

FISF130020: Introduction to Computer Science

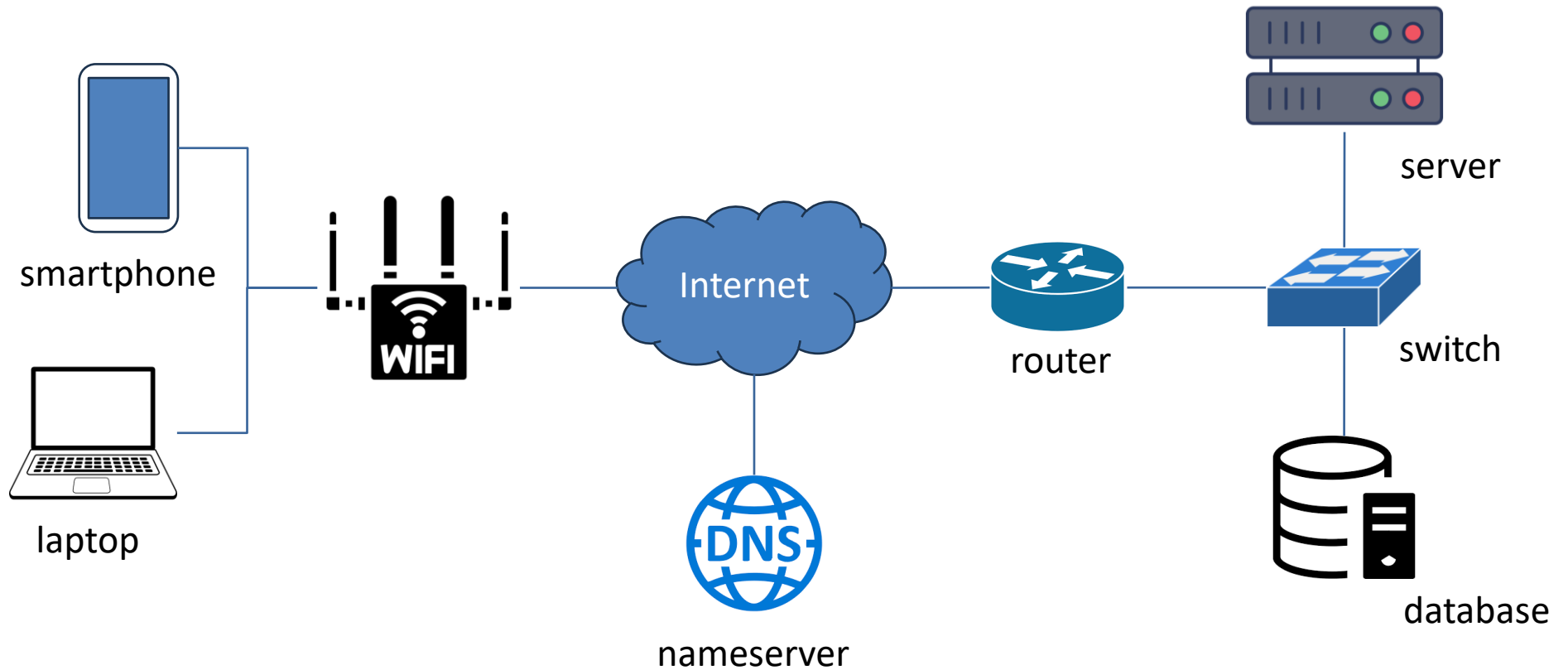
# Lecture 7: Network

Hui Xu

xuh@fudan.edu.cn



# Scenario



❖ What happens when we access the service of EastMoney?

# Outline

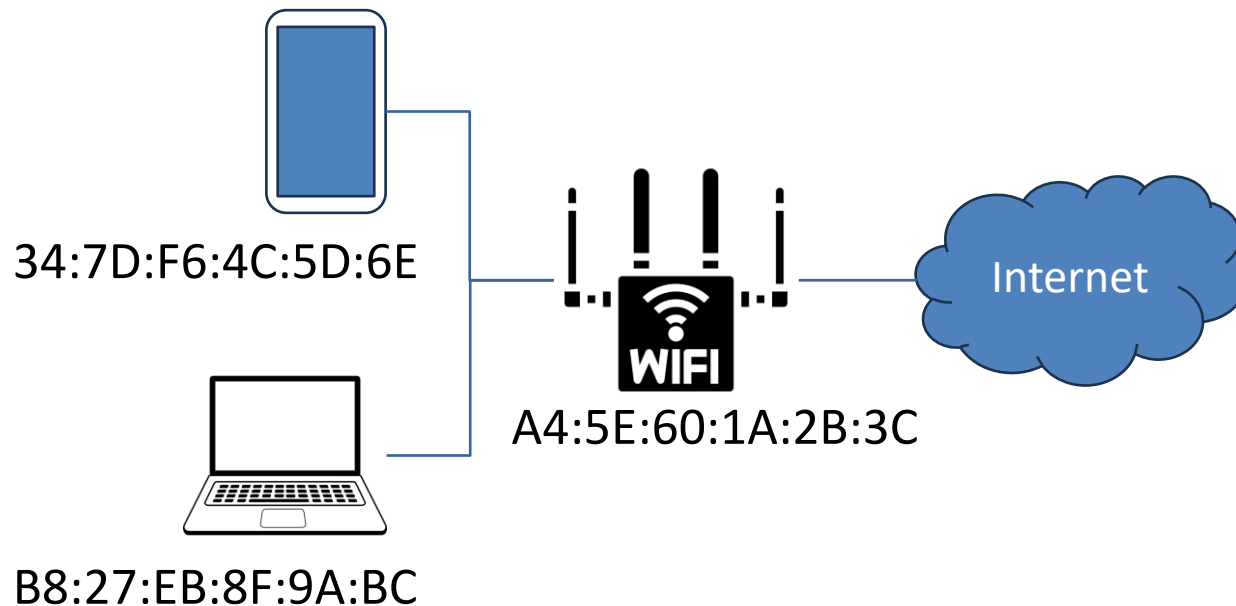
- ❖ 1. Local Area Network
- ❖ 2. Wide Area Network
- ❖ 3. In-class Practice

# 1. Local Area Network

---

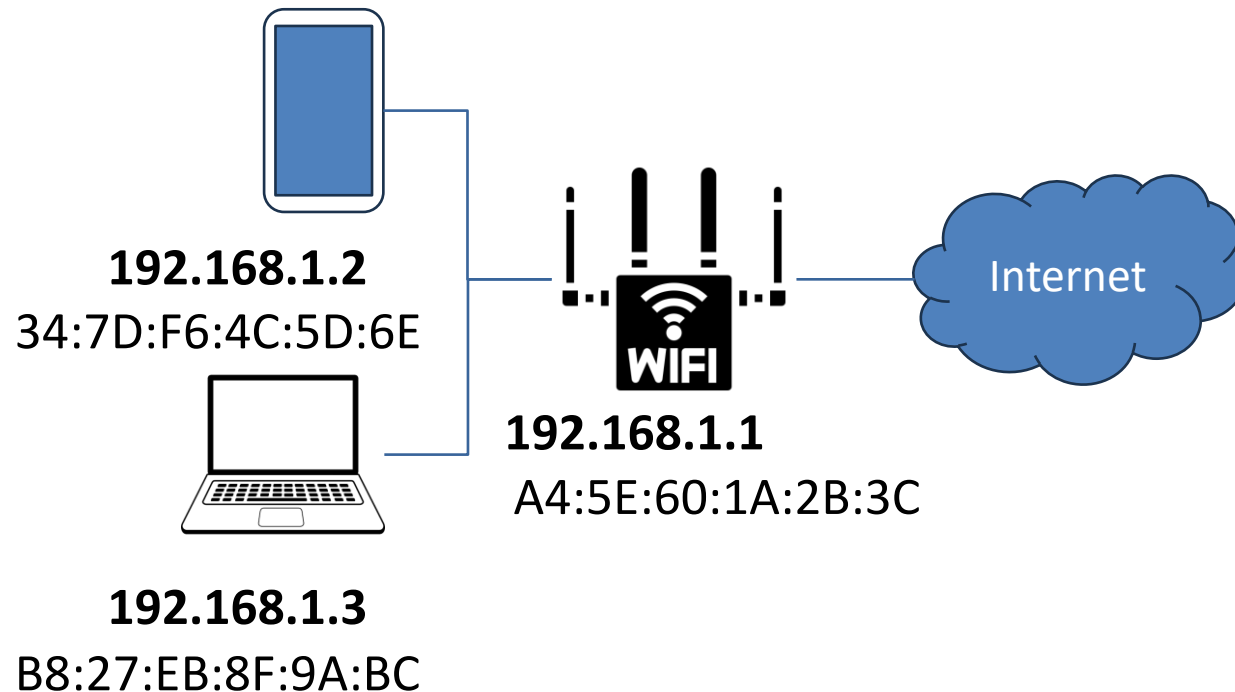
# MAC: Media Access Control

- Each network interface controller (NIC) has a unique MAC address
- 48 bits:
  - 24 bits: manufacturer specific
  - 24 bits: manufacturer's organizationally unique identifier
- Designed for local network communications



