Full understanding

IP Address and Communication Mechanism

- Mechanism to identify devices from all over the world.
- Routing technology for acquiring destination routes.
  (The role of subnet mask and default gateway)
- The role of MAC addresses in Ethernet.

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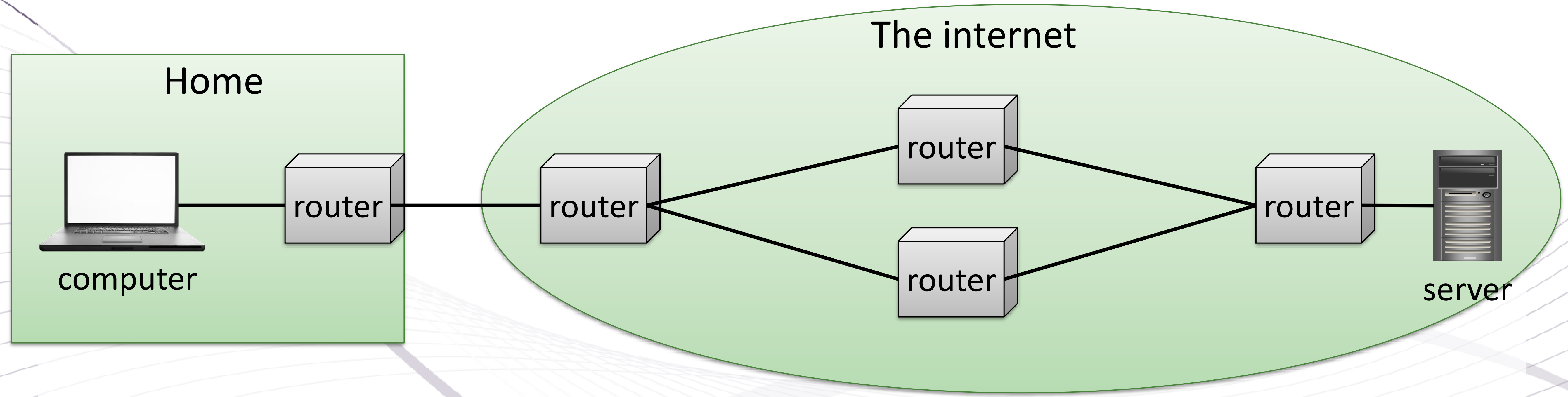
1-1. What are RFCs?

All devices involved in Internet communication must handle data using a predetermined technology.
Therefore, standardization (arrangement) of Internet technology is being carried out.
This standardization is called RFC.



- **Standardization organization: IETF (Internet Engineering Task Force)**
- **Standardized regulations: RFC (Request for Comments)**

1) **IP: RFC791 (IPv4), RFC8200 (IPv6)**
2) **TCP: RFC9293**

1-2.　What is TCP/IP?

- **TCP/IP**　Regulations for communication on the Internet.

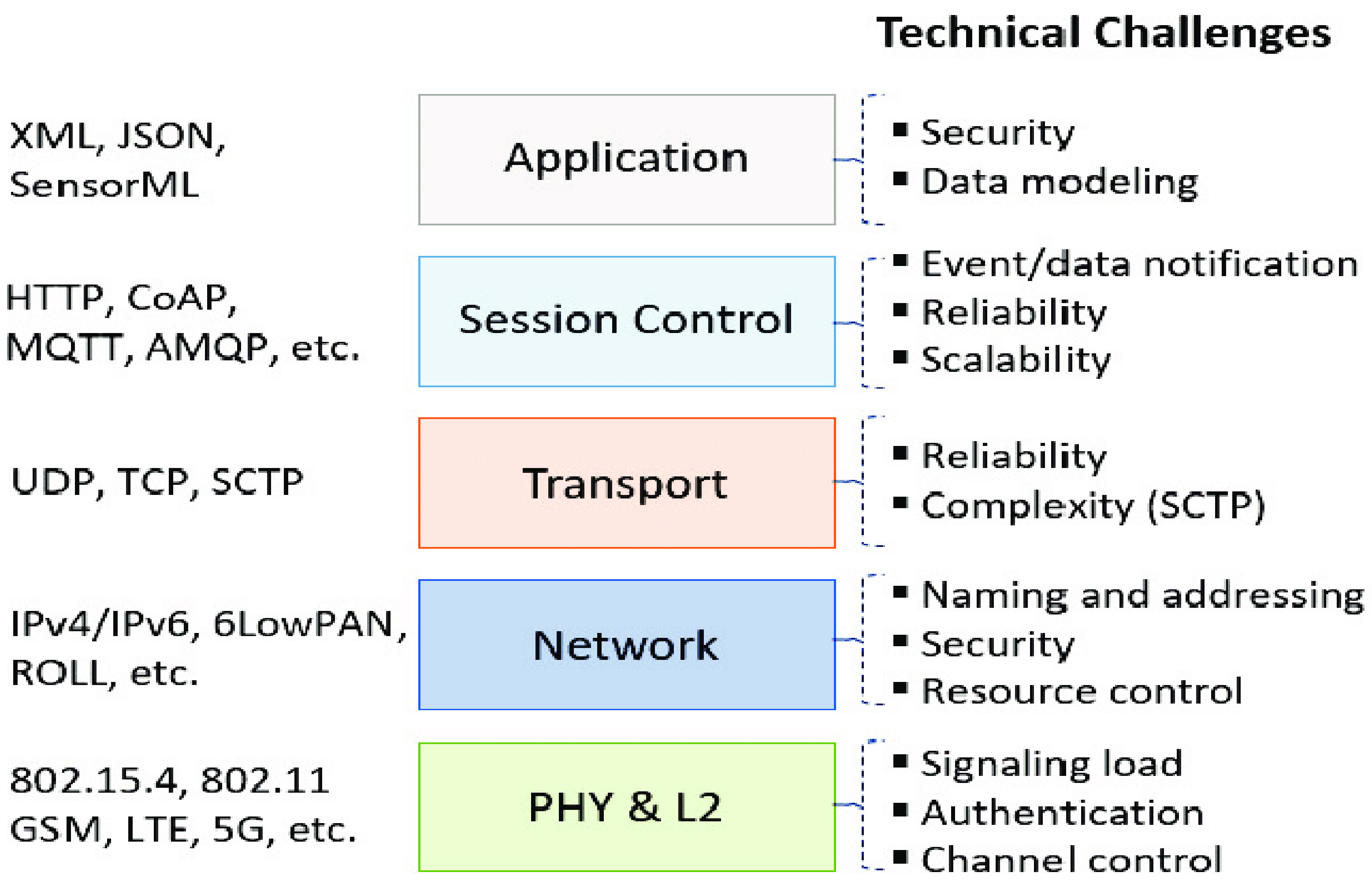
  ①IP　：The role of representing addresses on the Internet.

  ②TCP：The role of delivering data efficiently and reliably according to the state of the communication path.

- **UDP/IP**

  ③UDP：It does not perform communication control just to deliver.

