中国科学院大学
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CS101

Network Thinking

Web over Internet
The HTTP/TCP/IP Protocol Stack

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Outline

- What is network thinking?
- Network terms
- Connectivity
  - Naming
  - Topology
- Protocol stack
  - The Web over TCP/IP stack
  - Web programming
- Network laws
  - Performance metrics
  - Network effect
- Responsible computing

These slides acknowledge sources for additional data not cited in the textbook

4. Protocol stack

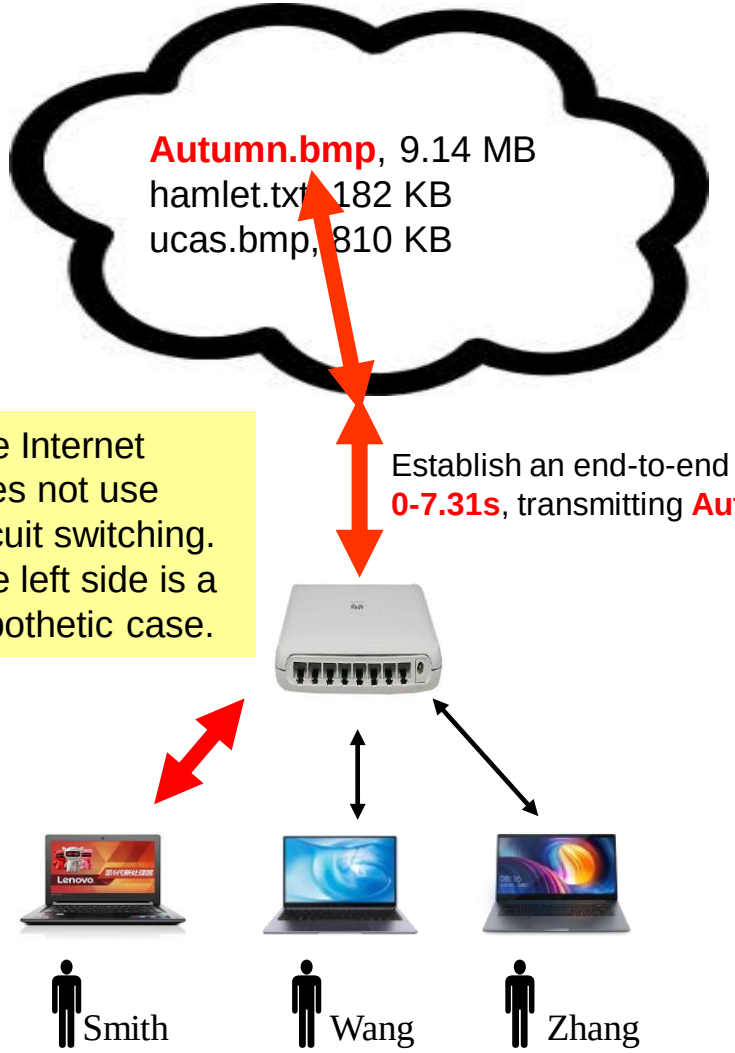
- A network uses a protocol stack to communicate messages
  - A set of layers of protocols
- We focus on one stack
  - Web over Internet
- Key terms
  - Message and packet
    - Packet is part of a message
  - Circuit switching versus packet switching
  - The Web over Internet stack
    - HTTP
    - TCP
    - IP
    - Ethernet or WiFi
    - Wired versus wireless

The Web over Internet Stack

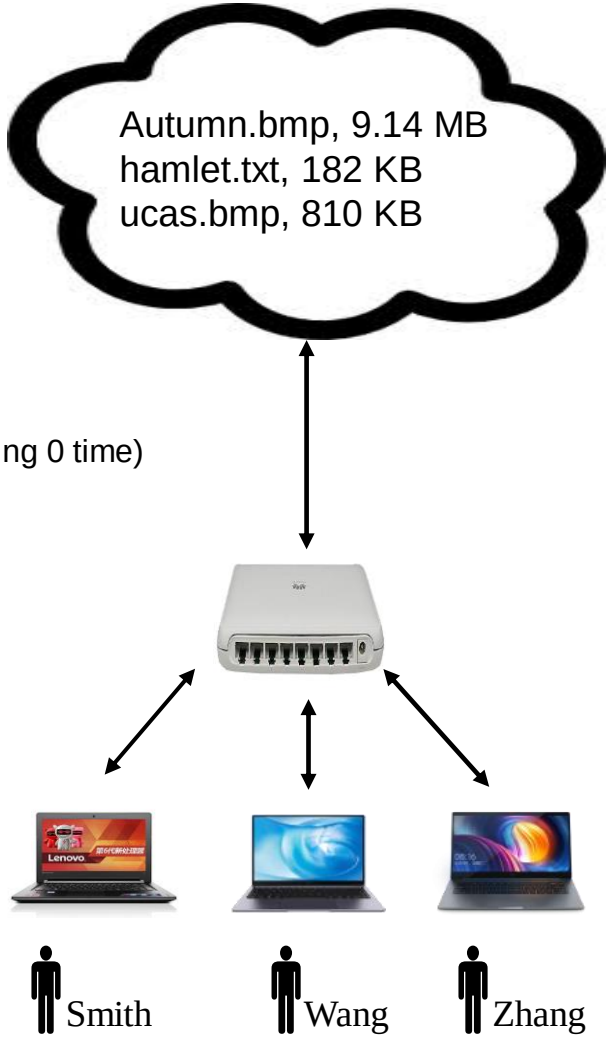
Layer	Protocol	Purpose
Application Layer Layer 5	HTTP	Access hypertext resources on a Web server from a Web client
Transport Layer Layer 4	TCP	Reliably transfer packets between two Internet hosts
Network Layer Layer 3	IP	Transfer packets between two Internet hosts in the best-effort way
Data Link Layer 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

Circuit switch vs. packet switch

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



The Internet does not use circuit switching. The left side is a hypothetic case.



