Basics of the Internet

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Introduction

Target

- Beginners who are interested in the mechanisms of the Internet
- People who have set up a network using a computer with a book and don't quite understand the mechanisms
- People who begin to manage network

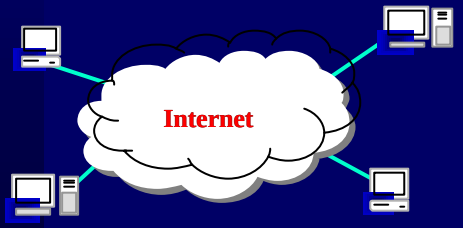
Structure of this tutorial

- The Mechanisms of the Internet
- TCP/IP
  - its role and functions
  - real-life examples and review
- Conclusion

The Mechanisms of the Internet.

Image of Internet

- Metaphor of a cloud is often used.

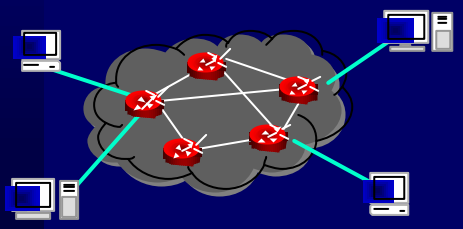


What is the Internet?

- a multiple network (clouds) connected to each other
- the Internet was initially created for military purposes.
  - Research labs and universities in the U.S were connected.
  - Later, Corporations and general public groups were also connected, expanding to the current Internet.
- Various kind of data can be exchanged.
  - anything that can be done on a computer

The Mechanisms of the Internet

- Let's get rid of the abstract cloud image.



Mechanism inside the cloud

- Internet is an aggregation of the network
- To communicate with each other, we need certain agreements.
  - Mechanism to communicate among systems of various makers, OS and CPU.

Protocol

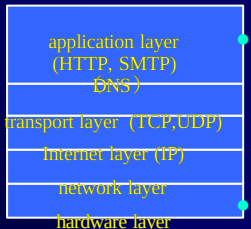
What is Protocol?

- Like a rule of daily life
  - When one person speaks Japanese and another speaks English, they cannot understand each other.
    - We need to make a rule.
- Computer protocol
  - a set of agreements for communication procedures
    - How the data is interpret / How the data is sent as electronic signals

Internet and TCP/IP

- Protocol is necessary for the Internet.
  - TCP/IP
- What is TCP/IP?
  - The innermost core of Internet protocol
    - TCP: Transmission Control Protocol
    - IP: Internet Protocol
- Internet has a structure of several different layers.
  - the functions necessary for communication are divided up and split into different layers

Hierarchical structure of TCP/IP



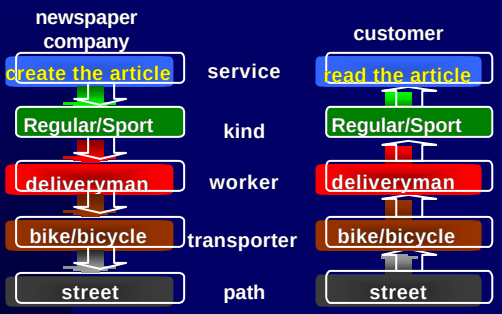
- the functions necessary for communication are divided.
  - These split-up units are called "layers"
- introduce a hypothetical situation to understand hierarchical structure.

“Newspaper Model”

- call the newspaper office, and subscribe
- order a regular newspaper and a sports newspaper
- receive a newspaper tomorrow

there are a number of mechanisms and an assignment of roles

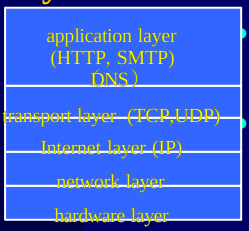
An example of newspaper model



Role assignments in newspaper model

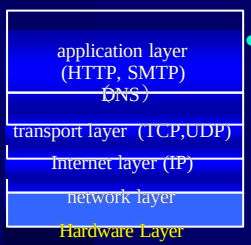
- Roles are assigned to each function and work.
  - Each role is called "layer“.
- Each layer concentrates on its own job and together achieves a large service.
- This concept is actually important in considering the mechanism of the Internet.

Role and function of each layer of TCP/IP



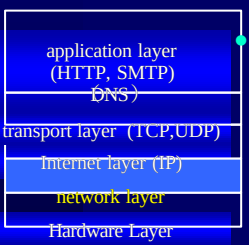
- the function of each layer is very simple
- there is a concept of top and bottom layers
  - the closer to the bottom layer, the more physical
  - Towards the top are more logical aspects

Hardware Layer



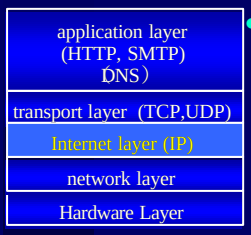
- Hardware Layer
  - the cable in which the electronic signal flows
  - the cable such as phone lines
  - the size and shape of connector and the arrangement of the pins are also defined.

