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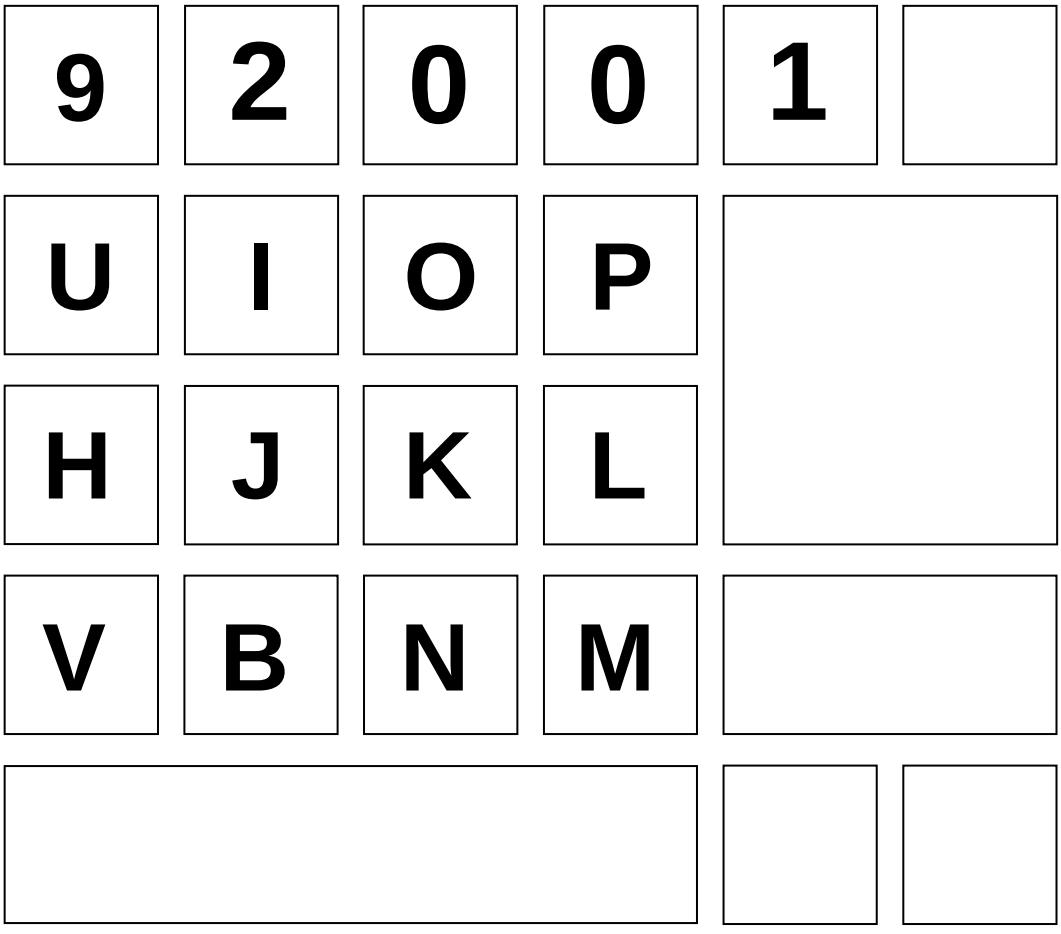
Textbook for Fundamental Information Technology Engineers

NO. 4

NETWORK AND DATABASE TECHNOLOGIES



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No. 4 NETWORK AND DATABASE TECHNOLOGIES

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Part 1

NETWORK TECHNOLOGY

Introduction

This series of textbooks has been developed based on the Information Technology Engineers Skill Standards made public in July 2000. The following four volumes cover the whole contents of fundamental knowledge and skills required for development, operation and maintenance of information systems:

No. 1: Introduction to Computer Systems
No. 2: System Development and Operations
No. 3: Internal Design and Programming--Practical and Core Bodies of Knowledge--
No. 4: Network and Database Technologies
No. 5: Current IT Topics

This part gives easy explanations systematically so that those who are learning network technology for the first time can easily acquire knowledge in these fields. This part consists of the following chapters:

1 Protocols and Transmission Control

Chapter Objectives

In network systems using computers, communication is conducted based on common protocols. Network architecture is necessary in order to define and regulate these protocols. When actual communication is performed, transmission controls containing various transmission procedures are used.
This chapter will provide the reader with an overview of network architecture and its significance for learning about transmission control procedures.

① Understanding the necessity of network architecture, standardization, types of architecture, and de facto standards, etc.
② Obtaining an overview and understanding of the representative network architectures, i.e. OSI and TCP/IP, their hierarchical structuring, the role played by each layer of the hierarchy, etc.
③ Learning about the mechanisms of transmission controls, and understanding the representative transmission control procedures such as "Basic Mode Link control" and "HDLC procedure."

Introduction

The open network connectivity has progressed in a great deal together with the spread of the Internet and Intranet. Constructing open network systems that allow communications with other organizations is not simply a matter of connecting different hardware from different manufacturers via transmission media.

When building network systems, it is indispensable to agree on communication protocols on which communications will be based. The communication protocols vary with the computer systems and communication lines, and many different protocols have been adopted both in Japan and abroad, ranging from vendor-specific types to types standardized by public organizations. Together with the increase in systems connected with other network systems, such as the Internet, network architecture is becoming of even more importance.

(1) Communication protocols

A communication protocol is a set of rules to enable communication. When you communicate by telephone or by letters, there are predetermined rules you follow to enable communication. Conversely, you can say that if both parties observe the rules, reliable communication becomes possible.
As data communication also involves communication with other parties (the destinations of the transmitted data) via communication lines, certain rules (communication protocols) for the communication are required, and when these rules are observed, reliable communication becomes possible.

(2) Network architecture

Network architecture is the underlying structure of a network, and it specifies system design logically not only for protocols, but also for message formats, codes, and hardware. However, earlier network architectures were of a closed nature in most cases. Since a number of vendor (hardware manufacturers) specific network architectures (like IBM's SNA, etc.) could form their proprietary networks, there were many networks unable to interoperate with networks based on different network architectures.

On this background, the International Organization for Standardization (ISO) proposed and standardized the so-called OSI (Open Systems Interconnection) network architecture as an internationally standardized network architecture, which is independent from vendor-specific factors. Even if it is not an international standard, the TCP/IP (Transmission Control Protocol/Internet Protocol), employed as the standard protocol for the Internet, is widely used and has become the de facto industry standard for data transmission.

Based on the situations outlined above, in this chapter you will learn about the significance, purpose and indispensability of network architecture through learning about communication protocols (mainly OSI and TCP/IP).

1.1 Network Architecture

According to the JIS (Japanese Industrial Standard) definition, "network architecture" is the "logical structure and operating principle of a network system." However, this is a very abstract definition. So let us first look at the birth of network architecture to gain an understanding of its significance. Then we will move from an overview to an explanation of the detailed components of network architecture.

1.1.1 The Background of the Birth of Network Architecture

Earlier network systems were "host-centric systems," i.e., the host computer determined what terminals and peripheral equipment should be used. The normal situation was that the host computer manufacturer was the pivotal point in the construction of systems. The systems themselves were also constructed to comply with the requirements of the each application.

However, the following issues have been raised.

- In the case of "host-centric systems," it is difficult to reconfigure or extend systems even with the same vendor systems environment.
- With the increasing complexity and increased number of systems, the development costs related to communications network have become greater and greater.
- As the structure of software increases its complexity, communication software faces scalability challenge in support of ever increasing number of terminal connections.
- The borders between hardware and communication control and application functions have become blurred.

The downsizing, movement has accelerated the transition from "host-centric systems" to "distributed systems," and the necessity for building multivendor systems environment using open systems became important factors for the birth of network architecture.

As a matter of fact, the trend toward open systems has been accelerated by the proliferation of the Internet on a worldwide scale, and this requires that computers can be connected regardless of the manufactures or the employed applications. Accordingly, it can be expected that the necessity of network architecture, which prescribes the logical structure and operating principles of network systems and defines the communication protocols required for real-world data exchange, will increase further in the future.

1.1.2 Outline and Standards of Network Architecture

(1) What is network architecture?

The meaning of network architecture was touched upon in abstract terms above, and we will now proceed to look at the contents in more specific terms.

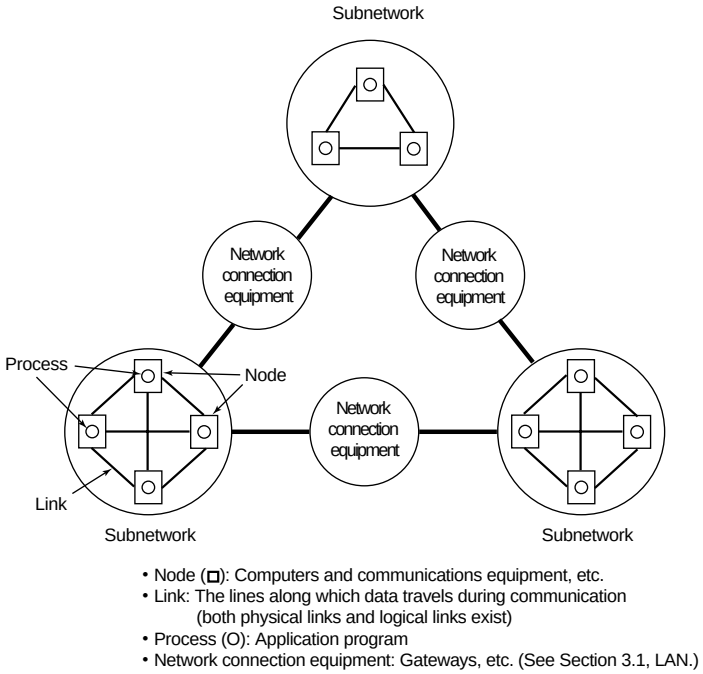
Network architecture defines and classifies all the functionalities (connector and access control methods, etc.) required for data transmission. Additionally, it determines "hierarchical structures" according to each classification and specifies protocols and interfaces between layers of the hierarchical structure. By establishing system structure using those determined interfaces and protocols, it enables effective operation of network systems.

(2) Logical network

Within the network architecture, all the network's physical elements (equipment and programs, etc.) are modeled and structured and treated as a logical network. More specifically, the main components of the logical network are:

- "node," i.e., hardware, such as computers and communication processing equipment,
- "link," i.e., communication lines,
- "process," i.e., application programs.

Figure 1-1-1
Logical network



In the logical network, the subnetworks linking the nodes (computers, etc.) are tied together by network connection equipment (gateways, etc.) as shown in Figure 1-1-1.

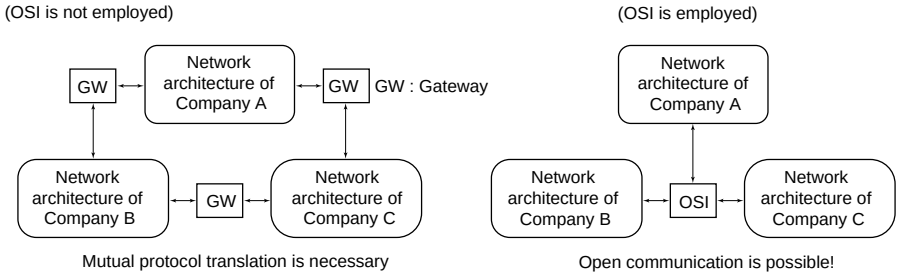
(3) Standardization of network architecture

Standardization of network architecture yields the following benefits.

- If the architecture is the same, a system can be built by adjusting the interfaces even when products from different manufacturers are combined. Earlier, system building was manufacturer-driven but the standardization of network architecture has made it possible for users to employ the products that best suit their purpose. (Multi-vendor system building)
- Employing a system compliant with standard interfaces makes it easy to develop, expand and maintain the system.
- Even independently developed systems can be easily integrated, which provides large effect especially on building distributed systems.
- The entire network can be treated logically (logical network); for example, no matter what type of the network system is, it will not affect the structure, etc.

Figure 1-1-2 compares the employment of a typical standard network architecture (OSI) versus a non-standard type.

Figure 1-1-2 OSI employed/not employed

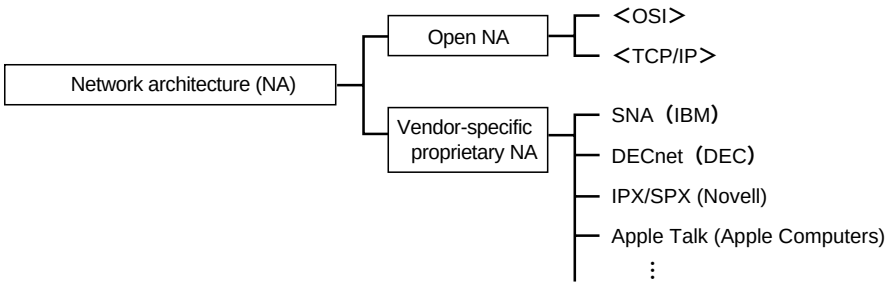


As shown in Figure 1-1-2, communication is not possible without the translation of protocols unless a standard architecture like OSI is employed.

1.1.3 The Types of Network Architecture

There are a number of network architectures, including vendor-specific architectures (IBM's SNA, etc.), internationally standardized architectures, as well as de facto standards. Among all these, the representative network architectures are OSI (Open Systems Interconnection) and TCP/IP (Transmission Control Protocol/Internet Protocol).
Figure 1-1-3 shows various network architectures.

Figure 1-1-3 Types of network architectures



1.1.4 De Facto Standards

Network architectures include some typical architectures like TCP/IP and OSI. However, unlike OSI, TCP/IP is not an architecture established by ISO or similar standardization organization. TCP/IP is employed for the world's largest network, the Internet, and it is also a standard characteristic of UNIX, the main operating system for workstations and servers. In other words, it has become an industrial de facto standard.

The relations between TCP/IP and OSI are explained in Section 1.3 TCP/IP.

1.1.5 Network Topology and Connection Methods

(1) Network topology (the connection configurations of networks)

Connecting computers and terminals, etc. through communication lines makes it possible to create a variety of network configurations in accordance with the scale and purpose of use.
Typical network configurations are shown in Figure 1-1-4.

① Ring type

The ring type is a configuration in which the nodes (computers, etc.) are connected in a closed loop by communication lines. The transmission lines are short in this kind of network configuration and easily controlled. The drawback is that if just one node fails, it might affect the entire network.

② Mesh type

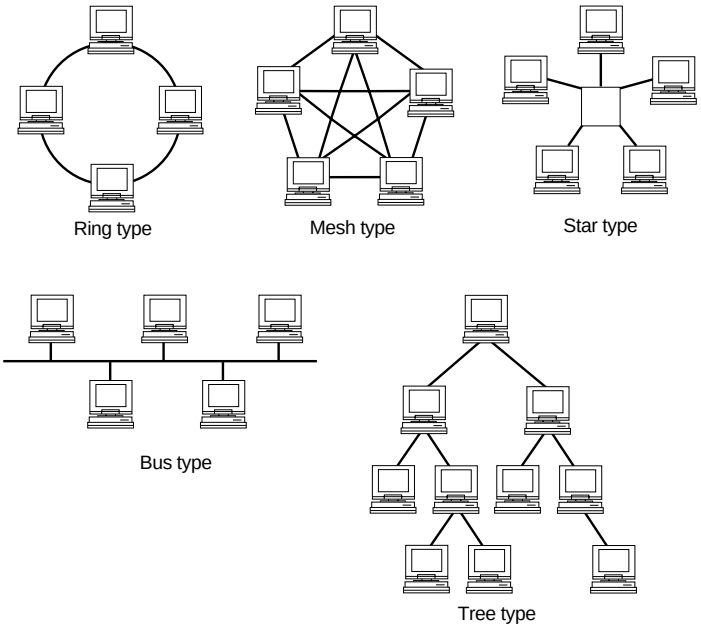
In the mesh type, two or more paths lead to each node so that the overall structure becomes that of a mesh. This means that even if a node fails, that node can be bypassed by routing (selection of communication path), meaning that the reliability of this type of network is very high.

③ Star type

In the star type, each node is connected to a central node (line concentrator, etc.) in a star-shaped configuration.

Even if one node fails, this will have no effect on the overall system, but if the central node fails, the entire network will no longer be functional.

Figure 1-1-4
Network topology



④ Bus type

In the bus type, all nodes are connected to a common communication line.
The bus configuration makes it easy to add or remove nodes without affecting the overall system and at the same it is economical. However, when there are many nodes and the traffic load (the information load carried in a specific interval) increases, data collisions may occur on the common communication line and the transmission efficiency (throughput) may deteriorate suddenly.

⑤ Tree type

In the tree type, several child nodes are connected to a parent node. This configuration is also called a cascade connection.
Recently, this configuration has become more widely adopted, but if the parent node is malfunctioning it will affect all the subordinate nodes.

(2) Line connection methods (methods for connecting networks)

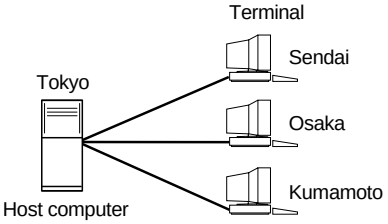
To ease understanding, we will use a simple network with one central computer connected by several terminals through communication lines as an example for explaining the methods for connecting networks.
There are three typical connection methods that are used in accordance with what best suits the communication distance and data load, etc. These are:

- Point-to-point connection
- Multipoint connection
- Switched connection

① Point-to-point connection

In the point-to-point connection, the computer is connected one-to-one to each terminal through leased communication lines.
This configuration is appropriate if the heavy data traffic between two points is required but it is uneconomical if the data traffic is not heavy enough. As the number of terminals are increased, the same number of communication lines will also have to be added.

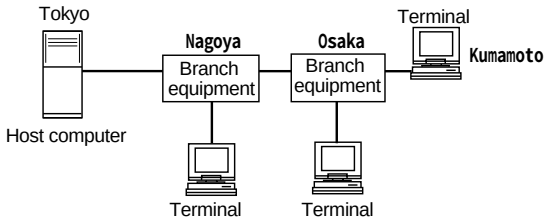
Figure 1-1-5
Point-to-point connection



② Multipoint connection (multi-drop system)

In the multipoint connection, multiple branching devices are connected sequentially to the same communication line. Terminals are then connected to the branching equipment.
This configuration allows construction of a network that is cheaper than using the point-to-point configuration when the communication distance is long and the data traffic is light. However, since the main communication line is shared, other terminals have to wait while one terminal is transmitting data.

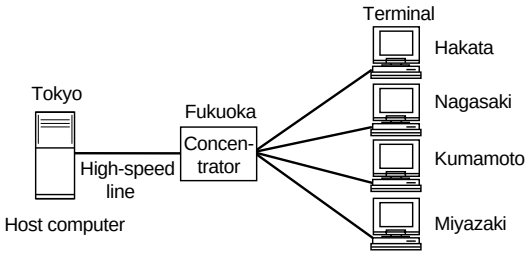
Figure 1-1-6
Multipoint configuration



③ Concentration connection

In the concentration connection, the lines from several terminals are connected to a concentrator, which is connected to the host computer through a high-speed line. (Figure 1-1-7).
This can be the same communication method as that employed by the point-to-point configuration in which each terminal is separately connected to the host computer. However, the cost of leased lines is smaller than in the case of the point-to-point configuration allowing for economical network construction but attention has to be paid to the capacity of the line between the host computer and the concentrator. In other words, the data load from each terminal connected to the concentrator must be taken into consideration to design network.

Figure 1-1-7
Concentration configuration



1.2 OSI – Standardization of Communication Protocols

This section gives an overview of the internationally standardized network architecture OSI (Open Systems Interconnection) established by the ISO (International Organization for Standardization) and explains the roles of the layers of this model and relations with headers, etc.

1.2.1 Overview of OSI

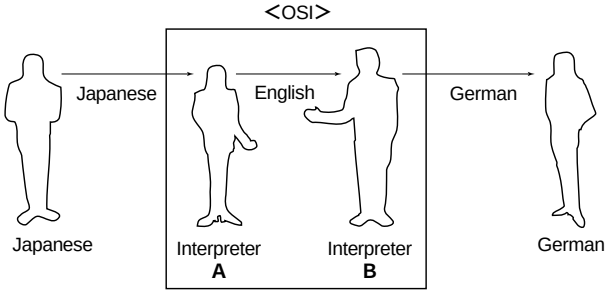
(1) OSI as an international standard

OSI is an international standard established primarily by the ISO and ITU-TS (International Telecommunication Union-Telecommunication Standardization Sector). In other words, OSI is manufacturer-independent, international standard network architecture.

(2) The role played by OSI

The role that OSI plays is outlined in Figure 1-2-1.
Let us assume that the Japanese person only can speak Japanese, and that the German can only speak German. If these two persons have to work together, how can communication and conversation be carried out between the two?

Figure 1-2-1 Communication between a Japanese and a German



Interpretation has to be done to act as a bridge and allow communication between the two. English or another internationally common language is employed for the interpretation. The role played by the common language is the role that OSI plays in network architectures.
In other words, no matter what kind of software is running on a network, and regardless of what kind of data is transmitted, problem-free data communication will be possible on the OSI compliant network.

(3) Hierarchical structuring

When several different networks have to be connected, communication functionalities become complex, manifold and intertwined. Gaining an overview is facilitated by grouping the functionalities in a hierarchical structuring. OSI came up with this idea, and the OSI model comprises 7 layers. The actual contents of the 7 layers (protocol hierarchy) are explained in detail in Section 1.2.2.
When summing up the merits of layering, we get the following:

- Even if the protocol of one layer is modified, it has not effect upon the other protocols meaning that development can be done easily.
- Lower order layers can be treated as black boxes meaning that complicated communication functionalities can be simplified.

Layering is extremely important in network architecture, because considerations must always be given to ensure:

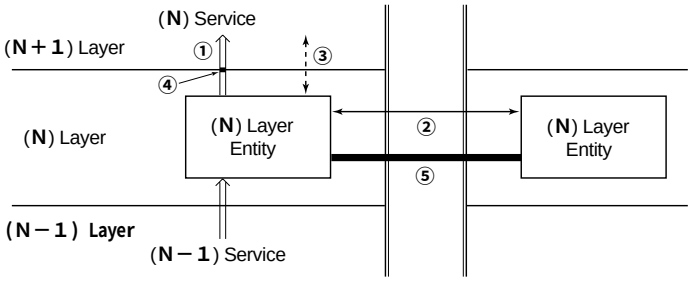
- Horizontalness: Protocols are determined between the same layers.
- Independence: Even if one layer is modified, this does not affect other layers.

In the basic OSI reference model and other open models, each layer is abstracted as "(N) layer," and all its concepts and relations to each of the other layers are grasped logically.

(4) Relations between higher layers and lower layers

To perform communication between open systems, functional modules, such as communication programs called "entities," are required, and two or more entities exist in each (N) layer. The relations between the (N) layer and the higher and lower layers are shown in Figure 1-2-2.

Figure 1-2-2 Relations between (N) layer and higher and lower layers



Using Figure 1-2-2, the relations between the different layers are briefly explained in the following.

① The service, which the (N) layer provides for the layer above (N + 1), is called (N) Service. Normally, the (N) layer integrates the services it receives from the (N-1) layer with its own functionalities and provides this in the form of (N) Service.

② The protocol used between (N) entities is called the (N) Protocol.

③ The action (service) performing the function of exchanging information between the (N) layer and the higher and lower layers, i.e., acting as interface between layers, is called (N) Service Primitive. (There are four primitives, such as "request.")

④ The access point between the layer receiving the (N) Service and the (N) layer is called (N) Service Access Point (SAP).

⑤ The logical communication channel used for the exchange of data between (N) Entities is called (N) Connection.

1.2.2 OSI Basic Reference Model

(1) Structure

Figure 1-2-3 shows the structure of the OSI basic reference model.

Figure 1-2-3 OSI basic reference model

Application layer	7th layer	Provides communication services required for applications
Presentation layer	6th layer	Data representation, format translation and mapping
Session layer	5th layer	Dialog management, synchronization point control, etc.
Transport layer	4th layer	Guarantees data transmission between end-to-end, etc.
Network layer	3rd layer	Routing functions, etc.
Data-link layer	2nd layer	Guarantees data transmission between adjacent systems, error control, etc.
Physical layer	1st layer	Connector and pin shapes, transmission media, etc.

These seven layers can be divided into upper and lower layers as shown in the following.

- Upper layers from the Application layer to the Session layer provides communication service functionalities
- Lower layers from the Transport layer to the Physical layer: Data transmission functionalities

The lower layers mainly ensure high-quality transfer of data, and the upper layers utilize the functions of the lower layers to provide communication services for applications.