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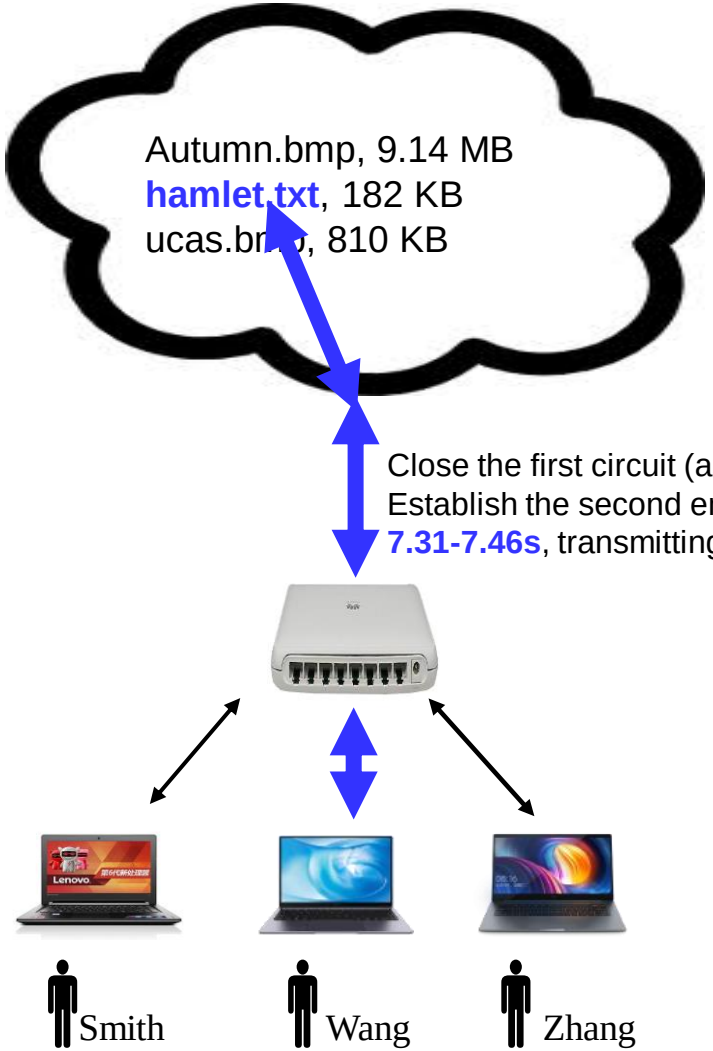

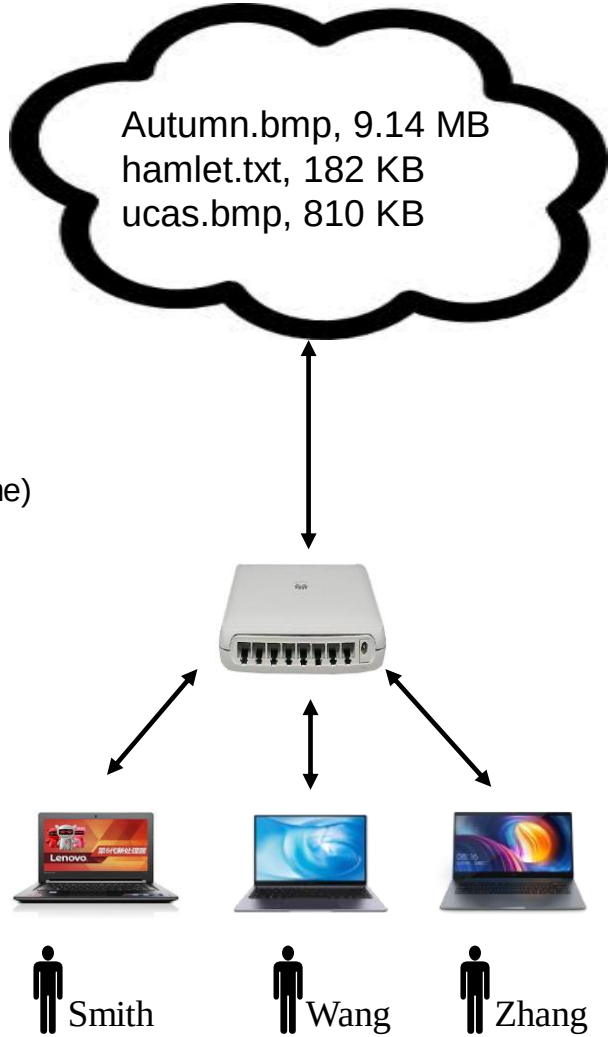

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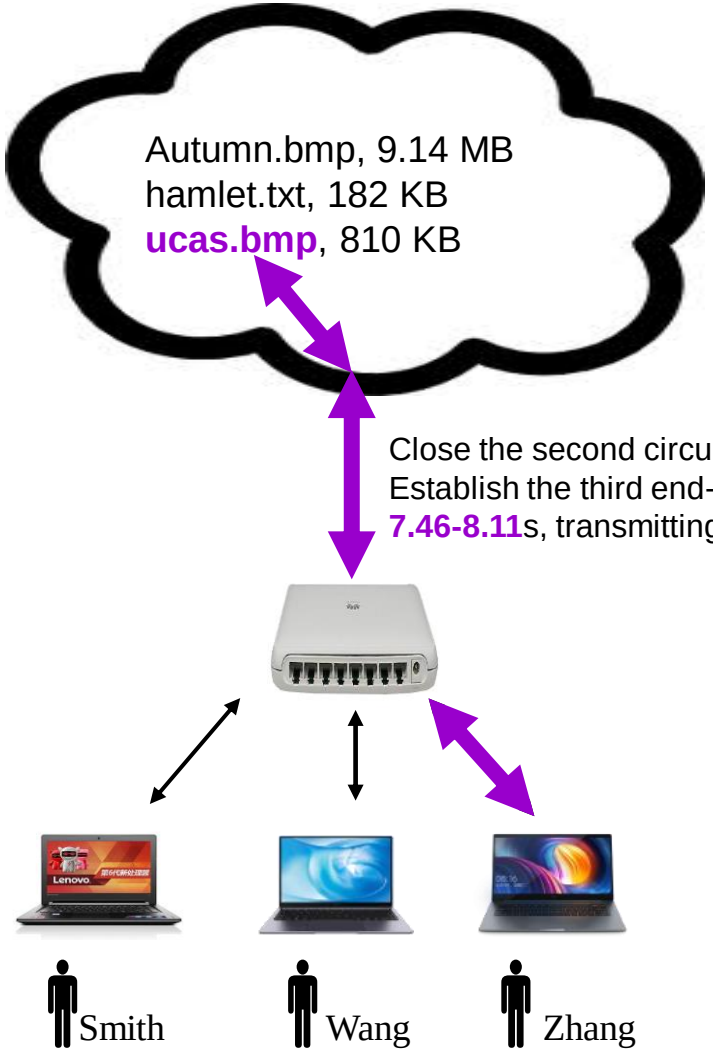