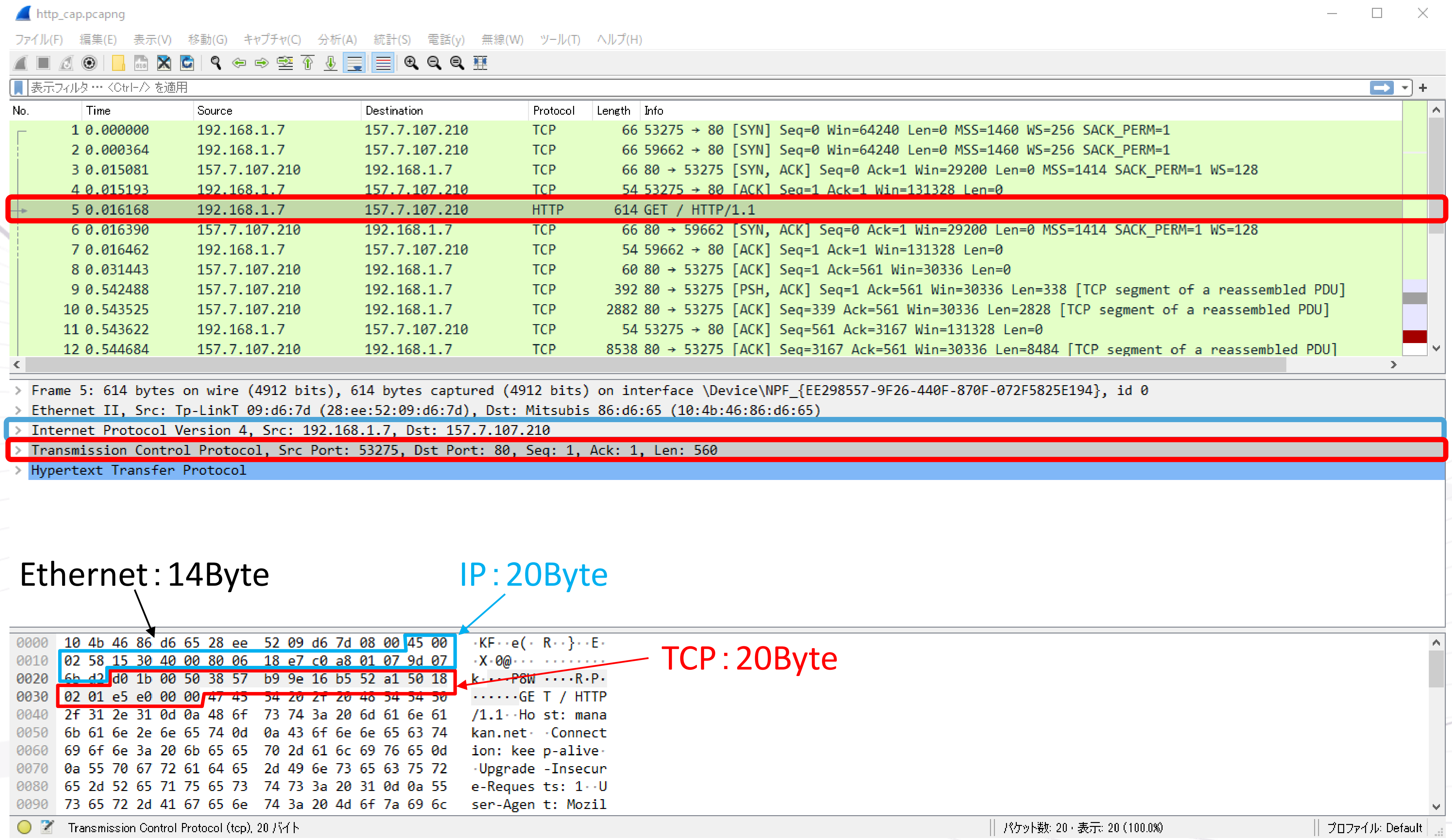
1-3. Protocol stack



https://www.researchgate.net/figure/Protocol-Stack-and-Technical-Challenges_fig1_320453832

- Match the rules used by each layer at the transmitting and receiving terminals.
- There is no dependency between layers.
  Determine the rules to be used for each layer.

1-4. Packet capture（WireShark）



1-5. "IPv4" and "IPv6"

Difference in number of bits used for address

- **IPv4 Identify with 32bit.** ⇨ 2 to the 32nd power, so "4,294,967,296 (about 430 million)"

Decimal	192	.	168	.	1	.	7
Binary	1100 0000		1010 1000		0000 0001		0000 0111
	8bit		8bit		8bit		8bit

(Binary place values: 128 64 32 16 8 4 2 1)

8bit is represented by 0 to 255 in decimal notation

8bit × 4
total **32Bit**

(340282366920938463463374607431768211456)

- **IPv6 Identify with 128bit.** ⇨ 2 to the 128th power, so "3.4 x 10 to the 32nd power"

Hexadecimal	2	0	0	1	: 0	D	b	8	: all zeros can be omitted			
Binary	0010	0000	0000	0001	0000	1101	1011	1000	0000	0000	0000	0000
	4bit	4bit	4bit	4bit	4bit	4bit	4bit	4bit	4bit	4bit	4bit	4bit

000 • • • (omit)

(Binary place values: 8 4 2 1)

4bit is represented by 0 to f in hexadecimal notation

total **128Bit**

1-6. IP data format (Excerpt from the prescribed RFC)

- **IPv4 RFC791**

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                  32bit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                32bit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The basic size is 20 bytes (1 line is 32bit, so 4 bytes)

[Optional] variable in size depending on the required options.

- **IPv6 RFC8200**

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version| Traffic Class |           Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Payload Length        |  Next Header  |   Hop Limit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+                         Source Address                        +
|                                                               |
+                                          32bit * 4line        +
|                                          = 128 bit            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+                      Destination Address                      +
|                                                               |
+                                          32bit * 4line        +
|                                          = 128 bit            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The basic size is 40 bytes (1 line is 32bit, so 4 bytes)

2. Types and allocation of IP addresses

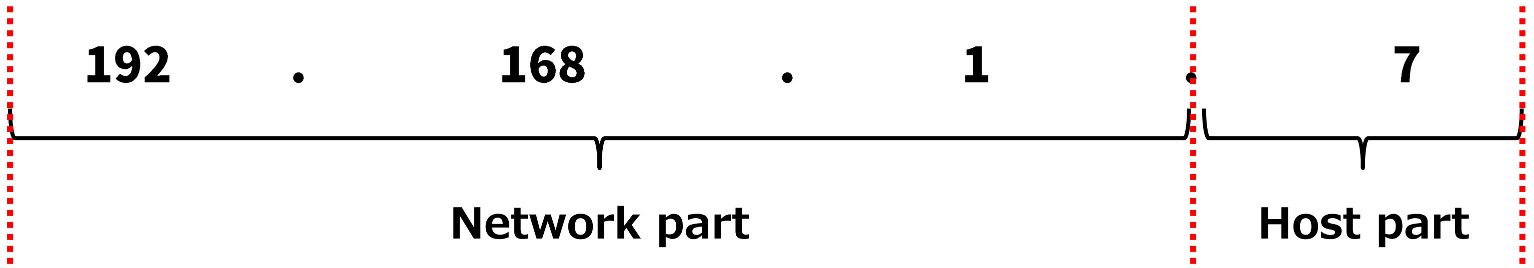
2-1. Classes and CIDR

2-2. IP address management organization and allocation

2-3. Global and private

2-4. Internet communication with a private IP address

2-1. Classes and CIDR



- **Class: As shown in the table below, build a network in units of a predetermined size** ⇨ **more waste**