Network Layer



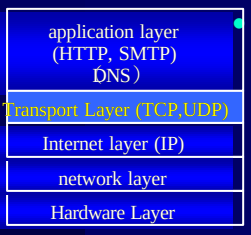
- Network Layer
  - procedure of communication and standards for communication are defined.
  - This layer converts data to electronic signals

Internet layer



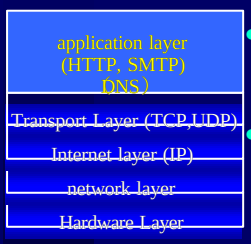
- Internet layer
  - Identify the recipient of communication
  - Decide the way to send the data

Transport Layer



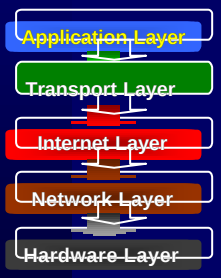
- Transport Layer
  - Determine which program to pass the received data to.

Application layer



- Application layer
  - portion that the user can touch directly
- Services provided to users
  - Home Page
  - Email
  - Chat
  - etc

Role assignments in hierarchical structure



write an e-mail

types up the content of the email

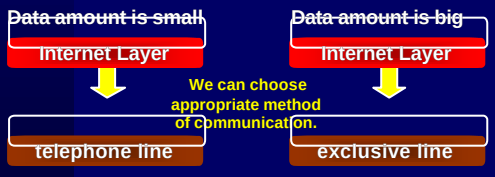
decide the destination and method of delivery

convert data to electronic signals

The electronic signals flow in cables

Merits of hierarchical structures

- Depending on the quality of service or volume, it's possible to use accordingly the different technology in each layer.

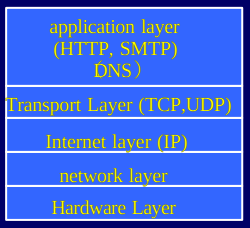


TCP/IP

Procedure to explain roles and functions of each layer

- I'll start from the bottom layer and describe the functions and roles of each.
- Example such as "One day I was told this."
- Explain the functions and roles of each layer.
- Introduce examples of set-up procedures

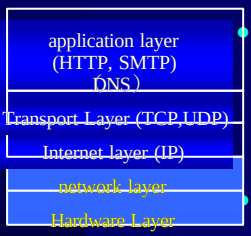
Roles and functions of each layer



"One day I was told this." Part 1

- "I bought a new hub, so will you plug in that 10BaseT cable over there? I'm counting on you."
- "Wait a minute. What's a hub? I don't understand."
- These words have to do with network layer and hardware layer.

network layer / hardware layer



- Roles
  - converting data to electronic signals
  - Equipment and cables connecting machines physically.
- Keywords
  - network equipment
  - cable

What is network equipment?

- Physical hardware for communication
  - this is where the electronic signals flow.
- Examples of network equipment
  - Network interface card
  - Hub
  - Router

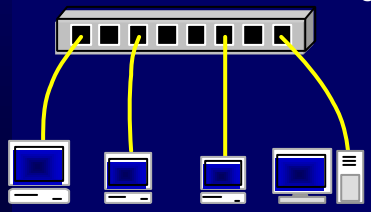
Network Interface Card

network interface card

- NIC (Network Interface Card)
  - This card connects PC to the network.
  - the data is converted to electronic signals
  - You need the card which would match communication standard you use.

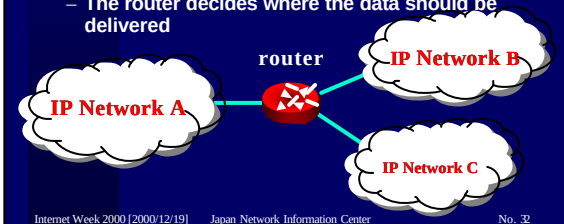
Hub

- Correcting device to connect a multiple number of equipments
- It receives and sends electronic signals.



Router (1)

- Equipment to connect different IP networks
  - "IP network" is explained in detail in the next Internet layer
  - The router decides where the data should be delivered



Router (2)

Routers used in ISP

Cisco4500

Cisco7505

* Dial-up router used at home is one of routes

Cable (1)

- a physical line that connect network equipment
  - The electronic signals flow through here.
- Typical cables used for LAN
  - Ethernet (10BASE-T, 100BASE-T)
    - UTP cable
  - Giga-bit Ethernet (1000BASE-SX)
    - optical fiber cable
  - FDDI、ATM
    - optical fiber cable

Cable (2)

UTP-5 cable

optical fiber cable

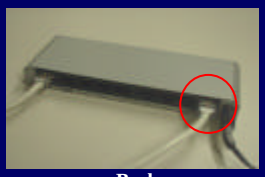
What was that request?