# IP: Internet Protocol

- Each device can be configured with one or several IP addresses.
  - 32 bits for IPv4
  - 128 bits for IPv6
- Each IP address is within a local area network (LAN)



# IP Configuration

**IP address:** 192.168.1.2

**Mask:** 255.255.255.0

**Gateway:** 192.168.1.1

**Broadcast address:** 192.168.1.255

**Network Address:** 192.168.1.0

Numbers of addresses supported in a LAN

Proxy from an inner IP to an outer IP

**IP address:** 192.168.1.2

**Mask:** 255.255.255.0



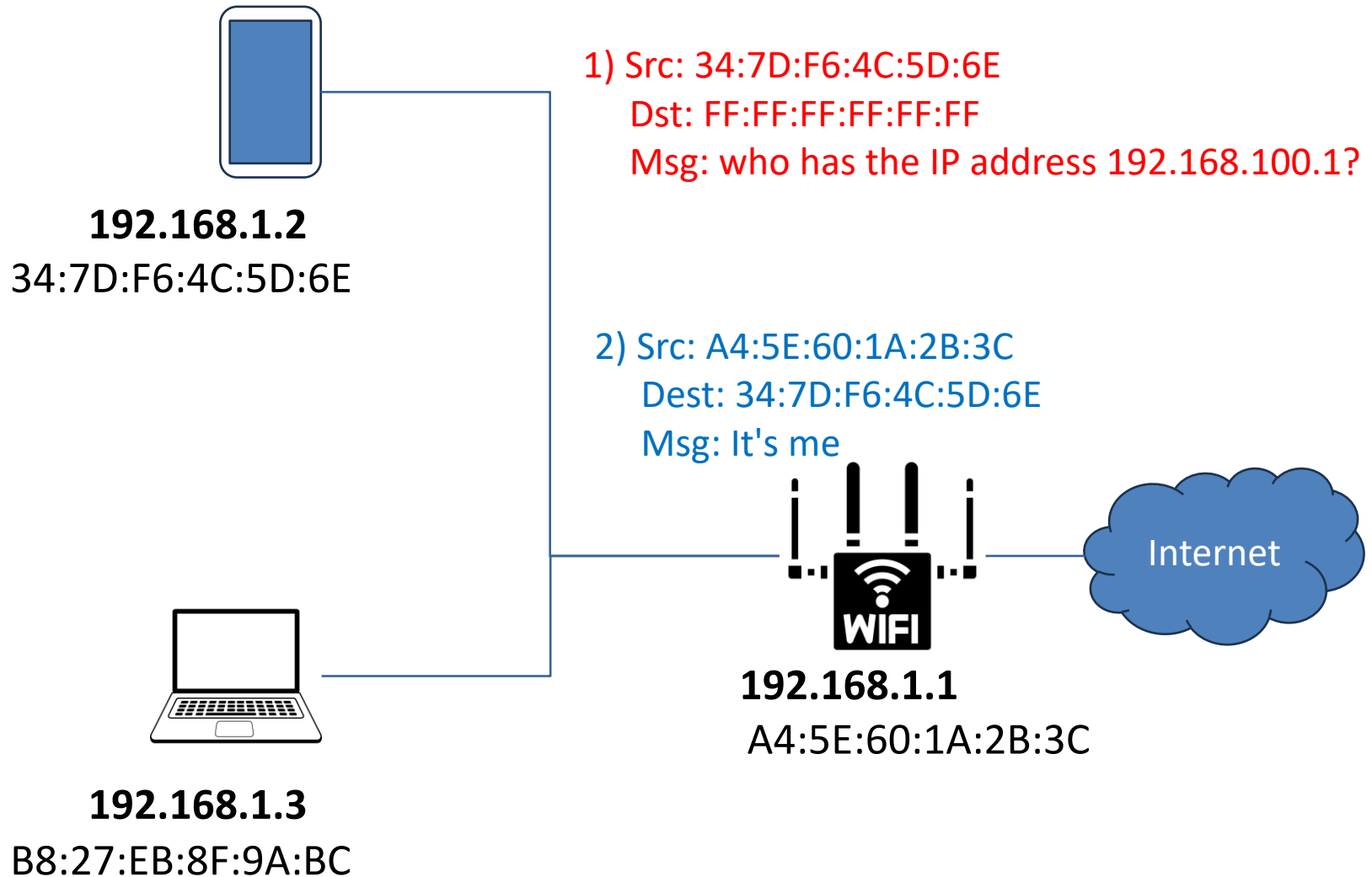
192.168.100.2/24

simplified form

Question: How does 192.168.1.2 receive messages from 192.168.1.1?

# ARP: Address Resolution Protocol

- Translate an IP address to the MAC address



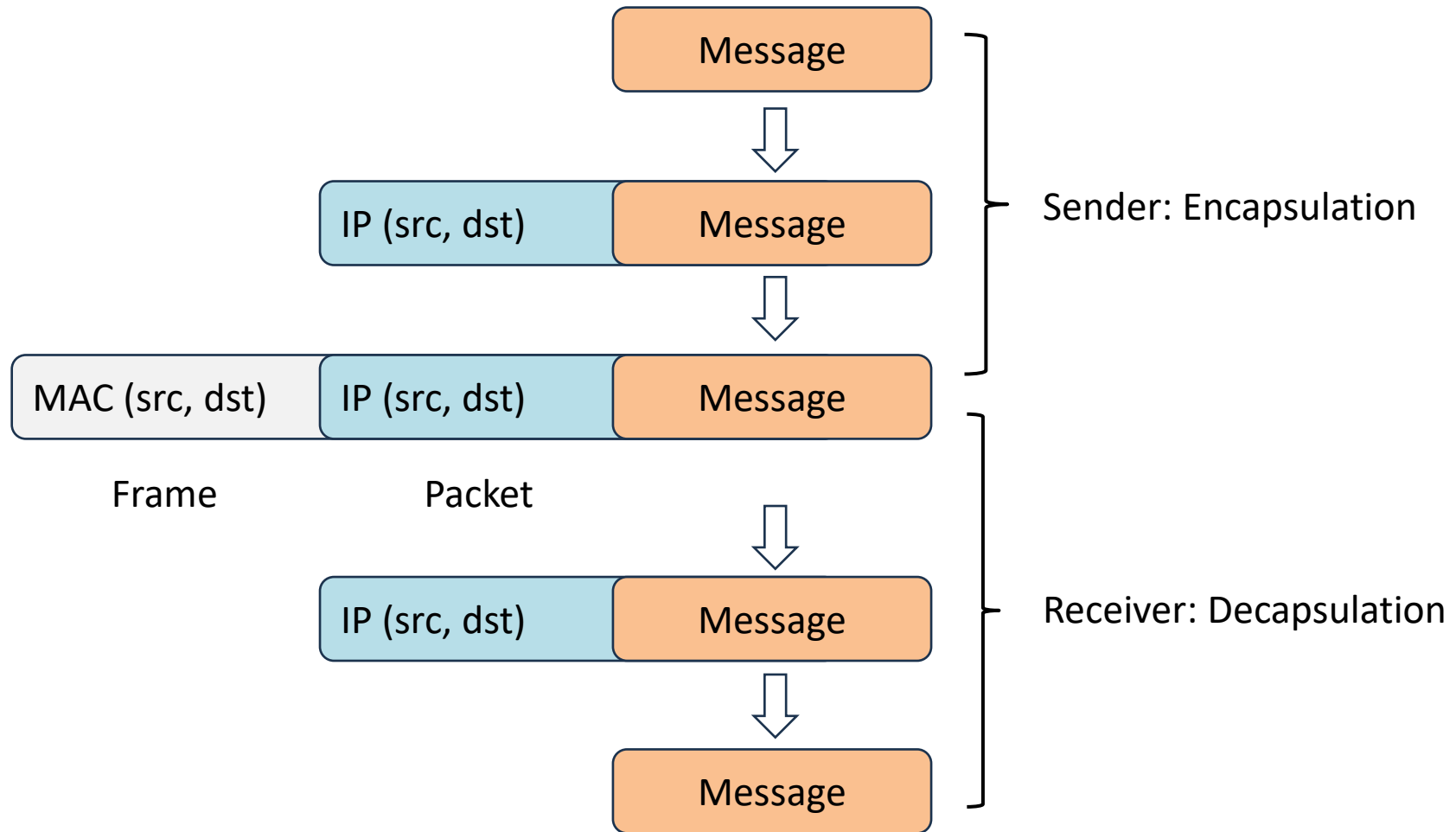


# Example

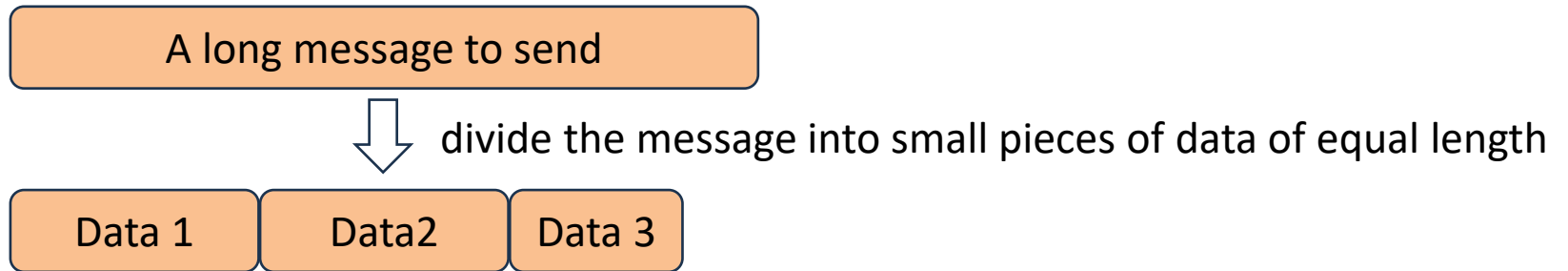
```
888 73.928771 Chongqin_... Broadcast ARP 60 Who has 192.168.1.100? Tell 192.168.1.107
889 73.928779 IntelCor_... Chongqin_... ARP 42 192.168.1.100 is at 50:eb:71:bd:fc:f4
```