Class	address range	Network part	number of terminals
Class A	0.0.0.0 ～ 127.255.255.255	8 Bit	about 16 million
Class B	128.0.0.0 ～ 191.255.255.255	16 Bit	about 65000
Class C	192.0.0.0 ～ 233.255.255.255	24 Bit	254
Class D/E	224.0.0.0 ～ 255.255.255.255	(for multicast and reservation)	-

- **CIDR（Classless Inter-Domain Routing）：Free use regardless of class** **This is commonly used**

Set a subnet mask to clearly separate the network part and the host part.

example) 1.0.16.0 / 20
192.168.10.0 / 23

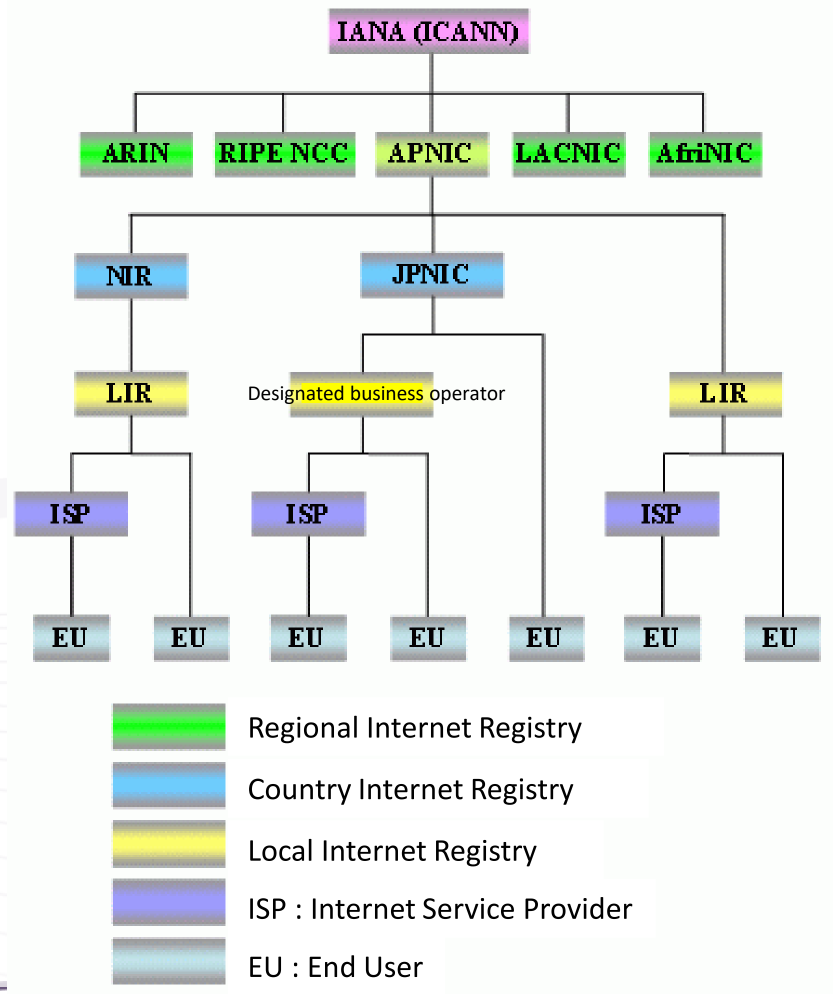
2-2. IP address management organization and allocation

- Strictly manage IP addresses so that they do not overlap around the world
- In Japan, they are distributed and managed in the following order, so that the location can be specified.
  IANA → APNIC → JPNIC → ISP → End user

● IP address management organization

Region	Management organization	Note
world	IANA (Internet Assigned Numbers Authority)	Managed on a global level
Asia	APNIC (Asia-Pacific Network Information Centre)	Dividing world into 5 regions
Japan	JPNIC (Japan Network Information Center)	Managed at country level

● Management organization structure



https://www.nic.ad.jp/ja/ip/admin.html

● Assignment to Japan

https://ipv4.fetus.jp/jp

« ‹ 1 2 3 › »

CIDR	IPアドレス	割り振り日	レジストリ
1.0.16.0/20	1.0.16.0 - 1.0.31.255	2011/04/12	APNIC
1.0.64.0/18	1.0.64.0 - 1.0.127.255	2011/04/12	APNIC
1.1.64.0/18	1.1.64.0 - 1.1.127.255	2011/04/12	APNIC
1.5.0.0/16	1.5.0.0 - 1.5.255.255	2011/04/01	APNIC
1.21.0.0/18	1.21.0.0 - 1.21.63.255	2010/06/16	APNIC
1.21.64.0/19	1.21.64.0 - 1.21.95.255	2010/06/16	APNIC
1.21.96.0/20	1.21.96.0 - 1.21.111.255	2010/06/16	APNIC
1.21.112.0/20	1.21.112.0 - 1.21.127.255	2010/06/16	APNIC
1.21.128.0/20	1.21.128.0 - 1.21.143.255	2010/06/16	APNIC

Japan: 190,438,656

- **4.43% of total address space**
- **5.14% excluding reservations**

2-3. Global and private IP addresses

About IPv4

● **Global IP address**

Unique address in the world

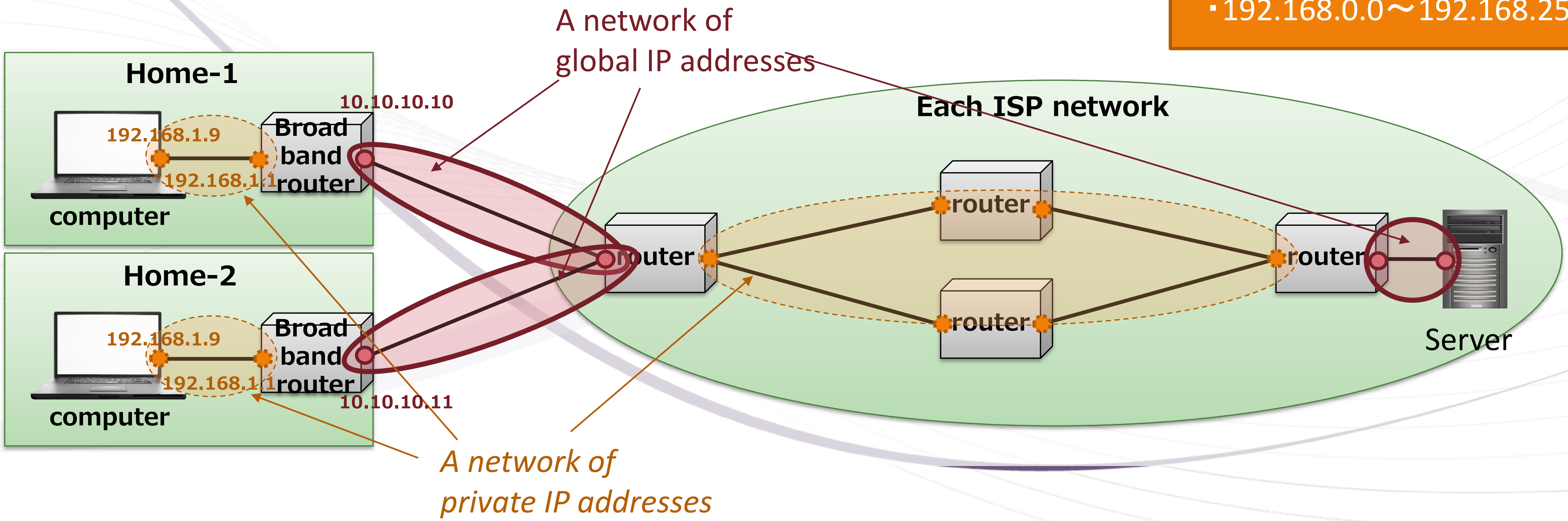
(can be identified from all over the world, so it is used for internet communication)