- "I bought a new hub, so will you plug in that 10BaseT cable over there? I'm counting on you."
- "Ah, that's what he meant!"

real-life example

- Connect PC and Hub
  - You would only need to connect an particular cable.
  - The type of cable : LAN cable（UTP-5）

Front



Back

“One day I was told this.” Part 2

- “The new machine arrived, so could you set up the network? The IP address is 192.168.0.10, and the netmask is 255.255.255.0. I'm counting on you."
- "Wait a minute. What's IP? I don't understand."
- These words have to do with IP of Internet layer.

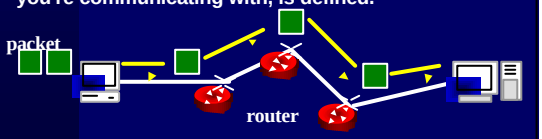
Internet Layer (1) IP

application layer (HTTP, SMTP) DNS）
Transport Layer (TCP,UDP)
Internet layer (IP)
network layer
Hardware Layer

- Roles
  - Identify the recipient of communication
  - Create packets
- Keywords
  - IP Address
  - Netmask

Functions and roles of IP

- The data to be sent is broken down into small packages called "packets."
- Packets are transported by routers.
  - In case of congestion, the packet is sometimes thrown away.
  - IP is "Best-Effort protocol."
- IP address, an unique number to identify the party you're communicating with, is defined.

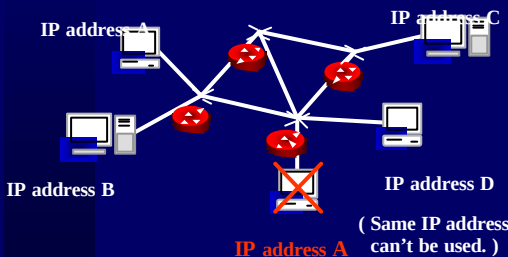


What is IP address? (1)

- IP address is an unique number to identify the party you're communicating with.
- In order to communicate using IP protocol, the equipment needs at least one IP address.
- It is impossible to have duplicate IP addresses on the Internet.

What is IP address? (2)

- Example of assigning IP address to hosts



IP address and binary numbers

- IP addresses are represented by binary numbers.
- What is binary numbers?
  - numbers represented only by 0 and 1
  - the digit of a binary number is called a "bit."

binary number	decimal number
0	0
1	1
10	2
11	3
100	4
:	:

- the scale of using binary numbers to represent decimal numbers
  - 4 digit decimal number : 0 to 9999 (10,000 different options)
  - 4 digit binary number : 0 to 1111 (16 different options)
  - 4 digit binary number : 0 to 11111111 (256 different options)

How the IP address is written out?

- The IP address is created with a 32bit (32 digits) binary number

11000000101010000000000000001010

- It's almost impossible to memorize. So, after every 8bit, it's cut by a period, and each block is written as a decimal number.

11000000 . 10101000 . 00000000 . 00001010

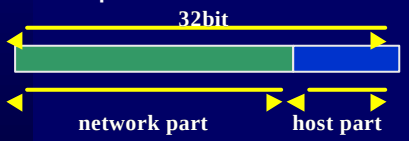
192 . 168 . 0 . 10

Identification of the party you are communicating with

- Internet is an aggregation of networks.
- It would be easier if you could specify which network he/she belongs and which host he/she uses.
- IP address enables that.
  - This network is called IP network.

Structure of IP Address

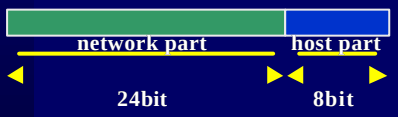
- IP address is split up into the "network part" and "host part".



- It would basically be the same as the name of an apartment and the apartment number.
  - Example: JPNIC Apartments, Room 202

Length of network part

- Once the length of the network part is decided, then the length of the host part is determined



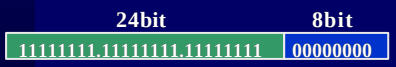
In this example, 8bit were allocated as the host part, the host part would have 256 options.

Where the network number part ends?

- Just by looking at IP address, you can't tell where the network number part ends.
- A marker called netmask is used.

Netmask

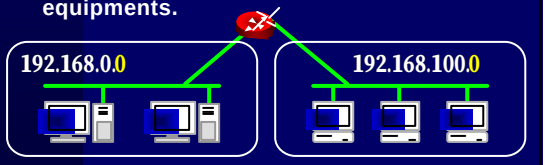
- It's in a 32bit format, same as the IP address.
- The network part is indicated with all 1s. Then the remaining host part is indicated with 0s
  - Note that netmask is just a mark, not an address.