(2) The role of each layer

① Application layer (7th layer)

The application layer is the 7th layer and the highest level and deals primarily with providing services such as:

- FTAM (File Transfer Access and Management)
- RDA (Remote Database Access)
- VT (Virtual Terminal)

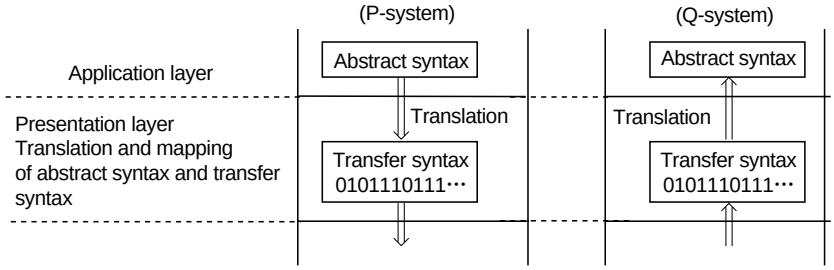
Figure 1-2-4 Primary functions of the application layer

FTAM	File transfer access and management
RDA	Remote database access
VT	Virtual terminal
TP	Transaction processing
MHS	Message handling system

② Presentation layer (6th layer)

The presentation layer is one level below the application layer and performs translation of data formats, etc. to ensure efficient transmission of various types of information. In the upper application layer, description is normally done using the representation system called "abstract syntax" but in order to enable efficient exchange of information between network systems, abstract syntax is translated to a data format (called "transfer syntax") in the presentation layer in which mappings of abstract syntax and transfer syntax, etc. is also taking place. These presentation layer functions allow the application layer to provide services without being conscious of the data encoding and physical representation of the other party's computer.

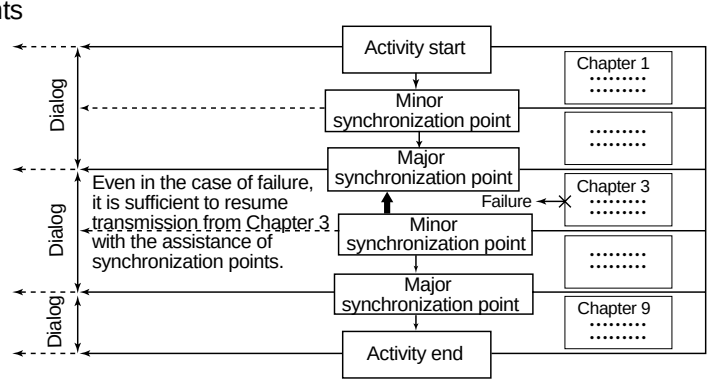
Figure 1-2-5 Translation between abstract syntax and transfer syntax



③ Session layer (5th layer)

The session layer is one level below the presentation layer and primarily performs "dialog management." Dialog management controls and manages the data flow between applications and systems by employing the end-to-end data transfer capabilities provided by the transport layer.
The communication mode can be set freely. In the case of normal communications (E-mail transmission, etc.), for instance, half-duplex transmission (one direction at a time) is employed. In the case of simultaneous two-way communication (as in video conference systems, etc.), full-duplex transmission (both directions simultaneously) is used. By establishing synchronization points, transmission can be restored from a synchronization point in case transmission fails due to one reason or another during the data transmission. Time loss can thus be minimized.

Figure 1-2-6
Synchronization points



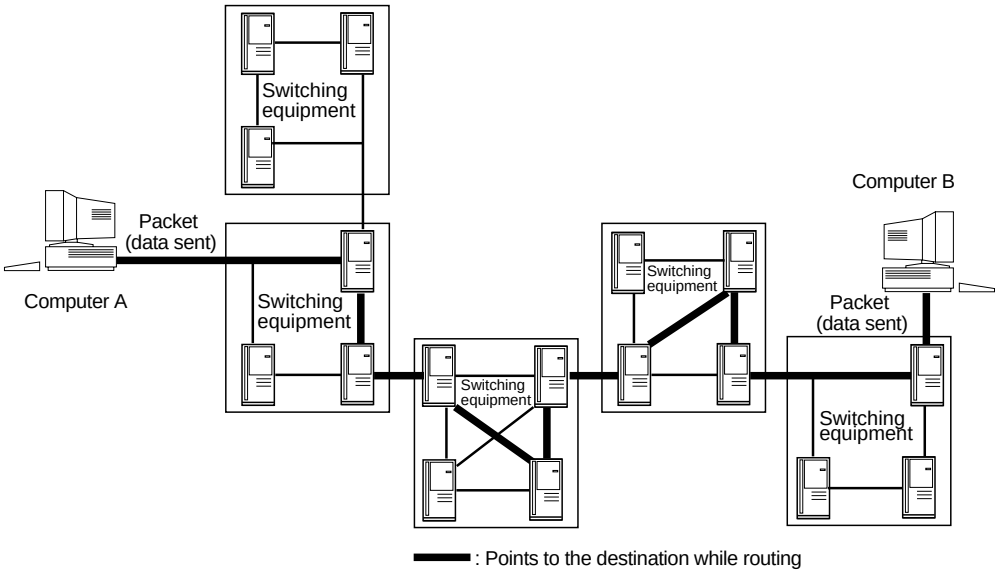
④ Transport layer (4th layer)

The transport layer is one level below the session layer and its function is to guarantee the quality of data transfer between system ends (from end-to-end). Accordingly, if the quality of the services provided by the layers below is insufficient, the transport layer compensates for the lower quality by additional error detection and recovery.

⑤ Network layer (3rd layer)

The network layer is one level below the transport layer and is concerned primarily with path selection (routing) and relays. The ITU-T recommendation X.25 (see Section 1.5.2 X-series) packet level protocol is well known.

Figure 1-2-7
Routing function



While the transport layer one level above guarantees the data transmission between system ends, this layer is concerned with selecting the most appropriate paths and ensures "transparent" data transmission.

⑥ Data-link layer (2nd layer)

The data-link layer is one level below the transport layer and ensures transparent and error-free data transmission.
In general, the roles of the data-link layer comprise transmission controls, such as HDLC (High-level Data Link Control), establishment of data-link connection, error control (CRC (Cyclic Redundancy Check), coding, etc. (For details on transmission control procedures, see Section 1.6 Transmission control.)
In LAN (Local Area Network), this layer is also concerned with access controls, such as CSMA/CD (Carrier Sense Multiple Access/Collision Detection) and token passing, and logical link controls, such as LLC (Logical Link Control), etc.

⑦ Physical layer (1st layer)

The physical layer is one level below the data-link layer and transmits electric signals ("0" and "1") using transmission media (twisted pair cables or coaxial cables, optical fiber cables, etc.)
Some of the actual DCE (Data Circuit terminating Equipment) and DTE (Data Terminal Equipment) interfaces are:

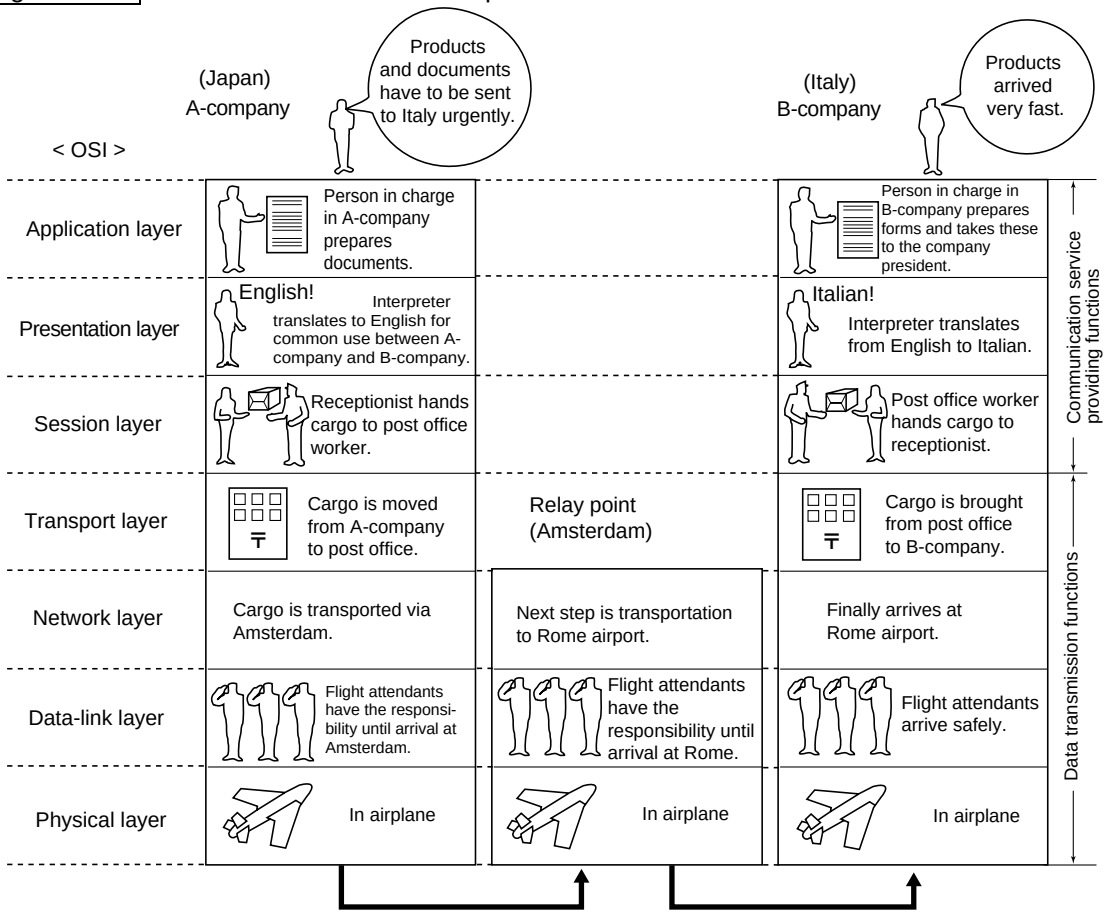
- ITU-T recommendation X-series: X.21 and others; defines the shape of connectors and pin array, etc.
- V-series: V.24 and others, defines modems, etc. for use with analog lines
- ISDN (Integrated Services Digital Network) terminal interface I-series: defines TA (Terminal Adapter), etc.

For details on the interfaces, see Section 1.5 Terminal Interfaces.

1.2.3 Communication Procedures in OSI

Figure 1-2-8 likens OSI with the steps involved in transactions between a Japanese and an overseas company.

Figure1-2-8 Transactions between companies

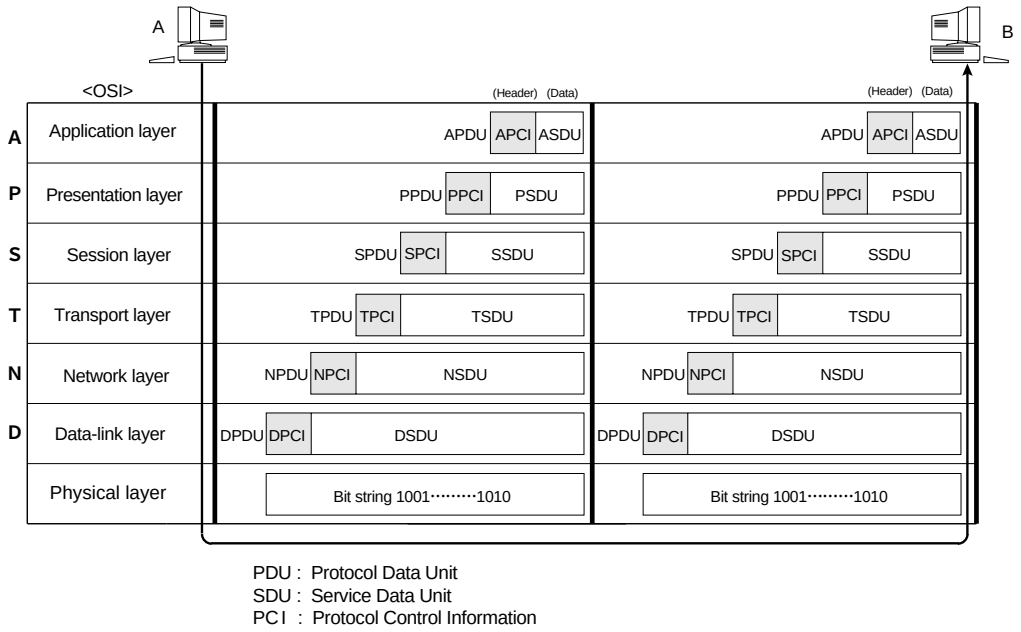


When communication is carried out using OSI in reality, the following procedures are carried out.

1. When a request for communication is issued, the communication channel is secured first of all (establishment of connection).
2. When the data passes through each layer at the sender side, headers (control information) are attached to the user data before the data is sent onward.
3. When the data passes through each layer at the receiver side, headers are removed sequentially.
4. When data transmission is completed, the communication channel is closed (connection is disconnected).
5. Communication resources are released and the process is completed.

The headers attached by the (N) layer are called (N)-PCI (Protocol Control Information), and (N) layer user-data is called (N)-SDU (Service Data Unit). The data combined by both of them is called (N)-PDU (Protocol Data Unit). I.e., (N)-PDU is supported by (N-1)-SDU (Figure 1-2-9).

Figure 1-2-9 Relations between headers and layers



PDU : Protocol Data Unit
SDU : Service Data Unit
PCI : Protocol Control Information

1.3 TCP/IP – The De Facto Standard of Communication Protocols

TCP/IP has become the de facto standard protocol for the world's largest network, i.e., the Internet. This section gives an overview of and explains the hierarchical structure and roles played by each layer of the protocol while comparing it with the OSI model.

1.3.1 Overview of TCP/IP

(1) What is a TCP/IP?

TCP/IP (Transmission Control Protocol/Internet Protocol) has become the standard protocol for the Internet. Due to the worldwide spread of the Internet, TCP/IP has become the de facto standard network protocol. There is a close relationship between the TCP/IP and the Internet, and the historical background for this is explained in details in Section 3.2.1 The Historical Background of the Development of the Internet.
TCP/IP was developed as part of ARPANET (explained later) in the 1970s, and it is a stack of flexible protocols that ensure high reliability and high speed transmission. This stack of protocols is comprised of the "TCP protocols" and the "IP protocols") but normally the TCP/IP protocol is taken to refer to the protocols that define the communication mode used on the Internet. (Sometimes it is also referred to as the "TCP/IP protocol architecture" or the "TCP/IP protocol suite.")

(2) Hierarchical structure

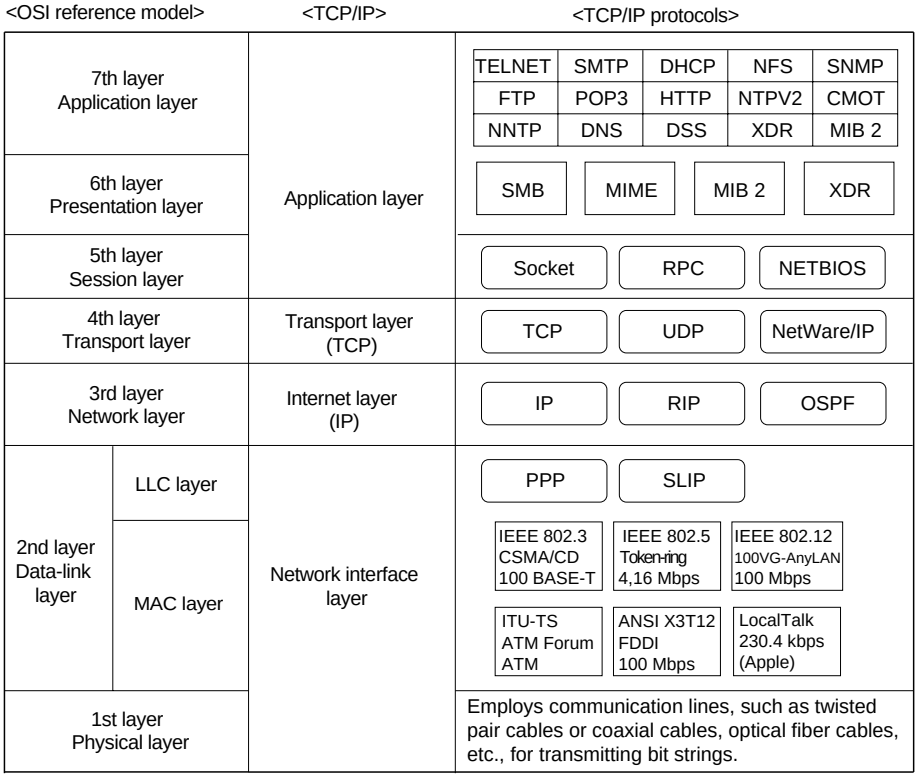
As the OSI model, the TCP/IP also has a hierarchical structure. Basically, it is constructed from the four layers shown below, with each layer containing several protocols (hierarchical protocol).

- Application layer
- Transport layer
- Internet layer

- Network interface layer

Comparison between OSI and TCP/IP is show is Figure 1-3-1.

Figure 1-3-1 Comparison of the hierarchical structures of TCP/IP and OSI



TCP and IP are both important protocols, each having the following functions.

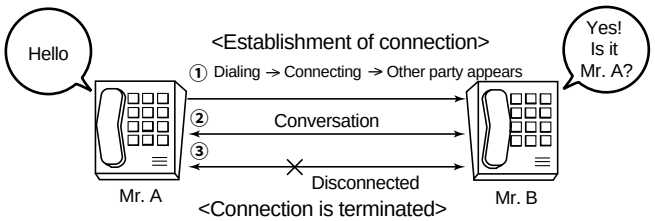
- TCP (transport protocol; connection-oriented mode) = ensures high reliability
- IP (Internet protocol; connectionless mode) = ensures high-speed data transmission.

The connection-oriented and connectionless modes are explained briefly in the following.

① Connection-oriented mode (TCP)

The connection-oriented mode requires a direct connection (logical channel) to be established between the sender and the recipient before data is transmitted. Data is transmitted through this channel to arrive at the target terminal. When the transmission is completed, the connection is disconnected. The establishment of the connection results in communication with high reliability.
The workings are shown in Figure 1-3-2, using telephones as examples.

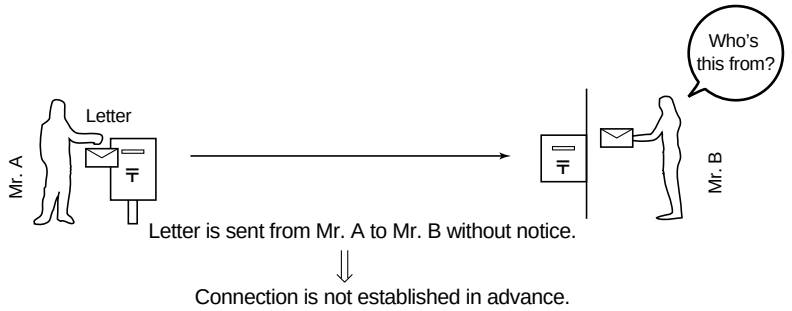
Figure 1-3-2 Connection-oriented image (telephone)



② Connectionless mode (IP)

The connectionless mode skips the establishment of a direct connection and reservation of a communication channel before data is transmitted, meaning that there is no guarantee that the data will reach the other party. On the other hand, it enables high-speed data transmission. Accordingly, it is a precondition for use of the connectionless mode that communication takes place on a highly reliable communication line in order to raise the probability that the data reaches the other party.
The workings are shown in Figure 1-3-3, using postal mail as an example.

Figure 1-3-3 Connectionless image (postal mail)



As shown above, a role is allotted to each of TCP and IP in the TCP/IP model to enable highly reliable and high-speed transmission on the Internet. I.e., TCP ensures highly reliable data transmission, so that this function can be omitted by IP, which results in high-speed data transmission.

(3) The roles of each layer

① Application layer

The application layer is the highest level and is concerned with services related to user applications. Services on the Internet are made possible by the protocols of this layer.
The key protocols are indicated below. (For details, see Section 3.2, The Internet.)

- DNS (Domain Name System): A protocol matches domain names and IP addresses.
- HTTP (Hyper Text Transfer Protocol): A protocol for transmitting files in the HTML markup language.
- FTP (File Transfer Protocol): A protocol for transmitting files.
- SMTP (Simple Mail Transfer Protocol): A protocol for transmitting simple mail.
- POP3 (Post Office Protocol Version 3): A protocol for receiving mail from mail servers.
- NNTP (Network News Transfer Protocol): A protocol for transmitting network news.
- TELNET (TELecommunication NETwork): A protocol that enables log on to a remote terminal.
- SNMP (Simple Network Management Protocol): A protocol for management of simple networks.
- DHCP (Dynamic Host Configuration Protocol): A protocol for automatic setting of IP addresses.

② Transport layer

The transport layer is one level below the application layer and its function is to provide the service for data transfer between system ends (end-to-end).
The following two protocols ensure reliability and high speed.

- TCP: Ensures high reliability.
- UDP: (User Datagram Protocol): Instead of ensuring high reliability this protocol ensures high speed.

As mentioned earlier, the mode of the TPC protocol is the connection-oriented but the UDP protocol is connection-less. Which of the two protocol should be used is determined by the higher level application layer. TCP is appropriate when a large amount of data should be transmitted sequentially, and UDP is appropriate when small size data (packet) is transmitted intermittently.

③ Internet layer

The Internet layer is one level below the transport layer and its function is to provide routing (selection of communication path) and relaying capabilities for data transmitted via networks, such as the Internet.
The IP protocol plays an extremely important role in this layer, as it affixes IP headers (control information) and sends IP datagrams (data information unit used in TCP/IP) from sender to recipient. At this point, the other party is recognized through the IP address (described later) contained in the IP header, and the optimal routing is carried out to send the data to the recipient.
The following protocols are employed for routing.

- RIP (Routing Information Protocol): Protocol containing information for selection of the communication route.

- OSPF (Open Shortest Path First): Protocol that offsets the defects of RIP.

④ Network interface layer

The network interface layer is one level below the Internet layer and performs error-free transparent transmission of any kind of data.
The TCP/IP network interface layer is a layer that combines the functionalities performed by the physical layer and data-link layer of OSI. For convenience' sake, OSI Reference Model's data-link layer is divided into the LLC layer (Logical Link Control) and the MAC layer (Media Access Control) groups of protocols.
Three protocols are described in the following.

- SLIP (Serial Line Internet Protocol)
  SLIP is a protocol for point-to-point connection using public lines (telephone lines, etc.) and measures against failures and error control are handled by higher-level layers.
- PPP (Point to Point Protocol)
  PPP is a protocol that basically performs the same functions as SLIP but is designed to provide improved functions in terms of management, etc.
- ARP (Address Resolution Protocol)
  ARP is a protocol for mapping IP addresses to MAC addresses (MAC layer addresses are described later).

1.3.2 Communication Procedures in TCP/IP

The communication procedures in TCP/IP are the same as those taking place in OSI.

1. When a request for communication is issued, connection is established.
2. On the sender side, headers (control information) are affixed to the user data when it passes through each layer before the data is sent out.
3. On the receiver side, headers are sequentially removed as the data passes through each layer.
4. When transmission of the data is completed, the connection is disconnected.
5. The communication resources are released and the session is completed.

1.4 Addresses Used for TCP/IP

Addresses are used to specify the destination node, etc. when transmission is conducted.
TCP/IP uses the following two types of addresses to specify the transmission destination.

- IP address (logical address)
- MAC address (physical address)

1.4.1 IP Address

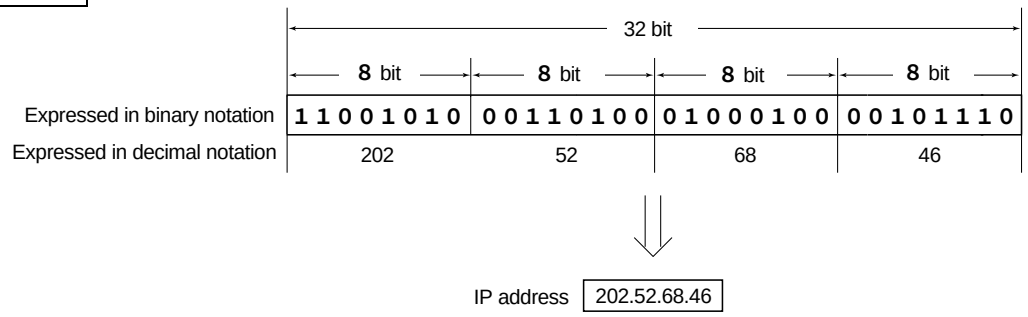
(1) What is an IP address?