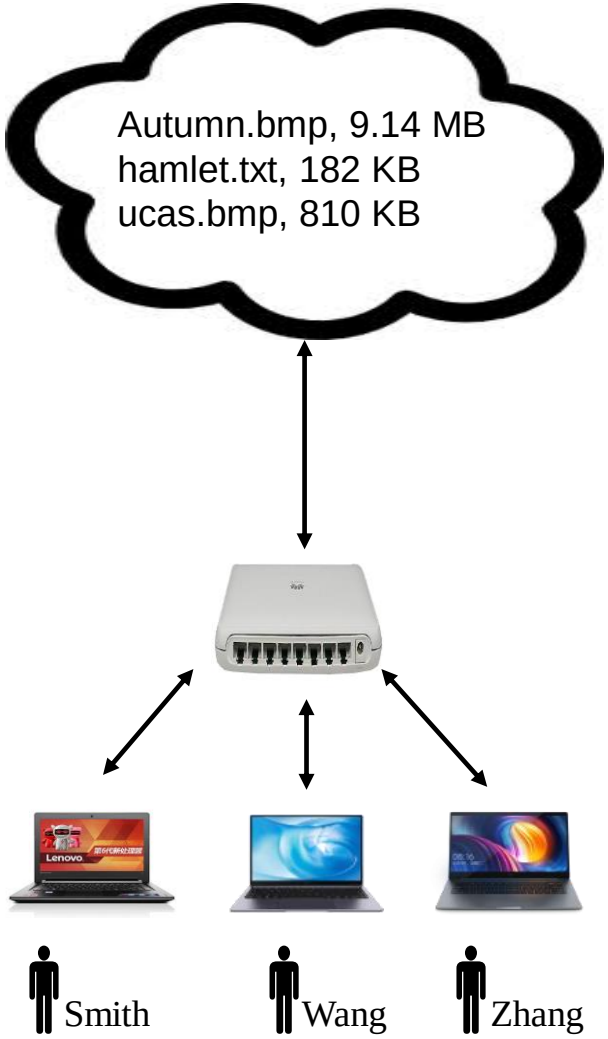

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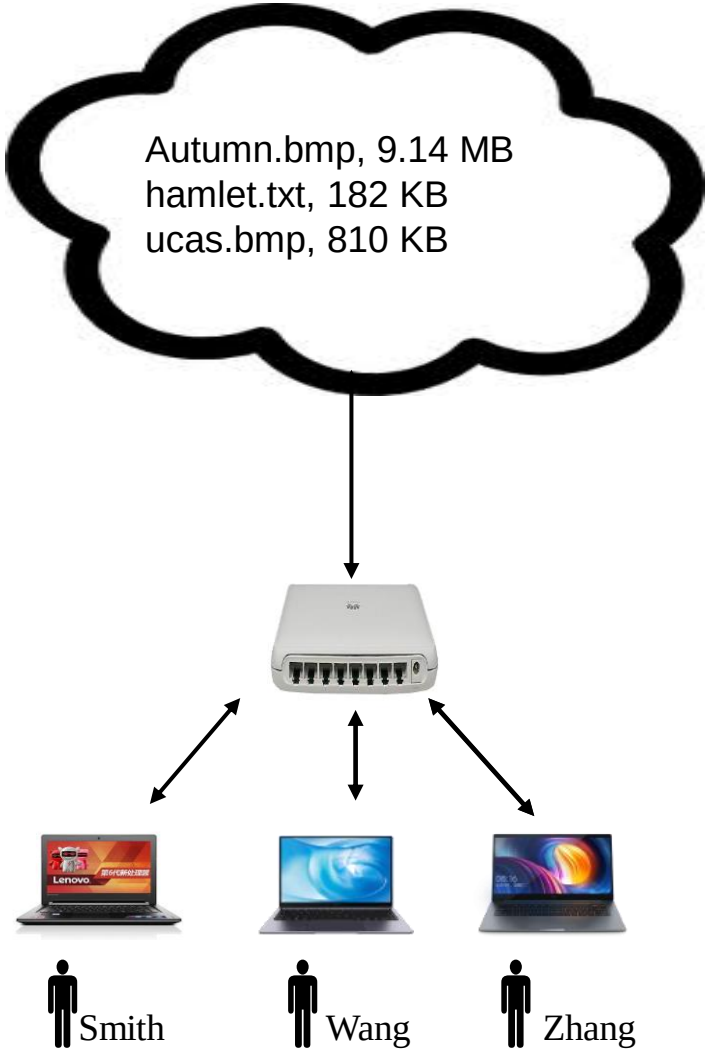
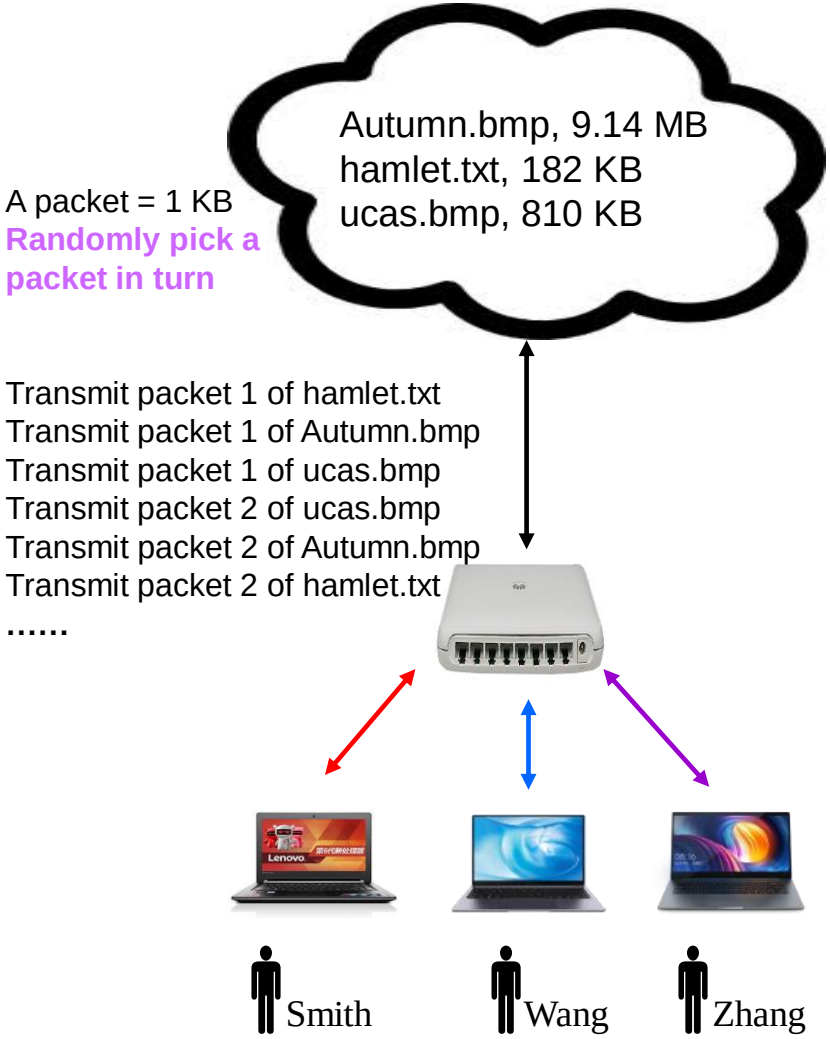
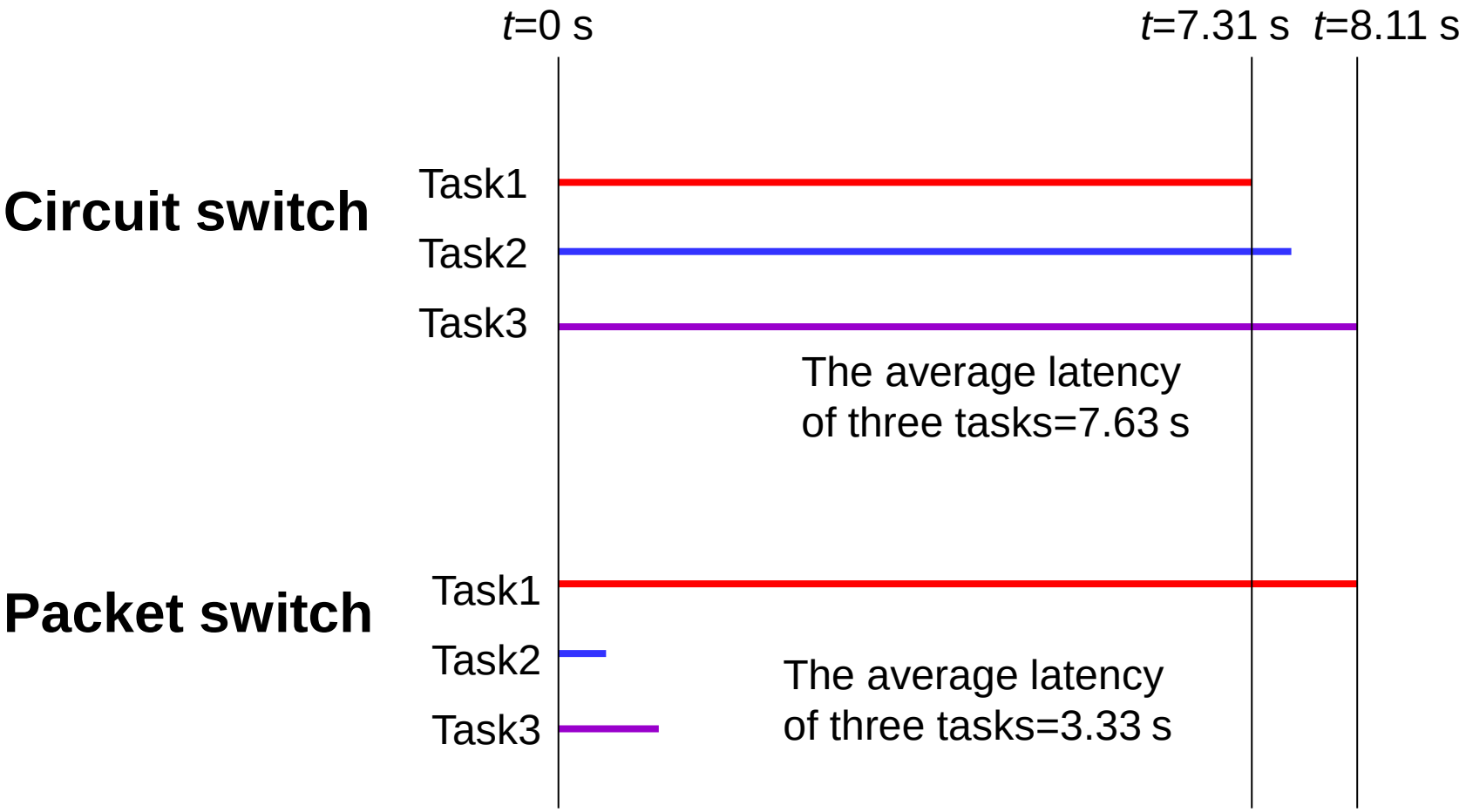




Assume 10 Mbps is divided equally by the three downloading tasks



Any packet has two parts: header and body

- Packet body is the payload data
- Packet header holds various metadata
  - **Addresses** of source and destination nodes
  - Error check information, e.g., Cyclic Redundancy Check (CRC)
  - Other information, e.g., control information
  - Part of header may come after body
- Think of post mail
  - Body = Letter
  - Header = Envelop

Format of an Ethernet packet

How many bytes are used for packet header?

