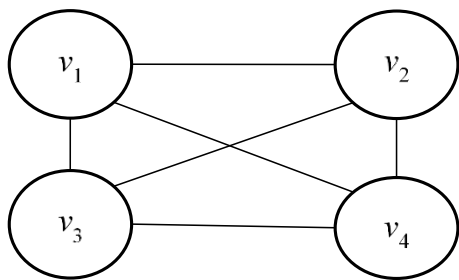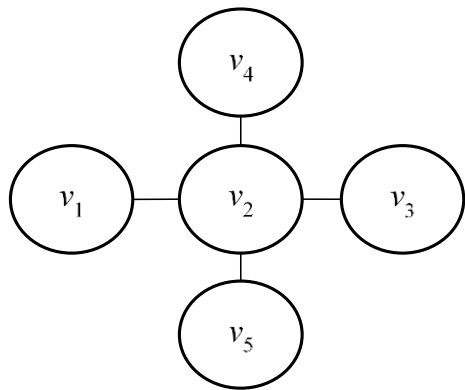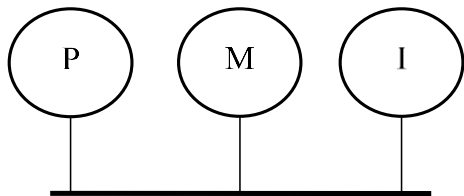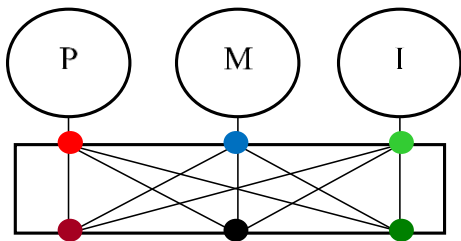
Nodes connected by (c) a bus

(d) a crossbar switch

在某个时刻，互联网是哪一类网络？

THE ARPA NETWORK
DEC 1969
4 NODES

1969年：4个节点

联网设备
交换机、路由器

服务端宿主机
服务器、超级计算机

客户端宿主机
智能手机、PC、Pad

IoT设备

2025年：数十亿节点

21
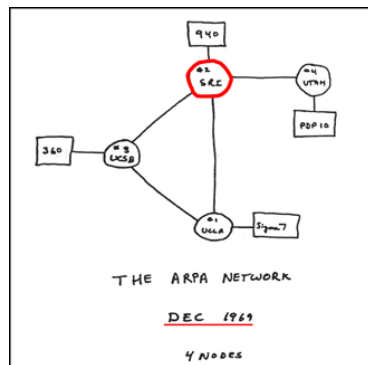
How does a dynamic network work?

- Bus arbitration 总线仲裁例子
  - Time interval 1: CPU connects to Ethernet
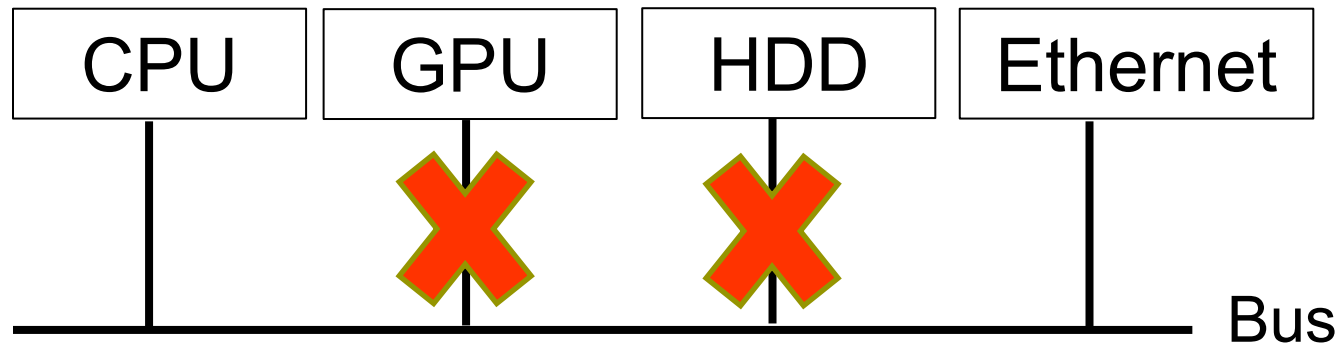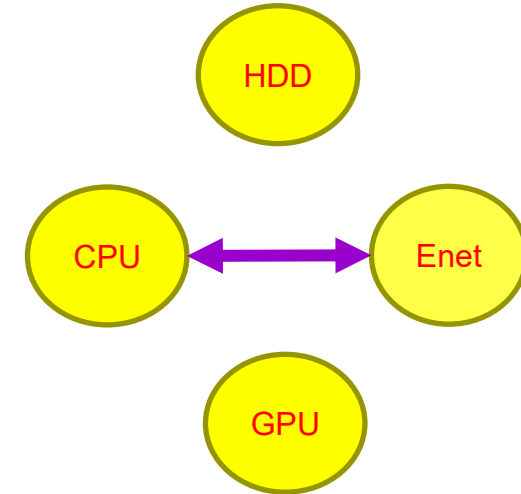
How does a dynamic network work?

- Bus arbitration
  - Time interval 1: CPU connects to Ethernet
  - End of interval 1: Bus arbitration operation
    - Switch to a new connection

| CPU | GPU | GPU | Ethernet |

Bus
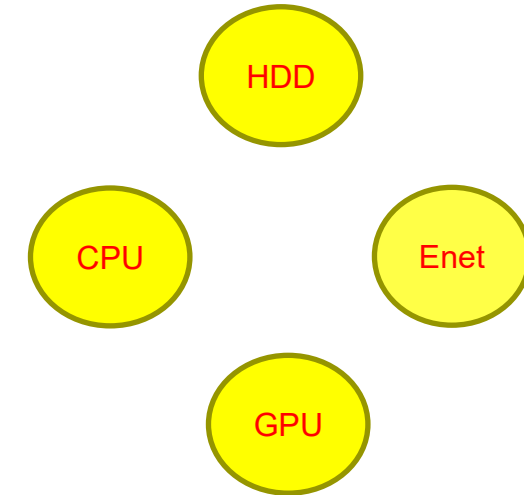
How does a dynamic network work?

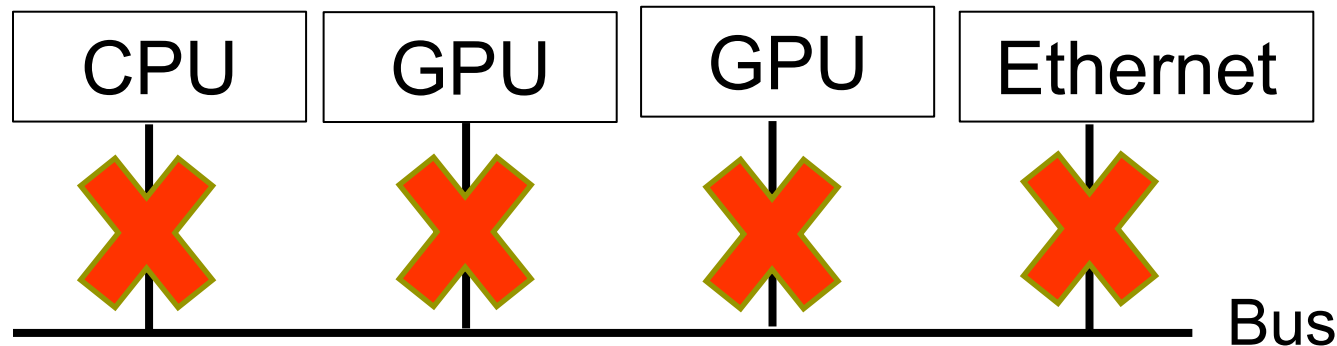- **Bus arbitration**
  - Time interval 1: CPU connects to Ethernet
  - End of interval 1: Bus arbitration operation
    - Switch to a new connection
  - Time interval 2: CPU connects to GPU
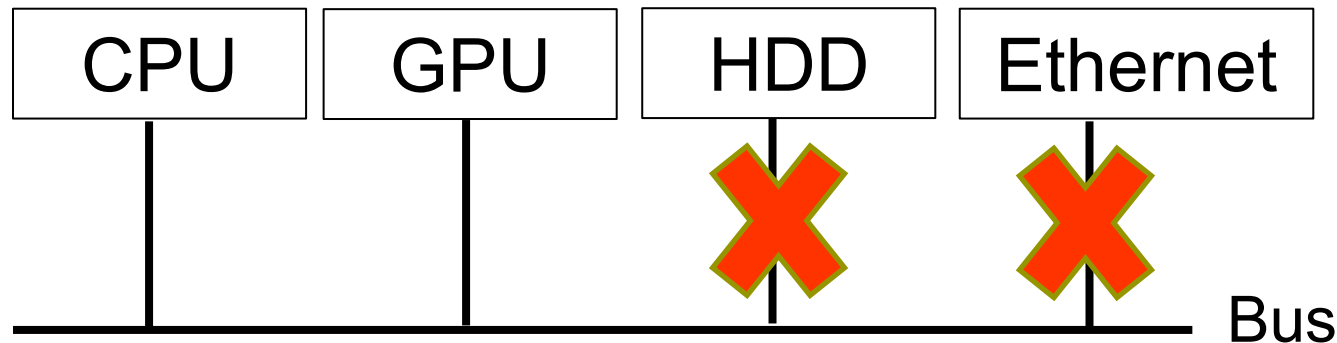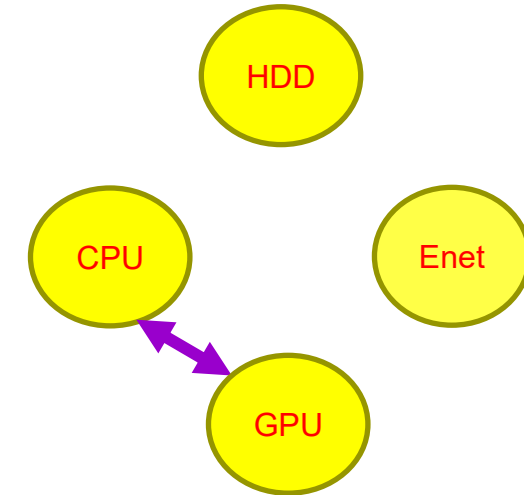
Switch 交换机 交叉开关，比总线成本更高