Computers connected on the Internet are assigned a 32-bit IP (Internet Protocol) address. Because IP address under no circumstances must be duplicated, the Network Information Center (NIC) has been put in charge of worldwide, centralized management and allocation of IP addresses. In Japan, Japan Network Information Center (JPNIC) is in charge of domestic allocation of IP addresses. This means that an IP address must be obtained from JPNIC when you plan to construct a network for which it is a prerequisite to be connected to the Internet.
IP addresses are allocated after consideration of the scale of a network, etc.

(2) IP address classes

Figure 1-4-1 shows the structure of IP addresses.

Figure 1-4-1 Structure of IP addresses



The two parts of an IP address show the following:

- Network address part: Which network the IP address belongs to
- Host address part: The address of the computer

IP addresses are grouped into the following four classes A to D in accordance with contents and size of the network address parts and host address parts.

Figure 1-4-2 IP addresses (Class A to Class D)

	Adaptive network scale	No. of networks applicable to	No. of host addresses allocable per network
Class A	Large	Few	Many
Class B	↓	↓	↓
Class C	Small	Many	Few
Class D	(Only used for special communication modes)		

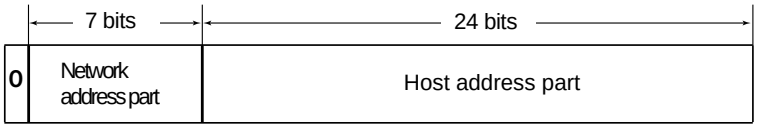
IP addresses in which the 32 bits are all "0" or "1," and the network part is "127" are only used in special cases and is not normally used.

① Class A

Class A is for use in very large-scale networks. Figure 1-4-3 shows the structure of Class A.

Figure 1-4-3 Class A structure

<Structure of IP addresses for use in very large-scale networks hosted by a large number of computers>

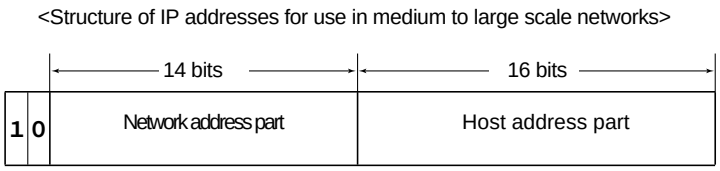


- Leading bit: "0"
- Network address part: 7 bits
- Host address part: 24 bits
- No. of networks for which allocable addresses are available: 126
- No. of host addresses available for allocation to one network: 16,777,214

② Class B

Class B is used for large and medium sized networks, in which the shortage of available addresses is becoming a serious issue. Figure 1-4-4 shows the structure of Class B.

Figure 1-4-4 Class B structure

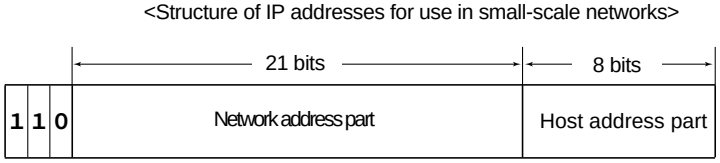


- Leading bit: "10"
- Network address part: 14 bits
- Host address part: 16 bits
- No. of networks for which allocable addresses are available: 16,382
- No. of host addresses available for allocation to one network: 65,534

③ Class C

Class C is used for comparatively small-scale networks in which the number of hosts are smaller than in Class A and B.
Figure 1-4-5 shows the structure of Class C.

Figure 1-4-5 Class C structure

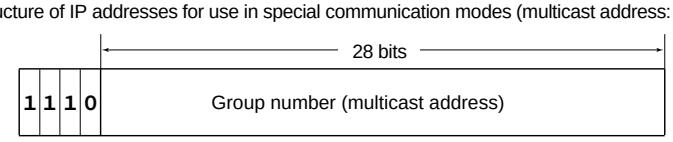


- Leading bit: "110"
- Network address part: 21 bits
- Host address part: 8 bits
- No. of networks for which allocable addresses are available: 2,097,150
- No. of host addresses available for allocation to one network: 254

④ Class D

Class D addresses do not contain the host address part and are only used for special communication modes.
Figure 1-4-6 shows the structure of Class D.

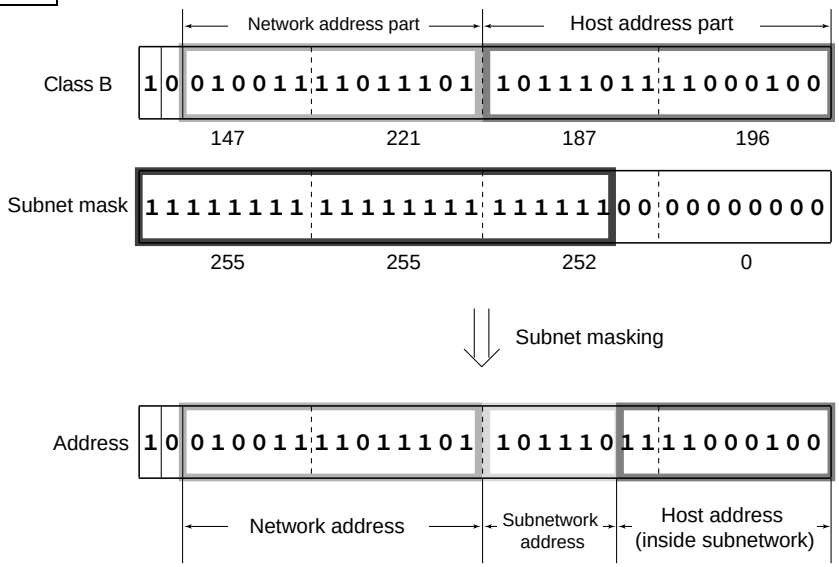
Figure 1-4-6 Class D structure



(3) Subnet mask

Subnet mask is a technique born out of the necessity for effective use of IP addresses as the number of available addresses are becoming scarce.
In the case of a Class B address, for example, the maximum number of host addresses that can be allocated to one network is 65,534. However, currently it is difficult to imagine a network comprising such a large number of computers. The subnetwork address is therefore used to increase the number of network addresses by only using a part of the host address. The method used for this is called "subnet mask." In other words, the subnet mask indicates the range of the network address and subnetwork address. To be more specific, the subnet mask indicates the network address part as "1" and the host address part as "0," as shown in Figure 1-4-7.

Figure 1-4-7 Subnet mask



In this way, even if the network address is the same, the subnetwork addresses will be different and form a completely separate network and IP addresses can thus be allocable to extended number of users.

(4) Special IP addresses

Some IP addresses have special meanings. These are:

- Network addresses
- Broadcast addresses
- Multicast addresses

① Network addresses

Network addresses are addresses in which the host address part of the IP address consists entirely of 0, and it is appropriate to think of these as network nameplates.

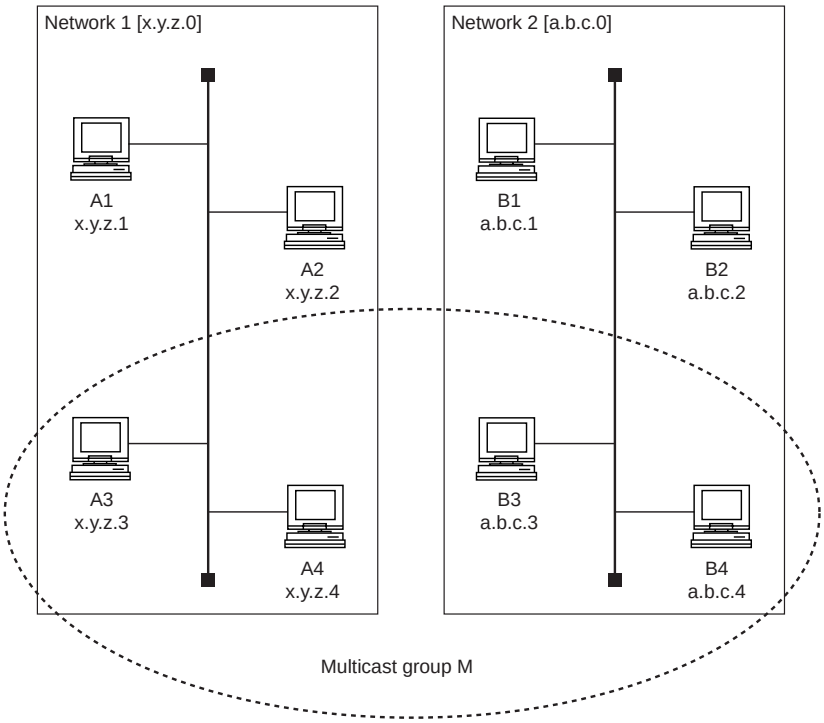
② Broadcast addresses

Broadcast addresses are addresses in which the host address part of the IP address consists entirely of 1. These addresses are used for broadcasting data to all the nodes belonging to a network, etc. In contrast to what a broadcast address is used for, an address used to send to a specified node only is called a "unicast address."

③ Multicast addresses

Multicast addresses are used for sending data to all the nodes belonging to a specific group. A Class D IP address is used for identifying the specific group (multicast group).
In Figure 1-4-8, a Class C IP addresses are used in Network 1 and 2.
Consequently, the host address parts (lower-order 8 bits) consist entirely of 0, i.e., "x.y.z.0" and "a.b.c.0," but these are the network addresses of the respective networks.
Conversely, when a host address part consists entirely of 1, i.e., "x.y.z.255" and "a.b.c.255," this is the broadcast address. When data is addressed to this address (tentatively "x.y.z.255,") the data is transmitted to all the nodes (A1 to A4) belonging to this network (Network 1 in this example).
Conversely, if you only want to send data to B2, for example, a unicast address such as "a.b.c.2" is used.
A multicast address is used to send data to all the nodes (A3, A4, B3, B4) belonging to the multicast group M.

Figure 1-4-8
Special IP addresses



1.4.2 MAC Addresses

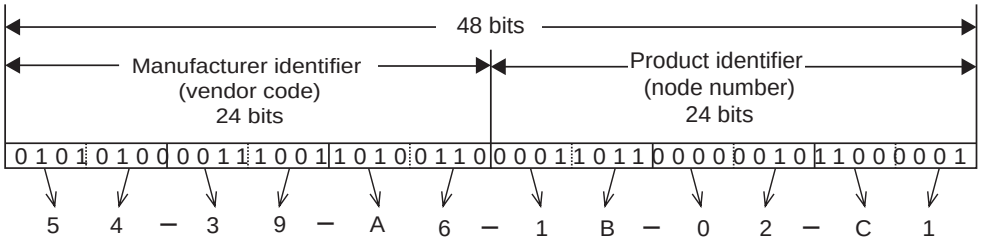
(1) What is a MAC address?

IP addresses are used to distinguish the nodes connected to a network. However, the IP address identification takes place on the Internet layer of the TCP/IP protocol. Consequently, an address that is capable of performing identification on the network interface layer (one level below the Internet layer) is required to carry out physical communication. This is the MAC (Media Access Control) address.

(2) The structure of the MAC address

The MAC address is a 48-bit address allocated to each piece of hardware (LAN port: Device used for connecting to the network).
Figure 1-4-9 shows an example of a MAC address structure.

Figure 1-4-9 Example of MAC address structure



The MAC address consists of:

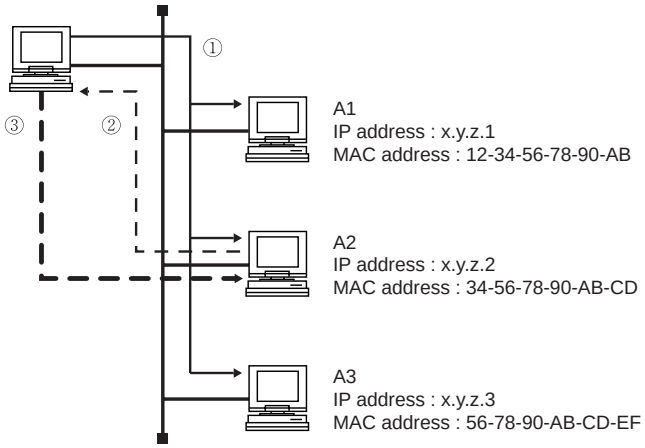
- Manufacturer identifier: ID number specific to the manufacturer
- Product identifier: ID number specific to the hardware and attached by the manufacturer

The MAC address is expressed in hexadecimal notation with each byte separated by "–" or ":." For example, the address in Figure 1-4-9 can be expressed as "54 – 39 – A6 – 1B – 02 – C1" or "54 : 39 : A6 : 1B : 02 : C1."

(3) ARP (Address Resolution Protocol)

In the TCP/IP model, the IP address is used as the address for the recipient of the transmission. However, in order to actually deliver data to the recipient within the network, the recipient's MAC address must be specified. It is therefore necessary to map the IP address to the MAC address. ARP plays the role of this mapping.
ARP is a protocol for converting the IP address into the MAC address, and the actual arrangement is shown in Figure 1-4-10.

Figure 1-4-10 ARP mechanism



① The ARP packet including the recipient IP address (x.y.z.2) is sent to all the nodes by broadcasting.
② The node (A2) having the recipient IP address included in the ARP packet returns its unique MAC address (34-56-78-90-AB-CD) to the sender.
③ Based on the obtained MAC address, data is transmitted.

It takes time and lowers efficiency if this procedure is used to convert the IP address into the MAC address every time. Consequently, the mapping of once investigated IP addresses and MAC addresses are preserved in lists, and mapping can thus be performed by using these lists as indices.

1.5 Terminal Interfaces

Terminal interfaces refer to arranged conditions and transmission control methods to ensure that transmission is performed between terminals. More specifically, this concerns connector types and standards for signal levels, and standards for operation conditions. The following three types are typical terminal interfaces, and each of these was define upon ITU-T recommendation.

- V-series: Interface between DTE and DCE with analog lines
- X-series: Interface between DTE and DCE with digital lines
- I-series: Interface for connecting to ISDN lines

The following outlines and explains the special characteristics of each series. Further details and explanation of the equipment and lines mentioned in the tables are given from Chapter 2.

1.5.1 V-series

The V-series documents the interfaces between DTE-DCE (MODEM) used for data transmission with analog lines.

Figure 1-5-1 V-series interfaces

Interface name	Definitions
V.10 (X.26)	Electrical characteristics of general-purpose unbalanced double-current interchange circuits used in IC devices in the field of data transmission
V.11 (X.27)	Electrical characteristics of general-purpose balanced double-current interchange circuits used in IC devices in the field of data transmission
V.21	300-bps modems for use on public switched telephone networks; full-duplex transmission
V.22	1,200-bps modems for use on public switched telephone networks and leased lines; full-duplex transmission
V.23	600/1,200-bps synchronous or asynchronous modems for use on public switched telephone networks
V.24	Definition of interchange circuits between data terminal equipment and data circuit-terminating equipment
V.26	2,400-bps modems for use on four-wire leased lines
V.26bis	1,200/2,400-bps modems for use on public switched telephone networks; half-duplex transmission
V.26ter	2,400-bps modems for use on two-wire lines; full-duplex transmission
V.27	4,800-bps modems with manual equalizer for use on four-wire (full-duplex) or the wire (half-duplex) leased lines
V.27bis	2,400/4,800-bps modems with manual equalizer for use on four-wire (full-duplex) or the wire (half-duplex) leased lines
V.27ter	2,400/4,800-bps modems for use on public switched telephone circuits; half-duplex transmission
V.28	Electrical characteristics of unbalanced double-current interchange circuits
V.29	9,600-bps modems for use on point-to-point four-wire leased circuits; full-duplex (4-wire) half-duplex (2-wire)
V.32	9,600-bps modems for use on two-wire lines; full-duplex transmission
V.33	14.4-kbps modems for use on four-wire leased lines
V.35	48-kbps data rate trunk interface using 60 - 108 kHz bandwidth lines

1.5.2 X-series

The X-series documents the interfaces between DTE-DCE (Digital Service Unit; DSU) used for transmission with digital lines. X.20, X.21 and X.25 (packet switching) are widely used.

Figure 1-5-2 X-series interfaces

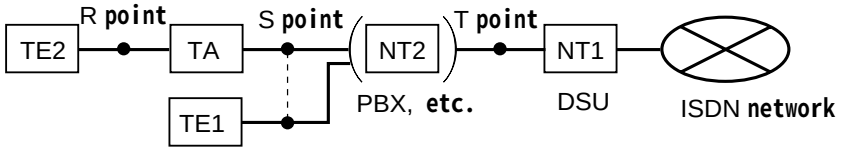
Interface name	Definitions
X.20	DTE-DCE (asynchronous communication) interface between data terminal equipment (DTE) and data circuit terminating equipment (DCE) for start-stop transmission on public switched telephone networks.
X.20bis	Specification for data terminal equipment (DTE) designed for interfacing to asynchronous two-wire V-series modems for use on public-access networks.
X.21	Interfaces between data circuit-terminating equipment (DCE) and data terminal equipment (DTE) for synchronous operation on public switched telephone networks.
X.21bis	Specifications for DTE designed for interfacing to synchronous V-series modes in public switched telephone networks.
X.24	Lists the definitions for interchange circuits between data circuit-terminating equipment (DCE) and data terminal equipment (DTE) for use in public switched telephone networks.
X.25	Interfaces between data circuit-terminating equipment (DCE) and data terminal equipment (DTE) for devices with direct connection to packet switched public telephone networks.

1.5.3 I-series

The I-series defines the interfaces used for connecting terminals to ISDN lines. It is also referred to as user/network interface. It also defines the logical connection points between DTE-DCE for use with ISDN.

Figure 1-5-3 I-series interfaces and ISDN

Interface name	Definitions	
I. 430	ISDN basic rate physical layer user/network interface	Layer 1 specifications
I. 431	ISDN primary rate physical layer group user/network interface	Layer 1 specifications
Q. 921	ISDN frame format at the data-link layer	Layer 2 specifications
Q. 922	ISDN frame mode bearer service (Frame Relay)	Data-link layer specifications
Q. 931	ISDN user/network interface for message type and content	Layer 3 specifications



- TE1: ISDN standard terminal equipment
- TE2: ISDN non-terminal equipment
- TA: Terminal adapter
- NT1: Digital service unit (DSU)
- NT2: PBX, etc.
- R, S, T points: Each interface point (defined by the I. 400-series)

ISDN comprises logical interface reference points like R, S and T in Figure 1-5-3. Separate points are found between R to T.
However, when TE1 is directly connected to the DSU, S and T becomes the same point. Also, if the DSU and TA functionalities are integrated in the same equipment, the three points become the same point.
The user/network interface comprises basic interfaces and primary group interfaces, and these details are mainly defined in the I. 400-series.

1.5.4 RS-232C

RS-232C (Recommended Standard 232C) is a standard adopted by the EIA (Electronic Industries Association, USA) that has become the ITU-T recommendation V.24. RS-232C defines various characteristics used for asynchronous transmission between DTE-DCE (MQdd Modulator/DEModulator; MODEM) for data transmission with analog lines. Because MODEM only handles serial data, RS-232C also is defined for serial data.

1.6 Transmission Control

Transmission control is the control capabilities used to ensure high-quality, efficient and reliable transmission of data. The steps involved in this are codified in a series of rules called "transmission control procedures."

1.6.1 Overview and Flow of Transmission Control

(1) Overview of transmission control

A number of controls and procedures are required to ensure efficient and reliable data transmission. Collectively, these controls and procedures are labeled "transmission control," which comprises the following four controls.

① Line control

A control exercised in the case of circuit switching that controls the switching between connection and disconnection of data transmission lines. In the case of leased lines, since the relationship between sender and recipient are fixed, line control is not necessary.

② Synchronous control

Synchronous control coordinates the timing for data exchange as well as data flow "flow control."
Synchronous control comprises modes like start-stop synchronization, SYN synchronization, and frame synchronization, etc. Flow control regulates the data transfer rate.
(For details on synchronization, see Section 2.2.2 Synchronous Control.)

③ Error control

Error control detects, corrects and retransmits erroneous data.
(For error detection methods, see Section 2.2.1 Error Control.)

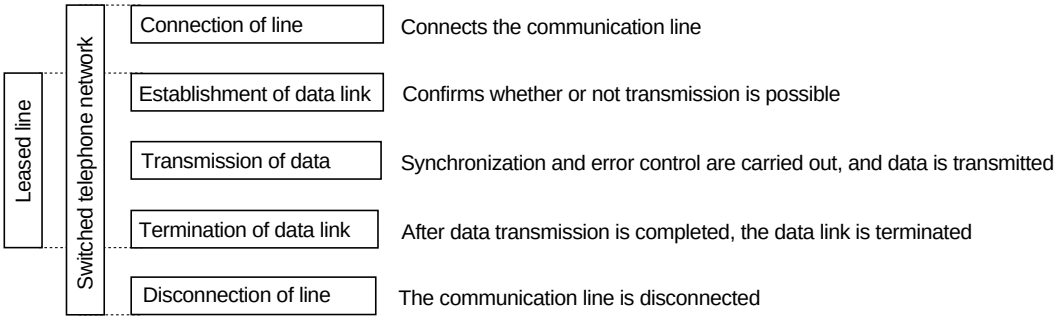
④ Data link control

Data link is the path that physically enables communication between the sender and the recipient. Data link control establishes the data link and performs data transmission according to a specified procedure and then terminates the data link.

(2) The flow of transmission control

The general flow of transmission control in switched telephone networks and leased lines is shown in Figure 1-6-1.

Figure 1-6-1 Data link establishment and lines



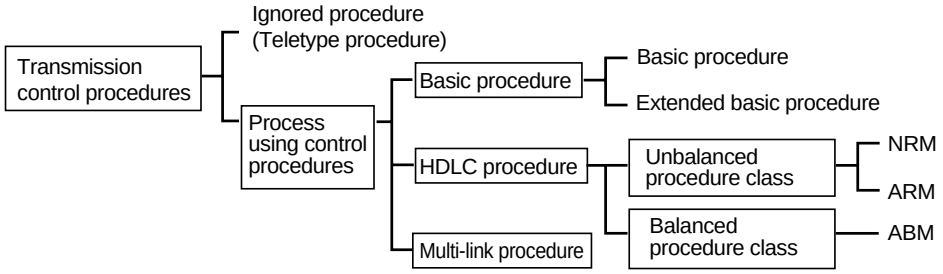
1. Phase 1 (line connection) (not necessary on a leased line)
   Simultaneously with dialing the other party and connecting the line, the necessary communication equipment (MODEM, etc.) is set to the functional state.
2. Phase 2 (establishment of data link)
   The other party is called, and it is inquired whether communication with the party is possible and the answer is confirmed. If the answer is "communication enabled," the first data link is established at this point.
3. Phase 3 (transmission of data)
   By establishing the data link, data transmission is performed while various controls (synchronous control and error control, etc.) are carried out.

4. Phase 4 (termination of data link)
   After data transmission is completed, it is checked that communication between the two parties has ended, and then the data link is terminated.
5. Phase 5 (disconnection of line) (not necessary on a leased line)
   The line is disconnected.

1.6.2 Transmission Control Procedures

Figure 1-6-2 shows typical transmission control procedures used to ensure efficient, reliable transmission of data.

Figure 1-6-2 Transmission control procedures



(1) Teletype procedure (TTY mode)

In the TTY (TeleTYpewriter) mode, the operator performs the control with regards to the data transmission. Since the transmission control procedures are ignored, it is called ignored procedure. This is widely used for personal computer communications using low-speed lines (300-bps class).
TTY is a mode in which a character flows along the communication line the moment that it is typed with a key. Since only the lowest level of control required for data transmission is in effect, the operator is required to take remedial actions if troubles occur (transmission errors, etc.).
In TTY mode, the sender transmits the data upon the issue of a request for data transmission. No controls are exercised, such as confirming the state of the other party, etc.
Basically, only the following three controls are used in TTY mode, and therefore reliability is low.

- The recipient confirms the delimitation of the data by delimiters, such as CR (Carriage Return).
- Flow control codes are used to start and stop data transmission to accommodate differences in processing speed on the sender and recipient side, respectively.

(2) Basic procedure (basic mode data link control)

Historically, the basic procedure is the oldest as it was established as the JIS X 5002 standard in 1975.