● **Private IP address**

An address that is used repeatedly in a network in each home or company.

(It cannot be specified from all over the world, but it is unique within the network without duplication))

【Private IP address Range】
- 10.0.0.0～10.255.255.255
- 172.16.0.0～172.31.255.255
- 192.168.0.0～192.168.255.255



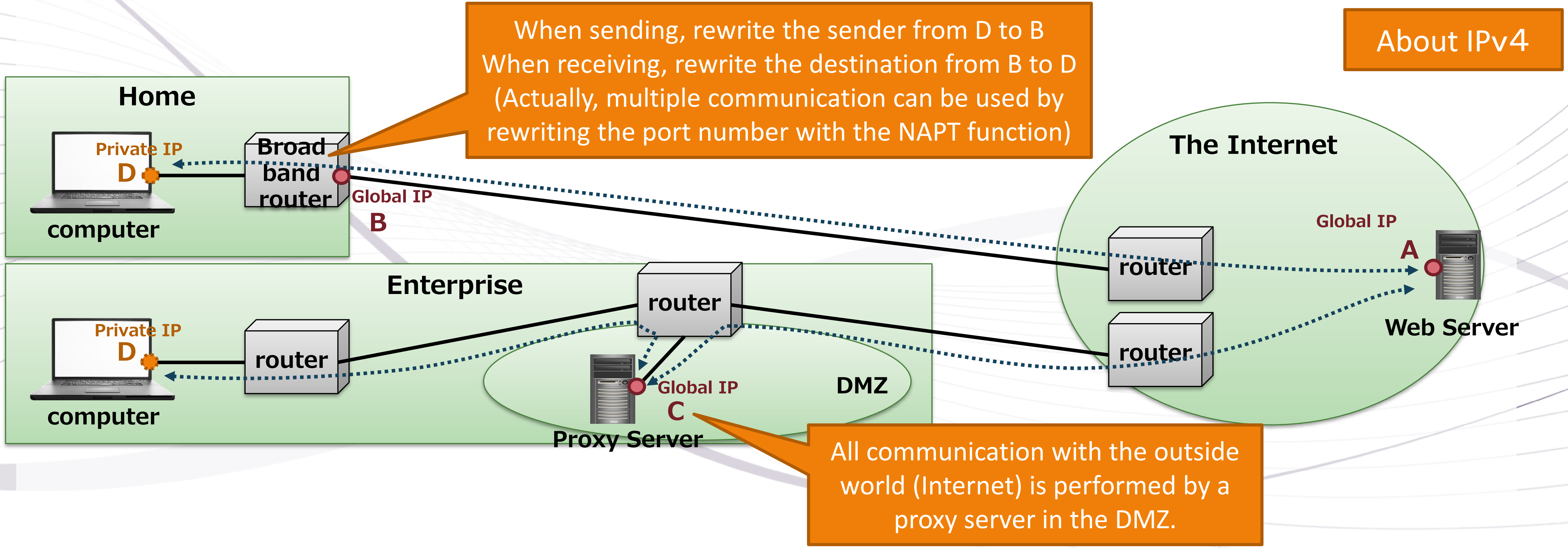
2-4. Internet use with private IP address

- **Use of private IP at each home**

  Communication by replacing the global IP address with the private IP address on the broadband router.

- **Use of private IP by each company**

  The proxy server in the DMZ relays and communicates with the outside.



3. Mechanism of routing

3-1. What is routing?