- ▼ Ethernet II, Src: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
  - › Destination: Broadcast (ff:ff:ff:ff:ff:ff)
  - › Source: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98)  
Type: ARP (0x0806)  
Padding: 00000000000000000000000000000000
- ▼ Address Resolution Protocol (request)
  - Hardware type: Ethernet (1)
  - Protocol type: IPv4 (0x0800)
  - Hardware size: 6
  - Protocol size: 4
  - Opcode: request (1)
  - Sender MAC address: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98)
  - Sender IP address: 192.168.1.107
  - Target MAC address: 00:00:00\_00:00:00 (00:00:00:00:00:00)
  - Target IP address: 192.168.1.100
- ▼ Ethernet II, Src: IntelCor\_bd:fc:f4 (50:eb:71:bd:fc:f4), Dst: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98)
  - › Destination: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98)
  - › Source: IntelCor\_bd:fc:f4 (50:eb:71:bd:fc:f4)  
Type: ARP (0x0806)
- ▼ Address Resolution Protocol (reply)
  - Hardware type: Ethernet (1)
  - Protocol type: IPv4 (0x0800)
  - Hardware size: 6
  - Protocol size: 4
  - Opcode: reply (2)
  - Sender MAC address: IntelCor\_bd:fc:f4 (50:eb:71:bd:fc:f4)
  - Sender IP address: 192.168.1.100
  - Target MAC address: Chongqin\_4f:6c:98 (ec:5c:68:4f:6c:98)
  - Target IP address: 192.168.1.107