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	42-1500 bytes	4 bytes
Preamble	Frame Delimiter	**Destination MAC Address**	**Source MAC Address**	Type	**Data (Payload)**	CRC

WiFi与以太网消息包（Frame）格式

- 包头+包体，部分包头也可以出现在包体后面
  header + body
- 包体也称为
  数据data、
  负载payload
- 包头也称为
  元数据metadata
  - 关于数据的数据
  - 包括
    - 地址
    - 查错信息
    - 其他控制信息

字节数		包头			包体	总计
		小计	查错	地址		
以太网	小包	38	4	12	42	80
	大包	38	4	12	1500	1538
WiFi	小包	34	4	24	0	34
	大包	34	4	24	2312	2346

Ethernet (802.3) Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	42 to 1500 bytes	4 bytes	12 bytes
Preamble	Start of Frame Delimiter	**Destination MAC Address**	**Source MAC Address**	Type	Data (payload)	CRC	Inter-frame gap

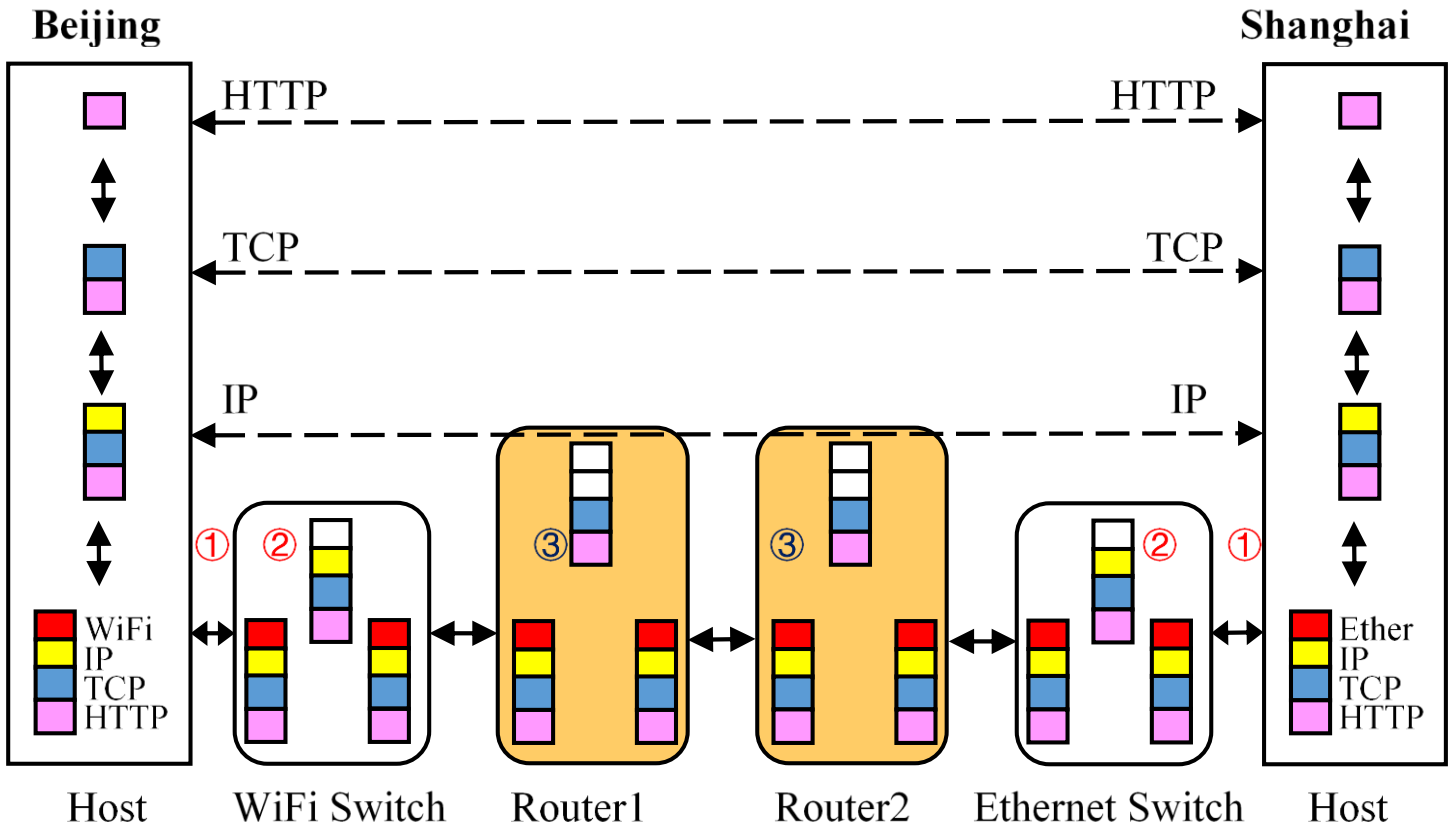
For TCP/IP communications, the payload for a frame is a packet

WiFi (802.11) Frame Format

2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes	0 to 2312 bytes	4 bytes
Frame Control	Duration	MAC Address 1 (Destination)	MAC Address 2 (Source)	MAC Address 3 (Router)	Seq Control	MAC Address 4 (AP)	Data (payload)	CRC