3-2. Subnet mask and Default Gateway

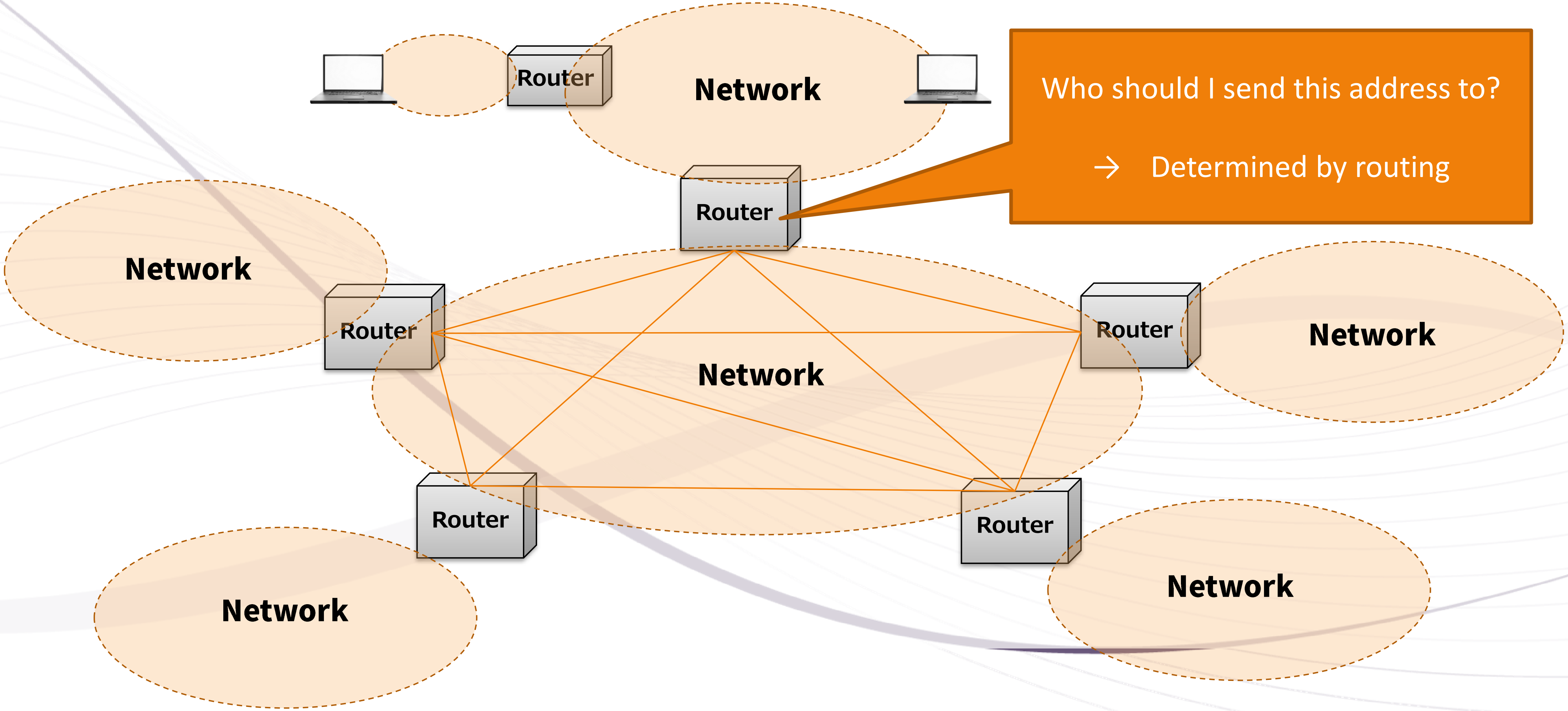
3-3. Decision by routing table

3-4. Priority of routing decisions

3-5. Internet routing

3-1. What is routing?

The destination address determines to whom in the connected network to send.



3-2. Subnet mask and Default Gateway

- The subnet mask represents the length of the network part (represents the size of the network)
  ⇒ The same network is determined by whether the network part has the same bit string
- The network part of the default gateway is set to zero, so "all addresses are applicable"

If the subnet mask is "255.255.255.0", Network part is 24bit.

Decimal	255 .	255 .	255 .	0
Binary	128 32 / 64 16 8 4 2 1 1111 1111 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255	1111 1111 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255	1111 1111 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255	0000 0000 0
	Network part [24bit]			Host part

Subnet description

255.255.255.0

exactly the same

192.168.1.7 / 24

Can also be written in numbers

When the destination IP address is "192.168.1.7"

● **Network is「192.168.1.0/24」**

Dest :	1100 0000	1010 1000	0000 0001	0000 0111
NW :	1100 0000	1010 1000	0000 0001	0000 0000

"Same network" because the network part is the same bit strings

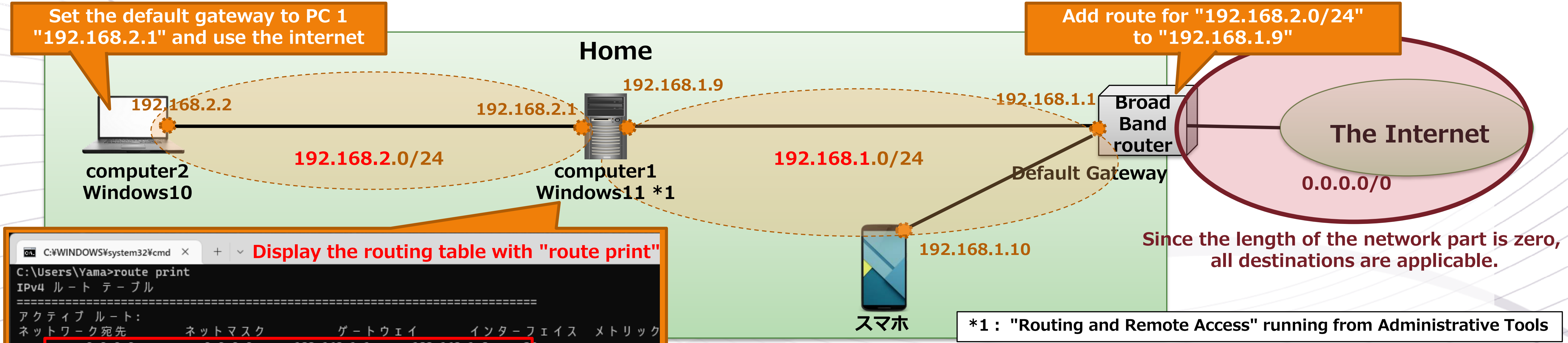
● **Network is「10.10.10.0/24」**

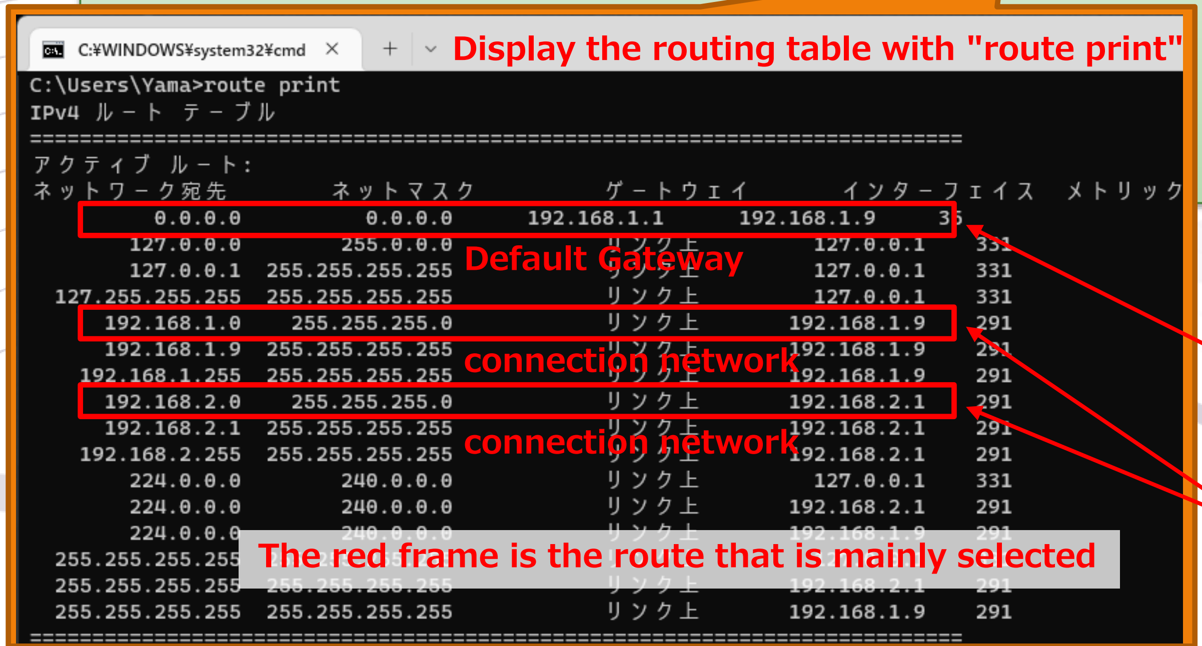
Dest :	1100 0000	1010 1000	0000 0001	0000 0111
NW :	0000 1010	0000 1010	0000 1010	0000 0000

"Not the same" because the bit strings in the network part are different

3-3.　Decision by routing table

- Terminals such as personal computers and routers have routing tables for resolving destinations.
- For the destination address, find the destination with the same network address from the routing table.
- Send the packet to the destination (Next-Hop) of the relevant network address.