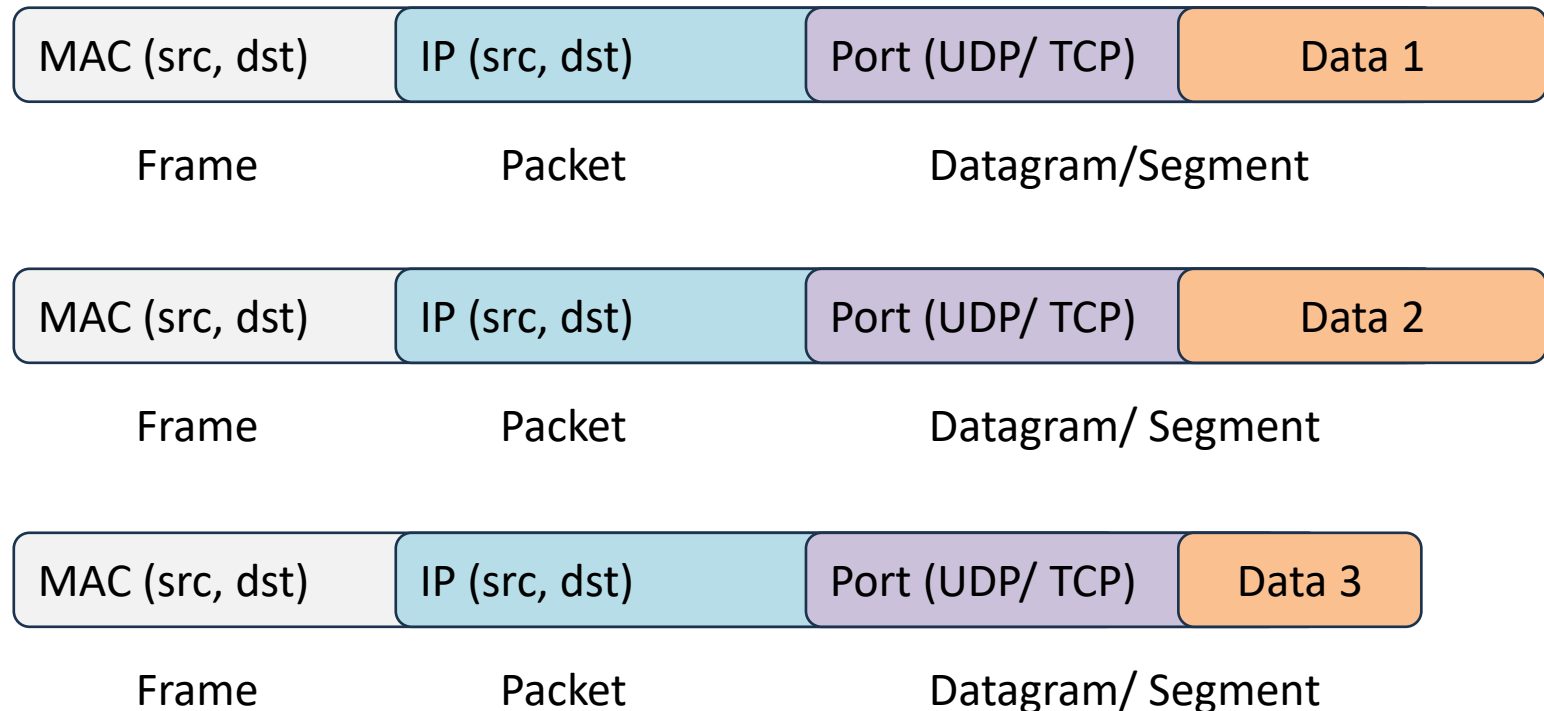
# Message Encapsulation/Decapsulation



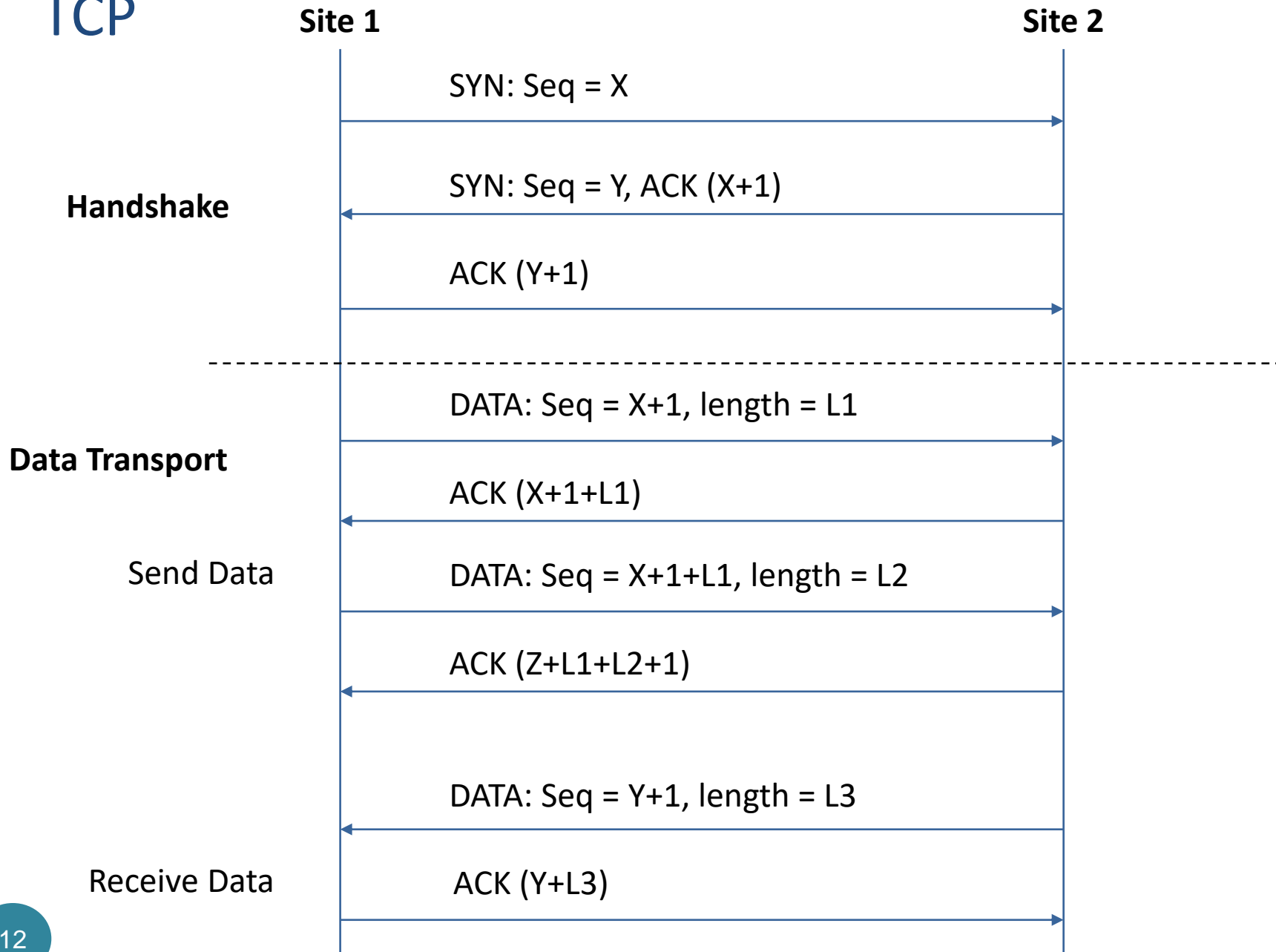
# Message Encapsulation



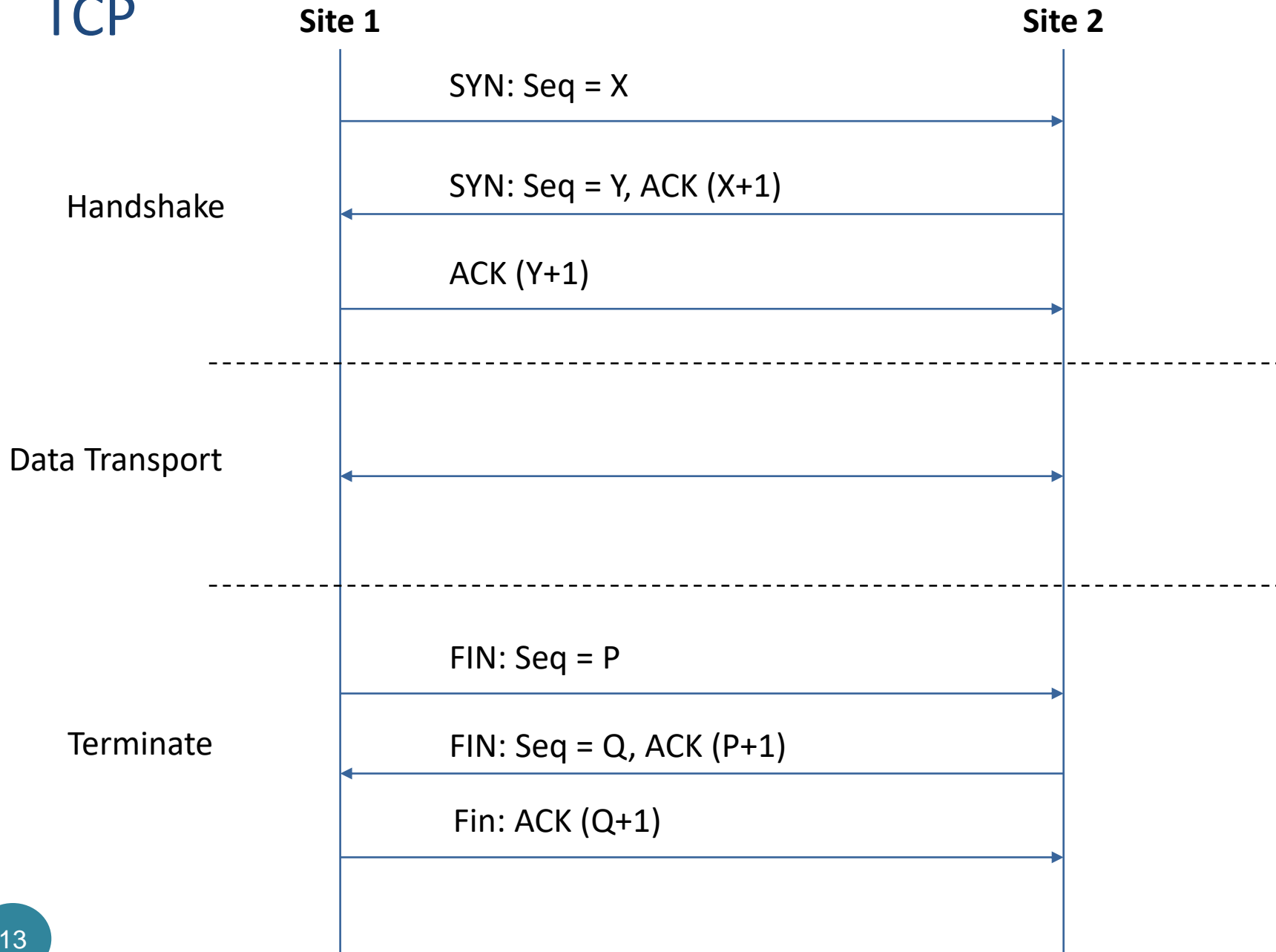
**Encapsulate each piece of data:**



# TCP



# TCP



# TCP Handshake: SYN

tcp.stream eq 17						
No.	Time	Source	Destination	Protocol	Length	Info
97	4.69...	192.168.1.3	220.249.46.34	TCP	66	51188 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM=1
98	4.72...	220.249.46.34	192.168.1.3	TCP	66	80 → 51188 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1440 SACK_PERM=1 WS=256
99	4.72...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=1 Ack=1 Win=132352 Len=0
100	4.72...	192.168.1.3	220.249.46.34	HTTP	238	GET /api/toolbox/geturl.php?h=853EA31B28F6A2BAA86434EA7564E605&v=9.5.0.3517&r=0000_sogou_pinyin_94a1 HTTP/1.1
101	4.75...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [ACK] Seq=1 Ack=185 Win=30464 Len=0
102	4.75...	220.249.46.34	192.168.1.3	HTTP	208	HTTP/1.1 200 OK
103	4.75...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [FIN, ACK] Seq=185 Ack=155 Win=132096 Len=0
104	4.79...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [FIN, ACK] Seq=155 Ack=186 Win=30464 Len=0
105	4.79...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=186 Ack=156 Win=132096 Len=0

▼ Transmission Control Protocol, Src Port: 51188, Dst Port: 80, Seq: 0, Len: 0

Source Port: 51188  
Destination Port: 80  
[Stream index: 17]  
[TCP Segment Len: 0]  
Sequence number: 0 (relative sequence number)  
Sequence number (raw): 2844094833  
[Next sequence number: 1 (relative sequence number)]  
Acknowledgment number: 0  
Acknowledgment number (raw): 0  
1000 .... = Header Length: 32 bytes (8)  
> **Flags: 0x002 (SYN)**  
Window size value: 64240  
[Calculated window size: 64240]  
Checksum: 0xc41c [unverified]  
[Checksum Status: Unverified]  
Urgent pointer: 0  
> Options: (12 bytes), Maximum segment size, No-Operation (NOP), Window scale, No-Operation (NOP), No-Operation (NOP), SACK permitted

# TCP Handshake: SYN-ACK

tcp.stream eq 17						
No.	Time	Source	Destination	Protocol	Length	Info
97	4.69...	192.168.1.3	220.249.46.34	TCP	66	51188 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM=1
98	4.72...	220.249.46.34	192.168.1.3	TCP	66	80 → 51188 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1440 SACK_PERM=1 WS=256
99	4.72...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=1 Ack=1 Win=132352 Len=0
100	4.72...	192.168.1.3	220.249.46.34	HTTP	238	GET /api/toolbox/geturl.php?h=853EA31B28F6A2BAA86434EA7564E605&v=9.5.0.3517&r=
101	4.75...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [ACK] Seq=1 Ack=185 Win=30464 Len=0
102	4.75...	220.249.46.34	192.168.1.3	HTTP	208	HTTP/1.1 200 OK
103	4.75...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [FIN, ACK] Seq=185 Ack=155 Win=132096 Len=0
104	4.79...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [FIN, ACK] Seq=155 Ack=186 Win=30464 Len=0
105	4.79...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=186 Ack=156 Win=132096 Len=0

Transmission Control Protocol, Src Port: 80, Dst Port: 51188, Seq: 0, Ack: 1, Len: 0

Source Port: 80  
Destination Port: 51188  
[Stream index: 17]  
[TCP Segment Len: 0]  
Sequence number: 0 (relative sequence number)  
Sequence number (raw): 911860538  
[Next sequence number: 1 (relative sequence number)]  
Acknowledgment number: 1 (relative ack number)  
Acknowledgment number (raw): 2844094834  
1000 .... = Header Length: 32 bytes (8)  
> **Flags: 0x012 (SYN, ACK)**  
Window size value: 29200  
[Calculated window size: 29200]  
Checksum: 0x336c [unverified]  
[Checksum Status: Unverified]  
Urgent pointer: 0  
> Options: (12 bytes), Maximum segment size, No-Operation (NOP), No-Operation (NOP), SACK permitted, No-Operation (NOP), Window scale