Figure 1-6-3 Characteristics of the basic procedure

Link code	JIS 7-unit code
Link control	Link control performed by 10 transmission control characters
Transmission unit	Block unit
Data length	Character (8-bit) times an integer
Synchronization	SYN synchronization
Error control	Parity check
Adaptive line speed	Appropriate for lines with a speed of up to 9,600 bps
Transmission efficiency	Normal (better than the ignored procedure mode)
Communication mode	Half-duplex (Extended mode uses full-duplex)

① Transmission control characters

In the basic procedure, the 10 transmission control characters shown in Figure 1-6-4 are used for transmission control.

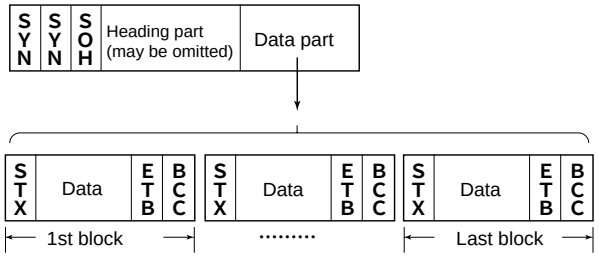
Figure 1-6-4 Transmission control characters

Code	Name	Definition
SOH	Start of Heading	Character for starting the basic mode.
STX	Start of Text	Transmission control character to indicate start of text. When heading is present, it is used for ending.
ETX	End of Text	Ends one text.
EOT	End of Transmission	Indicates the end of transmission of one or more texts.
ETB	End of Transmission Block	Indicates the end of a block split due to transmission considerations.
SYN	Synchronous idle	Ensures synchronization in the state in which other characters are not sent and maintains synchronization.
ENQ	Enquiry	Used for requesting an acknowledgement from the other party.
ACK	Acknowledge	Transmission control character sent from the recipient as an acknowledgement to the sender.
NAK	Negative Acknowledge	Transmission control character sent from the recipient as a negative acknowledgement to the sender.
DLE	Data Link Escape	Transmission control character used when adding transmission control to change the meanings of the following finite number of characters.

② Message format

The message in the basic procedure consists of the heading part and the data part.

Figure 1-6-5 The message format of the basic procedure



- Heading part: Contains control information for transmission (may be omitted).
- Data part: Data is divided into a number of blocks for transmission, and the BCC (Block Check Character) is added at the end of each block (normally attached as longitudinal parity bit, and the type is odd parity).

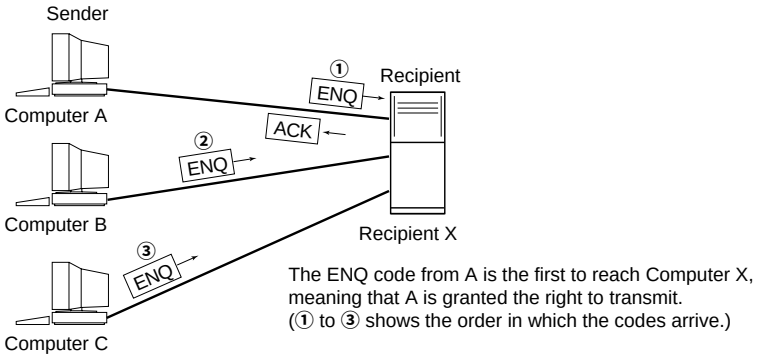
③ Establishment of data link

The basic procedure characteristics two methods for establishment of data link: Contention and polling/selecting.

a. Contention

Contention is the method used in the case of point-to-point connection. The sender (master station) sends the ENQ code, and after receiving the ACK code from recipient, transmission of data is commenced. I.e., in order to obtain the right to transmit, the ENQ code must be sent first, and therefore this method is sometimes referred to as the "first-come, first-served" method.

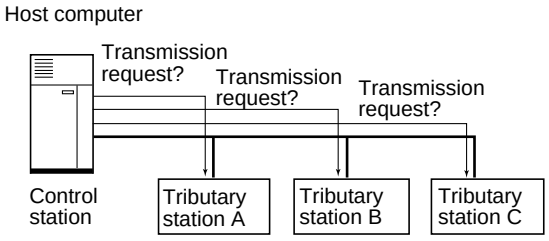
Figure 1-6-6
Contention



b. Polling/selecting

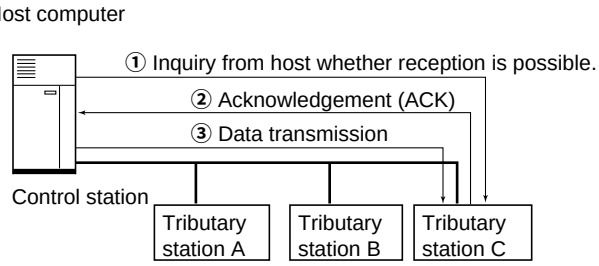
The polling/selecting method is used when several tributary stations are connected to a primary station (control station). The host computer, called the "control station," controls all the sending and reception of data within the network system.
This method consists of the following two operations.
<Polling>
In a specified order, the control station inquires all the tributary stations (stations other than the control station) whether or not they have transmission requests.

Figure 1-6-7
Polling



<Selecting>
In a specified order, the control station inquires a tributary station for which it has a request for transmission whether this tributary station is able to receive.

Figure 1-6-8
Selecting



(3) HDLC procedure (High-level Data Link Control)

The HDLC (High-level Data Link Control) procedure is a transmission control procedure for advanced, high-speed data communication.

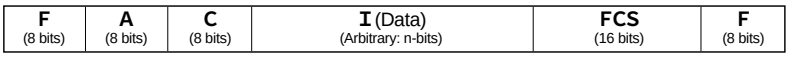
Figure 1-6-9
Characteristics of HDLC

Link code	-
Link control	By command/response
Transmission unit	Frame (up to 8 frames can be sent consecutively)
Data length	No restrictions
Synchronization	Frame synchronization
Error control	CRC (Cyclic Redundancy Check)
Adaptive line speed	2,400-bps or higher medium- or high-speed lines
Transmission efficiency	Good
Communication mode	Full-duplex

① Frame structure

In the HDLC procedure, information is transmitted in frames.

Figure 1-6-10 Frame structure



a. Flag sequence (F; 8-bits)

In the flag sequence, codes are inserted for synchronization to indicate the separation between frames, and these codes have the "01111110" bit pattern. In order that this bit pattern does not appear in other areas, the sender must insert 0 after 1 has appeared consecutively 5 times, and the sender must remove the 0 after 1 has appeared consecutively 5 times. Implementing this enables transmission of any bit pattern.

b. Address field (A; 8-bits)

The address field contains the address of the frame's sender and recipient.

c. Control field (C; 8-bits)

The control field contains information on the frame type, frame serial number, etc.
There are three frame types:

- Information (I) frame: For transmitting information
- Supervisory (S) frame: Used for confirming reception of I-frames and request for retransmission
- Unnumbered (U) frame: For control, such as mode setting, etc.

Frame serial numbers are attached in consecutive order to frames to be sent consecutively to enable check of whether frames are missing. The numbers 0 to 7 are available, allowing up to 7 frames to be sent consecutively.

d. Information field (I; n-bits)

Transmission data of an arbitrary bit length can be entered in the information field.

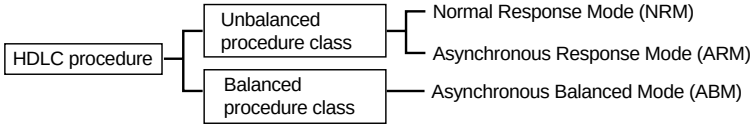
e. Frame check sequence (FCS; 16-bits)

CRC codes (16-bits) for error detection are entered in the frame check sequence.

② Establishment of data link

The data link establishment methods of the HDLC procedure comprise two classes; unbalanced procedure class and balanced procedure class.

Figure 1-6-11 The HDLC procedure methods for data link establishment



a. Unbalanced procedure class

In the same manner as the polling/selection of the basic procedure, the unbalanced procedure class is made up of one primary station and several secondary stations with the primary station controlling transmission. The frames sent from the primary station are called "commands," and those going the other way are called "responses."
In the unbalanced procedure class data is exchanged using the following two modes:

- Normal Response Mode (NRM)
  When the transmission permission is issued from the primary station, the response can be sent from the secondary station, but other than this, only commands from the primary station are allowed.
- Asynchronous Response Mode (ARM)
  Even if the transmission permission is not issued from the primary station, the response can be sent from a secondary station.

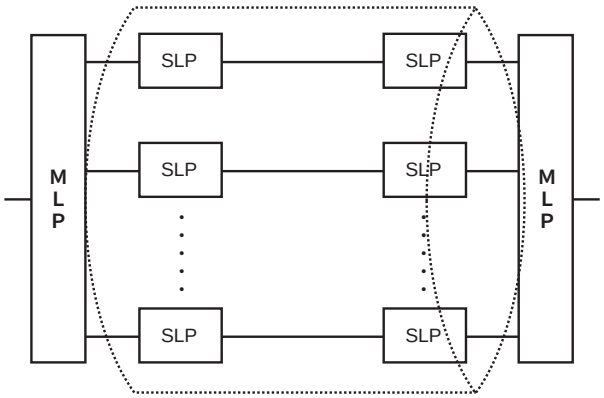
b. Balanced procedure class

In the balanced procedure class, combined stations, which possess the functionalities of both a primary station and a secondary station, are in charge of all transmission control. In the same manner as the contention mode used in the basic procedure each station can send command and response. In the balanced procedure class, data is exchanged using the Asynchronous Balanced Mode (ABM) in which both command and response can be sent even without obtaining the transmission permission from the combined station that is the other party in the communication.

(4) Multi-link procedure

The multi-link procedure combines multiple data links (single links), and is used for providing one data link offering various transmission capacities. Representative examples of this use are INS Net-64 and INS Net-1500 using ISDN lines. ISDN lines are provided with multiple channels (data links) for transmission of information, and the transmission capability of one channel is 64 kbps, but by using the multi-link procedure it becomes possible to provide data links having multiple transmission capabilities.
MLP (Multi Link Procedures), which executes the multi-link procedure, simultaneously controls parallel SLP (Single Link Procedures) that execute single-link procedures. Difference of transmission capability, etc. of the SLPs working in parallel operation does not matter. Figure 1-6-12 shows a diagram indicating the relations between MLP and SLP.

Figure 1-6-12
Relations between MLP and SLP



- Bundles several data links together to treat them as one data link.

The single-link procedure uses a single data line and is a data link protocol for establishing the data link, data transmission and disconnection of the data link. The multi-link procedure combines the data units for sending into a multi-link frame and hands it over to the SLPs. The SLPs transmit the received multi-link frame and notifies the MLP of the result. Based on this notification, MLP performs post-processing (recovery of transmission irregularities, etc.,) and closes the chain of control.

Exercises

Q1 **The figure shows the hierarchical structure of the OSI basic reference model. Please enter the correct terminology instead of A, B and C.**

Application layer
A
Session layer
B
C
Data-link layer
Physical layer

	A	B	C
a.	Transport layer	Network layer	Presentation layer
b.	Transport layer	Presentation layer	Network layer
c.	Network layer	Transport layer	Presentation layer
d.	Presentation layer	Transport layer	Network layer
e.	Presentation layer	Network layer	Transport layer

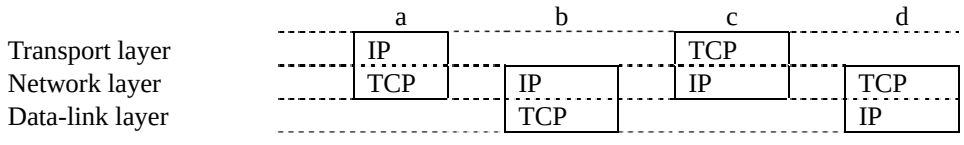
Q2 **Which of the following is the correct explanation of the "Network Layer" of the OSI basic reference model?**

a. Performs setting and release of routing and connections in order to create a transparent data transmission between end systems.
b. This is the layer closest to the user, and allows the use of file transfer, e-mail and many different applications.
c. Absorbs the differences in characteristics of physical communication media, and secures a transparent transmission channel for upper level layers.
d. Provides transmission control procedures (error detection, retransmission control, etc.) between adjacent nodes.

Q3 **Which of the following protocols has become a worldwide de facto standard? The protocol is used by the ARPANET in the USA, and is built into the UNIX system.**

a. CSMA/CD b. FTAM c. ISDN
d. MOTIS e. TCP/IP

Q4 **Which of the following illustrations appropriately shows the relationship between the 7 layers of the OSI basic reference model and the TCP and IP protocols used on the Internet?**



Q5 **Which protocol is used for file transfer on the Internet?**

a. FTP b. POP c. PPP d. SMTP

Q6 **What is the maximum number of host address that can be set within the one and same subnet when the 255.255.255.0 subnet mask is used with the Class B IP address?**

a. 126 b. 254 c. 65,534 d. 16,777,214

Q7 **Which is the most appropriate description of the ARP of the TCP/IP protocol?**

a. A protocol for getting the MAC address from the IP address.
b. A protocol that controls the path by the number of hops between the gateways.
c. A protocol that controls the path by the network delay information based on a time stamp.
d. A protocol for getting the IP address from a server at the time of system startup in the case of systems having no disc drive.

Q8 **Which ITU-T recommendation specifies the communication sequence between data terminal equipment (DTE) in data communication systems and packet switched networks?**

a. V.24 b. V.35 c. X.21 d. X.25

Q9 **In transmission control, what performs the following processing?**

- Supervises data circuit-terminating equipment (Modems, etc.).
- When used with telephone networks, it issues the dial tone and connects to the recipient, and disconnects the line after communication is completed.

a. Error control
b. Line control
c. Data-link control
d. Synchronous control

Q10 **There is a data communication system in which multiple terminals are connected on one line coming from the center. After the center control station inquires the tributary stations on the terminal side whether or not they have data to send, or after inquiring the state of readiness for signal reception, data transmission is carried out. What is this method called?**

a. Contention
b. Synchronous transmission
c. Asynchronous transmission
d. Polling/selecting

Q11 **Among the transmission control characters used in the basic mode data link control (basic procedure), which is the one that indicates acknowledgement of the received information message?**

a. ACK b. ENQ c. ETX d. NAK E. SOH

Q12 **In the information unit (frame) transmitted in the High-level Data Link Control procedure (HDLC procedure), which is the field employed for error detection?**

a. A b. C c. FCS d. I

Q13 **Which description most appropriately describes the multi-link procedure?**

a. A protocol for enhancing the reliability of each of the data links when multiple lines are multi-step connected in series.
b. A protocol that relays multiple parallel data links.
c. A protocol that treats multiple parallel data links as one logical data link.
d. A line-multiplexing protocol that divides one physical line logically into multiple data links.

2 Encoding and Transmission

Chapter Objectives

Various technologies are required in order to transmit data. These technologies include converting data into signals which can be easily transmitted, and securing the timing between the parties involved in the communication.
This chapter will provide an overview of the meanings, the mechanisms and characteristics of transmission technologies.

① Understanding the modulation and encoding techniques for converting data into transmittable signals.
② Understanding the mechanisms of error handling and synchronous control that are necessary to ensure correct transmission.
③ Understanding multiplexing methods and compression and decompression methods used to ensure efficient use of communication lines.
④ Understanding the types of lines used for transmission and the mechanisms of switching systems.

Introduction

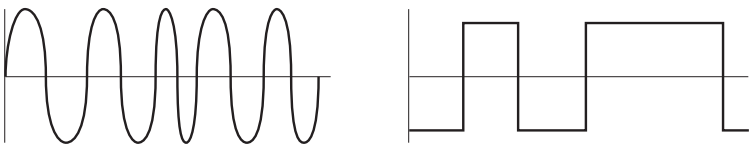
A physical communication line is necessary to transmit data from the sender to the recipient in a network. The type of communication line determines the kind of signals that can flow along the line. Consequently, it is necessary to have a mechanism that converts the data to the transmittable signals in accordance with the physical communication lines.

2.1 Modulation and Encoding

As explained in the foreword to this chapter, the techniques for data conversion are called "modulation" and "encoding." These two methods are used to transform the data into signals that can be transmitted. There are two types of convertible signals:

- Analog signals: Signals with a continuous waveform, such as audio and radio waves.
- Digital signals: Signals made up of discontinuous (discreet) pulses, and used inside computers.

Figure 2-1-1 Analog and digital signals



2.1.1 Communication Lines

A communication line is the physical transmission channel actually used for transmission of signals. These lines are broadly divided into analog lines and digital lines in accordance with the kind of signals that they can carry.

(1) Analog line

Analog lines are communication lines for transmission of analog signals. Analog signals are waveform signals, and audio signals are a typical analog signal type. Public telephone networks designed for transmission of audio signals represent the most widely used analog lines.

(2) Digital line

Digital lines are communication lines for transmission of digital signals. Digital signals are the kind of signals that are used inside computers. Digital lines for transmitting this kind of signals are lines designed for data communications. ISDN lines (explained later) are representative of digital lines.

2.1.2 Modulation Technique

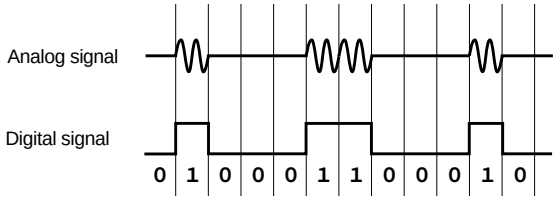
When transmitting data using an analog line, the computer's digital signals must be converted to analog signals using a MODEM (modulator/demodulator (explained later)). This is called "modulation" (the opposite is called "demodulation.")
Three methods are typically used for modulation in a MODEM:

- Amplitude modulation
- Frequency modulation
- Phase modulation

(1) Amplitude modulation (AM)

Amplitude modulation is a method in which the analog signal output is turned ON and OFF in accordance with ON (1) or OFF (0) state of the digital signal. This method is susceptible to noise; but it is the simplest modulation method, and uses narrow frequency band for effective utilization of transmission bandwidth.

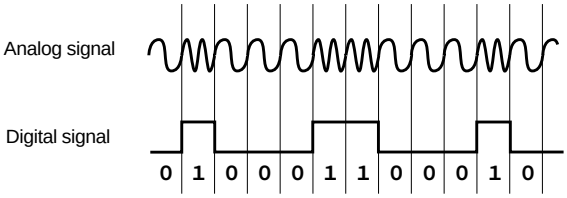
Figure 2-1-2
AM method



(2) Frequency modulation (FM)

Frequency modulation is a method which modulates the ON (1) and OFF (0) states of digital signals into two frequencies in different bands.
The drawback of this technique is that the required frequency band is wide but the method ranks as the second simplest method following the amplitude modulation method. It is also resistant to noise, etc.

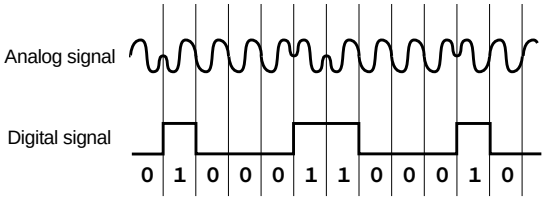
Figure 2-1-3
FM method



(3) Phase modulation (PM)

Phase modulation is a method in which the phase of the carrier is shifted to represent the ON (1) or OFF (0) states of the digital signal.
The simplest method is the 180-degree shifting method in which the phase is inverted when the digital signal is ON (1) and the carrier is output as it is prior to modulation when the signal is OFF (0).
This method is resistant to noise and allows much information to be sent simultaneously.

Figure 2-1-4
PM method



2.1.3 Encoding Technique

(1) PCM

When transmitting data using a digital line, it is necessary to convert analog signals, such as audio, to digital signals. This is called "encoding." PCM (Pulse Code Modulation) is a technique used for encoding.

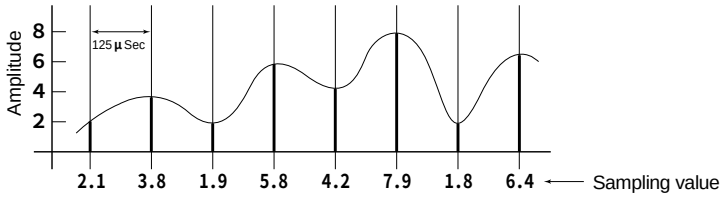
(2) Encoding procedures

The procedures involved in encoding (digitizing) analog signals, like audio signals, and sending these to another party are:
Sampling → Quantization → Encoding
On the receiver side, this process is reversed to obtain analog signals.

① Sampling

The sampling theorem (Shannon's theorem) is an important part of sampling. This theorem states "if the highest frequency of the target analog signal is "f," the recipient can restore the original analog signal if the signal is sampled at a frequency of 2f or higher for transmission."

Figure 2-1-5
Sampling

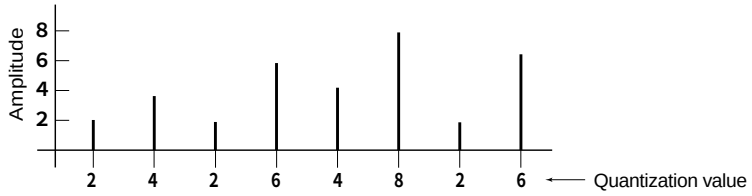


Example 300 - 4,000 Hz audio signal
As the highest frequency is 4,000 Hz, it is enough to sample the signal at 8,000 Hz according to Shannon's theorem. In other words, if 8,000 oscillations are performed per second, this audio signal will oscillate at the frequency of 125 μ (micron) second.

② Quantization

Quantization rounds the value of a measured signal to a finite number by rounding down or rounding up.

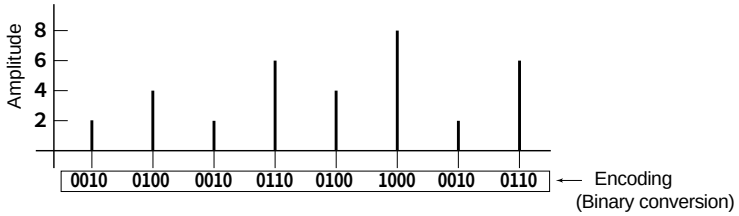
Figure 2-1-6
Quantization



③ Encoding

Encoding encodes the integral numbers obtained by quantization.

Figure 2-1-7
Encoding



Example Transmission speed when a signal sampled at 8,000 Hz is transmitted using 8-bit codes
As 8 bits must be sent every 125 μ sec, i.e., an 8-bit code must be sent 8,000 times per second, the transmission speed becomes
8 bits × 8,000/sec = 64,000 bps

(3) ADPCM (Adaptive Differential PCM)

ADPCM is a method that employs the PCM technique for audio compression.
ADPCM samples audio waves in the same manner as PCM, but it compresses encoding data by changing the quantization width in accordance with the differences in samples. When using the conventional PCM method, the line transmission capacity must be 64 kbps to enable transmission of audio data. Since this can be accomplished with 32-kbps lines with the ADPCM, this method has been adapted for use in PHS (Personal Handyphone System).

2.2 Transmission Technology

Many transmission technologies are employed to ensure reliable and correct transmission.
Some of these are:

- Conversion of analog signals and digital signals when exchanging data between computers using a communication line. → "Modulation, demodulation"
- Transmission accuracy → "Bit error detection"
- Timing control for data exchange → "Synchronization"
- Techniques for effective and economical use of communication lines → "Multiplexing," "Compression, decompression"

Modulation and demodulation have already been explained, and the following explains other transmission technologies.

2.2.1 Error Control

In data transmission it is necessary to establish countermeasures to prevent bit errors caused by electromagnetic induction, etc.
Two representative error control methods are:

- Parity check
- CRC

One error-correcting system is the family of codes called:

- Hamming code

(1) Parity check

The parity check technique is a method for bit error detection in which an additional bit for detection (called the parity bit) is appended to the bit string to be transmitted. Upon reception, the receiver side references the bit string and the parity bit (Figure 2-2-1).
There are two methods for appending the parity bit.

- Odd parity: 1 or 0 is appended to make the number of 1s in each set of bits odd.
- Even parity: 1 or 0 is appended to make the number of 1s in each set of bits even.

The two check methods are:

- Lateral parity check: Lateral inspection of the bit strings making up the characters.
- Longitudinal parity check: Longitudinal inspection of the bit strings making up the data block.

Normally, both methods are used in combination.