C:¥WINDOWS¥system32¥cmd

Display the routing table with "route print"

C:\Users\Yama>route print
IPv4 ルート テーブル

アクティブ ルート:

ネットワーク宛先	ネットマスク	ゲートウェイ	インターフェイス	メトリック
0.0.0.0	0.0.0.0	192.168.1.1	192.168.1.9	35
127.0.0.0	255.0.0.0	リンク上	127.0.0.1	331
127.0.0.1	255.255.255.255	リンク上	127.0.0.1	331
127.255.255.255	255.255.255.255	リンク上	127.0.0.1	331
192.168.1.0	255.255.255.0	リンク上	192.168.1.9	291
192.168.1.9	255.255.255.255	リンク上	192.168.1.9	291
192.168.1.255	255.255.255.255	リンク上	192.168.1.9	291
192.168.2.0	255.255.255.0	リンク上	192.168.2.1	291
192.168.2.1	255.255.255.255	リンク上	192.168.2.1	291
192.168.2.255	255.255.255.255	リンク上	192.168.2.1	291
224.0.0.0	240.0.0.0	リンク上	127.0.0.1	331
224.0.0.0	240.0.0.0	リンク上	192.168.2.1	291
224.0.0.0	240.0.0.0	リンク上	192.168.1.9	291
255.255.255.255	[illegible]	[illegible]	[illegible]	331
255.255.255.255	255.255.255.255	リンク上	192.168.2.1	291
255.255.255.255	255.255.255.255	リンク上	192.168.1.9	291

Default Gateway

connection network

connection network

The red frame is the route that is mainly selected

- The destination is sent to a destination that matches the bit string of the length of the network part indicated by the subnet mask.
- Since the length of the network part of the default gateway is 0, all destinations are applicable destinations, so all addresses for the Internet are selected.
- Because the length of the network part of the connected link is 24, it is selected with priority over the default gateway.

3-3. Priority of routing decisions

- Routing is determined by multiple factors, but there is a priority.
- Priority is as follows

Priority 1: Longest Match

The length of the network part (the length of the subnet mask) has the highest priority.

Example) When there are 1 and 2 in the routing table
The destination "192.168.1.1" corresponds to both of the following, but length 24 ① is selected

	Network Address	Next-Hop
①	192.168.1.0/24	192.168.1.1
②	192.168.0.0/16	192.168.1.11

← **This route with a longer network part is selected**

Priority 2: Administrative distance

It is decided which route type to prioritize

- **Static route**
  Route manually set by the operator
- **Dynamic routing**
  Automatically update route information using a routing protocol
  Dynamically update route information by notifying your route to the other party

《Standard setting》 (Excerpt)

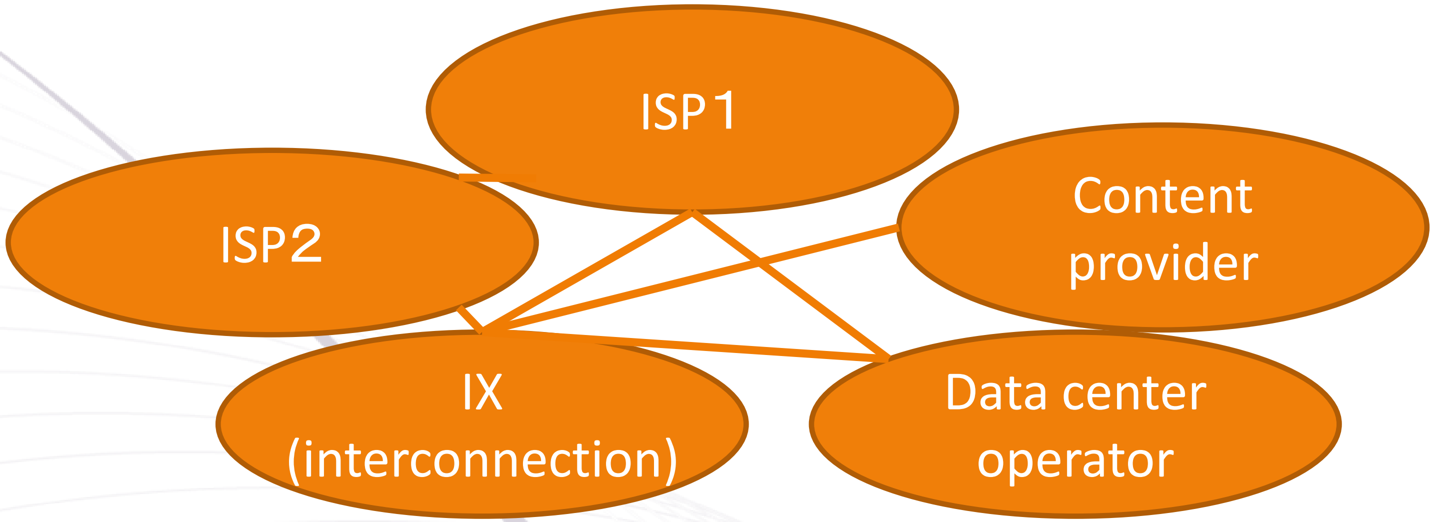
Route information source		Administrativedistance value
Direct connection (same network)		0
Static route (manual setting)		1
Dynamic Routing	BGP (external)	20
	OSPF	110
	RIP	120
	BGP (internal)	200

Priority 3: Metric

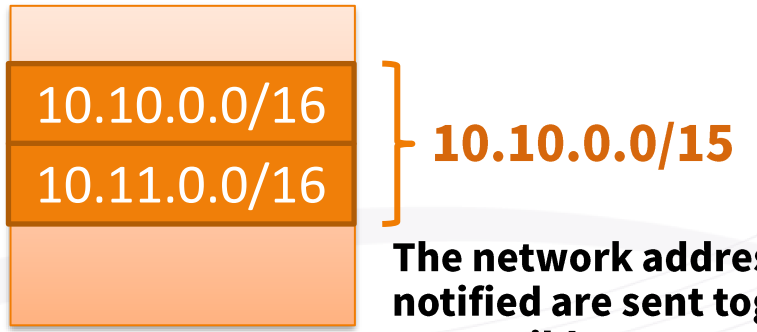
Used when manually setting the priority or operating the priority of the route based on the number of hops or cost.