- **All nodes of the network are dynamically connected**
  - Switch = dynamic fully-connected network
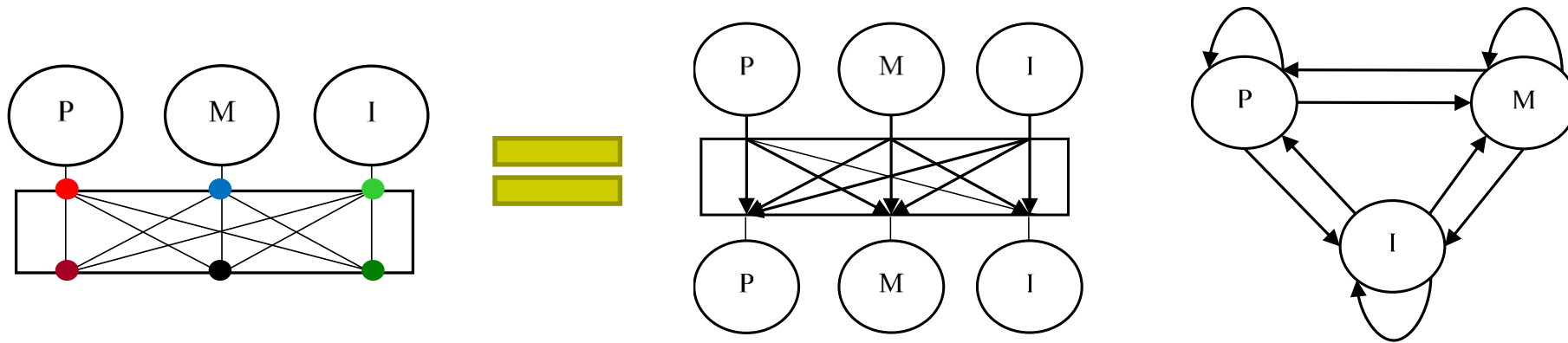
Switch 交换机 交叉开关（**crossbar switch**）

- All nodes of the network are dynamically connected
  - Switch = dynamic fully-connected network
- Can be configured to realize any connection
  - Interval 1: Permutation, {P→M, M→I, I→P}   置换
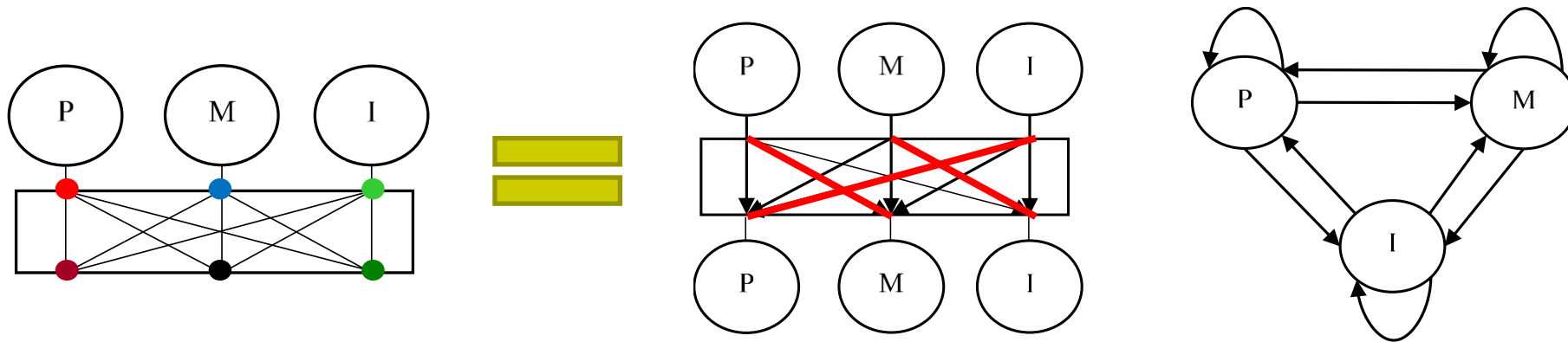
Switch 交换机 交叉开关

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  - Switch = dynamic fully-connected network

- **Can be configured to realize any connection**
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  - Interval 2: Broadcast, {P→P, P→M, P→I}   广播
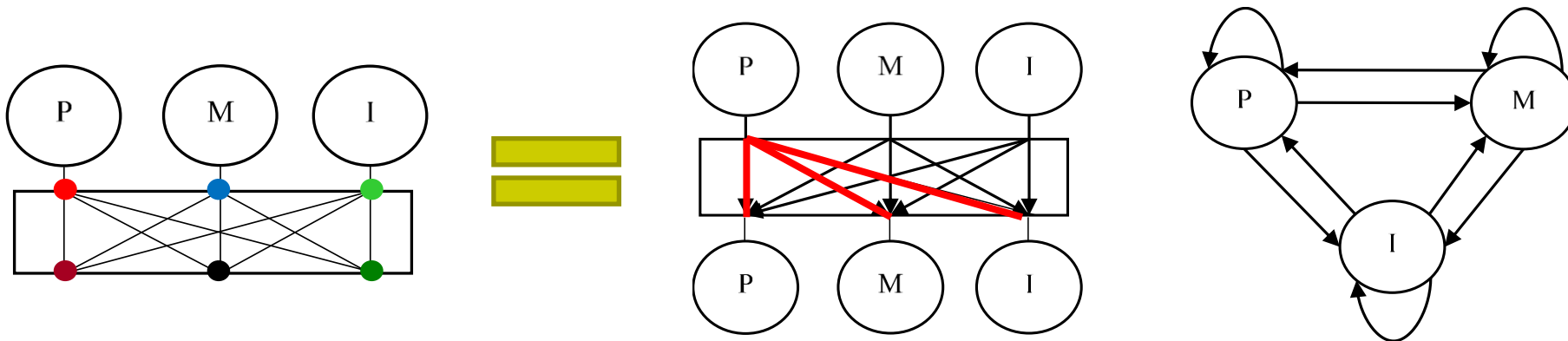
Switch 交换机 交叉开关

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  - Interval 1: Permutation, {P→M, M→I, I→P}
  - Interval 2: Broadcast, {P→P, P→M, P→I}
  - Interval 3: Point-to-point, {P→M}　　　　　点到点
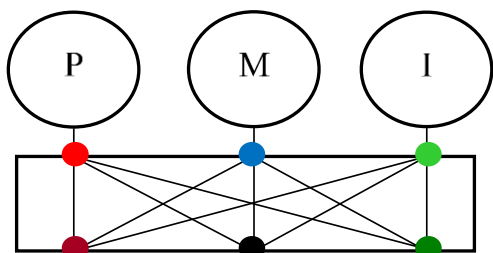
Switch 交换机 交叉开关；可实现任意连通？