255.255.255.0 in decimal number

IP address with special meaning (1)

- All numbers in host part are 0.
  - Example : 192.168.0.0
  - This address represents the apartment name.
  - This kind of IP address is not assigned to equipments.



IP address with special meaning (2)

- All numbers in host part are 1.
  - Example : 192.168.0.255
  - This is called a "Broadcast Address".
  - It is used to communicate with all machines within the same network.
  - It is not assigned to equipments.

Organization managing IP addresses

- As IP address is a shared resource of the world, Fairness is necessary.
- To avoid duplicates of IP addresses
- In Japan, JPNIC is managing IP Address.
  - JPNIC assigns IP addresses to ISP and ISP assigns some of them to users.

IP address is limited resource.

- Total number of IP address
  - 32bit = about 4.3 billion.
  - The total population of Earth is now approximately 6 billion, so it's not enough for everyone to get one IP address.
- We need to make good use of this limited supply.
  - use both global address and private address

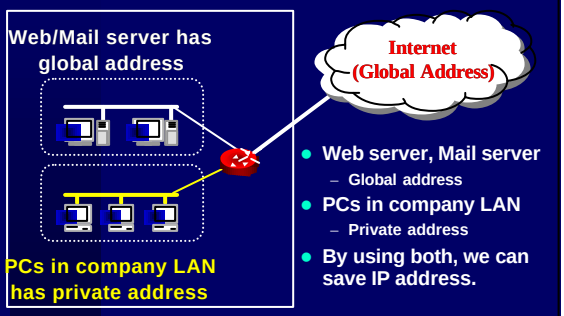
Global Address

- Global Address
  - It's accessible from anywhere in the world
    - Example : Web server, Mail server
  - It must be unique on the Internet

Private Address

- prevent the depletion of addresses
  - It can be used freely by individuals or companies.
  - There's no need to worry about an overlap of IP addresses.
  - It can't be accessed directly from the Internet.
- Range of private address
  - 10.0.0.0～10.255.255.255
  - 172.16.0.0～172.31.255.255
  - 192.168.0.0～192.168.255.255

How to use private address



- Web server, Mail server
  - Global address
- PCs in company LAN
  - Private address
- By using both, we can save IP address.

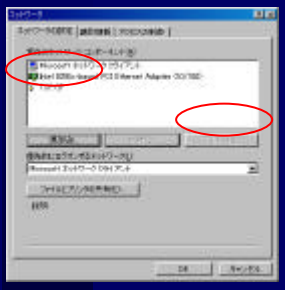
Restrictions of private address

- The Internet cannot be directly accessed with a private address.
  - "Proxy" solves this problem.
  - It's possible to use some of the services such as e-mail and website browsing.

What was that request?

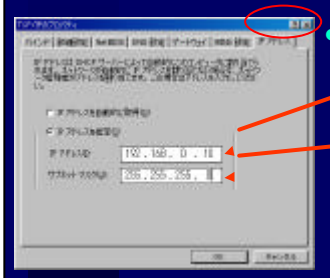
- "The new machine arrived, so could you set up the network? The IP address is 192.168.0.10, and the netmask is 255.255.255.0, I'm counting on you."
- "Ah, that's what he meant!"

Set up on Windows



- Open the "property" of "Network Computer"
- Open the "property" of NIC(it is said "TCP/IP" here)

Example :Set up IP address

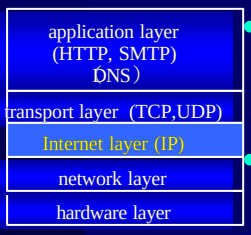


- Items to be set
  - IP address
    - 192.168.0.10
  - Netmask
    - 255.255.255.0

“One day I was told this.” Part 3

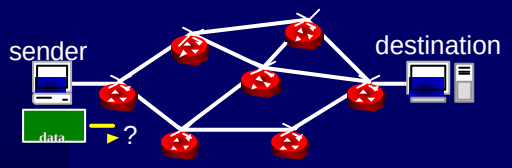
- “Oh, yeah. That machine from earlier- I forgot about setting up the route. Would you set the default gateway as 192.168.0.254? I'm counting on you.”
- "Wait a minute. What's a routing? I don't understand."
- These words have to do with routing, the way to deliver the packets.