15

# TCP Connection Termination: FIN

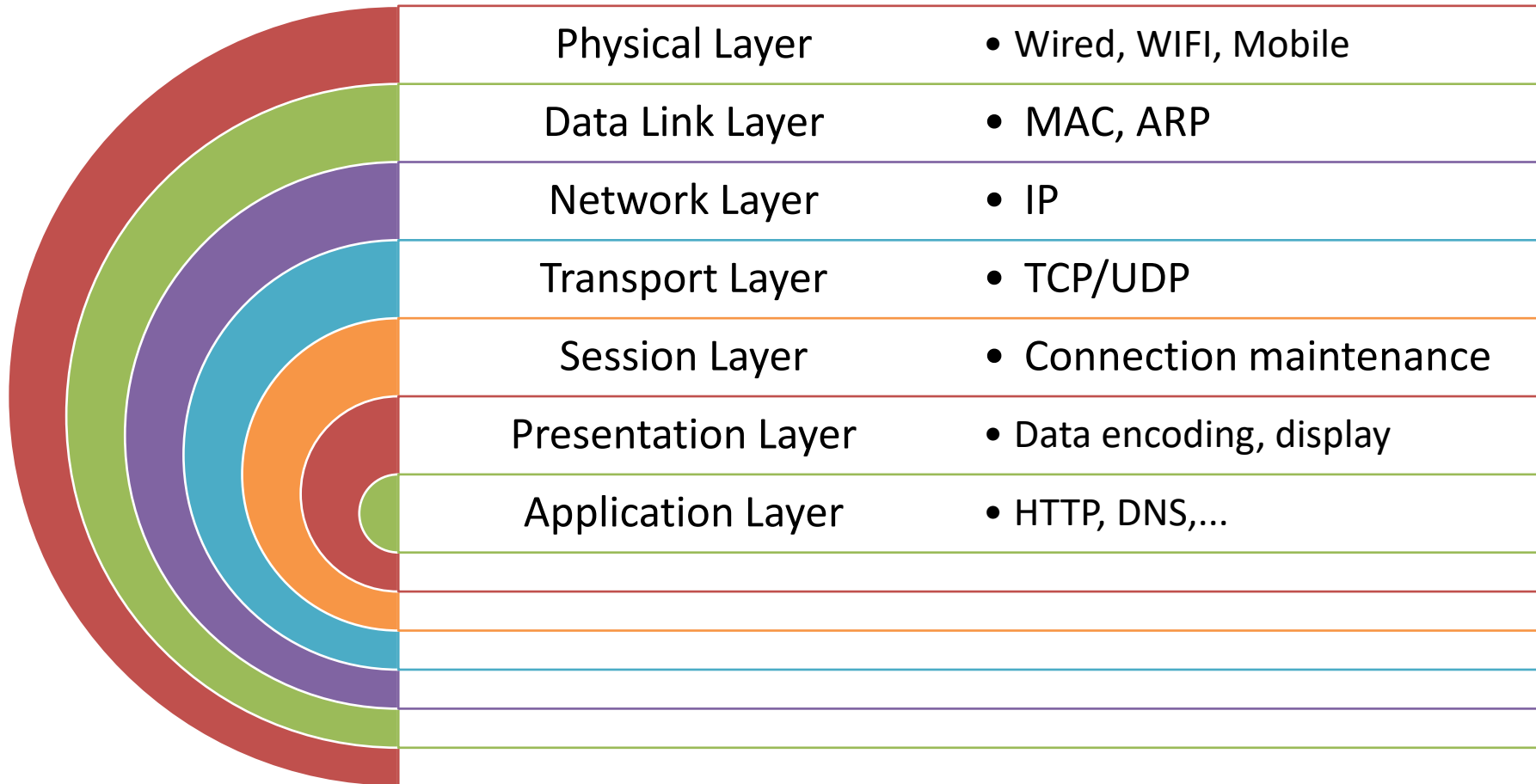
tcp.stream eq 17						
No.	Time	Source	Destination	Protocol	Length	Info
97	4.69...	192.168.1.3	220.249.46.34	TCP	66	51188 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256
98	4.72...	220.249.46.34	192.168.1.3	TCP	66	80 → 51188 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1
99	4.72...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=1 Ack=1 Win=132352 Len=0
100	4.72...	192.168.1.3	220.249.46.34	HTTP	238	GET /api/toolbox/geturl.php?h=853EA31B28F6A2BAA86434EA7
101	4.75...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [ACK] Seq=1 Ack=185 Win=30464 Len=0
102	4.75...	220.249.46.34	192.168.1.3	HTTP	208	HTTP/1.1 200 OK
103	4.75...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [FIN, ACK] Seq=185 Ack=155 Win=132096 Len=0
104	4.79...	220.249.46.34	192.168.1.3	TCP	54	80 → 51188 [FIN, ACK] Seq=155 Ack=186 Win=30464 Len=0
105	4.79...	192.168.1.3	220.249.46.34	TCP	54	51188 → 80 [ACK] Seq=186 Ack=156 Win=132096 Len=0

Transmission Control Protocol, Src Port: 51188, Dst Port: 80, Seq: 185, Ack: 155, Len: 0

Source Port: 51188  
Destination Port: 80  
[Stream index: 17]  
[TCP Segment Len: 0]  
Sequence number: 185 (relative sequence number)  
Sequence number (raw): 2844095018  
[Next sequence number: 186 (relative sequence number)]  
Acknowledgment number: 155 (relative ack number)  
Acknowledgment number (raw): 911860693  
0101 .... = Header Length: 20 bytes (5)  
Flags: 0x011 (FIN, ACK)  
Window size value: 516  
[Calculated window size: 132096]  
[Window size scaling factor: 256]