- **All nodes of the network are dynamically connected**
  - Switch = dynamic fully-connected network
- **Can be configured to realize any connection**
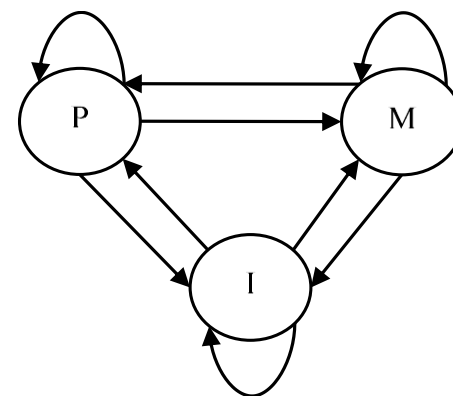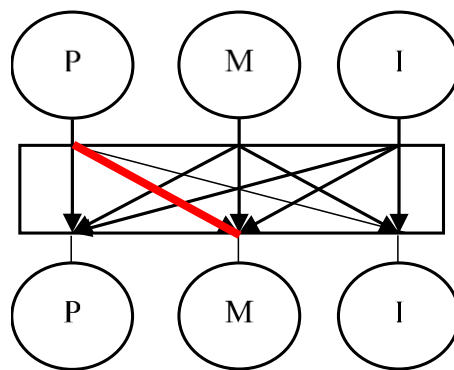 - Interval 4: {P→M, M→I, I→M}　　不行！
  - 可实现任意**无冲突连通**
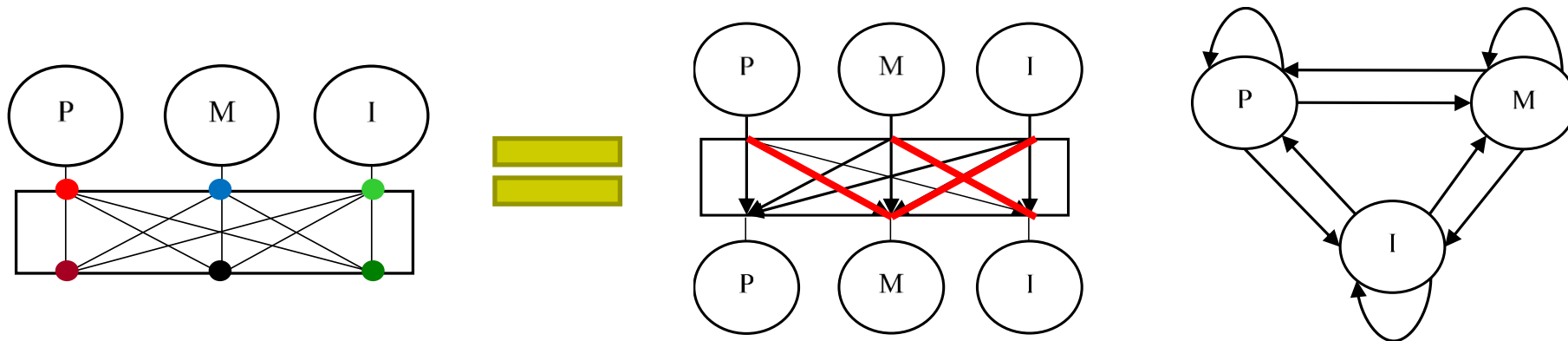
课堂小测验
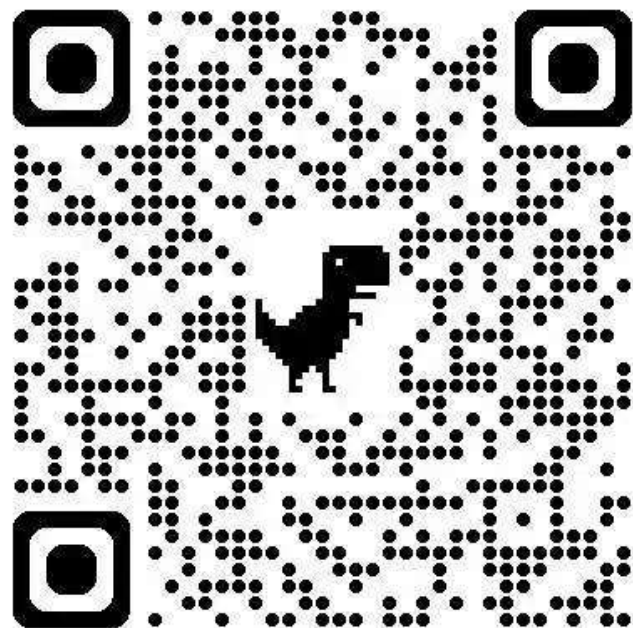
2. Protocol stack 协议栈

- A network uses a protocol stack to communicate messages
  - A set of layers of protocols
  - We focus on one stack
- Key terms
  - Message and packet
    消息 vs. 分组（包、数据包）
    - Packet is part of a message
  - Circuit switching
    versus packet switching
    线路交换 vs. 分组交换
  - The Web over Internet stack
    - HTTP
    - TCP
    - IP
    - Ethernet or WiFi
    - Wired or wireless

互联网协议栈
The Web over Internet Stack

Layer	Protocol	Purpose
Application Layer Layer 5	HTTP	Access hypertext resources on a Web server from a Web client
Transport Layer Layer 4	TCP	Reliably transfer packets between two Internet hosts
Network Layer Layer 3	IP	Transfer packets between two Internet hosts in the best-effort way
Data Link Layer Layer 2	Ethernet, WiFi	Reliably transfer packets between two homogeneously connected devices
Physical Layer Layer 1	Wired or wireless, electrical or optical, cables or waveforms	Provide physical communication channels Transfer signals of individual bits

2.1 线路交换与分组交换（包交换）

- 两种主要的通信方法
  - 传统的电话通信采用线路交换，计算机网络采用分组交换
- 线路交换（circuit switching）
  - 假设A与B要通话
    - 建立一条从A到B的物理线路
    - 在整个通话时间，这条物理线路一直被A和B的会话独占

    - 传统电话通信采用的线路交换技术使用了上百年，质量好，但通信线路效率低（2%）

线路交换与分组交换

- 两种主要的通信方法
  - 传统的电话通信采用线路交换，计算机网络采用分组交换
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    - 建立一条从A到B的物理线路
    - 在整个通话时间，这条物理线路一直被A和B的会话独占
- 分组交换（packet switching）
  - 假设A要送一条消息给B
    - 将消息拆成很多小单元，称为"包"或"分组"（packet）
    - 通信线路每个时刻只在传输一个包
    - 但在1秒钟的时段内，通信线路传递来自多个用户的多个消息的多个包
      - 100个用户感受到：多条消息同时在一条物理线路上传播

Circuit switch   vs.   packet switch

Assumptions for both systems: (1) 10 Mbps; (2) all three tasks start at 0; (3) ignore all overheads

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Establish an end-to-end circuit for Autumn.bmp (assuming 0 time)
0-7.31s, transmitting **Autumn.bmp**

互联网不用
线路交换

左边是一个
假想例子

Smith   Wang   Zhang

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Smith   Wang   Zhang

Circuit switch   vs.   packet switch

Assumptions for both systems:
(1) 10 Mbps; (2) all three tasks start at 0; (3) ignore all overheads

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Close the first circuit (assuming 0 time)
Establish the second end-to-end circuit (assuming 0 time)
7.31-7.46s, transmitting **hamlet.txt**

Smith   Wang   Zhang

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Smith   Wang   Zhang

Circuit switch vs. packet switch

Assumptions for both systems:
(1) 10 Mbps; (2) all three tasks start at 0; (3) ignore all overheads

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Close the second circuit (assuming 0 time)
Establish the third end-to-end circuit (assuming 0 time)
7.46-8.11s, transmitting ucas.bmp

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Smith   Wang   Zhang

Smith   Wang   Zhang

Circuit switch   vs.   packet switch

Assumptions for both systems:
(1) 10 Mbps; (2) all three tasks start at 0; (3) ignore all overheads

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

A packet = 1 KB
随机轮转传包

Autumn.bmp, 9.14 MB
hamlet.txt, 182 KB
ucas.bmp, 810 KB

Transmit packet 1 of hamlet.txt
Transmit packet 1 of Autumn.bmp
Transmit packet 1 of ucas.bmp
Transmit packet 2 of ucas.bmp
Transmit packet 2 of Autumn.bmp
Transmit packet 2 of hamlet.txt
......