3-4. Internet routing

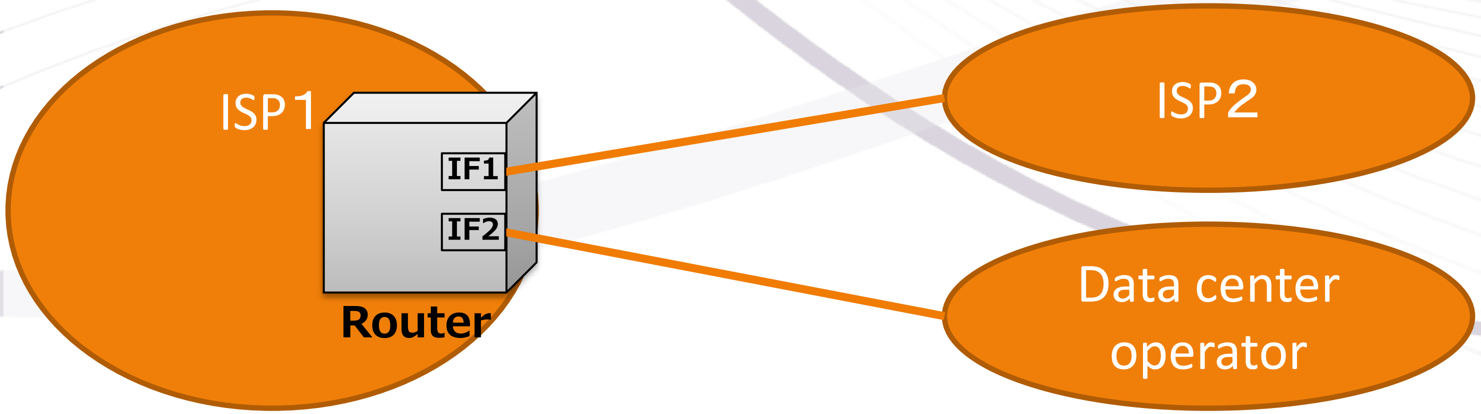
- Construct routing by exchanging network addresses in use between operators



Each operator notifies each other of the network address used by itself to the connection destination.
(Automatically notify each other using a protocol called BGP)



The network addresses to be notified are sent together as much as possible.

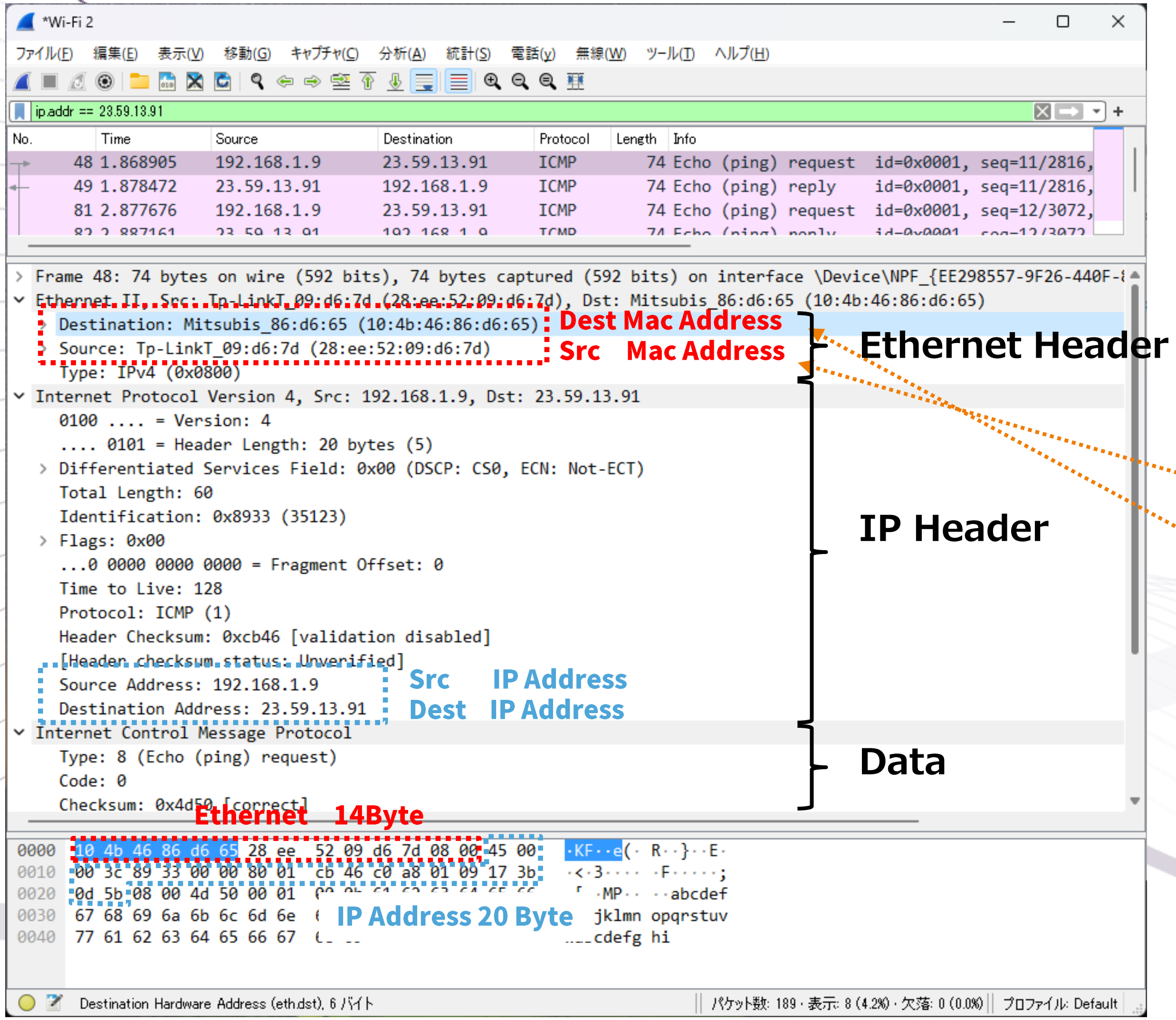


Basically, the network address notified by the other party is used by the business operator, so it becomes the destination.

4. Ethernet and MAC address

4-1. What is Ethernet?

- Ethernet is a communication technology of IEEE, layer 2 data link layer technology
- Ethernet uses MAC addresses for terminal identification.



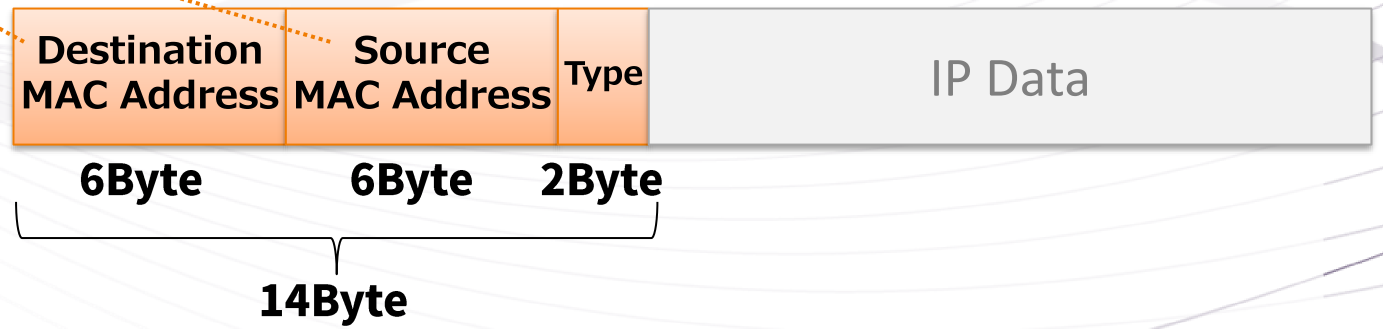
● Ethernet standard

- Wired: LAN cable, coaxial, optical cable
  Standardization IEEE802.3
- Wireless: Wi-Fi
  Standardization IEEE802.11 ac/a/n/g/b

● Positioning of the protocol stack

- Equivalent to the physical to data link layers of the OSI reference model (the layer below the IP address)

● Ethernet Data Format



● What is a MAC address?