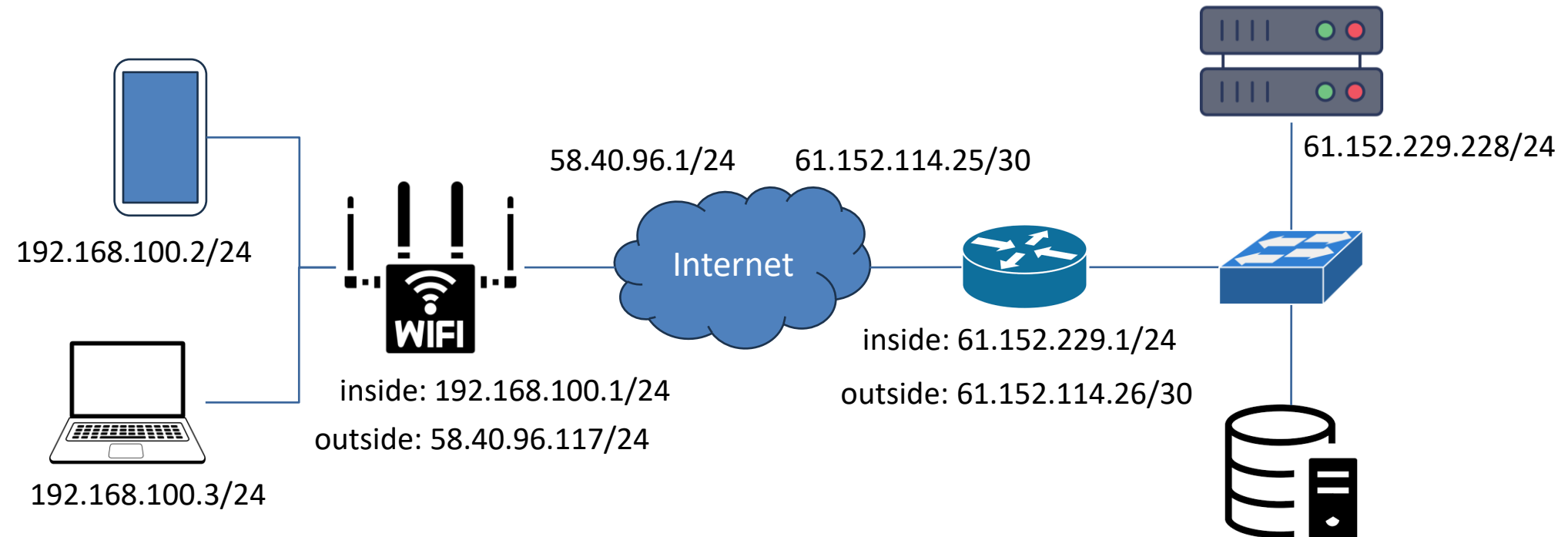
# The OSI Model



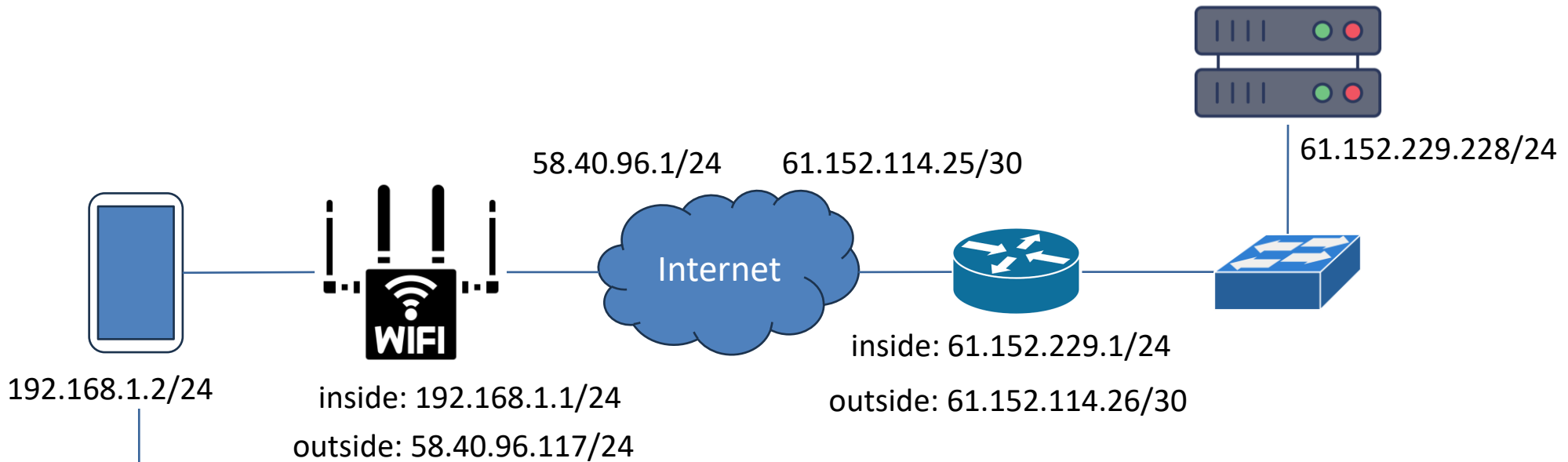
## 2. Wide Area Network

---

# Routing among Different Networks



# Routing Table

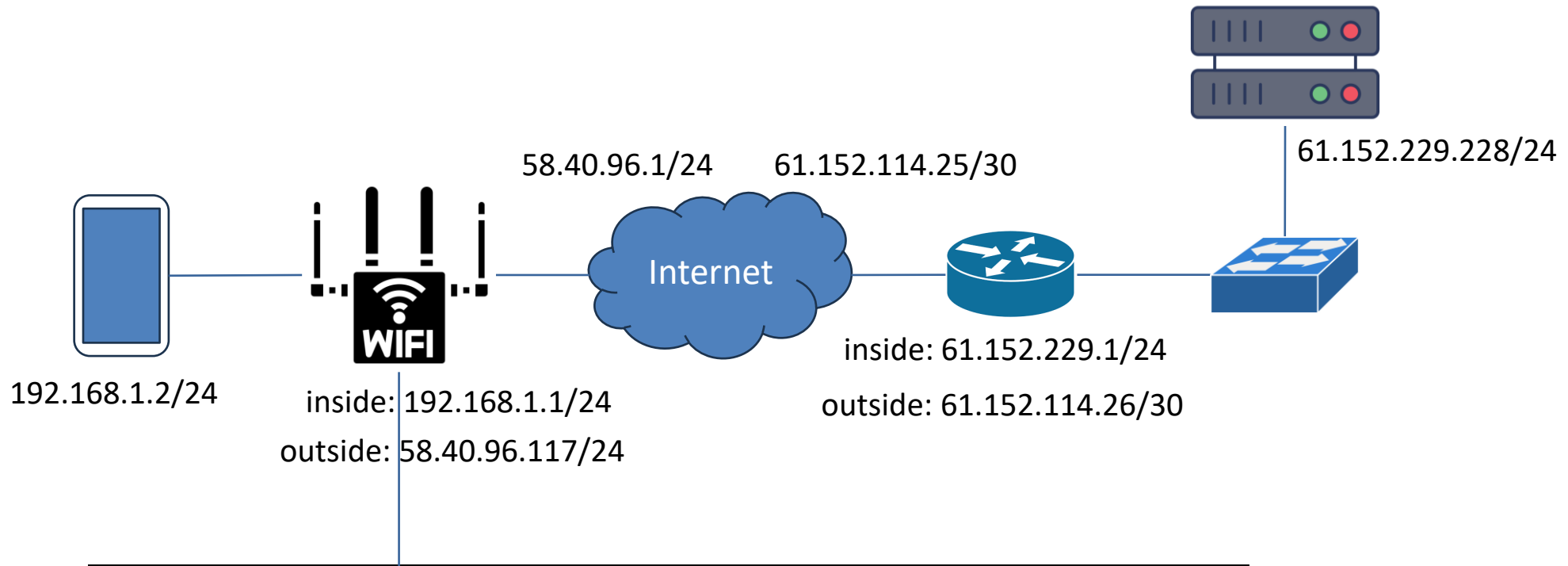


Destination	Next Hop
*.*.*.*	192.168.1.1

```
MacBook-Pro-2:artisan huixu$ netstat -rn
Routing tables

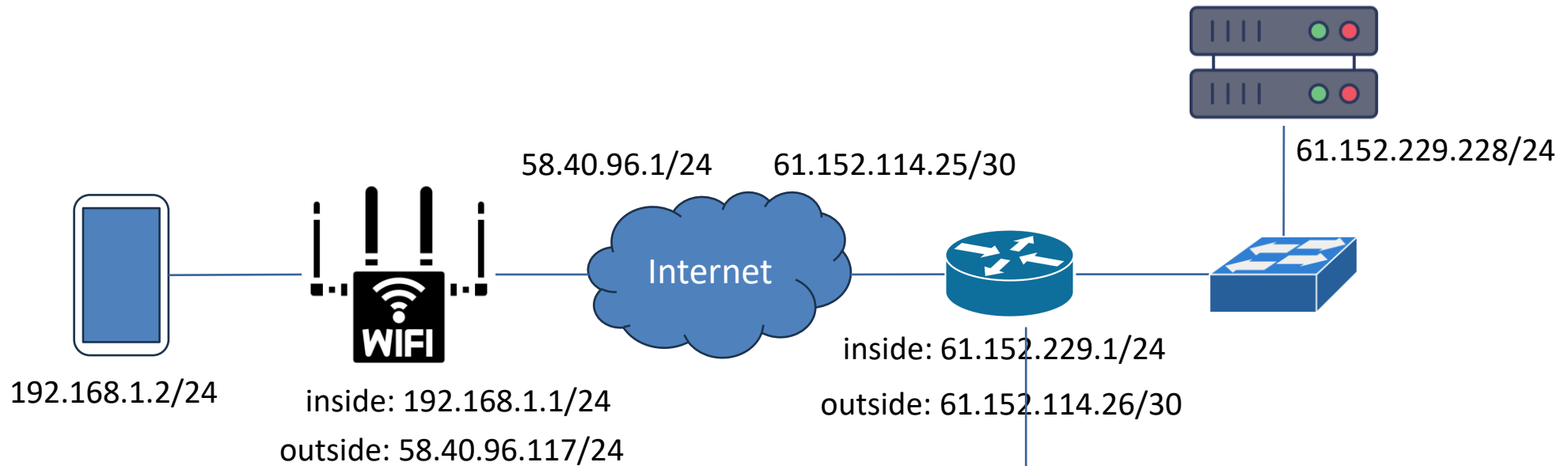
Internet:
Destination      Gateway           Flags
default          192.168.1.1      UGScg
127              127.0.0.1        UCS
127.0.0.1        127.0.0.1        UH
169.254          link#12          UCS
192.168.1        link#12          UCS
192.168.1.1/32   link#12          UCS
```

# NAT: Network Address Translation



Source Address		Translated Address	
IP	Port	IP	Port
192.168.1.2	12345	58.40.96.117	32123
192.168.1.2	12346	58.40.96.117	32124
192.168.1.2	12347	58.40.96.117	32125