Smith   Wang   Zhang

Smith   Wang   Zhang

假设三个下载任务使用**10 Mbps**带宽资源
分组交换平均延迟更小，且任务**1**没有阻塞其他任务

t=0秒　　　　　　　　　　　　t=7.31秒　t=8.11秒

Circuit switch
线路交换

任务1
任务2
任务3

三个任务
平均延迟=7.63秒

Packet switch
分组交换

任务1
任务2
任务3

三个任务
平均延迟=3.33秒
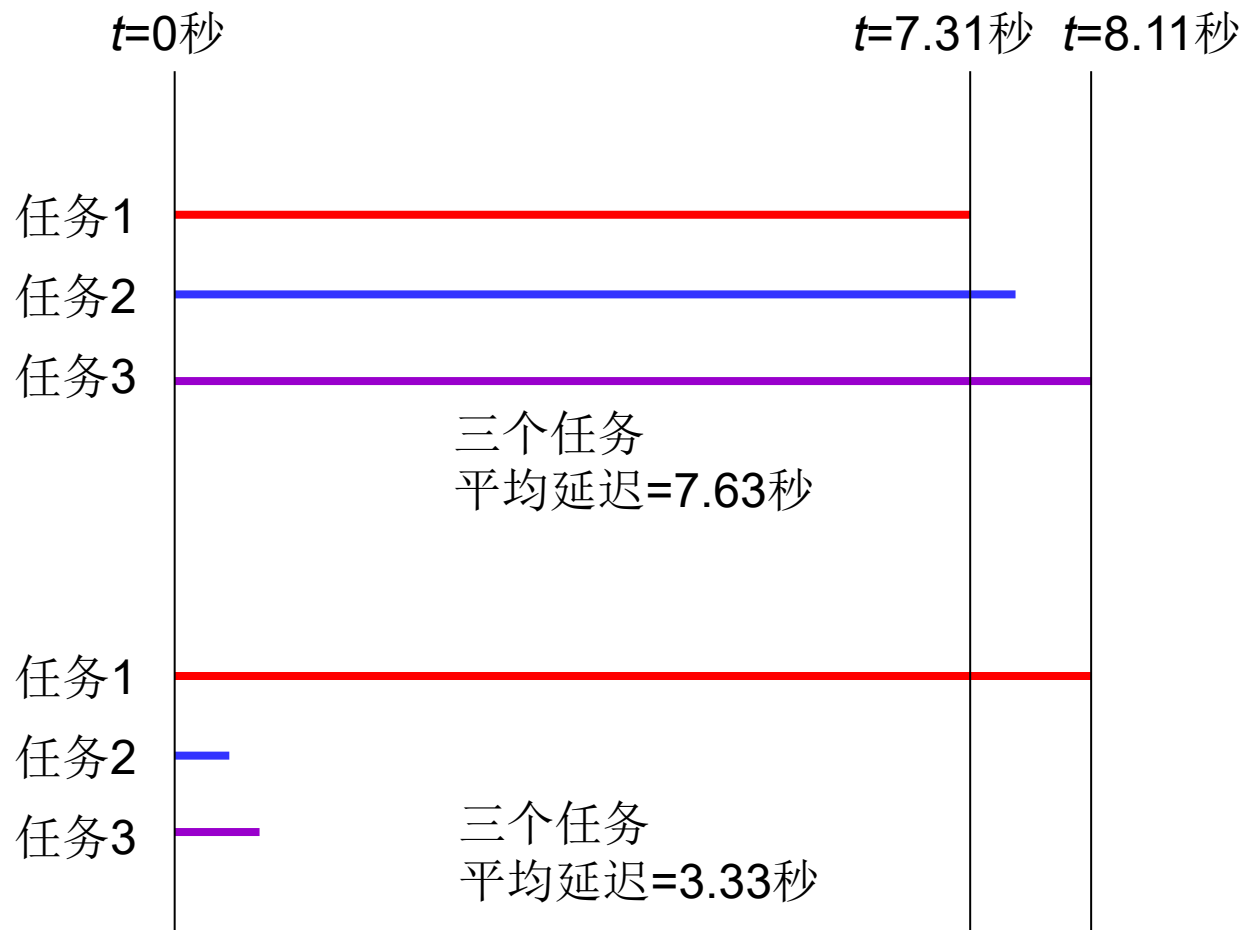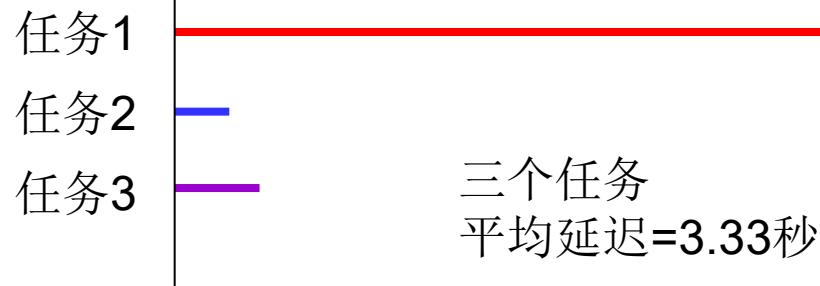
包格式 A packet has two parts
header and body

- Packet body is the payload data   包体是载荷数据

- Packet header holds various metadata   包头是3类元数据
  - **Addresses** of source and destination nodes   地址
  - Error check information, e.g., Cyclic Redundancy Check (CRC)   查错
  - Other information, e.g., control information   其他信息
  - Part of header may come after body

- Think of post mail
  - Body   =   Letter   包体 = 信
  - Header   =   Envelop   包头 = 信封

Format of an Ethernet packet 以太网帧

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	Frame Delimiter	Destination MAC Address	Source MAC Address	Type	Data (Payload)	CRC

以太网的帧格式 对比 **WiFi**的帧格式

字节数		包头				包体	总计
		地址	查错	其他	小计		
以太网 802.3	最小包	12	4	10	26	46	72
	最大包	12	4	10	26	1500	1538
WiFi 802.11	最小包	24	4	6	34	0	34
	最大包	24	4	6	34	2312	2346

以太网 (IEEE 802.3) 帧格式

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes
Preamble	Frame Delimiter	Destination MAC Address	Source MAC Address	Type	Data (Payload)	CRC

WiFi (IEEE 802.11) 帧格式

2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes	0-2312 bytes	4 bytes
Frame Control	Duration	Address 1	Address 2	Address 3	Sequence	Address 4	Data (Payload)	CRC

2.2 Protocol stack 协议栈

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    - a message is divided into one or more packets
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    线路交换 vs. 分组交换
  - The Web over Internet stack
    - HTTP
    - TCP
    - **IP (Internet Protocol)**
    - Ethernet or WiFi
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互联网协议栈

The Web over Internet Stack

Layer	Protocol	Purpose
Application Layer Layer 5	HTTP	Access hypertext resources on a Web server from a Web client
Transport Layer Layer 4	TCP	Reliably transfer **TCP packets TCP包** between two Internet hosts
Network Layer Layer 3	IP	Transfer IP datagrams 数据报 Between two Internet hosts in a best-effort way
Data Link Layer Layer 2	Ethernet, WiFi	Reliably transfer **frames 帧** between two homogeneously connected devices
Physical Layer Layer 1	Wired or wireless, electrical or optical, cables or waveforms	Provide physical communication channels Transfer signals of individual **bits 比特**

为什么需要IP？

● 邮局示例：徐志伟送新书图片给夏煜涵

  ● 明信片方式不能解决异构网络问题

Deutsche Region

English Region

美国纽约市
哥伦比亚大学
计算机科学系
夏煜涵收

Zhiwei Xu · Jialin Zhang

Computational
Thinking:
A Perspective on
Computer Science

Springer

中国北京市海淀区
科学院南路六号
徐志伟寄

中文区

Región Española

信件方式能够解决异构网络问题

Quell-IP:
123.123.123.2
Quell-Port: 12345
Ziel-IP: 98.76.54.32
Ziel-Port: 98765
Sonstiges

Computational Thinking: A Perspective on Computer Science

Deutsche Region

Gateway N

Source IP:
123.123.123.2
Source Port:
12345
**Destination IP:
98.76.54.32**
Destination Port:
98765
Other Information