Internet Layer (2) Routing



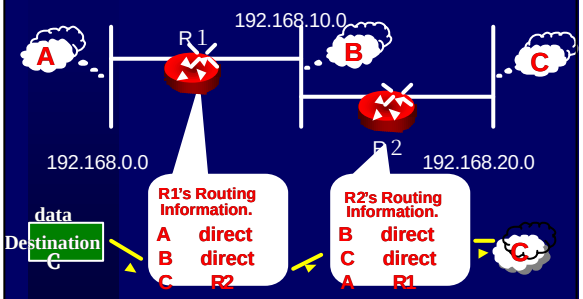
- Role
  - deliver the data to the destination
- Keyword
  - router
  - routing protocol
  - default gateway

How to carry?



- Routers carry the packets to the destination.
- A route is necessary to carry the data.
  - It’s called “routing Information“.
- Routers needs right routing information.

What is Routing Information?



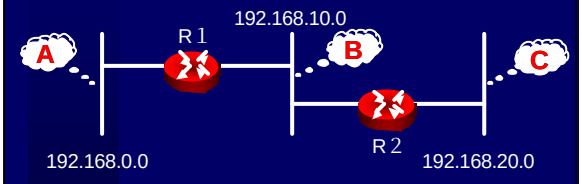
How to create routing information?

- Settings can be done manually.
  - If the scale of the network is large, it becomes difficult to do the settings manually.
  - There is constant change within the network.
- Mechanism to automatically create routing information
  - Routing Protocol
- Let’s learn about routing protocol!

Principle of routing protocol

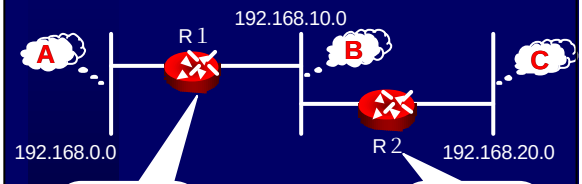
- Routers have directly connected networks in routing information
- Routers can communicate with other routers within the same network
- Routers exchange routing information each other and add routes.
  - Exchange is done periodically.

Create routing information (1)



Think about how the routing information is created by using routing protocol.

Create routing information (2)

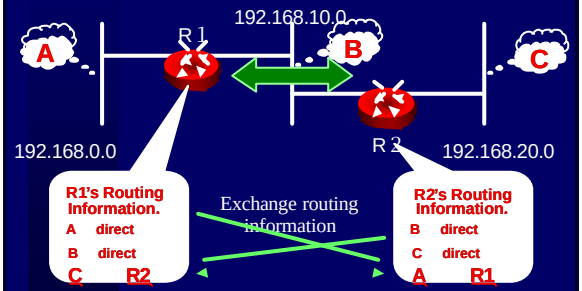


R1's Routing Information.
A direct
B direct

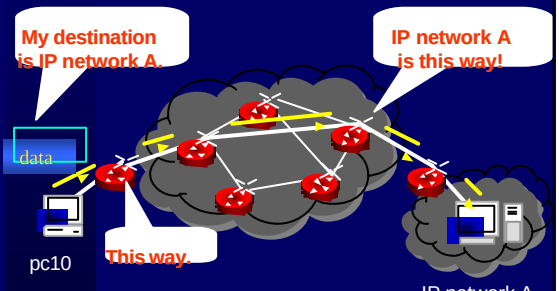
Routers have directly connected networks as routing information

R2's Routing Information.
B direct
C direct

Create routing information (3)



Sending data / Routing

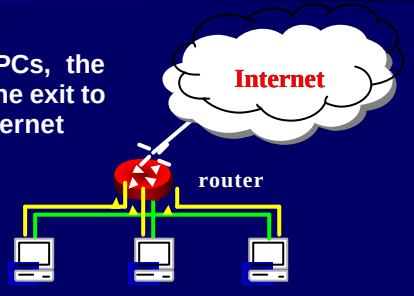


Other routing information

- default gateway
  - It's called "default route", too.
  - For end node, the router which is the closest is the exit to the outside network.
  - When you set the nearest router as default route, the routers on the Internet will deliver your data to the destination.

Default Gateway

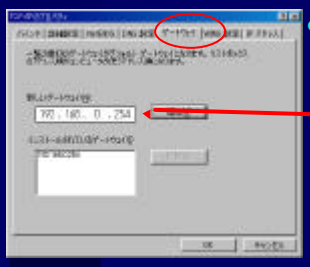
For each PCs, the router is the exit to the Internet



What was that request?

- “Oh, yeah. That machine from earlier - I forgot about setting up the route. Would you set the default gateway as 192.168.0.254? I'm counting on you.”
- "Ah, that's what he meant!"

Example : set up default gateway

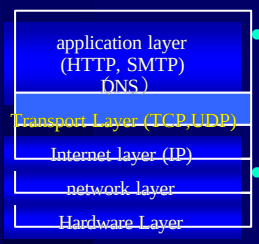


- Items to be set
  - default gateway
    - 192.168.0.254

“One day I was told this.” Part 4

- “You know http://www.example.co.jp, right? That website. I made a separate page with TCP port 8080, so take a look at it. I'm counting on you."
- "Wait a minute. What's a TCP port? I don't understand."
- These words have to do with transport layer and TCP/UDP.