Figure 2-2-1
Parity check techniques

	T	O	K	Y	O	
b_1	0	1	1	1	1	0
b_2	0	1	1	0	1	1
b_3	1	1	0	0	1	1
b_4	0	1	1	1	1	0
b_5	1	0	0	1	0	0
b_6	0	0	0	0	0	0
b_7	1	1	1	1	1	1
b_8	1	1	0	0	1	1

Longitudinal parity

Lateral parity

JIS 7 bit code is employed
(in the case of even parity)

(2) CRC (Cyclic Redundancy Check)

The CRC is a transmission method that judges the data strings using a polynomial expression, and appends a check data (CRC code), which is a remainder calculated using an arithmetic operation called "modulo," to

the data.
Figure 2-2-2 shows an example of CRC calculation.
This method is suitable for detecting burst (continuous) errors.

Figure 2-2-2 CRC calculation method (CRC-ITU-TS)

① Transmission data characters "TY" → "01010100 01011001"
② Polynomial expression of ① (K) = $\mathbf{0} \cdot X^{15} + \mathbf{1} \cdot X^{14} + \mathbf{0} \cdot X^{13} \cdots\cdots + \mathbf{0} \cdot X^{1} + \mathbf{1} \cdot X^{0}$
$= X^{14} + X^{12} + X^{10} + X^{6} + X^{4} + X^{3} + \mathbf{1}$
③ Generating polynomial $G = X^{16} + X^{12} + X^{5} + \mathbf{1}$ (decided in advance)
④ ② is multiplied by the highest order of ③ (X^{16})
$\mathbf{K}' = X^{30} + X^{28} + X^{26} + X^{22} + X^{20} + X^{19} + X^{16}$
⑤ The first 16 bits of K' are inversed.
$\mathbf{K}' = X^{31} + X^{29} + X^{27} + X^{25} + X^{24} + X^{23} + X^{21} + X^{18} + X^{17}$
⑥ ⑤is divided by ③ to find the remainder.

$$
\begin{array}{r}
X^{15}+X^{13}+X^{8}+X^{7}+X^{5}+X^{3} \\
\hline
X^{16}+X^{12}+X^{5}+\mathbf{1} \;\big)\; X^{31}+X^{29}+X^{27}+X^{25}+X^{24}+X^{23}+X^{21}\quad +X^{18}+X^{17} \\
X^{31}\quad +X^{27}\quad\quad +X^{20}\quad\quad +X^{15} \\
\hline
X^{29}\quad +X^{25}+X^{24}+X^{23}+X^{21}+X^{20}+X^{18}+X^{17}+X^{15} \\
X^{29}\quad +X^{25}\quad\quad +X^{18}\quad\quad +X^{13} \\
\hline
X^{24}+X^{23}+X^{21}+X^{20}\quad +X^{17}+X^{15}+X^{13} \\
X^{24}\quad\quad +X^{20}\quad\quad +X^{13}\quad\quad +X^{8} \\
\hline
X^{23}+X^{21}\quad +X^{17}+X^{15}\quad\quad +X^{8} \\
X^{23}\quad\quad +X^{19}\quad\quad +X^{12}\quad\quad +X^{7} \\
\hline
X^{21}\quad +X^{19}+X^{17}+X^{15}+X^{12}\quad +X^{8}+X^{7} \\
X^{21}\quad\quad +X^{17}\quad\quad +X^{10}\quad\quad +X^{5} \\
\hline
X^{19}\quad +X^{15}+X^{12}+X^{10}+X^{8}+X^{7}+X^{5} \\
X^{19}\quad +X^{15}\quad\quad +X^{8}\quad\quad +X^{3} \\
\hline
X^{12}+X^{10}\quad +X^{7}+X^{5}+X^{3}
\end{array}
$$

⑦ Finding the remainder:
$\mathbf{R} = X^{12} + X^{10} + X^{7} + X^{5} + X^{3} = 0001010010101000$
⑧ On the sender side, ⑦ is appended to ① for transmission.
⑨ On the receiver side, the same calculation is performed. If the result of the calculation matches the remainder added on the sender side, it signifies correct data reception.

(3) Hamming code

Hamming code is a technique in which a redundancy bit, called the Hamming code, is appended for error detection and correction. Using the hamming distance (the bit number that differs in the information bits of the same bit length), the following detection/correction becomes possible.

- If the hamming distance is m+ 1 or longer, m bit error can be detected.
- If the hamming distance is 2n+ 1 or longer, n bit error can be corrected.

Assuming that the transmission data is (b_4, b_3, b_2, b_1) = (0110), the procedure of the error detection of the Hamming code technique becomes as follows:

1. Transmission bits are grouped, and each group is calculated using the modulo 2 operation. The calculated result becomes the check bit (Hamming code) for the respective group.
   $S_1 = b_4 + b_3 + b_2 = 0 + 1 + 1 = 0 \ldots c_1$
   $S_2 = b_4 + b_3 + b_1 = 0 + 1 + 0 = 1 \ldots c_2$
   $S_3 = b_4 + b_2 + b_1 = 0 + 1 + 0 = 1 \ldots c_3$
2. The transmission bit string including the Hamming code is made.
   Transmission bit string = (b_4, b_3, b_2, c_1, b_1, c_2, c_3)
   = (0110011)
3. On the receiver side, the received bit string is disassembled.
   Received bit string = (d_7, d_6, d_5, d_4, d_3, d_2, d_1)
   = (b_4, b_3, b_2, c_1, b_1, c_2, c_3)
4. Each group bit (b) includes the Hamming code (c) and is calculated using modulo 2.
   The calculated result is converted to binary notation to identify the error bit.
   - In the case of the received bit string (0100011)
     $s_1 + c_1 = 0 + 1 + 0 + 0 = 1$
     $s_2 + c_2 = 0 + 1 + 0 + 1 = 0$ ↓ $(101)_2 = 5 \ldots d_5$ is wrong
     $s_3 + c_3 = 0 + 0 + 0 + 1 = 1$

(4) Bit error rate

The bit error rate is one indicator showing the transmission error rate for transmitted data, and it shows the percentage of errors in the total of transmitted bits.

$$\text{Bit error rate} = \frac{\text{No. of error bits}}{\text{Total number of transmitted bits}}$$

Example

A message is transmitted using a line with a bit error rate of 1/500,000. When the transmitted message consists of 100 characters (1 character equals 8 bits), it can be calculated how many messages can be transmitted on an average before a 1-bit error may occur.

① No. of bits in one message
= 100 characters/message × 8 bits/character
= 800 bits/message

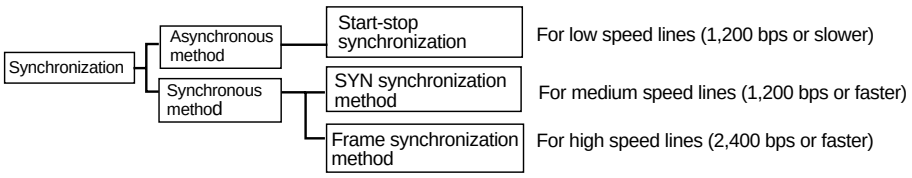
② Bit error rate = 1/500,000
→ On an average, a 1-bit error will occur for every 500,000 bits transmitted.

③ Average number of messages before a 1-bit error will occur
= No. of bits before error occurs ÷ No. of characters per message
= 500,000 bits ÷ 800 bits/message
= 625 messages

2.2.2 Synchronous Control

When playing catch ball, the thrower yells out and throws the ball after obtaining acknowledgment from the catcher. The one to catch the ball is helped to accomplish this, as he/she has been notified that the ball is to be thrown.
The same principle applies to data transmission. Transmitting the data while synchronizing the timing of the sender and receiver ensures reliable transfer of the data. This is called "synchronization."
Figure 2-2-3 shows the methods available for synchronization.

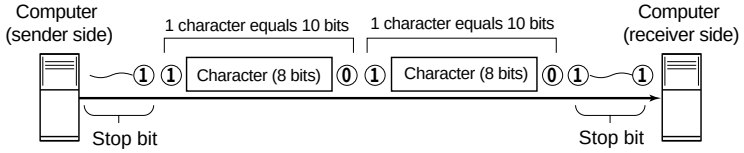
Figure 2-2-3
Types of synchronization



(1) Start-stop synchronization (Asynchronous)

Start-stop synchronization is asynchronous transmission that relies on a start bit (value "0," 1 bit) and a stop bit (value "1," 1 bit, 1.5 bit, 2 bits) being appended to the beginning and the end of each character of the data. When no data is transmitted, a stop bit is sent constantly.

Figure 2-2-4 Start-stop synchronization (example in which the stop bit is 1 bit)



Synchronization is easily achievable using the start-stop synchronization method but since at least 10 bits are required to send one character, the transmission efficiency is poor. Accordingly, this method is used for data transmission at relatively slow speeds (1,200 bps or lower).

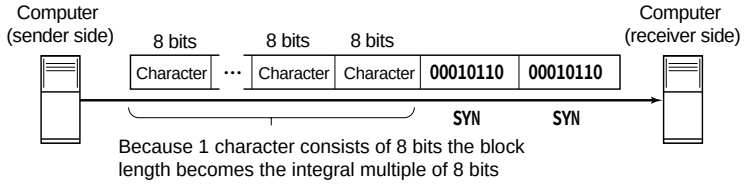
(2) Synchronous method

The synchronous method transmits data after appending a code for synchronizing the character strings of the data. The method is divided into SYN synchronization and Frame synchronization.

① SYN synchronization

The SYN synchronization method is also called the "character synchronization method" as it relies on sending a number of character codes, called SYN, before transmitting data. After synchronization between the sender and the receiver is accomplished with these codes, the data is sent consecutively. The receiver recognizes the SYN code as character data separated by a number of bits (8 bits) for one character.

Figure 2-2-5 SYN synchronization method

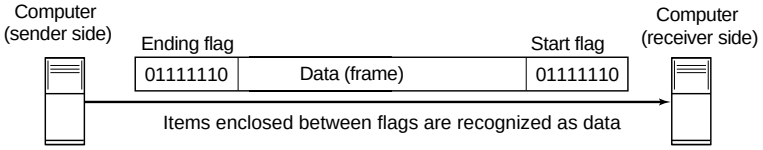


Compared with the start-stop synchronization method SYN synchronization allows data to be sent consecutively which enables efficient data transmission, making this method suitable mainly for transmission at rates of 1,200 bps or higher. However, because there is no code for block ending, the method has the limitation that the block length must be an integral multiple of the bits used for one character.

② Frame synchronization

Frame synchronization accomplishes synchronization by treating the part (frame) surrounded by the flag patterns (bit pattern "01111110") as one unit. This method is also called the "flag synchronization method" because it relies on the flag patterns (flag sequences).

Figure 2-2-6 Frame synchronization method



The sender sends flag patterns incessantly when there is no data for transmission, and when a send request is issued, data is sent following the flag pattern. Conversely, the receiver recognizes the data when bit patterns other than flag patterns are sent, and continues to receive the data until a flag pattern is sent.
Since there are no restrictions on the length of data, this synchronization method is suitable for sending large data loads at relatively high speed.

2.2.3 Multiplexing Methods

Fundamentally, if you have to transmit to "n" number of parties, "n" number of lines are required. However, this is uneconomical. Multiplexing is a technology that was developed to enable communication with multiple parties using just one communication line. In other words, "multiplexing" is a technique in which multiple communications are overlapping on one communication line. Some of the multiplexing methods are:

- Frequency division multiplexing (FDM) for multiplexing analog lines
- Time division multiplexing (TDM) for multiplexing digital lines

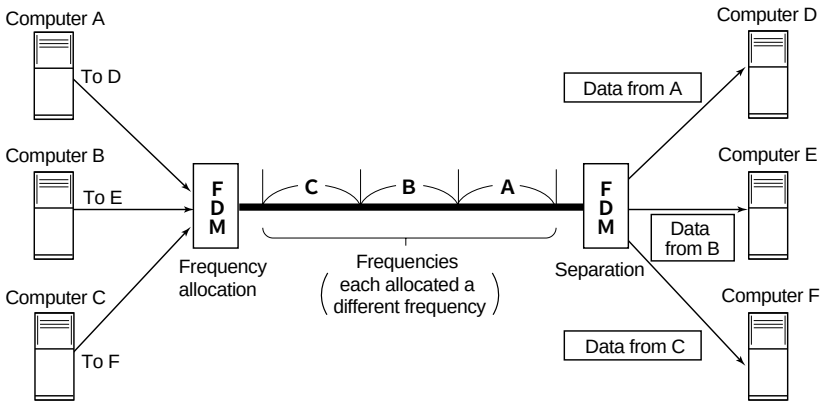
Other methods include code division multiplexing (CDM) used in mobile communications, and wavelength

division multiplexing (WDM) used for transmission with optical fiber cables.

(1) Frequency division multiplexing (FDM)

The FDM (frequency division multiplexing) method transmits using one high-speed analog line by allotting different frequencies to each of several low-speed analog lines. The receiver separates the communication lines for each of the different frequencies and receives data from each of these.

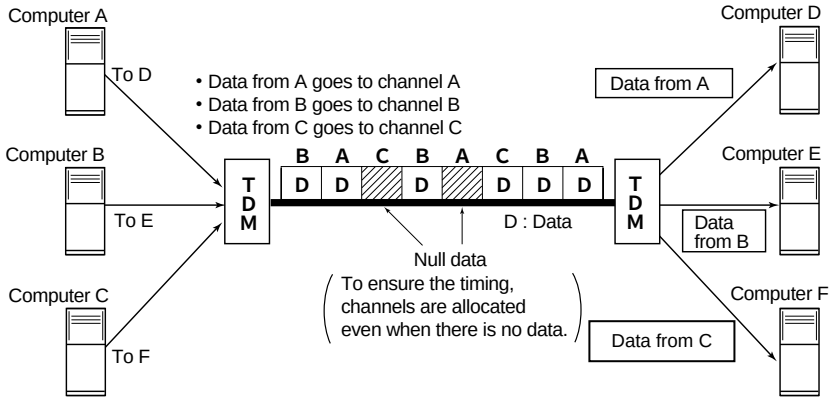
Figure 2-2-7 FDM



(2) Time division multiplexing (TDM)

The TDM (time division multiplexing) method transmits by combining multiple low-speed digital lines into one high-speed digital line. To ensure that the signals of the multiple digital lines are not overlapped, time switch is employed so that each signal is allotted its own fixed time (time slot) during which it is transmitted. Data is transmitted by repeating this process with regularity.
TDM is employed in most multiplexing equipment for digital data.

Figure 2-2-8 TDM



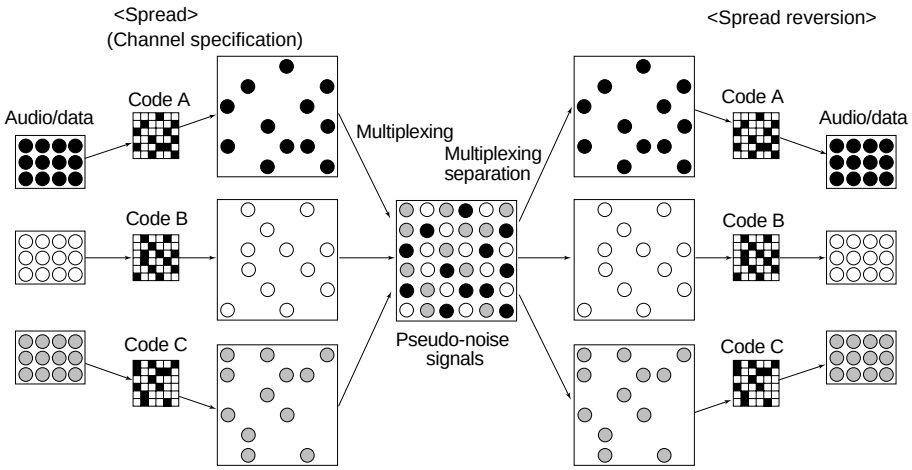
In addition to supporting satellite lines and ISDN, communication systems supporting ATM (explained later) such as B-ISDN have been appearing recently.

(3) Code division multiplexing (CDM)

The CDM (code division multiplexing) method is a multiplexing technology used in mobile communication systems, such as cellular phones. Even though all users use the same frequency, an individual code is allocated to each user to allow communications to each other.

As shown in Figure 2-2-9, inherent PN (Pseudo-Noise) codes are applied to the audio/data of multiple users, and then the system spreads all signals across the same broad frequency spectrum.
The receiver side uses the same PN codes to receive the original audio/data separated out of the pseudo-noise signals of the broad frequency spectrum.
Compared with the FDM or TDM method, each bandwidth can accommodate many channels for use. One of the characteristics of this method is the superior confidentiality obtained because demodulation is impossible without using the same codes as those used at the time of transmission.
Not only does the CDM method allow effective use of frequency bandwidth but it also results in reduced costs for land stations, while it enables high-speed data communication (14.4 kbps or higher). Although research is still being pursued, the commercial deployment of this method have started recently.

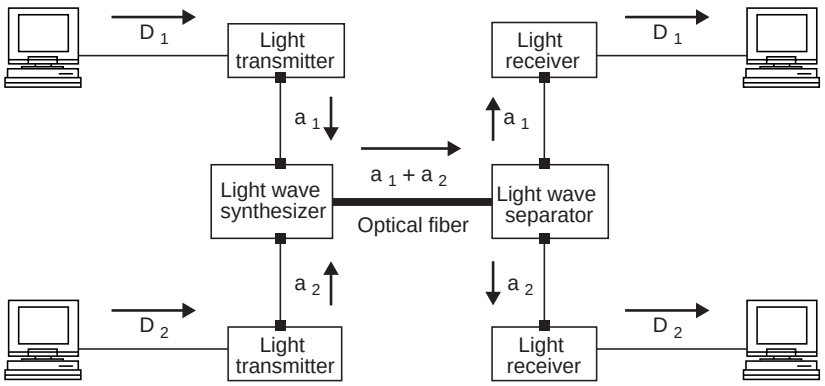
Figure 2-2-9 CDM



(4) Wavelength division multiplexing (WDM)

WDM (wavelength division multiplexing) is a multiplexing communication method used for optical fiber cables (cables that utilize light to transmit data). This method relies on altering the wavelengths of light to allow multiple signals to be transmitted simultaneously on the same fiber cable.
For example, as Figure 2-2-10 shows, when multiple signals (D_1, D_2) are transmitted, each of the signals is converted into separate signals (a_1, a_2) having a different wavelength by light transmitters, and these signals are then combined to a composite wave by a light wave synthesizer. On the receiver side, the light signal transmitted via the optical fiber cable is separate into two signals by a light wave separator, and then sent to the respective destination terminals.

Figure 2-2-10 WDM



At present, because the wavelengths that can be used effectively with optical fiber cables are limited, a method that separates into 4 wavelengths by using 2 cables for upstream and 2 cables for downstream is commonly used.

2.2.4 Compression and Decompression Methods

Previously, the only type of data using in data transmission was simple character data but these days a variety of data, including still images and video, is flowing along the lines. This has resulted in increasing data sizes and increased traffic together with increase in communication costs. When transmitting audio signals digitally, these must be transmitted at a speed of 64 kbps. Consequently, it is extremely important to compress the data to within a range where the original data is not damaged.
Compression of digital data is applied to a variety of data types, such as audio, still images and video (TV pictures), and is especially efficient and beneficial for the large information content and for items demanding high-speed transmission. In the case of TV images, for example, a moving image can be created by sending 30 frames per second, but if these are simply digitalized as they are, at transmission speed of 100 Mbps or more is required to reproduce the same quality. However, detailed analysis of images reveals that the background and other characteristics do not change very frequently. This means that the data that is required to be sent as information is only what is at the front of the image and the parts that have changed from the previous image. The information contents can be reduced considerably by only sending these parts (interframe prediction). Further efficient compression can be accomplished by employing methods (motion compensation) that predict the current position and shape of an object by the movement and shape of the object in frames that preceded the current one by several frames.
For mobile telephone systems in which the available frequency ranges are limited, audio signals can be compressed to 11.2 kbps. By further application of the half rate method, it is possible to compress the signals to 5.6 kbps.
Data compression and decompression methods are explained in the following.

(1) Huffman coding

Huffman coding is compression method developed by D.A. Huffman that replaces frequently occurring characters and data strings with shorter code.
Let us look at an example in which the symbol string R={vuxzvvyyzuvyzvzuyvuu} is encoded. The five types of symbols x, y, z, u, and v occur in the symbol string. In this state, 3 bits are necessary to represent each character using the normal method as shown in Figure 2-2-11. This means that 60 bits are required to represent 20 characters.

Figure 2-2-11 Normal representation method

Character	Bit string
x	000
y	001
z	010
u	011
v	100

Symbol string R

v	u	x	z	v	v	y	y	z	u
100	011	000	010	100	100	001	001	010	011

v	y	z	v	z	u	y	v	u	u
100	001	010	100	010	011	001	100	011	011

Huffman coding allocates specific codes based on the probability of "frequency of occurrence" (a value found by dividing the total number of symbols by the number of times each symbol appears in the symbol string).
In general, in symbol strings formed by M type symbols $\{a_1, a_2, ..., a_M\}$, the probability (frequency of occurrence) with which a_i appears is represented as P (a_i). Figure 2-2-12 shows the result when the probability of frequency of occurrences of all the symbols in the symbol string R has been calculated.

Figure 2-2-12
Frequency of occurrences of all the symbols in the symbol string R

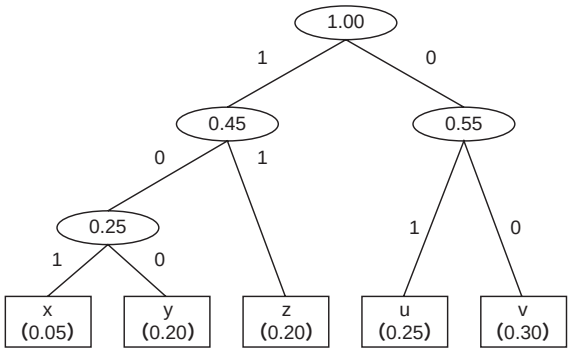
Character	No. of times appearing	Frequency of occurrence
x	1	0.05
y	4	0.20
z	4	0.20
u	5	0.25
v	6	0.30

The Huffman coding works in the way that symbols that do not appear often (have low frequency of occurrence) are allocated a code with long bit length and those appearing frequently (having high frequency of occurrence) are given a code with short bit length.
The procedures in Huffman coding are:

1. Arrangement of each symbol in descending order according to frequency of occurrence. It plays no role which symbol is placed first in case of symbols having identical frequency of occurrence.
2. The symbol with the smallest frequency of occurrence and the symbol with the next-smallest frequency of occurrence become leaf nodes, and a new node is established. This node is given the total frequency of occurrence of the two symbols combined. The branch from this node in the direction of the symbol with lowest frequency of occurrence is labeled 1, and the other branch is labeled 0.
3. Regarding the node created in Step 2 as a new code, Step 2 is repeated until no further new nodes can be created.
4. The sequence of labels granted the branches leading to each symbol from the root node becomes the Huffman code of that symbol.

Figure 2-2-13 shows the Huffman code of the symbol string R and reveals that 45 bits can represent the data of 20 characters.
Huffman coding is still used for compression of this kind of character data. At the present, Huffman coding is also used in JPEG, MPEG and other compression methods (explained later).

Figure 2-2-13 Huffman coding representation method



Character	Bit string
x	101
y	100
z	11
u	01
v	00

Symbol string R

v	u	x	z	v	v	y	y	z	u
00	01	101	11	00	00	100	100	11	01

v	y	z	v	z	u	y	v	u	u
00	100	11	00	11	01	100	00	01	01

(2) JPEG (Joint Photographic coding Expert Group)

JPEG is a worldwide standard for compression and decompression of still images using color/gray scale digitalization, normally relying on an irreversible compression method (DCT: Discrete Cosine Transform) (a reversible method also exists).
This method offers a very high compression ratio (from 1/8 to about 1/100), making JPEG the most commonly used method for distributing full-color still images on the Internet.
JPEG comprises two types of data compression.

- Reversible compression: After decoding of the encoded data, these are completely restored to their original form.
- Irreversible compression: After decoding of the encoded data, these are not restored completely to their original form, but visual observation will show almost no difference.

In addition to JPEG there is another method for compression of still images called LZW, which is used for GIF (Graphics Interchange Format) images. However, the JPEG method is technically superior.

(3) MPEG (Motion Pictures Coding Expert Group)

MPEG it is a set of standards for audio and video compression and decompression and is named after the standardization committee jointly established by ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission).
MPEG enables high compression with very high quality, but since it takes time for restoring the compression, the playback component is normally in the form of a piece of hardware.
Standardization of MPEG encoding is progressing with the division into the four types called MPEG 1, MPEG 2, MPEG 4 and MPEG 7.