Computational Thinking: A Perspective on Computer Science

夏

English Region

Gateway M

Gateway
事实上是
Router

Gateway P

源IP: 123.123.123.2
源端口: 12345
目标IP: 98.76.54.32
目标端口: 98765
其他信息

徐

信封

Computational Thinking: A Perspective on Computer Science

中文区

Gateway Q

Región Española

43
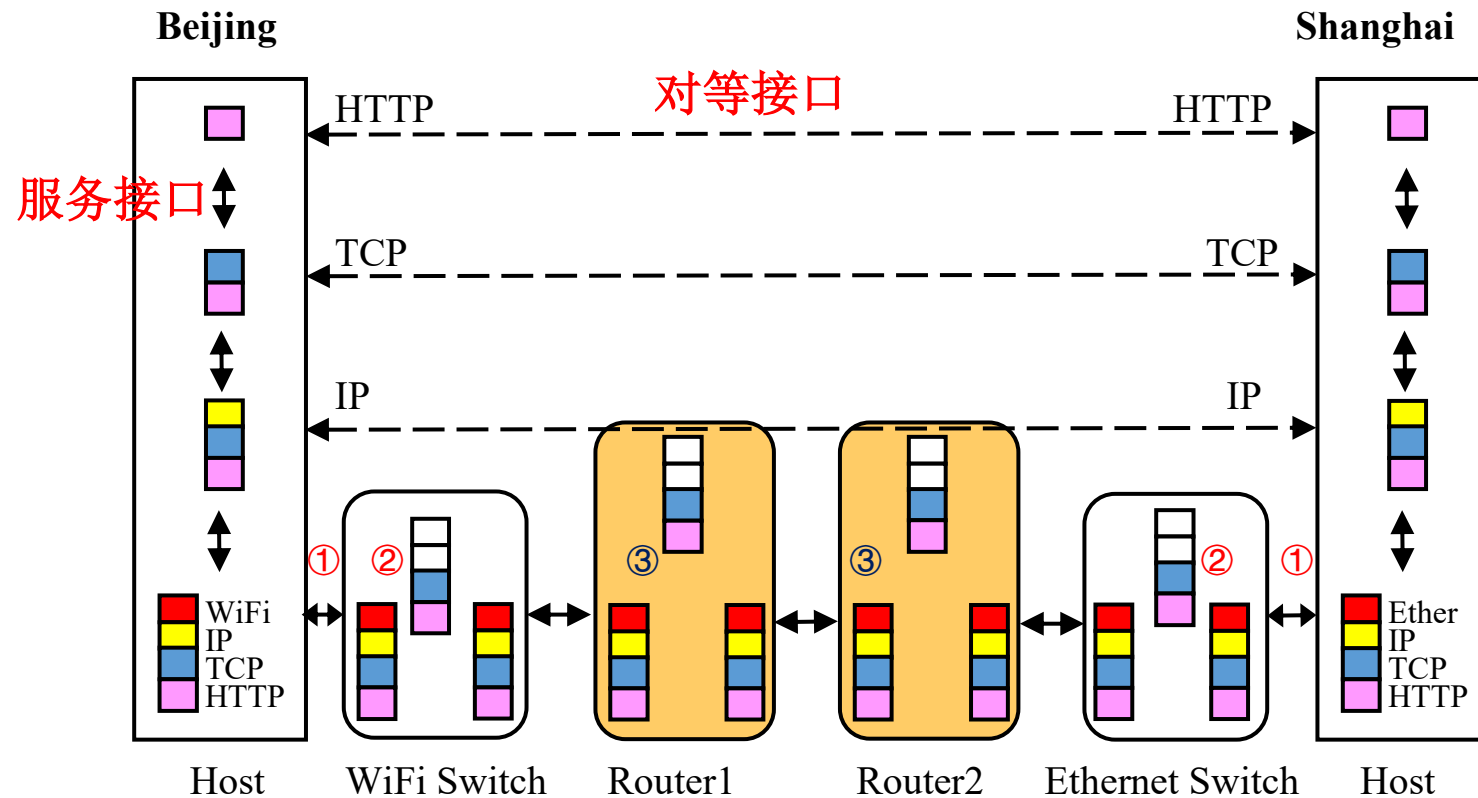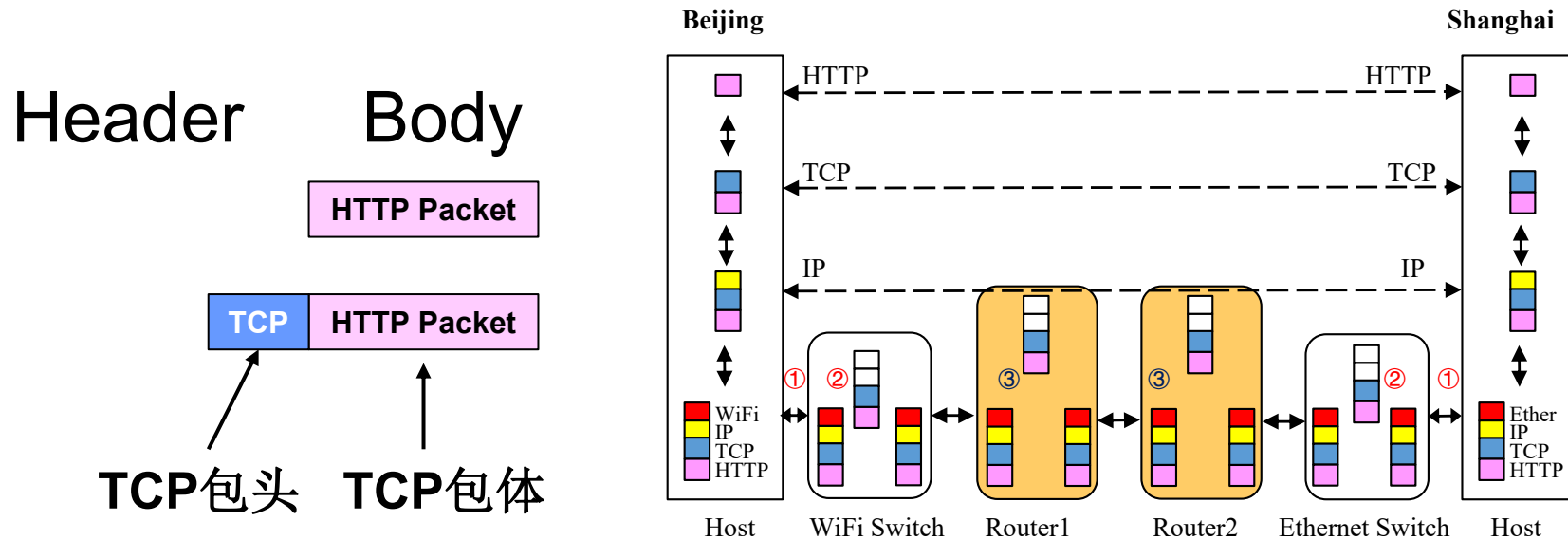
HTTP GET request and response messages

- Request message: http://www.shanghaitech.edu.cn/
  - Sent to the server as a stream of packets
- Response message: the contents of the home page
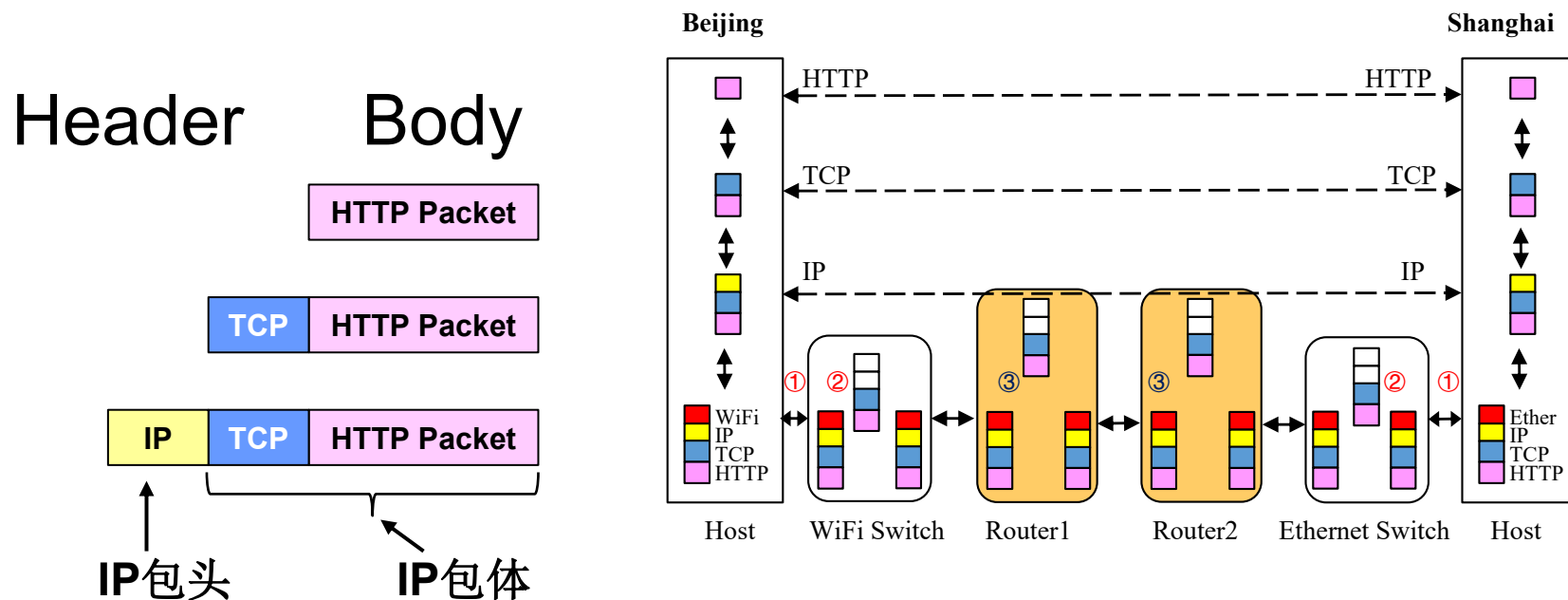 - Sent from the server as a stream of packets