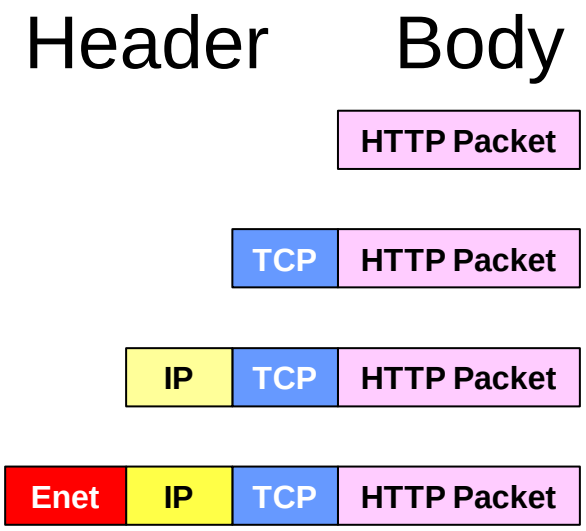
4.1 HTTP request and response messages

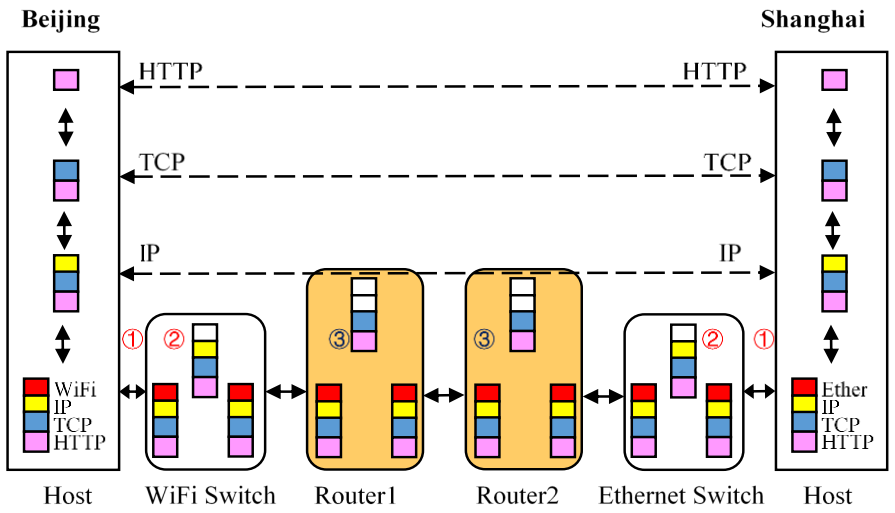
- Request message: http://www.shanghaitech.edu.cn/
  - Sent to the server as a stream of packets
- Response message: the contents of the home page
  - Sent from the server as a stream of packets



How is the response message communicated

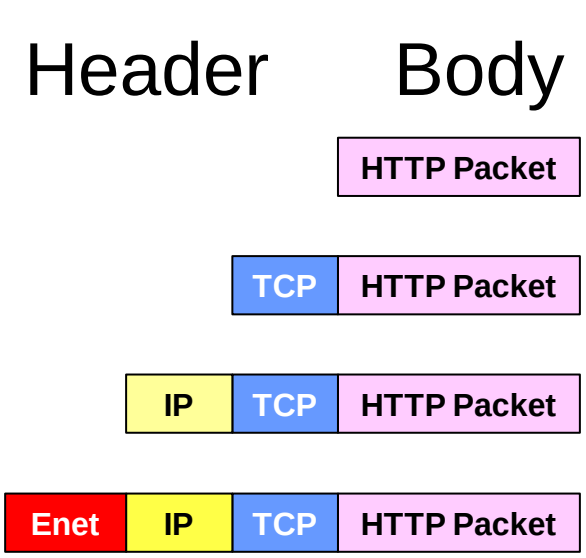
- Response message, i.e., the contents of the home page, is divided into a number of packets, i.e., slices of the message
  - Each HTTP packet is turned into an Ethernet packet as follows
    - HTTP packet (**pink**), actually a slice of the HTTP message, is handed to the TCP layer as the body of a TCP 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

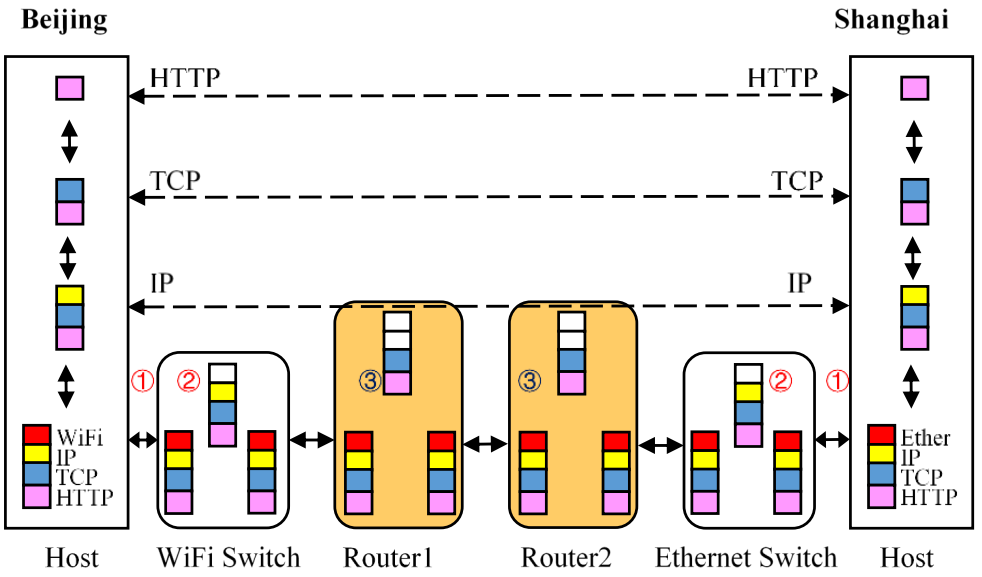




How is the response message communicated

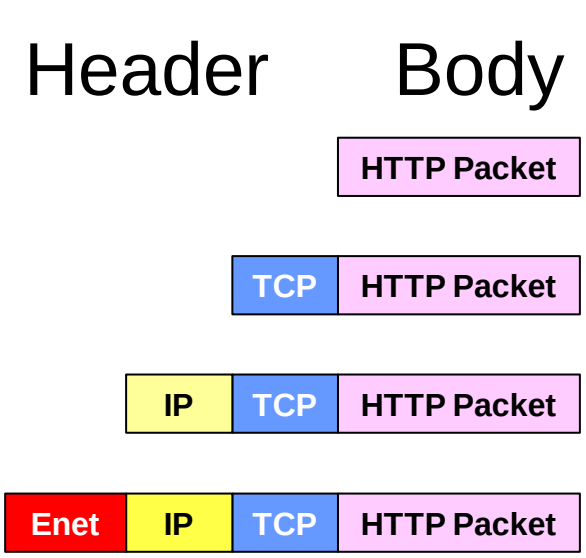
- Each HTTP packet is communicated as follows
  - ① The server host sends an HTTP packet, wrapped as an Ethernet packet, to the Ethernet switch
  - ② The switch opens the packet to reveal the Ethernet header, and then adds a new header (with a new MAC address) to form a new Ethernet packet
  - ③ When 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)