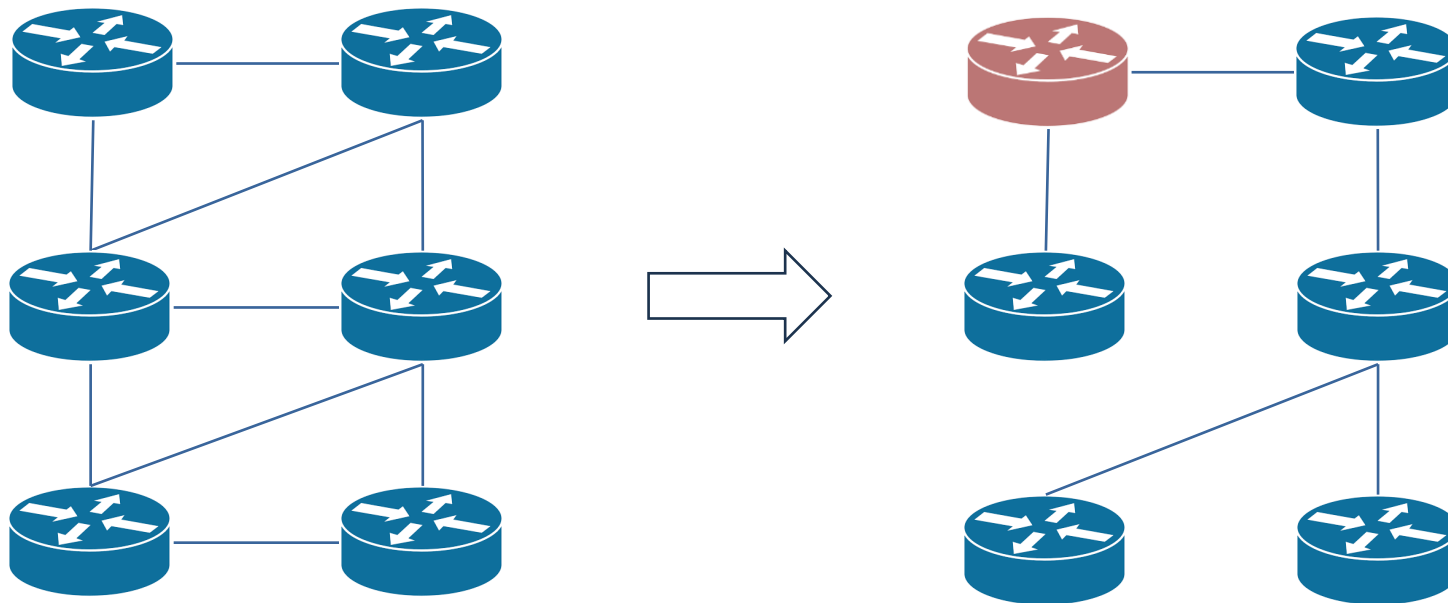
# Routing Table



Destination	Next Hop
61.152.229.0/24	61.152.229.1
*.*.*.*	61.152.114.25

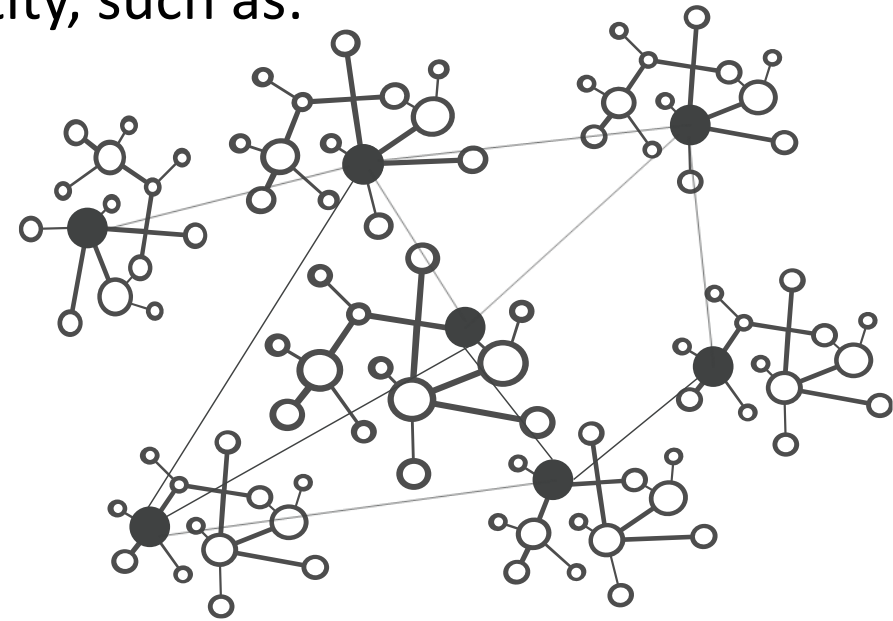
# OSPF: Open Shortest Path First

- OSPF is used within the same autonomous systems.
  - Find the shortest path to each destination based on Dijkstra's algorithm.
  - Convert a network topology to a spanning tree.



# Internet








- Composed of many autonomous systems (AS)
- Each AS is an independent network entity, such as:
  - Internet Service Provider (ISP)
  - Large high-tech organizations
- Within an Autonomous System:
  - Multiple routers manage multiple networks
  - Uses OSPF for internal routing
- Interconnection between Autonomous Systems:
  - Use BGP for communication between different ASes

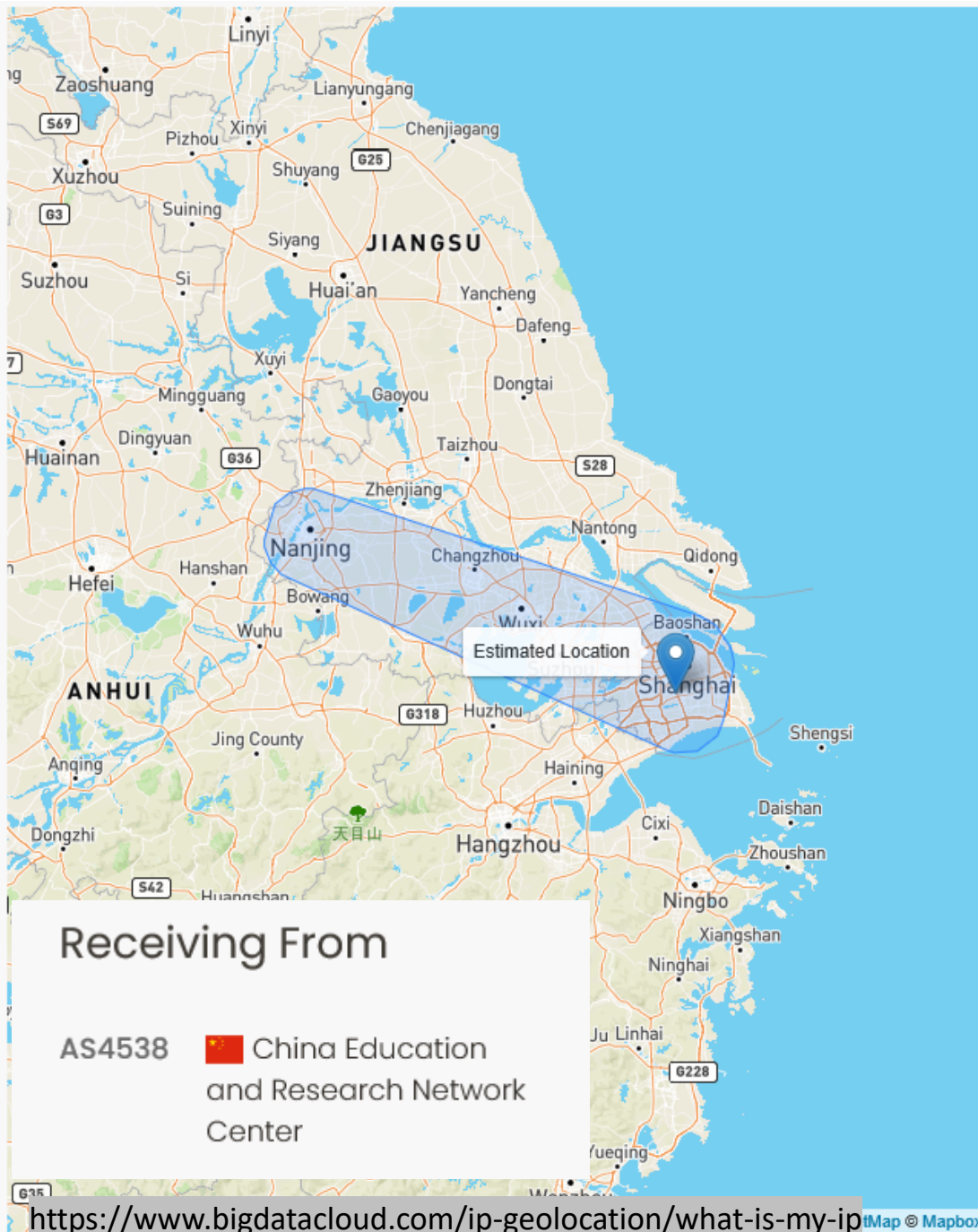





# Example AS

<https://www.bigdatacloud.com/insights/as-rank>











Rank ▾	AS Number	Organisation	Total IPv4 Addresses
1	<a href="#">AS749</a>	 DoD Network Information Center	224,675,888
2	<a href="#">AS4134</a>	 No.31,Jin-rong Street Beijing 100032	102,264,959
3	<a href="#">AS7018</a>	 AT&T Services, Inc.	92,705,503
4	<a href="#">AS7922</a>	 Comcast Cable Communications, LLC	69,615,412
5	<a href="#">AS8075</a>	 Microsoft Corporation	63,707,003
6	<a href="#">AS4837</a>	 CHINA UNICOM China169 Backbone	56,944,270
7	<a href="#">AS16509</a>	 Amazon.com, Inc.	48,741,833
8	<a href="#">AS4766</a>	 Korea Telecom	46,124,863
9	<a href="#">AS17676</a>	 SoftBank Mobile Corp. Tokyo Port City Takeshiba ..	40,782,687
10	<a href="#">AS701</a>	 Verizon Business	40,144,718



Ip Details	JSON View	JSON Raw
Security Risk	unknown	
Registered For	Fudan University Network and Information Engineering Center 5th Floor, Yifu Building 220 Handan Road	
UN Region	Asia/Eastern Asia	
World Bank Region	East Asia & Pacific	
World Bank Income Level	Upper middle income	
Country	 China	
ISO ALPHA-2	CN	
ISO ALPHA-3	CHN	
Principal Subdivision	上海市	
ISO 3166-2	CN-SH	
City		
Postal Code		
Latitude	31.05	
Longitude	121.4	
Timezone	(CST) China Standard Time	
Local Time	Sunday, September 27, 2020 10:38 am	
Confidence	moderate	
Carrier	CERNET2 IX at Shanghai Jiaotong University	
ASN	AS24364	
BGP Prefix	202.120.234.0/23	