① MPEG 1

MPEG 1 was standardized by ITU-T in 1992. Using this standard makes it possible to compress images with a quality like video to 1.5 Mbps.

② MPEG 2

MPEG 2 was standardized by ITU-T in 1994. Using this standard makes it possible to compress television images to about 3 to 6 Mbps, and detailed images, like high-definition television images, to about 10 to 20 Mbps.

③ MPEG 4

With transfer rates ranging from a few kbps to dozens of kbps, MPEG 4 envisioned to be used for mobile communications.

④ MPEG 7

MPEG 7 is under development and is envisioned for use as a high-speed search engine for multimedia information.

(4) Facsimile coding

Facsimile refers to equipment and techniques for transmitting data in the form of documents, drawings, etc. The international facsimile standard for use with analog lines is G3, and G4 is the standard for use on high-speed lines like ISDN lines.
In facsimile, data such as documents or drawings, etc. are captured as an image by scanning, etc., and then encoded by the CODEC method. At this point, the data amount will be very large if the image is encoded as it is. Compression is therefore commonly employed.
MH, MR, MMR, run-length, etc. are some of the techniques used in facsimile encoding.

① MH (Modified Huffman)

MH is facsimile compression encoding method standardized by ITU-T. This compression method builds on the thoughts behind the Huffman coding, and relies on a succession of white and black signals. Each scanned line is processed separately, making it a "one-dimensional encoding method."

② MR (Modified READ)

MR is standardized by ITU-T, and is one of the facsimile encoding methods that yield a higher compression ratio than that obtained with MH. This is a two-dimensional encoding method that also relies on the correlation between scanned lines in the vertical direction, making it more efficient than the one-dimensional encoding method.

③ MMR (Modified Modified READ)

MMR is a compression encoding method that includes partial modification in order to make it more efficient than the MR method.

④ Run-length

The run-length encoding method represents data in which the same elements are occurring consecutively by the elements and the number of times the elements are repeated. Using this method, data like "xxxxxyyyyxxxxxxx," for example, is represented as "05x04y07x."

2.3 Transmission Methods and Communication Lines

A physical network is required in order to transmit data. The following explains the types and characteristics of the networks actually in use.

2.3.1 Classes of Transmission Channel

Channels making up networks can be classified as follows.

- Physical category
- Category classified by communication mode
- Category classified by transmission method

(1) Physical channels

① Two-wire channel

The minimum requirement for one communication line is that it must have one channel for sending the electric signals and one channel for the returning electric signals. A communication line made up of these two channels is called a "two-wire channel."

② Four-wire channel

A communication line made up of four channels (two channels each made up of two lines) is called a "four-wire channel."

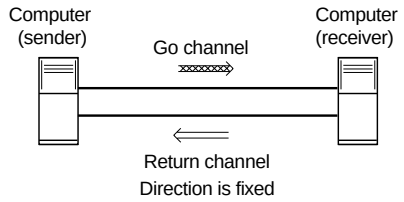
(2) Communication mode

Depending on the data flow direction, communication modes are divided into the following three types.

① One-way mode

In the one-way mode, data only flows in a single direction. Imagine television and radio broadcasting, they are one-way transmission. One-way communication uses a two-wire channel.

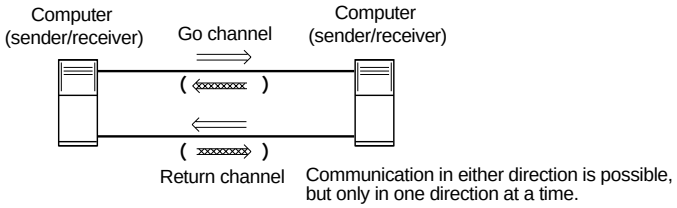
Figure 2-3-1
One-way mode
(two-wire channel)



② Half-duplex mode

Half-duplex allows two-way communication, but only in one direction at a time (Figure 2-3-2). This technique does not allow signals to pass in both direction concurrently, and is used in interactive systems, etc. Half-duplex communication also uses a two-wire channel.

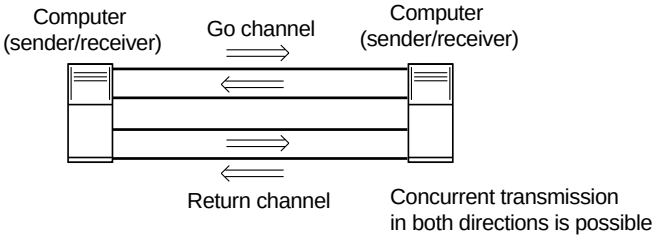
Figure 2-3-2
Half-duplex mode
(two-wire channel)



③ Full-duplex mode

This mode allows concurrent transmission in both directions and can be used with both two-wire channel and four-wire channel.

Figure 2-3-3 Full-duplex mode (four-wire channel)



(3) Transmission methods

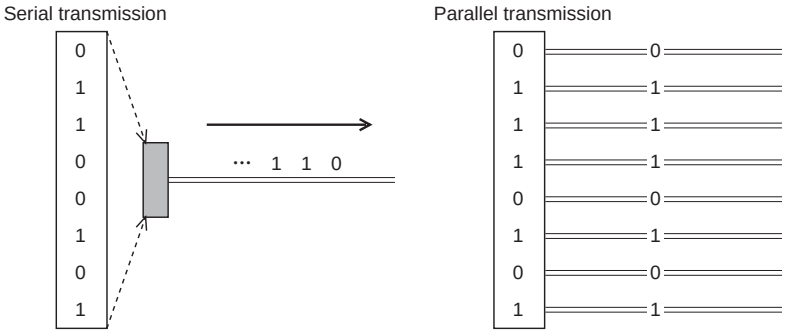
① Serial transmission

Serial transmission is transmission in which data is transmitted one bit at a time. The transmission technique is extremely simple, and low cost, but the transmission speed is slow.

② Parallel transmission

In parallel transmission, several bits are transmitted concurrently. This method is expensive but the transmission speed is high and the technique is used when large amounts of data are sent as a batch.

Figure 2-3-4 Serial transmission and parallel transmission



2.3.2 Types of Communication Lines

The following types of lines are used for transmission of data:

- Leased lines
- Switched telephone network

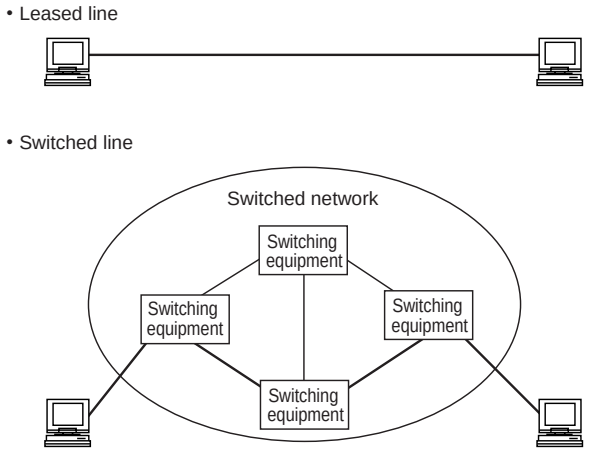
(1) Leased lines

Leased lines are dedicated lines wired directly between the communicating parties, and a flat fee is charged for this arrangement. You hold the right to use the leased line and this arrangement is suitable when large amounts of data have to be transmitted.

(2) Switched network

In switched networks, the communicating parties are not specified. When switched telephone networks are used, the other party must first be dialed to secure transmission channel. Representative examples of switched networks are public telephone networks and ISDN (explained later).

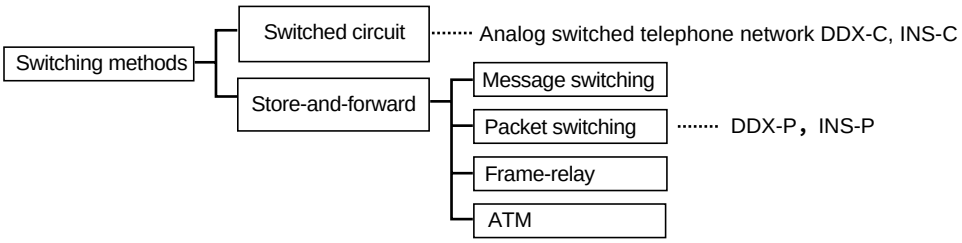
Figure 2-3-5 Leased lines and switched networks



2.3.3 Switching Methods

There are two switching methods available for use with switched networks: switched circuit and store-and-forward.

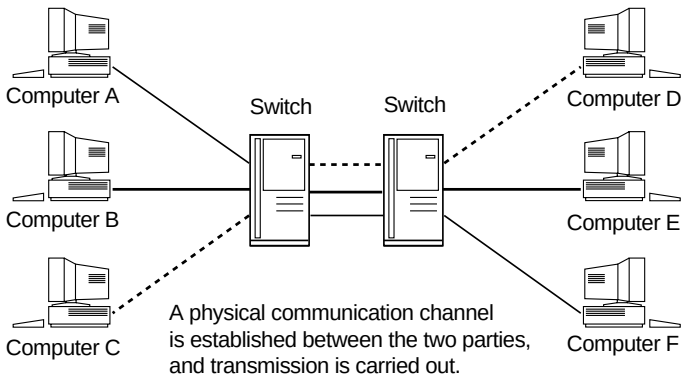
Figure 2-3-6 Switching methods



(1) Switched circuit

A switched circuit has the same structure as a public telephone networks. Each time a request for data transmission is issued, a physical communication channel is established and data transmission is carried out. Because the sender and recipient are physically connected, this method is applicable to relatively large data transmission, but it is restricted by the factor that the transmission rate must be the same in both directions. Analog switched telephone networks employ the circuit switching method.

Figure 2-3-7 Switching circuit



There are two switched circuits for digital data exchange.

① DDX-C (Digital Data eXchange-C)

DDX-C is a circuit switching service for digital transmission at 200 - 48,000 bps. Currently, the trend is towards use of INS-C and public telephone networks, and new initiatives using this method are not under consideration. (For details, see Section 3.6.2, Telecommunications Services and WAN.)

② INS-C (Information Network System-C)

INS-C is a circuit switching service using ISDN, and is offered for use on both of the basic interface (INS net 64; 2 B + D), and the primary rate interface (INS net 1500; 23B + D or 24B). (For details, see Section 3.6.3, Telecommunications Services and ISDN.)

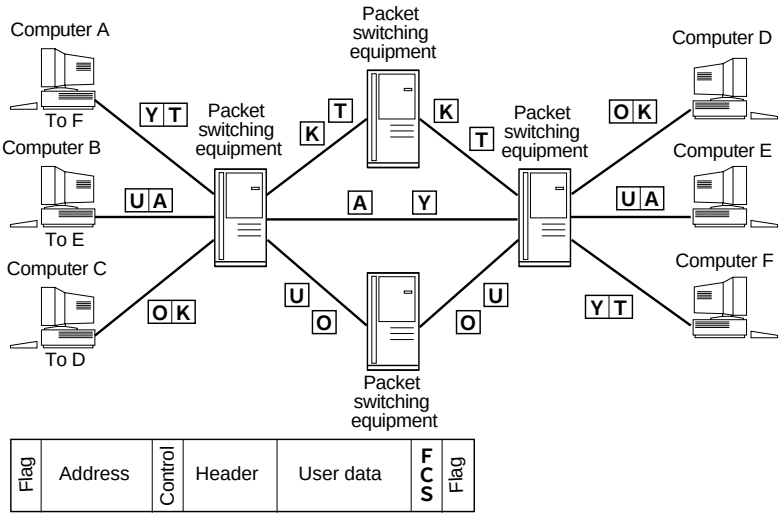
(2) Store-and-forward

Store-and-forward is a message-passing technique in which data is exchanged by means of addresses appended to the data units (packets) without the establishment of a physical communication channel to the recipient as in the case of circuit switching. X.25 is commonly used terminal interface for this technique.

① Packet switching

Figure 2-3-8 illustrates packet switching and its formats.

Figure 2-3-8 Packet switching and formats



<Characteristics>

- Data is divided into units, called packets, having a uniform length. An address and information (header) indicating the serial number of the packet, etc. is appended to the packet.
- The packets are stored in the switching equipment, which then sequentially forwards the packets taking traffic condition of the line into consideration. It is of no importance even if the transmission speeds of the recipient and the receiver are different. However, differences in transmission speeds can lead to "transmission delays."
- The PAD (Packet Assembly and Disassembly) interface is necessary to disassemble data into packets and later assemble the data again. This function is already installed if the terminal type is PT (Packet mode Terminal), but if the terminal type is NPT (Non-Packet mode Terminal), the function has to be performed by the switching equipment.
- Highly reliable communication is possible, because transmission confirmation and error control are performed at packet unit level, but transmission speed suffers from these characteristics.
- Circuit switching systems only require the same number of lines as the number of terminals. In packet switching, a packet is sent to the recipient via multiple circuits, so it is sufficient with only one trunk line between switching equipment. In packet switching, multiple logical lines are established on the same physical circuit enabling simultaneous communications with multiple terminals. This is called

"packet multiplexing."

The following two examples are typical packet switching services.

a. DDX-P, DDX-TP

Packet switching services employing digital data exchange (DDX) comprise DDX-P (Type 1 packet switching service) and DDX-TP (Type 2 packet switching service; DDX-P service using public telephone networks).

b. INS-P

INS-P is a packet switching services using ISDN, and it is available with both the basic interface (INS net 64; 2 B + D), and primary rate interface (INS net 1500; 23B + D or 24B). INS-P also allows packet transmission using the D channel. (For details, see Section 3.6.3 Telecommunications Services and ISDN.)

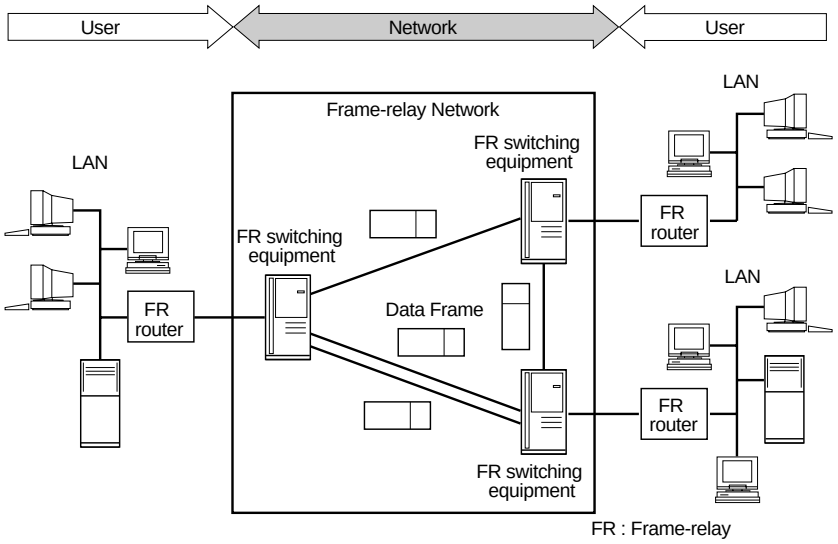
② Message switching

Message switching system is a technique in which all the data, such as files and images, etc., are transmitted as one message unit. The differences in data length cause problems in term of efficiency and transmission time, and it is rarely used these days.

③ Frame-relay

Briefly said, the frame-relay is a "high-speed version of packet switching." This transmission technology enables high-speed transmission and is used in WAN (Wide Area Network).
The frame-relay has inherited the X.25 packet switching protocol, and realized throughput enhancement up to about 1.5 Mbps by the employment of new techniques.
Figure 2-3-9 shows the network structure of the frame-relay system.

Figure 2-3-9 Frame-relay network

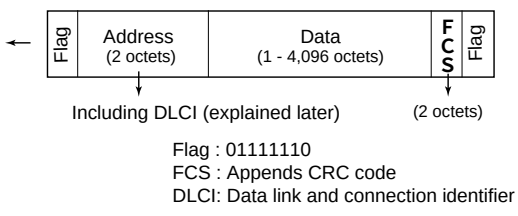


Basically, the frame-relay system transmits data by relay via FR (frame-relay) switch in the same manner as the packet switching system.

<Characteristics>

- Employs variable length frames
  Variable length frames are used for the message format that consists of flag, address field, data field, and FCS.

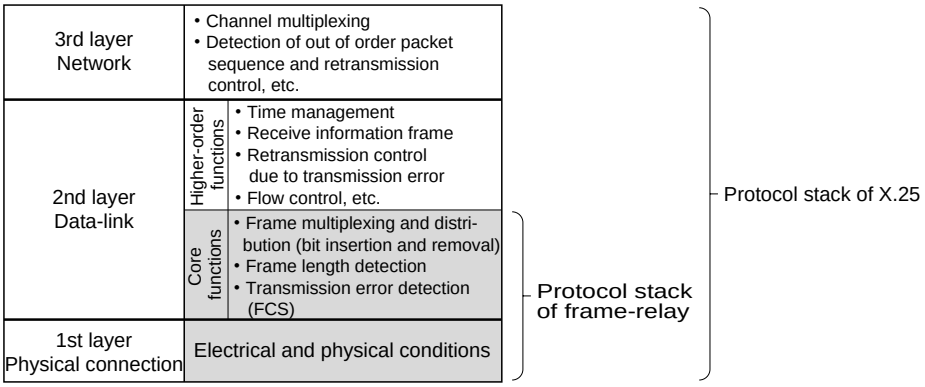
Figure 2-3-10 Message format



Flag : 01111110
FCS : Appends CRC code
DLCI: Data link and connection identifier

- High-speed transmission is possible at about 1.5 to 2 Mbps.
- Simplification of the X.25 protocol
  This protocol simplifies the ITU-T X.25 recommendation (omission of the resending control by means of packet units), and comprises only the basic controls, such as transmission error detection by FCS. This simplification makes high-speed transmission possible.

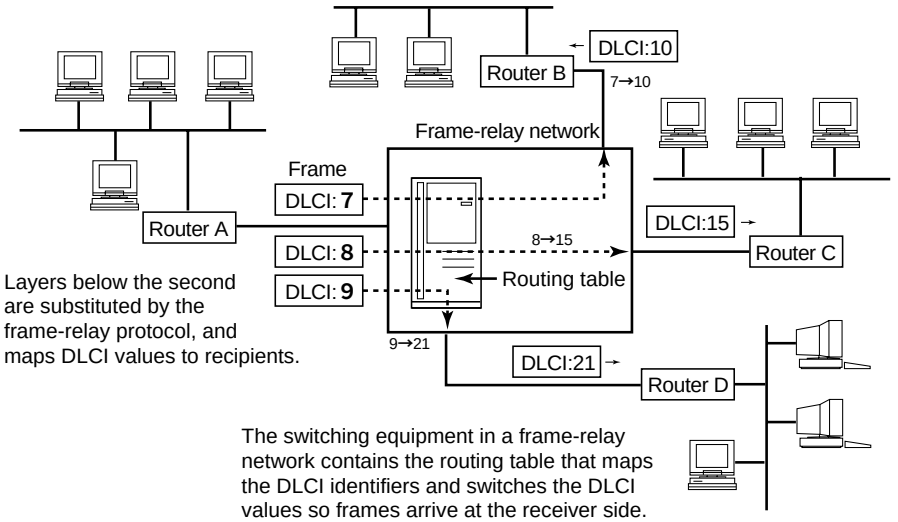
Figure 2-3-11 Frame-relay protocol



In frame-relay, only the core part of the second layer (data-link) of the OSI hierarchical structuring is defined. As frame-relay relies on the higher levels of protocols existed in other network systems, it is highly compatible with existing products.
Packet switching is based on the X.25 protocol, and the word "switching" is applied strictly to control each packet transmission. The word "relay" is used in connection with frame-relay, because this technique sends packets using the "bucket-relay" from the sender to the receiver via frame-relay switching equipment without confirming the transmission.

- Frame multiplexing
  Even though frame-multiplexing has the same characteristics as packet multiplexing, the frame's address field contains the DLCI (Data Link Connection Identifier). The destination can be identified by this DLCI.
  Consequently, simultaneous transmission of frames to multiple destinations physically using the same circuit is enabled by consecutively sending frames with different DLCI identifiers.

Figure 2-3-12 Frame multiplexing



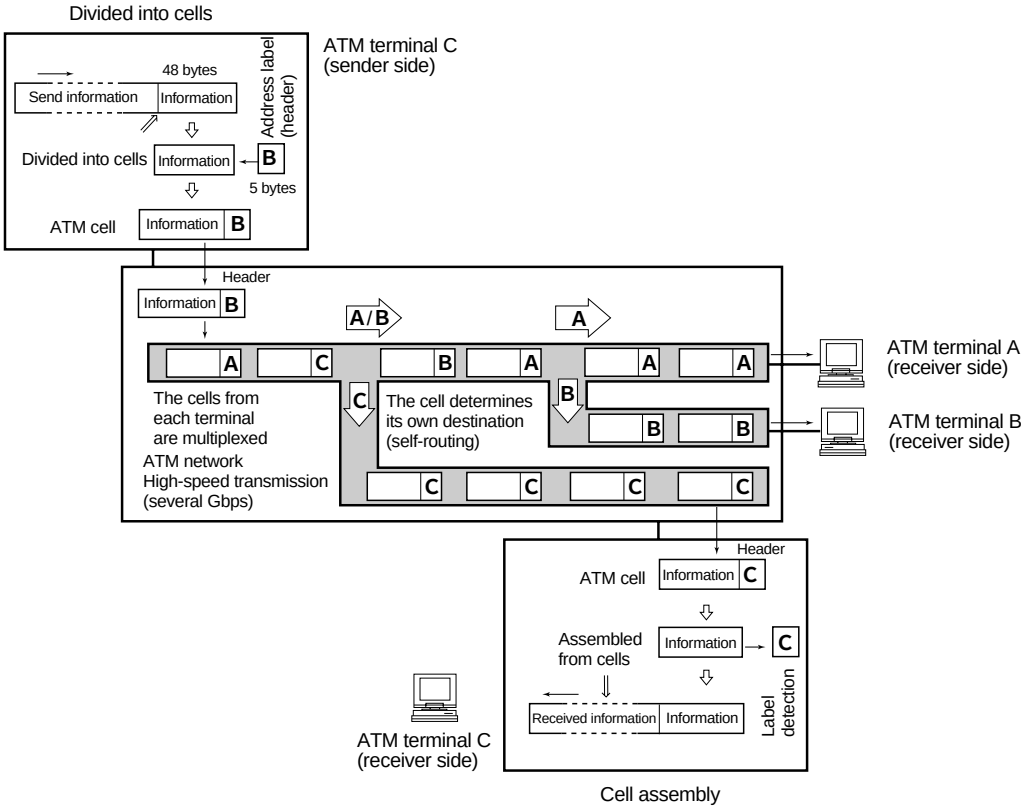
- CIR (Committed Information Rate)
  CIR denotes the information transmission rate guaranteed by the frame-relay network and is a newly established standard for frame-relay. The guaranteed rate differs in the speed under normal circumstances or congestive conditions (when the traffic on the network is excessive).

During congestions, the data load is controlled on the terminal side by using the guaranteed CIR value as the criterion.

④ ATM (Asynchronous Transfer Mode)

The ATM offers a much higher transmission rate (several megabits to several gigabits) than that of the frame-relay, and it is probably the technique that communications will come to rely on in the multimedia era. Research in order to commercialize this technique is under way in many countries.
B-ISDN (Broadband-ISDN) is closely related to ATM and enables data transmission at superfast speeds (156 Mbps and 622 Mbps, etc.). In the multimedia era, B-ISDN is likely to become an extremely effective means of communication for transmission of video that requires high quality images.
The two new communication methods STM (Synchronous Transfer Mode) and ATM are used with B-ISDN, but basically the efforts aim at integrated networks employing ATM.
A LAN technique incorporating ATM technologies and called "ATM-LAN" is also receiving much attention.

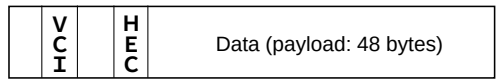
Figure 2-3-13 ATM image illustration



<Characteristics>

- Cell unit transmission
  ATM transmits data in cell units. This method is called cell-relay. ATM is one type of several cell-relay techniques.
  A cell consists of small units of data, image or other information, each unit having the size of 48 bytes (octet). A header (5 bytes) indicating destination address, etc. is appended as the head of the cell.
  The header includes a 1-byte header error detection code (CRC code).