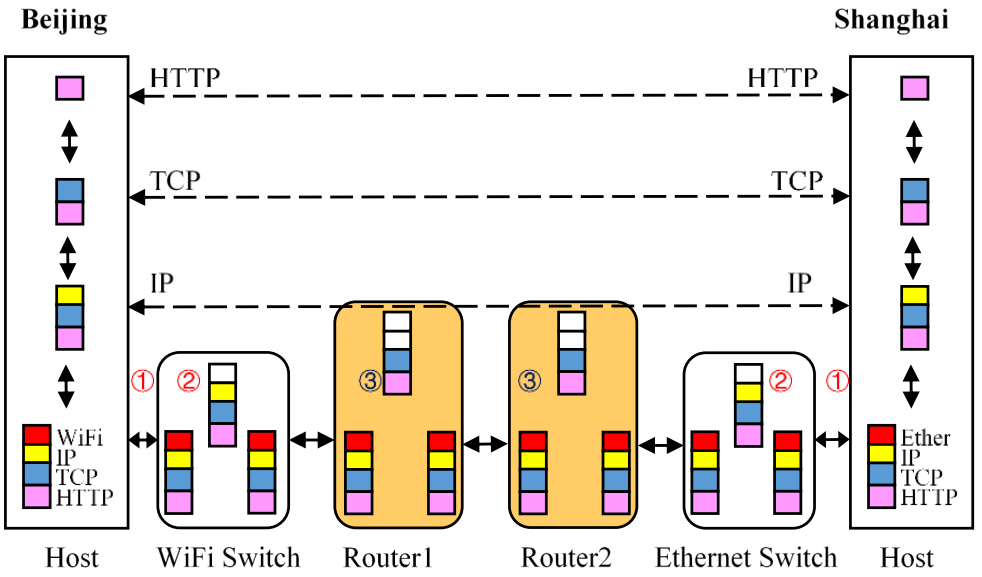




How is the response message communicated

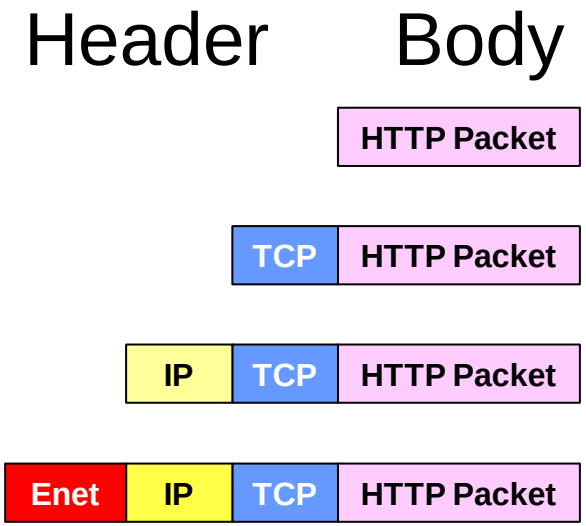
- Each HTTP packet is communicated as follows
  - After a WiFi packet arrives at the laptop computer host in Beijing, it is unpacked by the host (the laptop computer) to reveal
  - the IP packet,
  - the TCP packet, and finally
  - the HTTP packet, i.e., a slice of the message

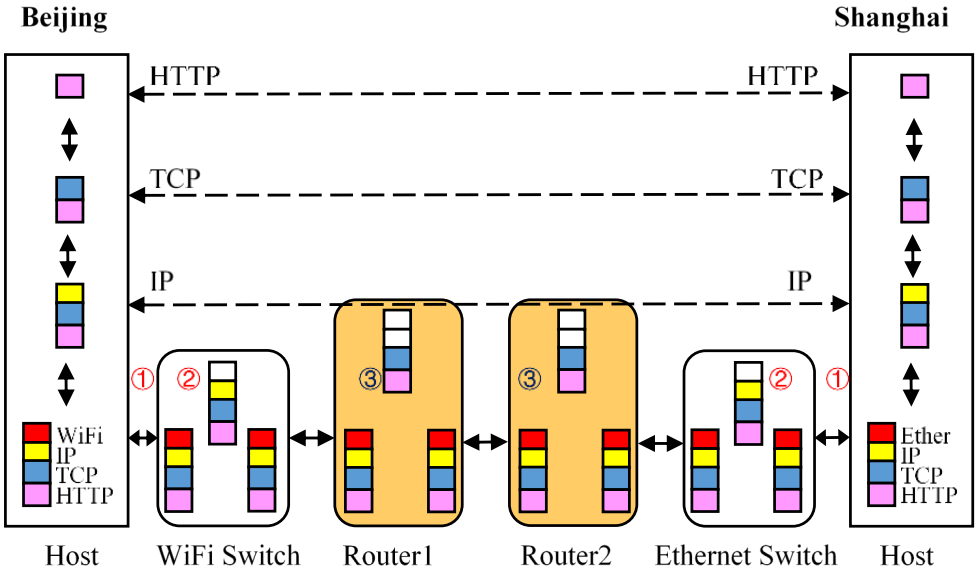




Does Zhang need to worry about TCP/IP and Ethernet when surfing the Web?