# AS4538

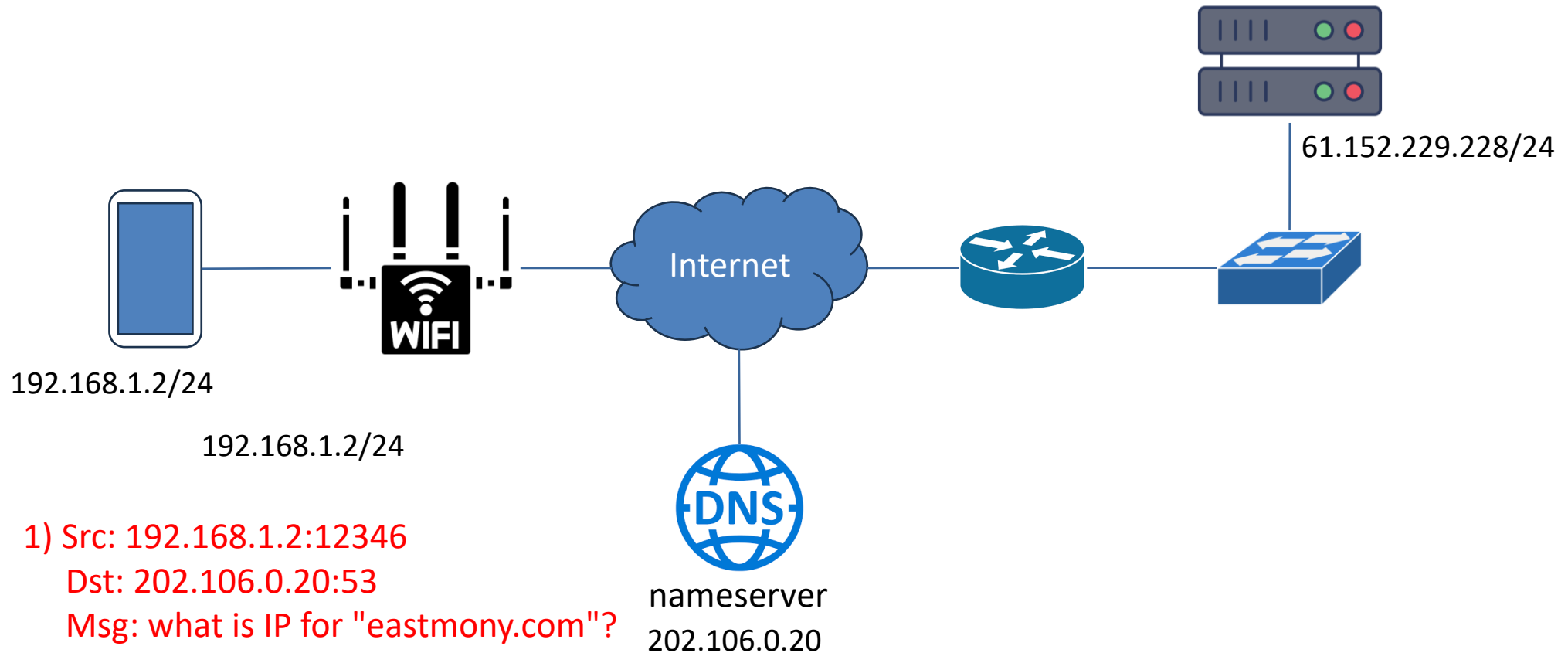
## Receiving From

AS174	 Cogent Communications	AS4134	 No.31Jinrong Street
AS4637	 Telstra International Limited	AS4789	 NAPI at CERNET
AS4837	 CHINA UNICOM China169 Backbone	AS6453	 TATA COMMUNICATIONS AMERICA INC
AS6939	 Hurricane Electric LLC	AS7497	 Computer Network Information Center
AS9808	 China Mobile	AS23911	 China Next Generation Internet Beijing IX

## Transit To

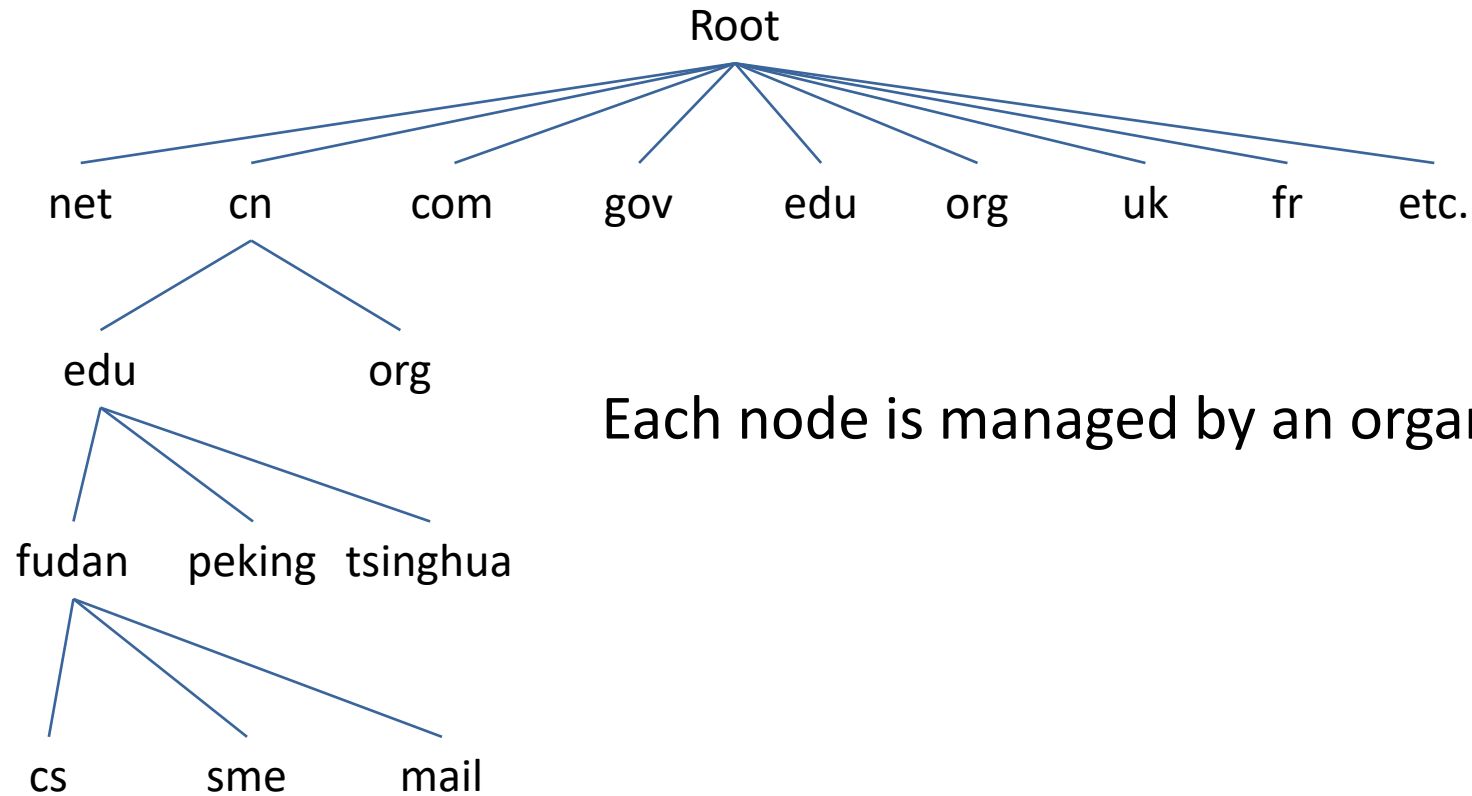
AS9405	 Test platform Service Center	AS23910	 China Next Generation Internet CERNET2
AS23911	 China Next Generation Internet Beijing IX	AS24348	 CERNET2 IX at Tsinghua University
AS24349	 CERNET2 IX at Peking University	AS24350	 CERNET2 IX at Beijing University of Posts and Telecommunications
AS24353	 CERNET2 IX at Xian Jiaotong University	AS24355	 CERNET2 IX at University of Electronic Science and Technology of China
AS24357	 CERNET2 IX at South China University of Technology	AS24358	 CERNET2 IX at Huazhong University of Science and Technology
AS24361	 CERNET2 IX at Southeast University	AS24362	 CERNET2 IX at University of Science and Technology of China
AS24363	 CERNET2 IX at Shandong University	AS24364	 CERNET2 IX at Shanghai Jiaotong University

# Domain Name Service



- 2) Src: 202.106.0.20:53  
Dst: 58.40.96.117:32124  
Msg: It's 61.152.229.228

# Domain Name in a Tree Structure



# Root DNS Server

- 13 root servers (A-M) and hundreds of mirrors around the world.



## 3. In-class Practice

---

# Network Traffic Analysis with Wireshark

- Download and install Wireshark:
  - <https://www.wireshark.org/download.html>
- Access a website (e.g., [www.fudan.edu.cn](http://www.fudan.edu.cn)) and capture the network traffic with Wireshark.
  - Filter related packets.
  - Interpret the meaning of each related packets.