Figure 2-3-14
Cell

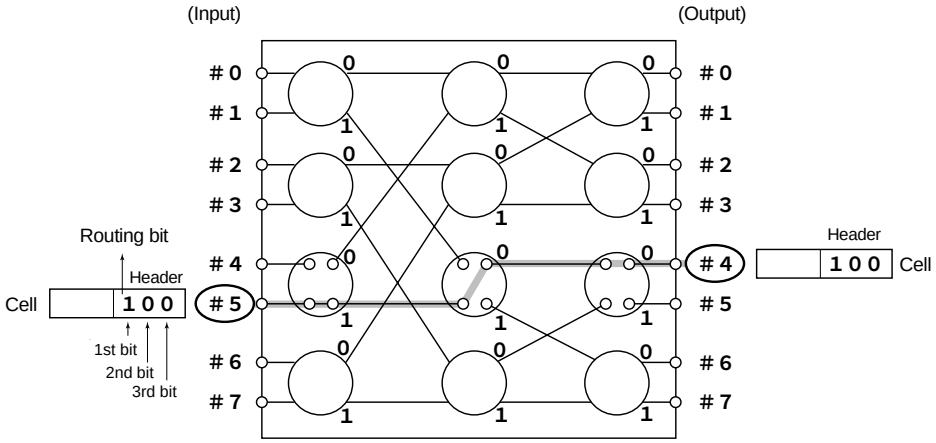


Header (5 bytes)

- VCI : Virtual Channel Identifier
  Corresponds to a telephone number.
  Until arrival at the receiver this is switched continuously within the ATM switching equipment.
- HEC: Header Error Control
  Performs header error control using CRC (this is not data error detection)

- Hardware switching
  ATM uses ATM switching hardware, which enables continuous transmission at extremely fast transmission rate.

Figure 2-3-15 Switch principles



The ATM switch decides the route for each cell based on the routing bit contained in the header.

ATM sends data in cell units but since the communication line is decided instantaneously by means of a hardware switch, the ATM is placed midway between "packet switching" and "circuit switching."

- ATM protocol
  As mentioned earlier, the frame-relay enables higher transfer rate by simplification of the X.25 protocol, and the ATM simplifies even further than the frame-relay in order to realize high-speed transmission.

Figure 2-3-16
ATM protocol

	Upper layer	
Layer 2	AAL (ATM adoption layer)	• Cell disassembly and assembly, etc.
Layer 1 (Physical layer)	ATM layer	• Cell and header generation, extraction • Cell multiplexing/separation, etc.
	Physical layer	• Cell synchronization • HEC generation/verification • Cell speed adjustment • Physical media dependence

- It is apparent that functionalities are concentrated in layer 1 to an even higher degree than in the frame-relay.

- Congestion control
  In advance, cells are arranged in priority order (included in the header) in accordance with their respective importance, and when congestion occurs, cells with high priority are not affected. Additionally, the technique is perfected by establishing congestion bypasses to maintain the best possible high-speed transmission.
- Allows transmission of all kinds of data
  ATM is independent of data types and forms and allows transmission of any kind of data.
- Applicable fields
  Due to its superfast characteristics and flexibility, ATM is expected not only to find employment in a variety of fields such as LAN and WAN but also in broadcasting and VOD (Video On Demand).

Exercises

Q1 **In order to transmit digital data using analog communication lines, the operation called "modulation" is required. Which of the following modulation techniques is the simplest to implement though it is susceptible to noise and fluctuations in signal levels?**

a. Phase modulation
b. Frequency modulation
c. Amplitude modulation
d. Quadrature amplitude modulation
e. Code multiplex modulation

Q2 **Which modulation technique is used for transmitting audio via digital networks?**

a. Phase modulation
b. Frequency modulation
c. Amplitude modulation
d. Pulse code modulation

Q3 **Which is the correct description of the parity check used to counter transmission errors in communication lines?**

a. 1-bit errors can be detected.
b. 1-bit errors can be compensated and 2-bit errors can be detected.
c. In the case of even parity 1-bit errors can be detected, and 1-bit errors cannot be detected in case of odd parity.
d. In the case of odd parity, odd figure bit errors can be detected, and even figure bit errors can be detected in case of even parity.

Q4 **A parity bit should be appended to a 7-bit character code so that the number of "1"s contained in the 8 bits, including the parity bit, becomes an even figure. The parity bit is placed at the higher-order position in the 7-bit character code. In this case, which of the following is the hexadecimal notation code representing 4F with the parity bit added to the character code?**

a. 4F
b. 9F
c. CF
d. F4

Q5 **Which is the error detection technique that adds a remainder, found by a certain generator polynomial expression, to the bit string on the sender side, and detects errors by whether or not the remainder is the same on the receiver side by dividing the received string using the same polynomial expression?**

a. CRC
b. Longitudinal parity check
c. Lateral parity check
d. Hamming code

Q6 **In memory error control technique, which of the following employs 2-bit error detection and 1-bit error correction functions?**

a. Even parity
b. Lateral parity
c. Check sum
d. Hamming code

Q7 **When using a line whose bit error rate is 1/600,000, and you send data at a transmission rate of 2,400 bits/sec, in how many seconds will one bit error occur on an average?**

a. 250
b. 2,400
c. 20,000
d. 600,000

Q8 **Which is the correct description of asynchronous transmission?**

a. The receiver side constantly watches for the bit string used for synchronization sent from the sender side, and when this is received, it regards what follows as data from the next bit.
b. The receiver side is able to recognize where characters start by the bits that the sender side has appended at the start and ending of each character.
c. The sender side appends a bit so that "1" bits in each character becomes an even number.
d. The sender side and receiver side retains timing by constantly sending a specific bit pattern on the communication line even when there is no data to be sent.
e. Timing signals for synchronization is always flowing on the communication line, and the terminals send and receive data in sync with these timing signals.

Q9 **The character T (JIS 7-unit code string 1010100) is sent using the start-stop synchronized data transmission technique that employs even parity as the character check method. Which is the correctly received bit string? The received bit string is written in order from the left beginning with the start bit (0), lower order bits to higher order bits of the characters, parity bit and stop bit (1).**

a. 0001010101 b. 0001010111 c. 1001010110 d. 1001010111

Q10 **What is the time required to transmit a data of 120 characters using the start-stop technique with a communication line having a transmission rate of 2,400 bit/sec? The data is an 8-bit code with no parity bit, and both the start signal and the stop signal are 1-bit length.**

a. 0.05 b. 0.4 c. 0.5 d. 2 e. 200

Q11 **What is the technique that combines multiple slow-speed lines into one high-speed line by time division multiplexing to convert the bit strings to be transmitted on the high-speed line?**

a. CDM b. FDM c. TDM d. WDM

Q12 **What is the name of the irreversible compression method for still images that has become an international standard?**

a. BMP b. JPEG c. MPEG d. PCM

Q13 **Which of the following adequately describes the characteristic of packet switching?**

a. Delays do not occur inside the switched network.
b. Suitable for transmission of large amounts of consecutive data.
c. Is not suitable for transmission of information between equipment where transmission speeds and protocols differ.
d. Enables efficient use of communication circuits (by sharing multiple communication path).

Q14 **Which is the correct description of packet switching?**

a. Packet switching service is not possible with ISDN.
b. Compare to circuit switching, the latency within the network is short.
c. In order to carry out communication by packet switching, both the sender and the receiver must be packet mode terminals (PT).
d. By setting multiple logical circuits, concurrent communication with multiple parties can be performed using one physical line.

Q15 What is the adequate description of the characteristic of frame-relay?

a. DLCI (Data Link Connection Identifier) enables frame multiplexing.
b. Based on the premise of the use on a low-quality communication line with errors frequently occurring.
c. As communication method, only the SVC (Switched Virtual Circuit) technique is used.
d. When a frame error is detected, the frame-relay switching equipment resends the particular frame.

3 Networks (LAN and WAN)

Chapter Objectives

Current network systems are mainly used as the LAN, which covers a limited local area, and are connected to the WAN, which covers a wide area.
In this chapter you will obtain knowledge required for using networks as you will learn about LAN and WAN, security technologies and various services that can be offered.

① Understanding the characteristics of LAN, connection methods, transmission media, access control methods, etc.
② Understanding the characteristics, mechanisms, and protocols of the Internet, and the services offered on the Internet, etc.
③ Understanding line capacities and traffic design related to network performance, and finding actual performance by calculations.
④ Understanding the types and contents of laws and regulations related to networks.
⑤ Understanding the meaning, types and technologies of network security.
⑥ Understanding the types and characteristics of a number of services provided over networks.

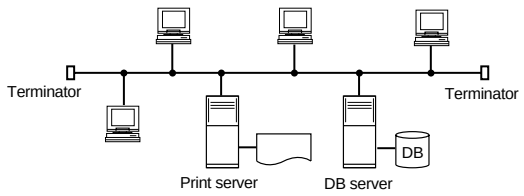
Introduction

The word "downsizing" had been the buzz word for a while in the computer industry. Since the birth of computers, their performance has shown continuous improvement thorough scientific and technological advancements. We have seen a transition from host computers to workstations to personal computers, with the size becoming smaller and smaller while the performance of the computers has improved dramatically. In concert with this transition, data processing has also moved from host-centric processing to distributed processing carried out on the local area network (LAN).
LAN covers a limited area such as within a corporation, and is designed to allow efficient use of system resources by sharing hardware connected by means of transmission media (cables). It is an area that is still accelerating advancements, with recent convergence of client/server systems and the Internet, and high-speed ATM-LAN, etc.

(1) LAN

LAN (Local Area Network) denotes network systems, which do not make use of the facilities (communication lines, etc.) of Type I telecommunications carriers, and cover a limited area (maximum range about 20 km) within factories, hospitals, schools, companies, etc. On a LAN, high-speed (transmission rate of 1 Mbps or higher) transmission media connect multiple computers and office automation equipment.

Figure 3-1-1
LAN example
(Bus-topology)



(2) WAN

WAN (Wide Area Network) denotes network systems that cover a wide area and use the facilities (high-speed digital lines, etc.) of Type I telecommunications carriers. The most significant difference from a LAN is the use of the communication lines of Type I telecommunications carriers (a LAN uses privately installed cables).
Conventionally, the most common WAN has been one in which a host computer is connected to terminals in remote locations. Recently, however, there has been an increase in systems in which a number of LANs connected to WAN to form a large network.

3.1 LAN

3.1.1 Features of LAN

Construction of a LAN has the following benefits.

- Resources, such as files, databases, printers, etc. can be shared.
- Management of otherwise individually managed information can be centralized.
- Highly reliable high-quality communication within a limited area, like on the same office floor, etc., is accomplished with cables (transmission media).
- Equipment expenses are involved but there is no charge for use of lines.
- Owing to the proliferation of groupware for LAN users, the trend toward a paperless office can be accelerated.
- Allows construction of open distributed systems.
- Users can access databases and other processing resources from where they are positioned.
- Using network connection equipment such as routers or gateways, LAN connects to other networks.
- There are few transmission errors compared with WAN that uses communication lines.

Despite the benefits mentioned above, however, LAN requires users to manage:

- The entire network.

3.1.2 Topology of LAN

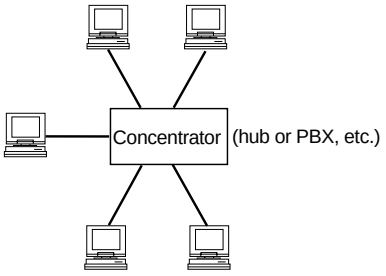
LAN connection is made based on a topology (shape in which a network is configured). Three typical topologies include:

- Star type
- Bus type
- Tree type

(1) Star type

In the star type, multiple terminals are connected to a concentrator (hub or PBX, etc.) in a star-shaped configuration (Figure 3-1-2).
Concentrators are broadly divided into two types according to whether they perform switching or not. Equipment with switching capabilities is called PBX (Private Branch eXchange), and the one especially used with digital lines is called DPBX (Digital Private Branch eXchange). A device with no switching functions is called a hub.

Figure 3-1-2
Star type LAN



The features of star networks are:

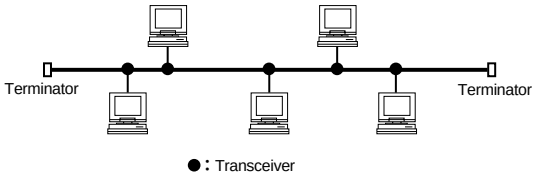
- It is easy to add and move terminals connected to the network.
- Depending on the capabilities of the concentrator, there are restrictions on the number of connectible

terminals and the transmission distance from the concentrator.
- Even if one terminal fails, this will have no effect on the overall system, but if the concentrator fails, the entire network will go down because data is exchanged by passing through the concentrator.

(2) Bus type

The bus type network is the most basic topology with all terminals connected to one trunk cable (bus).

Figure 3-1-3
Bus type LAN

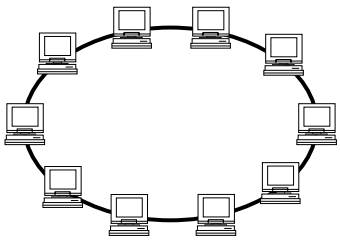


The features of bus networks are:
- This type of network features the simplest type of wiring but if a terminal is moved the bus wiring must be redone.
- There are certain restrictions on the length of the bus and the number of terminals that can be connected.
- Data sent from a terminal flows to all the other terminals enabling "multi-destination transmission" (broadcasting).
- The terminal seizes the received data if the destination address matches the terminal's.
- Unnecessary data may remain in the communication line but such data can be eliminated by "terminators" connected at both ends of the transmission cable.
- Collision may occur if data from multiple terminals is sent simultaneously.

(3) Ring type

The ring network is a configuration in which the terminals are connected in a closed loop.

Figure 3-1-4
Ring type LAN



The features of ring networks are:
- Data sent from a terminal passes around the ring in one direction.
- The terminal seizes received data if the destination address matches the terminal's. Otherwise, it passes the data along to the next terminal.
- Data transmission control (token passing) can be used to determine which terminal is allowed to transmit data to prevent collisions caused by simultaneous data transmission from two or more terminals.
- Establishment of bypass routes is necessary as the entire network goes down if just one terminal fails.

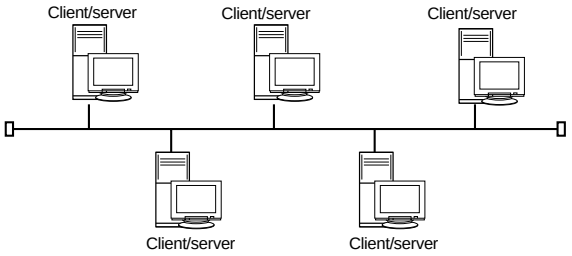
3.1.3 LAN Connection Architecture

LAN systems comprise many types of connection configuration, which can broadly be divided into:
- Peer-to-peer
- Client/server

(1) Peer-to-peer LAN

Peer-to-peer is a simple LAN configuration that requires no dedicated server machine (Figure 3-1-5). Application programs running on personal computers or workstations manage all printers and other system resources, and each machine is considered equal and each acts as a server or client to the others in the network.
This configuration is frequently used in relatively small LAN because peer-to-peer networks are simple and cheap to construct. However, they are not suitable for large-scale systems where heavy data loads have to be processed or advanced computation is required.

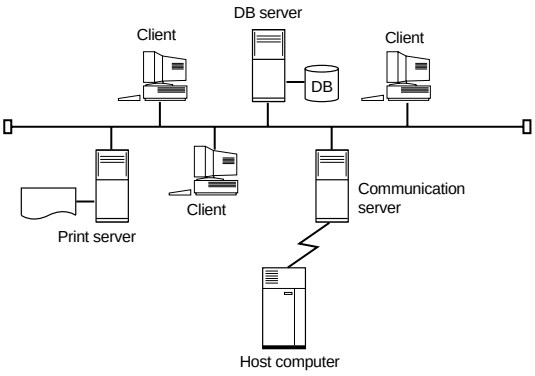
Figure 3-1-5
Peer-to-peer LAN



(2) Client/server

Client/server LAN is a typical computing processing system in which each computer is used for performing its dedicated role, and system resources in the network are allotted for specific roles.
For example, image processing may be performed on a workstation and the host computer may handle daily routine operations that generate a large volume of data. Business involving creation of normal documents or use of spreadsheet software may be done on personal computers.
In other words, this is system in which a number of different software programs running on different hardware and operating systems are linked to execute one application.
Client/server architecture is employed in relatively large-scale LAN systems.

Figure 3-1-6
Client/server LAN



3.1.4 LAN Components

The components that make up a LAN can be divided broadly into:

- Transmission media
- Peripheral equipment

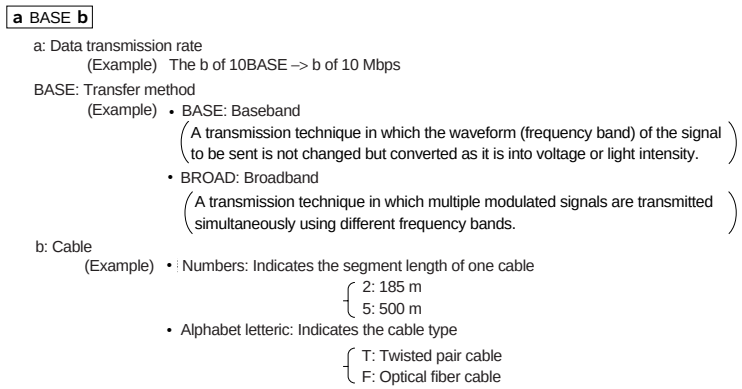
(1) LAN transmission media

The transmission media used in LAN are:

- Twisted pair cables
- Coaxial cables
- Optical fiber cables
- Wireless

The features of those cables are explained in the following, and access control of LAN is explained afterwards.
How to read Standard LAN Codes is laid down by the IEEE as shown in Figure 3-1-7.

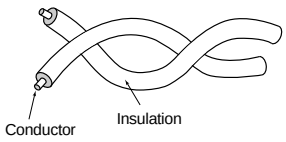
Figure 3-1-7 How to read Standard LAN Codes



① Twisted pair cable

Twisted pair is a cable widely used for telephone lines (Figure 3-1-8).

Figure 3-1-8
Twisted pair cable

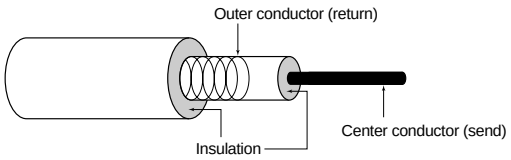


The characteristics of twisted pair cables are as follows:
- Maximum transmission rate: 100 Mbps
- Transmission distance: About several hundred meters
- Noise resistance: Easily affected.
- Price: Cheapest
- Cable installation: Easy
- Appropriate scale for application: Small-scale LAN on a same office floor.
- Access control method: CSMA/CD (10BASE-T is the standard), token-passing method.

② Coaxial cable

Currently, coaxial cable is the most popular cable for use as LAN cables. They are divided into the two types, baseband and broadband according to the different transmission modes.

Figure 3-1-9
Coaxial cable



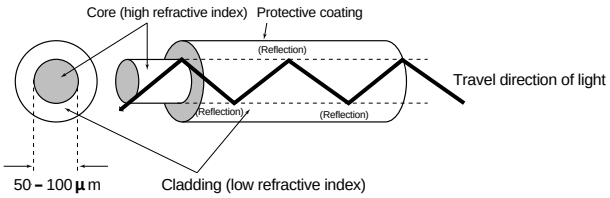
The characteristics of coaxial cables are as follows:
- Maximum transmission rate: Several Mbps to several hundred Mbps
- Transmission distance: 185 m to tens of kilometers (1 segment)
- Noise resistance: Relatively resistant
- Price: Somewhat expensive compared with twisted pair cable
- Cable installation: Requires time and effort compared with twisted pair cable
- LAN scale appropriate for application: Relatively large-scale LAN
- Access control method: CSMA/CD (10BASE5 or 10BASE2. 10BASE5 is the standard cable for Ethernet, cable length is 500 m. The 10BASE2 cable length is 185 m)

<Ethernet>
Ethernet is a LAN standard employing the CSMA/CD protocol that was invented by Dr. Robert Metcalf of Xerox Palo Alto Research Center in 1973 and later standardized by the IEEE. It enables transmission at a maximum speed of 10 Mbps.

③ Optical fiber cable

Optical fibers are cables constructed from materials of which quartz glass is the principal constituent that allow high-speed transmission. This transmission media will most likely become more and more used in the coming multimedia era as this type of cable enables transmission of large amounts of data.

Figure 3-1-10
Structure of optical fiber



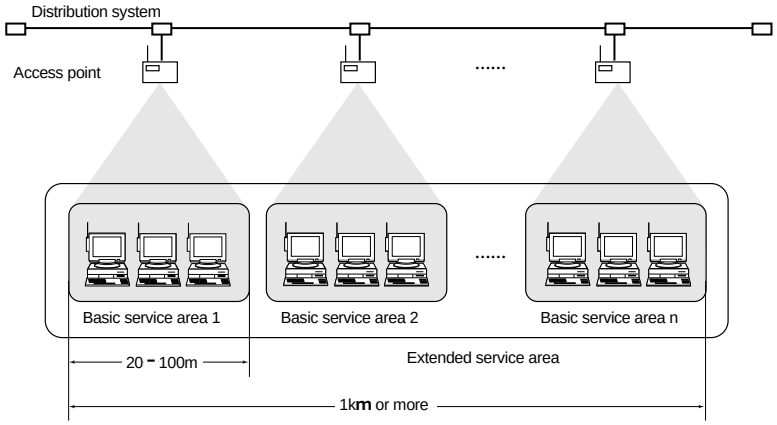
An optical fiber cable consists of several of the above optical fibers bundled together.
The characteristics of optical fiber cables are as follows:

- Maximum transmission rate: Several hundred Mbps
- Transmission distance: Up to about 100 km (low-loss characteristic makes long-distance transmission possible)
- Noise resistance: Exceptionally resistant
- Price: About the same as coaxial cables
- Cable installation: Installation is easy but technicians must undergo technical training since this is a relatively recent invention.
- Appropriate scale for application: High-speed LAN systems such as FDDI (explained later) and ATM-LAN (explained later).
- The media itself is lightweight, compact and very easy to handle.
- Light (signal) can only be transmitted in one-way direction.
- The cost of peripheral equipment is high.

④ Wireless

Because cables must be installed for the construction of a LAN, the system layout must necessarily be decided in advance, and thus makes it difficult to change the layout later. In this respect, wireless systems have the advantage that wiring is not necessary as they use radio waves or infrared rays (Figure 3-1-11). This makes it easy to move the equipment and LAN systems can be designed more freely. However, it has to be taken into consideration that wireless systems are susceptible to noise compared with cable-based systems.
Low-speed wireless LAN (48 kbps/32 kbps) was standardized a while ago but the transmission speed was rather low compared to cable-connected LAN systems. Improvements were made afterwards, and medium-speed wireless LANs (1 Mbps/2 Mbps) and 10 Mbps or more high-speed wireless LANs have now been standardized.

Figure 3-1-11 Outline of wireless LAN



(2) Peripheral equipment for LAN

In addition to cables, various hardware (equipment) and connectors are necessary for construction of a LAN as shown below.

① Terminator

In a bus type LAN, unnecessary data not seized by terminals will remain in the transmission line and it is therefore necessary to connect a "terminator," which removes unnecessary data, at each end of the transmission cable.

② Transceiver

A "transceiver" is a device that connects the trunk cable and the node from the terminal and it also has the function of detecting data collisions (Figure 3-1-12).

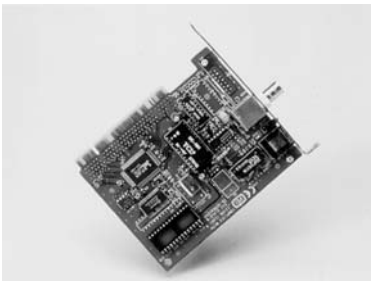
- For construction of a 10BASE5 LAN
  Transceiver is attached to cable and connected.
- For construction with 10BASE-T and 10BASE2
  A transceiver is already incorporated in the LAN adapter port, and in 10BASE2 it is connected by means of a connector.

Figure 3-1-12
Transceiver and connector

③ LAN adapter

A LAN adapter is an interface device for connecting the computer to the LAN. It is also called a LAN card.

Figure 3-1-13
LAN adapter



3.1.5 LAN Access Control Methods

A LAN system connects multiple terminals on one cable, and if the terminals transmit data at their own discretion, data collisions and other problems will occur frequently and inhibit correct transmission of data. Consequently, access control is one of the most important basic LAN technologies.
In the OSI basic reference model, LAN access control methods are defined by the MAC (Media Access Control) layer in the lower half of the 2nd layer (data link layer).
LAN access control methods are broadly divided into the following two types.