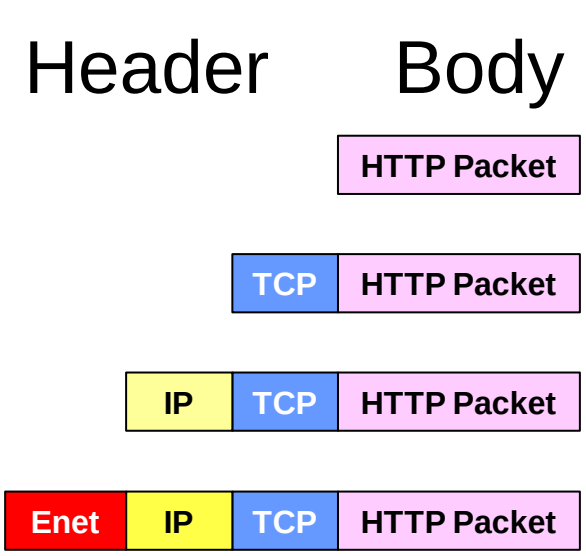
- No! A user only needs to know the peering interface HTTP
- Two types of interfaces
  - **Peering interface**:
  - **Service interfaces**:

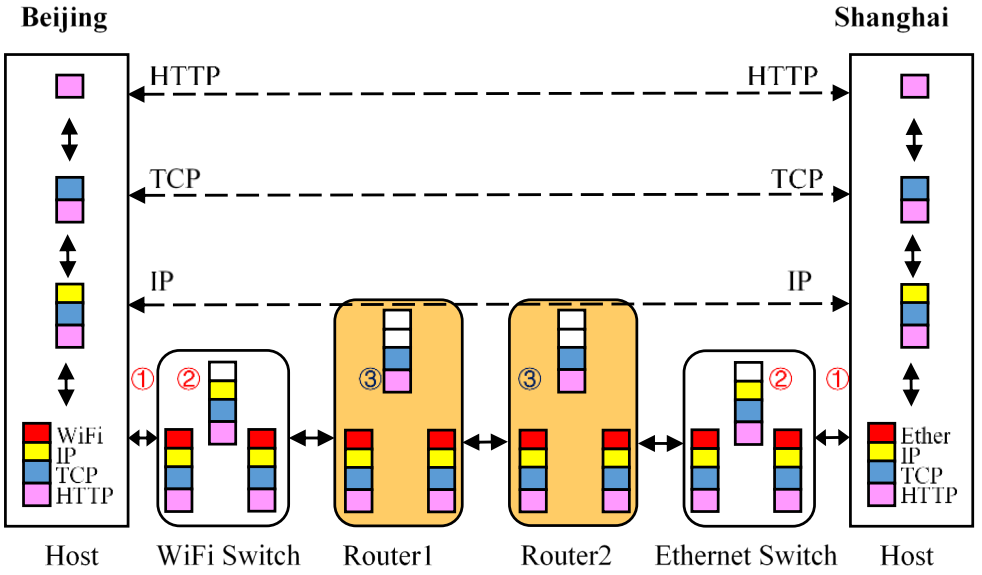




Can one send an upper layer packet without also sending a lower layer packet?

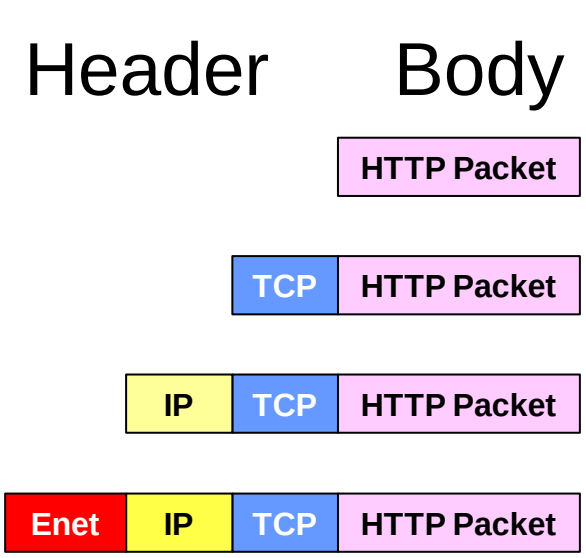
- Can the Web server in Shanghai send an HTTP packet to Zhang's Web browser in Beijing, without also sending a data link layer packet, e.g., an Ethernet frame?
- No!
  - Any information at the HTTP layer is wrapped in a data link layer packet, and eventually wrapped in a physical layer packet
  - One 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

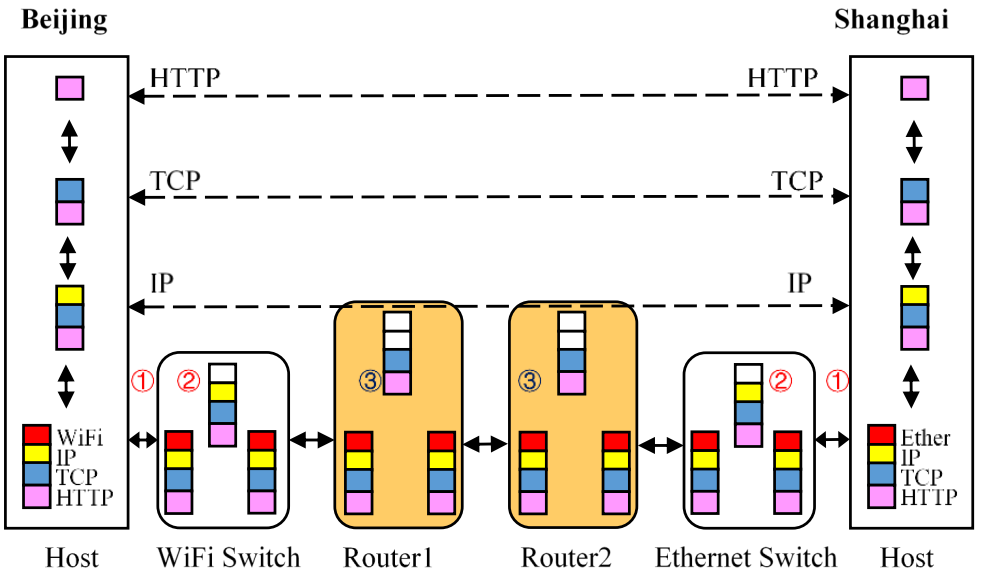




What is actually sent over the network hardware?

- Bit string of 0's and 1's
- 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?

- 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
    - 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