Transport Layer (TCP,UDP)



- Role
  - Forward the data sent from the Internet layer to applications
- Keywords
  - TCP
  - UDP
  - Port number

Role of TCP and UDP

- TCP（Transmission Control Protocol）
- UDP（User Datagram Protocol）
- attach a port number to identify the category of data
- Port number is assigned to each application (Web, Mail)

Port number

- All services has assigned port numbers and data type is defined by this number.
  - HTTP :TCP port 80
  - SMTP :TCP port 25
  - DNS :UDP port 23
- The port numbers 0 - 1023 is called “Well Known Port”.
  - Numbers over 1024 are available for users to use freely.

Characteristics of TCP

- Connection-oriented, establishing the connection between the end nodes.
  - It's like the two computers communicate with an awareness of each other
- The connectivity that could not be guaranteed by IP protocol is improved by this TCP.
- TCP is used when you want to be certain that the data will reach the destination.

Characteristics of UDP

- UDP is connectionless protocol
  - The sender isn't aware of the other party's status and send the data anytime it wants to.
  - Real-time communication is possible.
- The port number is marked on the data and the data is encapsulated to IP packet and sent.
  - Reliability of communication is not guaranteed.
  - Data can be lost.

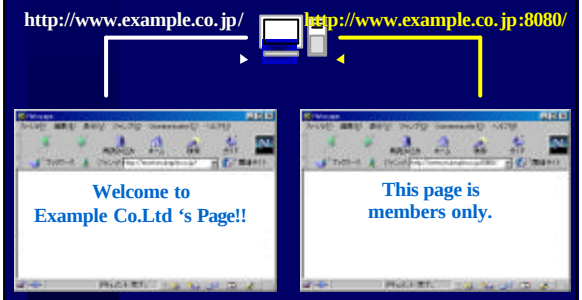
In what situations TCP and UDP should be used?

- TCP or UDP?
  - The user who creates the program (application) decides whether to use TCP or UDP.
- It depends on the type of service
  - TCP is used for E-mail so that E-mail can be delivered safely.
  - UDP is used for audio data so that audio can be delivered in real-time, even with some loss.

What was that request?

- "You know http://www.example.co.jp, right? That website. I made a separate page with TCP port 8080, so take a look at it. I'm counting on you."
- "Ah, that's what he meant!"
- How to specify a port number homepage address?
  - http://www.example.co.jp:8080/

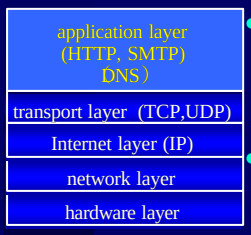
Example



"One day I was told this." Part 5

- "About that computer earlier, would you set up the domain name as example.co.jp, the host name as PC 10, and the name server is 192.168.0.1. I'm counting on you."
- "Wait a minute. What's a name server? I don't understand."
- These words have to do with the mechanism called DNS.

Application layer (1) DNS



- Role
  - a mechanism to make it easier for humans to use the Internet.
- Keywords
  - Domain name
  - DNS
  - Name server

Why is domain name/DNS necessary?

- Computers on the Internet can only communicate with an IP address
  - It's difficult to remember IP addresses.
- It would be nice if we can use names instead of numbers.

Domain name/DNS

What is domain name?

- Examples of domain name on the Internet:
  - http://www.example.co.jp/
  - matuura@example.co.jp
- characteristic of this domain name
  - It's easier to remember words comparing with IP address.

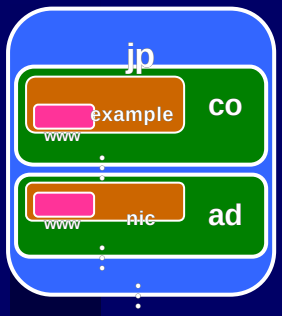
Structure of domain name (1)

- Furthest to the right is the large grouping, and it gets smaller.

www.example.co.jp

  - jp : country or area
  - co: company or organizations or group
  - example:company name or group name
  - www : host name
  - There is no distinction between capital letters and small letters.