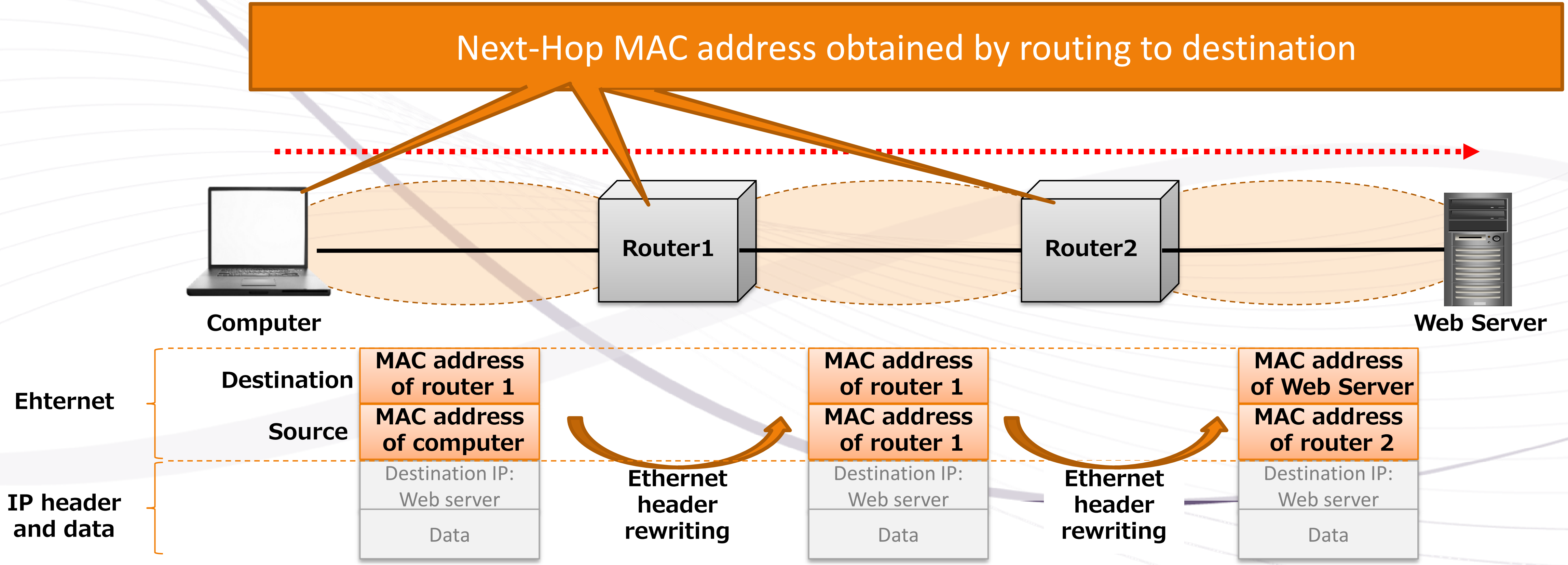
- A 6-byte address assigned to the interface. Given by the manufacturer.

4-2. Sending to Nex-Hop and Mac address

・ Send to the MAC address of the next-hop destination terminal acquired by routing.

● **Communication from personal computer to web server**

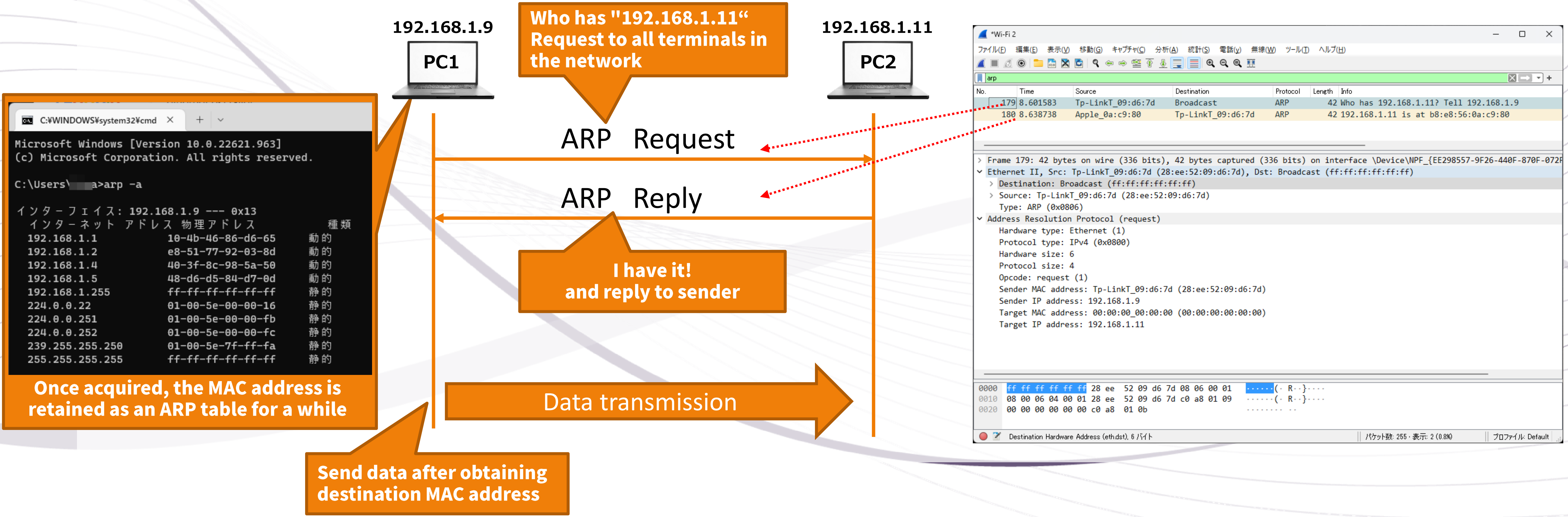
Terminals and routers create and send Ethernet headers to the Next-Hop MAC addresses obtained by routing. Therefore, every time it goes through a router, the Ethernet header is rewritten and communicated.



4-3. MAC address resolution mechanism "ARP“

- Since IP addresses are obtained in routing, a mechanism to obtain MAC addresses is required.
- The destination MAC address is obtained using ARP from the IP address obtained by routing.

When PC 1 communicates with PC 2



4-4. Summary of transmission processing on Ethernet terminals

Processing from determination of destination to data transmission.

Determine the destination (Next-Hop) from the routing table.

↓

Acquire the MAC address of the destination (Next-Hop) by ARP.

↓

Add Ethernet header, construct data and send.