How is the response message communicated

- Response message, i.e., the contents of the home page, is divided into a number of packets, i.e., slices of the message
  - Each HTTP packet is turned into an Ethernet packet as follows 打包
    - HTTP packet (**pink**) is handed to the TCP layer as the body of a TCP packet
    - TCP layer adds a TCP header (**blue**) to form a TCP packet
    - The TCP packet is handed over to the IP layer as the IP packet body
    - The IP layer adds an IP header (**yellow**) to form an IP packet
    - Finally, the IP packet is handed over to the data link (Ethernet) layer as the Ethernet packet body
    - The Ethernet layer adds an Ethernet header (**red**) to form an Ethernet packet

Header   Body

HTTP Packet

TCP **HTTP Packet**

TCP包头   **TCP**包体

Beijing   Shanghai

HTTP   HTTP
TCP   TCP
IP   IP

WiFi   Ether
IP   IP
TCP   TCP
HTTP   HTTP

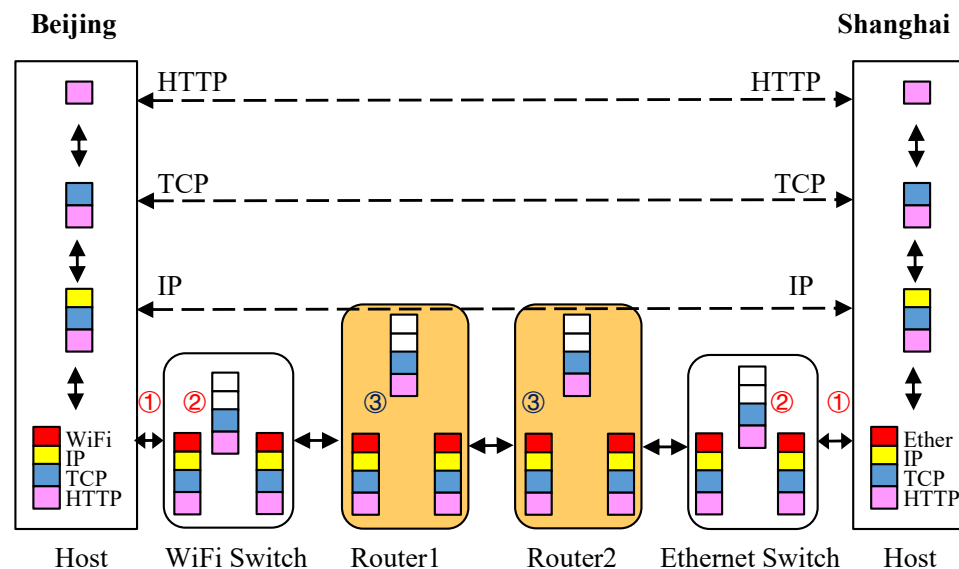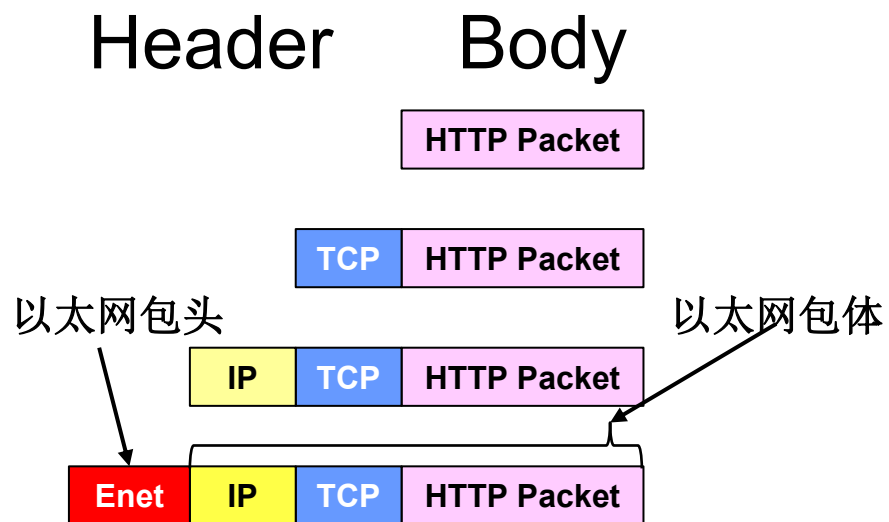Host   WiFi Switch   Router1   Router2   Ethernet Switch   Host

How is the response message communicated

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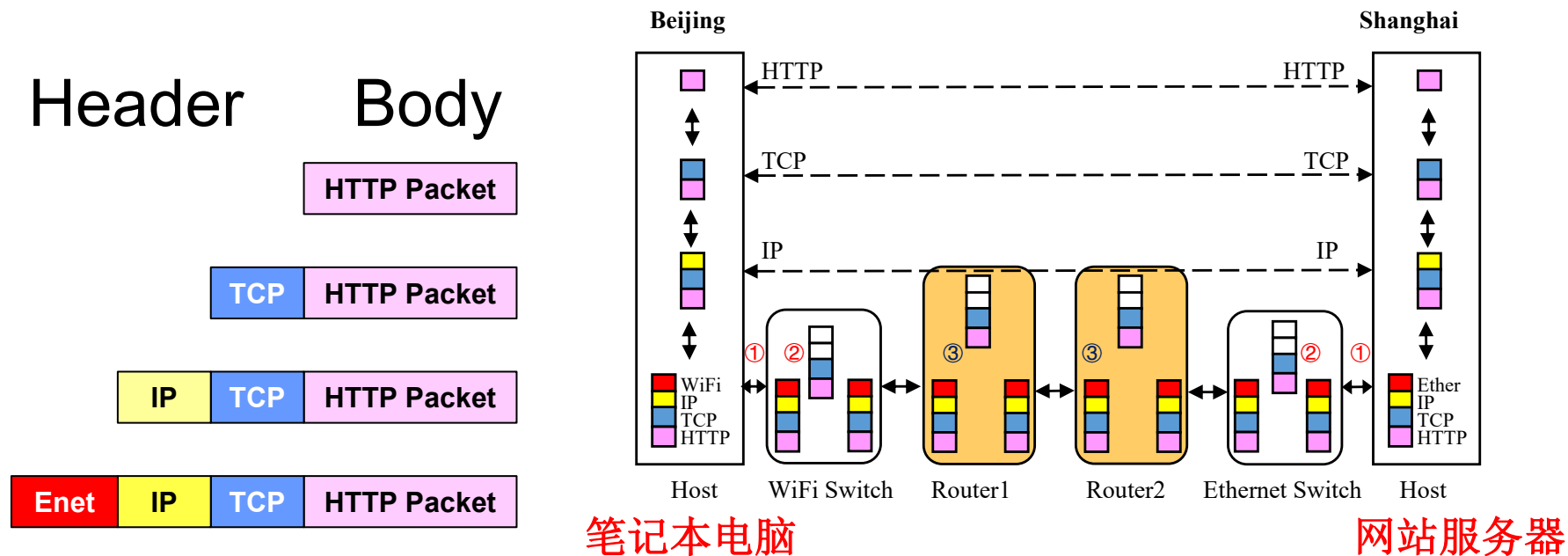
How is the response message communicated

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How is the response message communicated

- Each HTTP packet is communicated as follows 传输
  - ① The server host sends an HTTP packet, wrapped as an Ethernet packet, to the Ethernet switch
  - ② The switch opens the packet to reveal the Ethernet and the IP headers, and then adds a new header to form a new Ethernet packet
  - ③ When the packet arrives at Router2, the router opens the packet to reveal both the Ethernet and the IP headers and then form a new Ethernet packet by reformatting the packet and adding a new Ethernet header
  - Similar steps take place at Router1 (③) and the WiFi Switch (②), and then a WiFi packet arrives at the laptop computer host (①)