Structure of domain name (2)



www.example.co.jp

jp: top level domain

co: 2nd level domain

example: 3rd level domain

www: 4th level domain

What is DNS? (1)

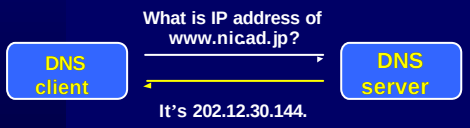
- DNS （Domain Name System）
- make domain name and IP address correspond to each other

www.nic.ad.jp ◀ ▶ 202.12.30.144

- The procedure of translating IP address from domain name is often called "name resolution"

What is DNS? (2)

- DNS is based on client - server model



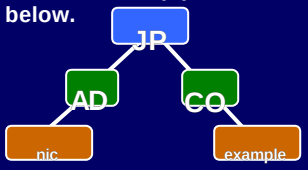
- Server：DNS server, Name server
- Client：Resolver (a kind of programs)

What is DNS? (3)

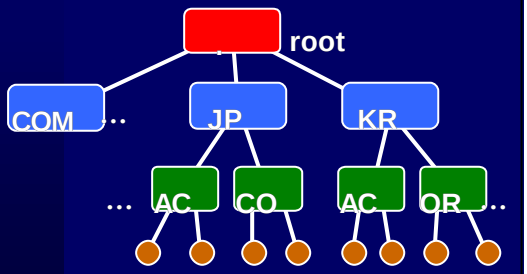
- There is always at least one name server, which manages its own domain within its network.
  - It has a database relating IP addresses and domain names.
- Name servers are spred out and placed in each organization.
  - Databases are spread out and placed in each organization.
- DNS has hierarchical Structure (tree structure)

What is DNS? (4)

- Hierarchical Structure (Tree Structure)
  - mechanism to coordinate the database, which has been divided up and spread out.
- The name server on top points to the name servers below.



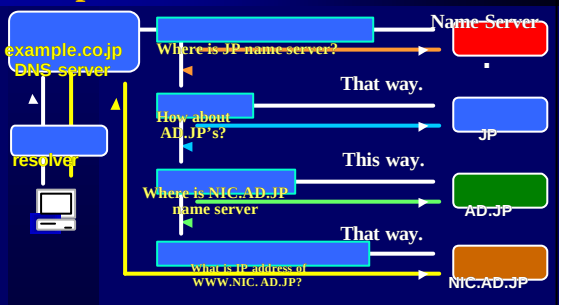
Tree Structure of DNS (1)



Tree Structure of DNS (2)

- JP, CO are sometimes referred to as "Zone"
  - A name server would manage a zone set.
- "root (.) zone" is at the very top.
  - Root name servers manage the root zone.

Steps of name resolution



IP address is 202.12.30.144.

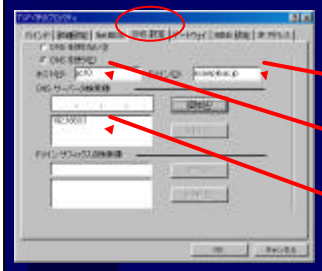
Root Server

- Root server is always asked when someone can't resolve names by themselves.
  - It is actually very important in DNS.
- There are currently 13 root servers.
  - a.root-servers.net ～ m.root-servers.net
  - In Japan, there is m.root-servers.net.

What was that request?

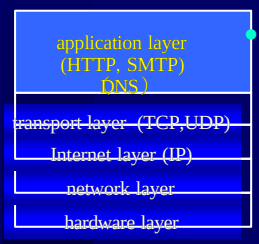
- "About that computer earlier, would you set up the domain name as example.co.jp, the host name as PC 10, and the name server is 192.168.0.1. I'm counting on you."
- "Ah, that's what he meant!"

Example



- Items to be set
  - Domain name
    - example.co.jp
  - Host name
    - pc10
  - Name server
    - 192.168.0.1

Application layer (2) others



- Roles
  - the layer that the user can actually touch
  - the layer providing services to the users

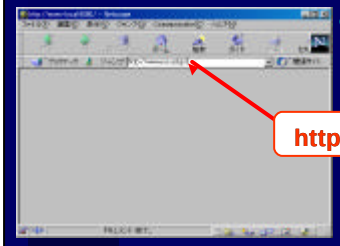
Providing services

- Services on the Internet
  - Viewing websites (HTTP)
    - Hyper Text Transfer Protocol
  - Sending/Receiving E-mail (SMTP/POP3)
    - Simple Mail Transfer Protocol
    - Post Office Protocol version3
  - File transfer (FTP)
    - File Transfer Protocol

Review

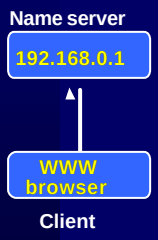
- Review the functions of each layer by taking an example where you view home page with the browser.

Typing the Home Page address



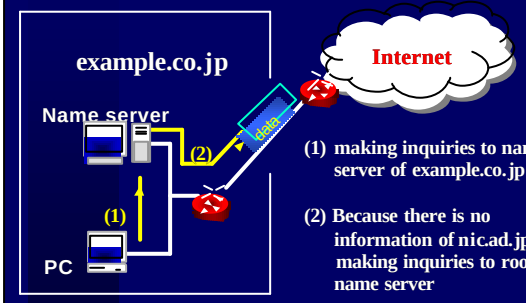
- Type the address into the space for the URL.

Inquiry to the name server



- Communicate with name server by using IP address
- Use UDP port number 53 when making inquiries
- Routing is done in order to deliver the packets.

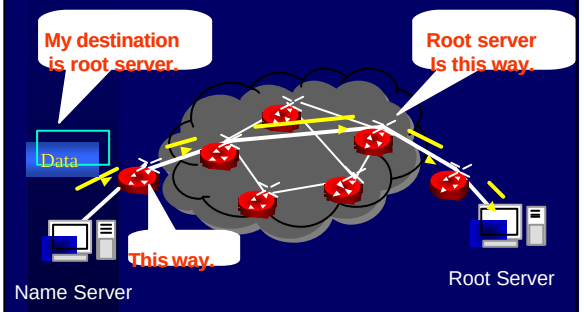
Routing in name resolution



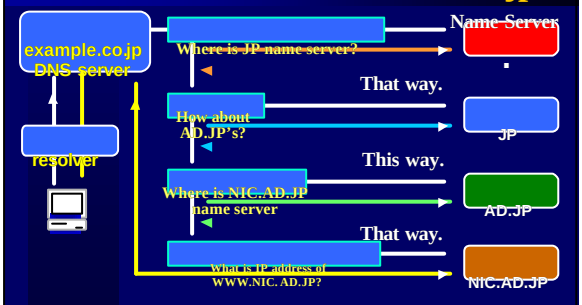
(1) making inquiries to name server of example.co.jp

(2) Because there is no information of nic.ad.jp, making inquiries to root name server

Routing



Get IP address of www.nic.ad.jp



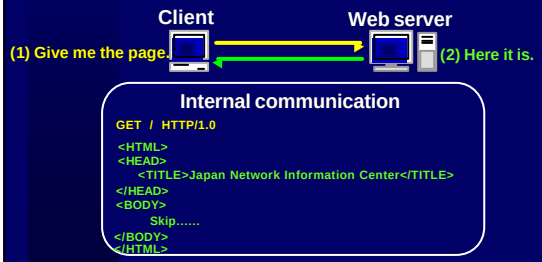
IP address is 202.12.30.144.

Access to Web server

- Access to Web server
  - The protocol is HTTP, so we use TCP number 80.
- Routing is done in order to deliver the packets. (skip)

Application layer (HTTP)

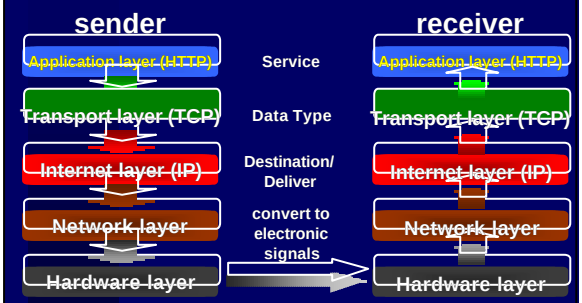
- Getting a page from Web server



Display Home Page

- Display the page sent by Web server

Procedure in hierarchical structure



Conclusion

Progress of the Internet

- Internet has developed due to these expansiveness and functions.
- There have been a number of issues surfacing along with the widespread use.
- New technology or a new mechanism is created to deal with it, and this is how the Internet has progressed.

New technology or a new mechanism

- New Internet Protocol
  - IPv6 (Internet Protocol Version 6)
  - It has many mechanisms to solve the problems of current IP.
- addition of new domain names
  - New TLD/New JP domain name
  - Developing multi-lingual domain names

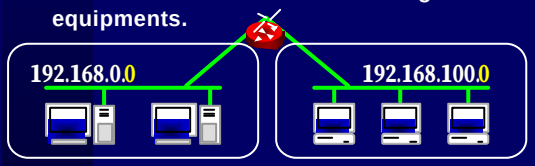
Everything's OK

- New technologies and mechanisms are extensions of what we discussed today.
- Please consider attending our other tutorials or more advanced tutorials in the upcoming year.

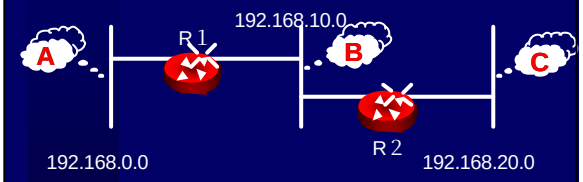
Questions and Answers

IP address with special meaning (1)

- All numbers in host part are 0.
  - Example : 192.168.0.0
  - This address represents the apartment name.
  - This kind of IP address is not assigned to equipments.



Create routing information (1)



Think about how the routing information is created by using routing protocol.