笔记本电脑   网站服务器

How is the response message communicated

- Each HTTP packet is communicated as follows 解包
  - After a WiFi packet arrives at the laptop computer host in Beijing, it is unpacked by the host (the laptop computer) to reveal
    - the IP packet,
    - the TCP packet, and finally
    - the HTTP packet, i.e., a slice of the message
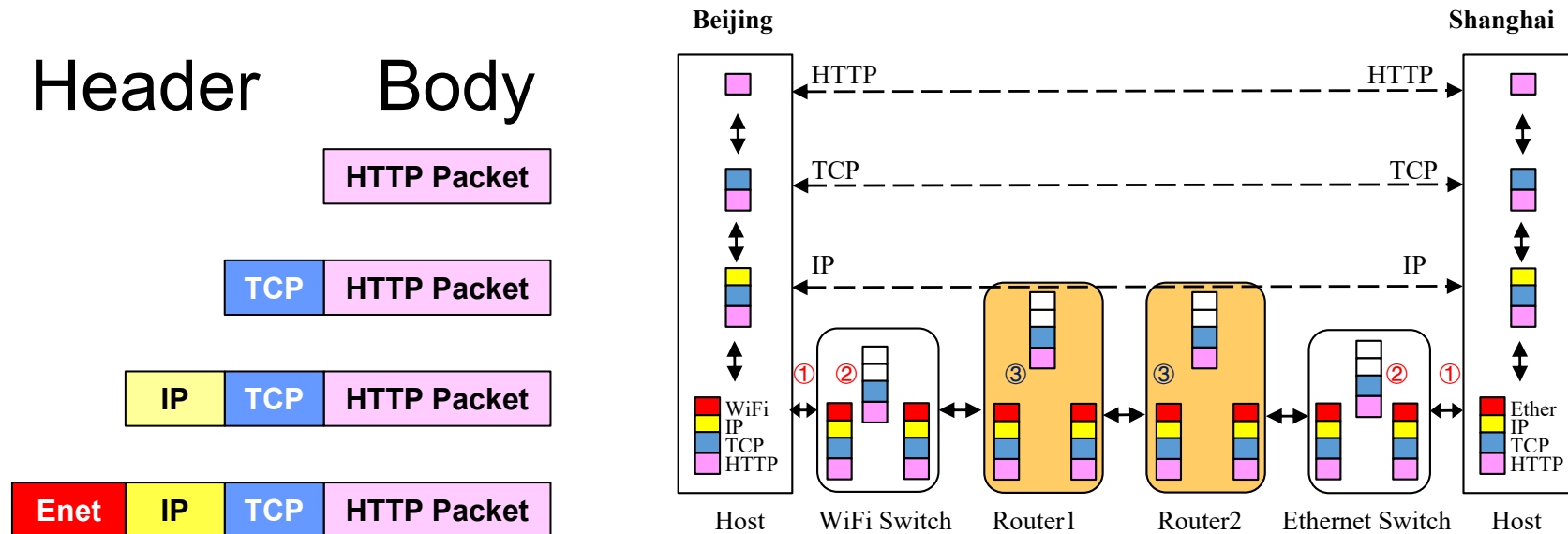
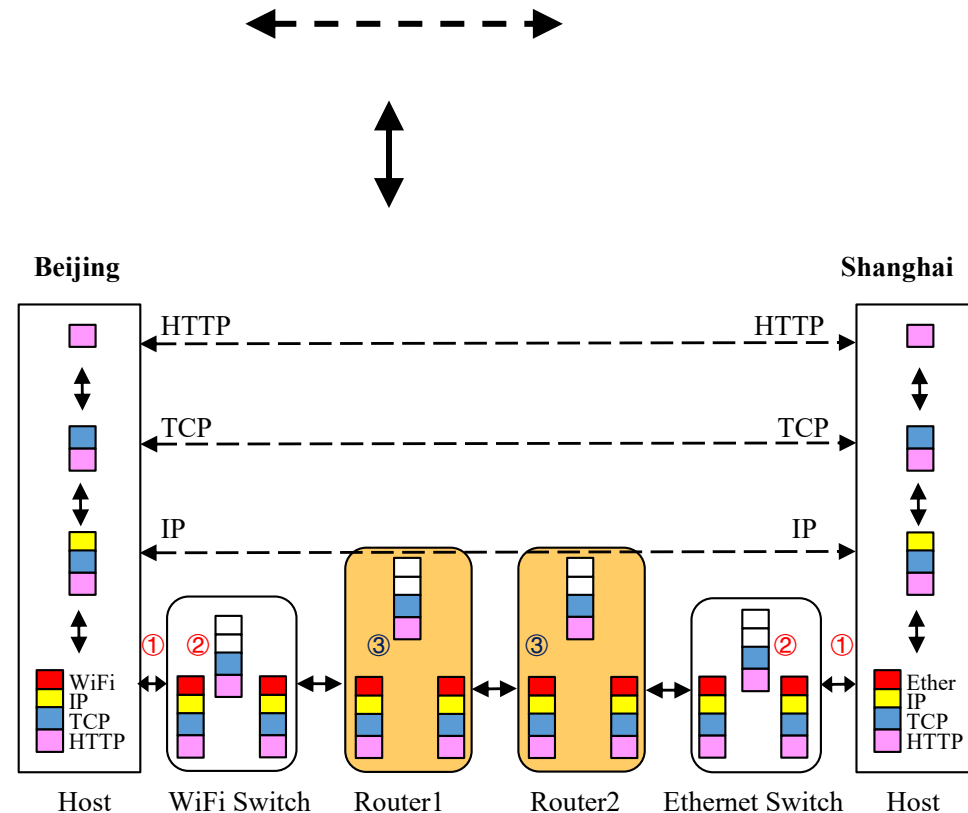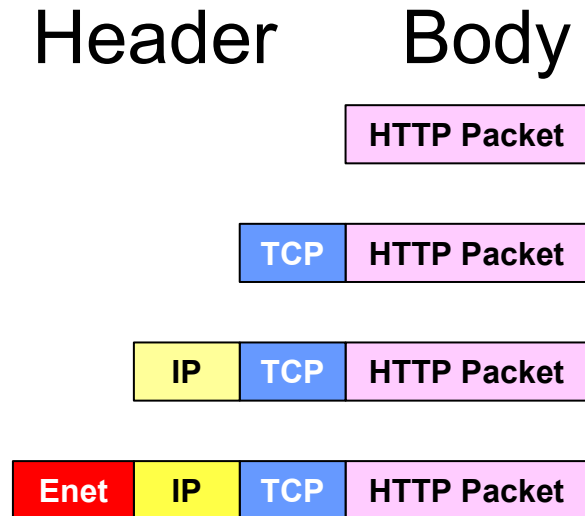# Does Zhang need to worry about TCP/IP and Ethernet when surfing the Web?
张蕾访问上海科大网站时，需要操心**TCP/IP**与以太网吗？

- No! A user only needs to know the peering interface HTTP
- Two types of interfaces
  - Peering interface for user

对等接口

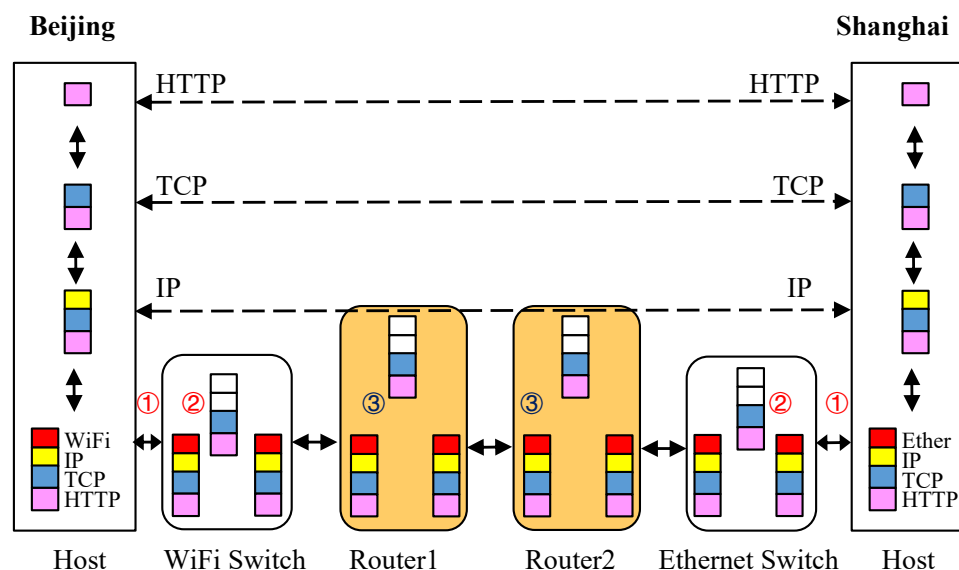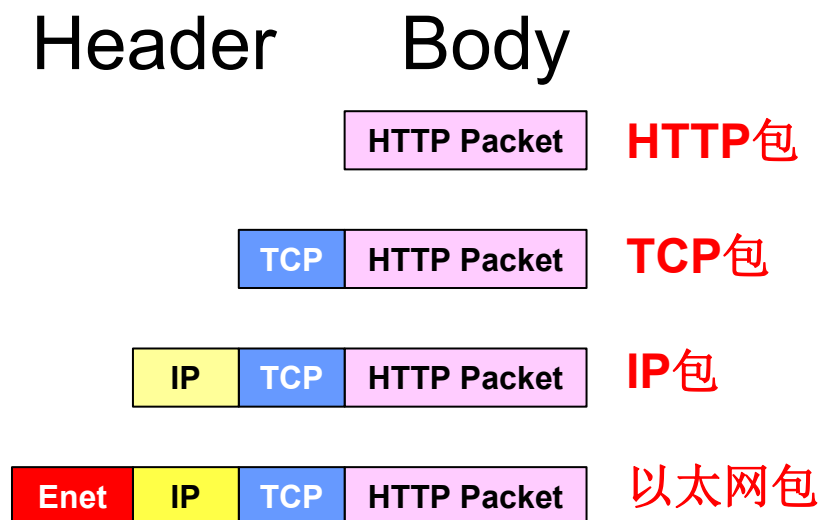 - Service interfaces for implementation

服务接口

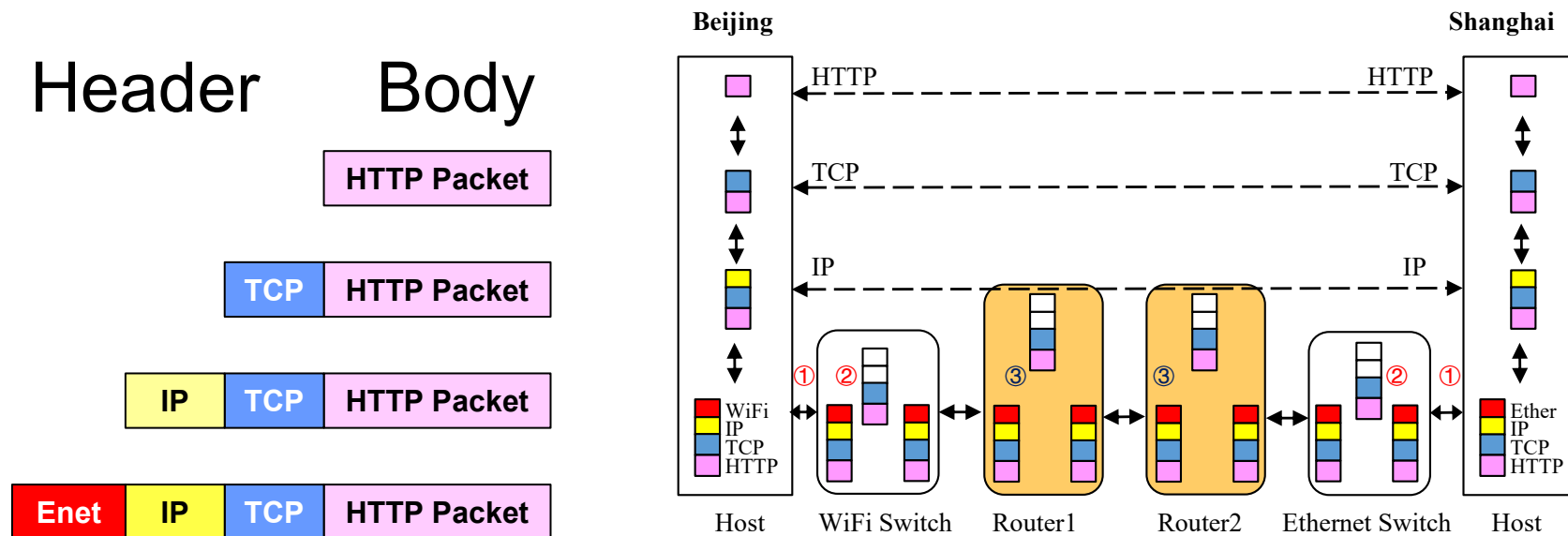# Can one send an upper layer packet without also sending a lower layer packet?　能否只传**HTTP**包　不传**IP**包

- Can the Web server in Shanghai send an HTTP packet to Zhang's Web browser in Beijing, without also sending an Ethernet frame?

- No!　不能只传上层数据包(如**TCP**包)，而不传下层包(**IP**包、以太网包)

  - Any information at the HTTP layer is wrapped in a data link layer packet, and eventually wrapped in a physical layer packet
  - One cannot send a high layer packet without also sending a packet of every layer below
  - When a packet enters a network, it is in a data link layer format and travels as wired and/or wireless signals

Header　Body

HTTP Packet	**HTTP**包
TCP	HTTP Packet	**TCP**包
IP	TCP	HTTP Packet	**IP**包
Enet	IP	TCP	HTTP Packet	以太网包

Beijing ... Shanghai; HTTP; TCP; IP; ① ② ③ ③ ② ①; WiFi IP TCP HTTP; Ether IP TCP HTTP; Host WiFi Switch Router1 Router2 Ethernet Switch Host
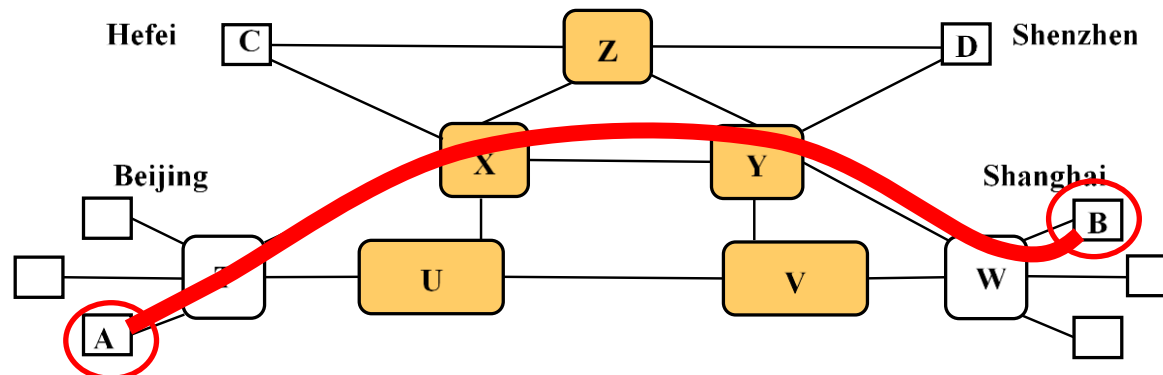
What is actually sent over the network hardware?

- Bit string of 0's and 1's
  任何数据包最终在物理层作为比特流传递，即一串0或1信号 （电、光）
- Any packet is eventually encapsulated as one or more physical layer packets, which travel as wired or wireless signals
  - A physical layer packet is sent through electrical cables, electromagnetic waveforms or optical fibers, in a bit string of 0's and 1's
  - A 0 may be represented as a LOW voltage pulse or a LIGHTOFF state, while a 1 may be represented as a HIGH voltage pulse or a LIGHTON state

Do all packets travel through the same physical path?
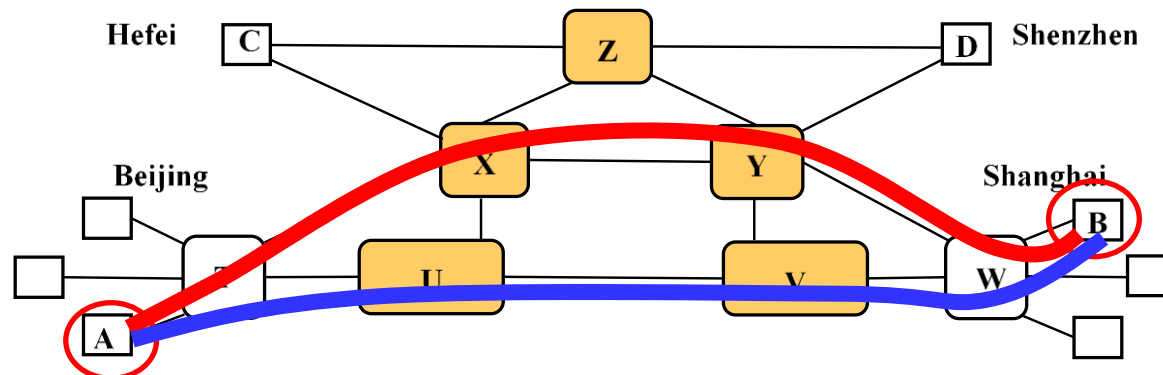## 从**A**到**B**的一条消息的数据包必然通过同一条通路吗？

- A message is sent from host A to host B
  - Do all packets of the message travel through the same physical path from host A to host B?
  - Not necessarily. Internet has built-in redundancy   不一定。互联网有冗余通路
    - Possible physical paths for a 99-packet message from A to B
      - 1st packet of the message travels along the physical path **A-T-X-Y-W-B**
      - 49th packet traverses path **A-T-U-V-W-B**
        - Arriving at B before 1st packet
      - 99th packet traverses path **A-T-X-Z-Y-W-B**
    - Complete message is reassembled from the packets by their numbers

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