- Deterministic access (TDMA)
  Deterministic access control is a method in which the transmission rights are allocated to terminals in advance. The terminals can send data in the allocated order, but a terminal will have to wait until it becomes its turn even if it wants to send something immediately.
- Nondeterministic access (CSMA/CD, token-passing)
  Nondeterministic access is a method in which transmission right control is carried out at the point of time when a transmission request is issued. This method works well when transmission rights can be obtained with good timing, but sometimes conflicts with other terminals occur, meaning that obtainment of transmission right is not always guaranteed.

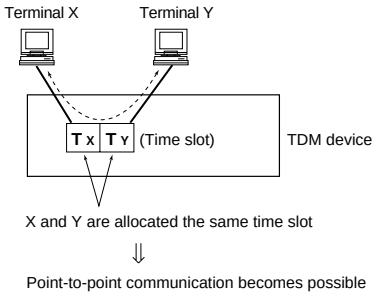
The following three access controls are typically found in LAN systems, and are explained below.

- TDMA
- CSMA/CD
- Token passing

(1) TDMA (Time Division Multiple Access)

TDMA (Time Division Multiple Access) controls access by dividing the data channel into specific time divisions and allocating units (called time slots) of these divisions to each terminal. It is a technique that applies the principles of time-division multiplexing (TDM).
Fundamentally, the technique allows point-to-point communication when data has to be transmitted from terminal X to terminal Y provided that these are given the same time slot.

Figure 3-1-14
TDMA



The features of TDMA are:

- Data collision does not occur as in the CSAM/CD method, enabling reliable data transmission.
- Waste is large as time slots are also allocated to terminals that have no request for transmitting.

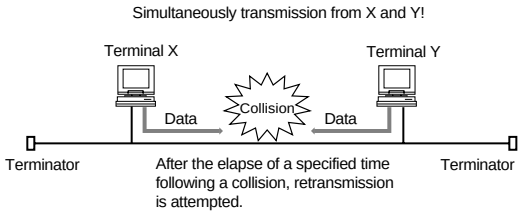
(2) CSMA/CD (Carrier Sense Multiple Access with Collision Detection)

The CSMA/CD (Carrier Sense Multiple Access with Collision Detection) is an access control method mainly used in bus topology LAN. 10BASE-T, which is designed around the CSMA/CD standard, physically looks like a star topology but logically it is bus topology.
The mechanisms of the CSMA/CD are as follows:

- All the terminals need to monitor whether data is passing on the cable.
- Transmission starts when no data is passed, and pauses for standby when data is passed.

- If several terminals transmit data simultaneously, data will collide on the bus. If a collision is detected, all terminals will have to wait a specified time (this time interval is calculated using backoff algorithms) before attempting retransmission.

Figure 3-1-15
CSMA/CD

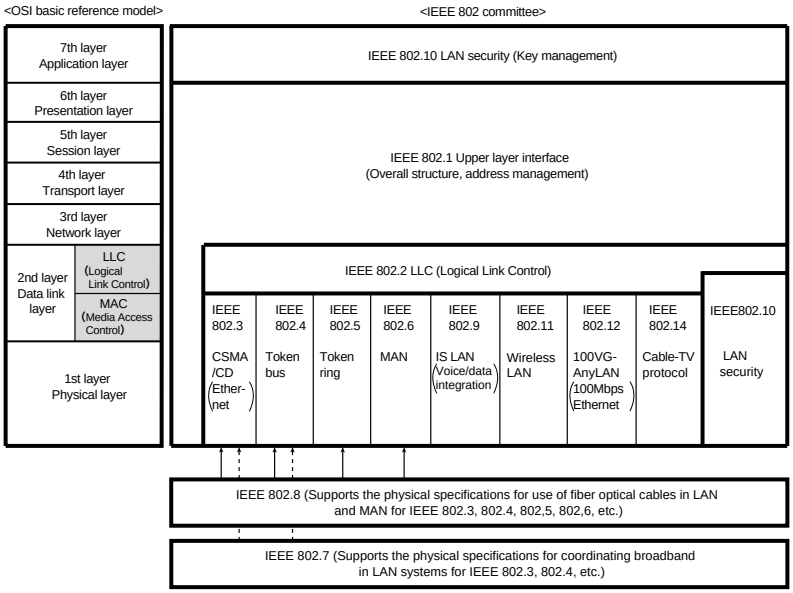


A disadvantage in this method is that the frequency of data collisions will increase as the amounts of transmitted data increase, and thus can rapidly degrade the transmission efficiency.
The transmission speed of LAN (Ethernet, etc.) employing the CSMA/CD method is 10 Mbps. Recently, the so-called Fast Ethernet with a speed of 100 Mbps has been introduced.
The CSMA/CD method is standardized as IEEE 802.3, and cable shapes, data transmission speed, transmission method, media access control (MAC), etc. have all been standardized. This standardization corresponds to the physical and data-link layers of the OSI basic reference model. However, the data-link layer of the OSI basic reference model has been divided into the following two sublayers, due to standardization factors.

- LLC (Logical Link Control): Controls the procedure for exchange of data.
- MAC (Media Access Control): Controls the access method of LAN.

<IEEE 802 Committee>
The IEEE 802 Committee was set up by the IEEE (Institute of Electrical and Electronics Engineers) in February 1980, and is an organ for promotion of standardization of LAN and MAN (Metropolitan Area Network) (Figure 3-1-16).

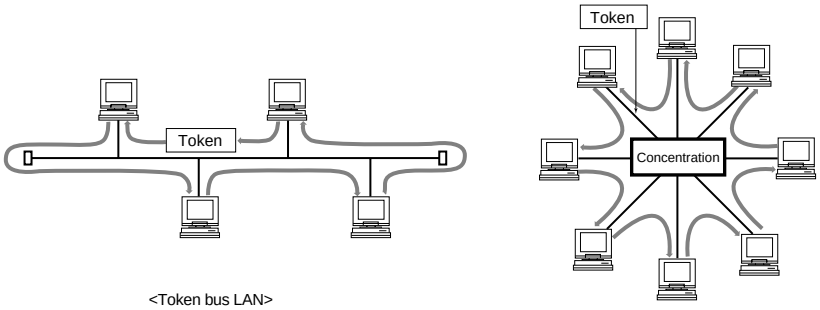
Figure 3-1-16 The relations between the IEEE 802 committee and the OSI basic reference model



(3) Token passing

Token passing method is an access control technique mainly used in ring topology LAN. Generally, the network is labeled token ring if it is of the ring-shape network, and if the same access control is used on a bus topology network, it is called "token bus."

Figure 3-1-17 Token bus LAN and token ring LAN



<Token bus LAN>

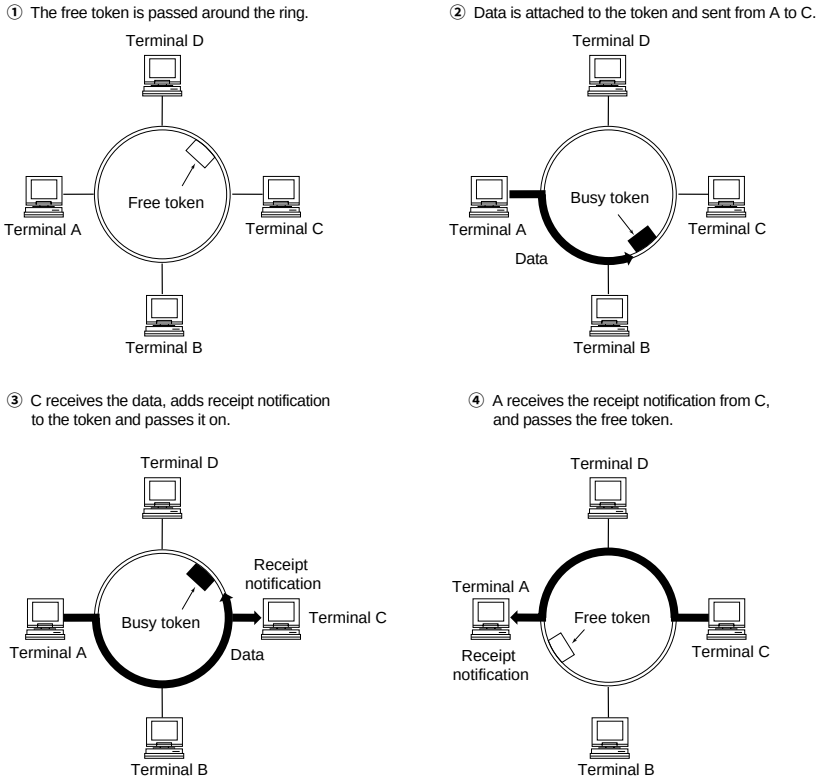
<Token ring LAN>

The mechanism of the token passing is as follows.

- A signal (token) carrying the right to transmit on the cable is passed around the network. Only one token is passed around. And the token carrying no data is called "free token," and the token carrying data is called "busy token."
- If a terminal that wants to transmit is not capable of seizing the token, it will not be able to transmit. Only the station that seizes the "free" token can transmit.
- The terminal that seizes the "free" token turns this into the "busy" token, and sends this together with the data to the destination terminal.
- When the terminal receives the "busy" token, it returns the "busy" token together with data for receipt notification to the original sender.
- When the sender receives the "busy" token, it changes it into the "free" token and passes it back on the cable, and discard the data notifying completion of transfer.

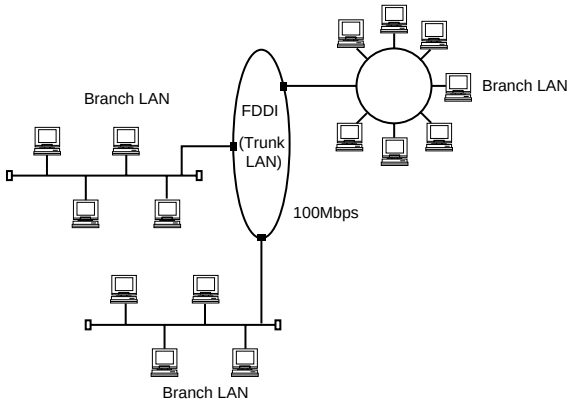
Figure 3-1-18 shows the access control procedure of the token ring method.

Figure 3-1-18 Token ring



The token bus method is physically a bus topology, but logically it is a ring topology. Physically, a token ring LAN has a star topology but logically it performs a ring topology mechanism. In this way it is more appropriate to think of LAN topology in logical rather than physically terms.
The transmission speeds of LAN (such as token ring, etc.) employing the token passing method are 4 Mbps (priority token) and 16 Mbps (early token release).
The token bus is standardized by IEEE 802.4. The token ring is standardized by IEEE 802.5.
Token passing also used in the FDDI (Fiber Distributed Data Interface) that extends the access control of the token ring to the larger networks. FDDI is mainly employed in backbone LAN connecting other networks. It employs optical fiber cables and features a transmission speed of 100 Mbps. FDDI further includes the FDDI-I that corresponds to packet switching for data transmission and FDDI-II that also allows transmission of voice and video. However, due to the rapid progress made in ATM-LAN technology (explained later) there is not much interest in FDDI-II at the moment.

Figure 3-1-19
FDDI



3.1.6 Inter-LAN Connection Equipment

There is a limit to the size of one LAN and it cannot be unreasonably expanded. The need for connecting two or more LAN systems may therefore arise. By connecting multiple LAN, business operations' efficiency may be increased further and more system resources will be available for sharing.
The following explains four representative examples of LAN connection equipment for connecting multiple LANs:

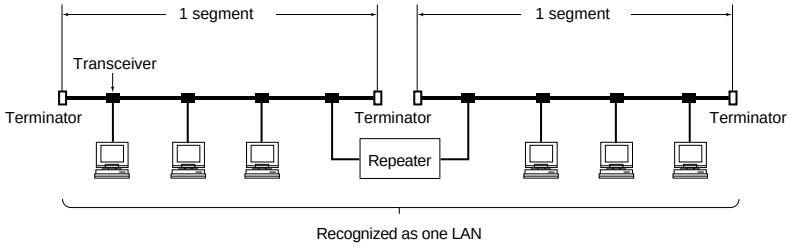
- Repeater
- Bridge
- Router
- Gateway

When studying LAN connection equipment, the OSI basic reference model will be referred to frequently, so please be sure to refer also to Section 1.2 OSI – Standardization of Communication Protocols.

(1) Repeater

A repeater is a device that performs relay functions on the physical layer, the first layer of the 7-layer OSI basic reference model. This is simply a piece of connection equipment that extends the transmission range of the LAN, and the same access control methods must be employed in both LAN systems. Accordingly, LAN systems connected by a repeater can logically be regarded as one LAN.
Recently, the favored transmission media for use in LAN has changed from conventional coaxial cables to twisted-pair cables that make LAN construction easier and also allow the use of cascade connections of hubs instead of using a repeater.

Figure 3-1-20 Repeater



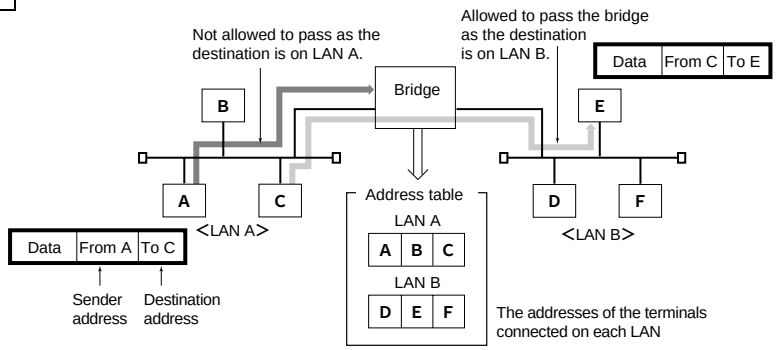
(2) Bridge

A bridge is a device that performs relay functions on the data-link layer, the second layer of the 7-layer OSI basic reference model. When connecting, it is of no importance whether or not the physical layers (transmission media) differ. Some bridges can also perform the relay functions even if the LAN systems use different access control methods.
Bridge types comprise:

- Local bridges for direct connection of LAN systems
- Remote bridges for connection of LAN systems via communication lines (leased lines)

The decisive difference between a repeater and a bridge is that the repeater only recognizes coming data as electrical signals (bit strings) whereas the bridge recognizes it as one piece of data (packet).
As Figure 3-1-21 shows, the basic role of the bridge is to determine, by means of the addresses (MAC address) contained in the data traveling on the LAN, whether or not the data should be passed to another LAN system.

Figure 3-1-21
Basic bridge functionalities



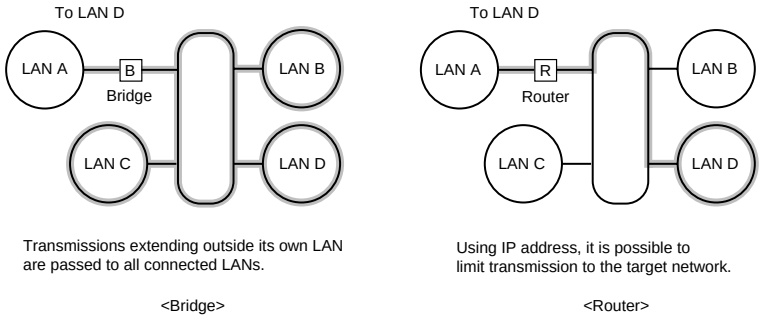
Note: The address is the MAC address (6 octets)

The bridge identifies the data flowing on the LAN and memorizes them in the address table inside the bridge. When data arrives at the bridge, it references the address table and the MAC address of the data. If the sender terminal and the receiver terminal of the data are located within the same LAN, the data is not allowed through the bridge but is passed directly to the destination terminal. If the sender terminal and the receiver terminal are located within different LAN systems, the terminal connects the two LAN systems and then let the data pass through.
Even if the transmission media is the same, in case the data loads are large, a bridge may be used instead of a repeater in order to reduce the traffic load on the LAN. Recently, so-called "switching hubs" that employ switching technology and have higher performance than bridges are frequently employed.
When several LAN systems are connected in parallel by means of multiple bridges, the network structure may become a loop. If broadcast address packets are sent under these circumstances, the packets will continue to circulate on the network. To prevent this situation, a representative bridge is selected to make the network a tree structure. The method to prevent packets traveling in loops and multiplying is called "spanning tree."

(3) Router

A router is a device that performs relay functions on the network layer, the third layer of the 7-layer OSI basic reference model. Interconnection between different networks becomes possible (even if transmission media and access control differ) because the linking function is performed on the network layer. Some routers (called "brouters") of bridges, and those complying with multiple protocols are called "multiprotocol routers."
When sending data from the sender terminal to a terminal on another LAN integrate the role connected by bridges, the data is passed to all the LANs connected, but a router only passes the data to the specified party (LAN). This is called "routing." When data has to be transmitted to a different LAN (network), the router identifies the address (IP address) of the data, and select the route along which the data will travel. This mechanism prevents the data to travel through other LANs (networks), because the data will arrive at the LAN (network) of the receiver along the route specified by the routing. Accordingly, employing routing can greatly reduce the traffic load on the network and also facilitates safeguarding of security.

Figure 3-1-22 Differences between bridges and routers

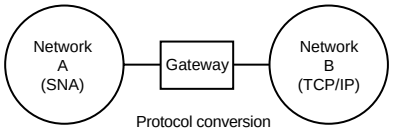


Many multiprotocol routers are normally equipped with PPP.

(4) Gateway

A gateway is a device for connecting networks in which the protocols of the 7-layer OSI basic reference model differ overall. Gateways are used, for example, to establish interconnection between an OSI network and a TCP/IP network. Gateways are also used to obtain interconnection between a network constructed with vendor-inherent protocols and a network constructed with the OSI system.

Figure 3-1-23
Gateway



3.1.7 LAN Speed-up Technology

These days, data is no longer limited to documents. Transmission and reception of data with large data sizes, in the form of images, video and audio, are becoming more and more frequent. To enable the user to send and receive data smoothly, speed-up of LANs and other network systems has become indispensable.
As representative LAN speed-up, the following technologies are introduced:

- 100BASE-T
- 100VG-AnyLAN
- Gigabit Ethernet
- Switching Hub
- ATM-LAN

(1) From 10BASE-T to 100BASE-T, 100VG-AnyLAN and Gigabit Ethernet

As the 100BASE-T label indicates, this is a LAN standard for transmission of data carrying 100 megabits per second. This standard represents an evolution of the 10BASE-T standard and standardization is promoted by the IEEE 802.3 standard. 100BASE-T is also called "Fast Ethernet" with reference to the conventional 10 megabits Ethernet. The 100BASE-T standard comprises the following types:

- 100BASE-T4
- 100BASE-TX

} (both using twisted-pair cable)

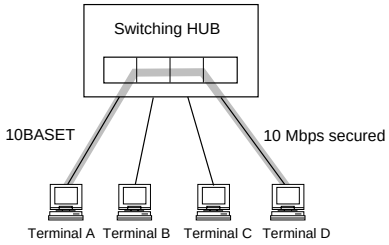
- 100BASE-FX (using optical fiber cable)

100VG-AnyLAN is another LAN standard that is also attracting attention as a media that allows transmission at the speed of 100 Mbps as the 100BASE-T standard. Standardization of the Gigabit Ethernet that should enable high-speed transmission at 1 Gbps is also progressing.

(2) Switching Hub

A switching hub is a communication device that employs switching technology to accomplish high-speed transmission on LAN (see Figure 3-1-24). There are two types, Ethernet switch and Token ring switch.

Figure 3-1-24
Switching hub



In the Ethernet standard, all the terminals share one cable (media sharing), and if terminals send data at the same time, data collision will occur, meaning that the physical performance will decrease considerably even if the logical transmission speed is 10 Mbps.
However, by using Ethernet switching, the data is switched to the destination terminal as the MAC address of the data is identified inside the switching hub, and this means that use of the cable can be monopolized (media possession). In other words, higher speeds than those obtainable with the conventional Ethernet standard become attainable because the entire 10 Mbps is secured by the switching hub.

(3) ATM-LAN (Asynchronous Transfer Mode-LAN)

ATM-LAN (Asynchronous Transfer Mode-LAN) is attracting much attention as it is seen as a full-fledged multimedia LAN solution.
ATM-LAN uses the ATM technology (see Section 2.3.3 Switching Systems) and enables data transmission at ultra-high speeds. Theoretically, transmission speeds in the class ranging from Mbps to Gbps are possible.
Differing from currently existing LAN, ATM-LAN offers variable transmission speeds and this allows the construction of more flexible network. Since this LAN is extremely fast, there will only be very little time lag when data is transmitted, making it ideal for multimedia communications such as transfer of video.
Furthermore, once the B-ISDN service employing ATM begins, ATM-WAN using both ATM-LAN and B-ISDN will make ultrafast data transmission possible over very wide areas.

3.2 The Internet

Up until only several years ago the Internet was only something used by a limited number of experts, but these days its is used by the young and old regardless of gender to exchange information in the form of e-mail or people surf the Net for searching and gathering information from around the world. Individuals also have homepages and the Net has become a base for transmitting information aimed at the entire world. In these ways, the use of the Internet has grown explosively.
One of the factors behind this is that together with the proliferation of WWW (World Wide Web) and the WWW browsers, it has become possible and easy to search for information without the need for special knowledge. Other factors include the higher performance of computers, not least personal computers, and the increased speeds offered by the lines connecting the Internet.
However, as information technology engineers we will have to turn our eyes from the usefulness of the Internet, and face the many problems that have followed on the heels of the spread of the Internet, such as serious security problems, ethical problems, scarcity of IP addresses, etc.
And it is still indispensable to understand the history of the Internet and the supporting technologies behind it.
The following explains the development of the Internet, security problems and other aspects. Based on this knowledge, the aim is to bring you to a level where you are able to discuss the Internet from the standpoint of an engineer.

3.2.1 The Historical Background of the Development of the Internet

This section traces back the historical developments from the birth of the Internet until today.

(1) The birth of the Internet

The Internet was born as a network developed for military purposes. A network called ARPANET (Advanced Research Projects Agency Network) developed for experiments and research by the US Department of Defense Advance Research Projects Agency (DARPA) in 1969 was the genesis of the Internet. At the time, computer systems were mainly host-centric systems and thought to be vulnerable to missile attacks, as all information could be destroyed by a single attack. ARPANET was therefore constructed as a research project into distributed computer systems.
In the beginning, the transmission speed was slow (56 kbps), and the system was made up of research institutes and universities inside the US connected by a packet network. Later technological progresses enabled the ARPANET to play a central role as a communications network in the following nearly 20 years.

(2) Development of the basic technology

The communications protocol TCP/IP is one of the fundamental technologies that cannot be neglected when you are talking about the development of the Internet. Because DARPA employed TCP/IP as the standard protocol for the ARPANET, TCP/IP since then developed into the standard protocol on the Internet.
LAN technologies, into which much research and development investments were made since the middle of the 1970s, have also contributed greatly to the development of the Internet.

(3) Development of networks (1980s)

In 1983, the part of the ARPANET that was focusing on military purposes was cut away (this was named MILNET (MILitary NETwork), and the remaining was changed into a network for science and research. TCP/IP was adopted as the transmission protocol at the same time.
The US National Science Foundation (NSF) developed and started operating its independent network called NSFNET in 1986.
Later, NSFNET and ARPANET were interconnected to form the prototype of the world's first Internet (NSFNET absorbed the ARPANET in 1990).
In Japan, the three universities University of Tokyo, Tokyo Institute of Technology and Keio University constructed the UUCP (UNIX to UNIX Copy: explained later) connected JUNET (Japanese University NETwork) for academic research. In 1988 this developed into the WIDE project (Widely Integrated Distributed Environment: WIDE) and further research was carried out. Following the JUNET, other networks for academic research and development were constructed, such as the Ministry of Education's academic network SINET (Science Information Network). In this way, the Japanese part of the Internet also has its roots in a variety of prototypes.

(4) The proliferation of the Internet (1990s)

① The birth of commercial networks

As the trend towards distributed networks continued, interest in the Internet further increased, and calls for commercial networks in order for the Internet to break out of the shell of academic and research oriented networks increased. This was the genesis of the concept of "providers" (Internet provider: explained later) that led to the explosive growth of the Internet.
In 1994 the operation of NSFNET was transferred to a private company, further reducing the official streak of the Internet and increasing public influence.

② NII plan

An indispensable element in the development of the Internet is the establishment of an information transmission infrastructure. One of the first to realize the importance of this was the then Vice-president of the United States, Al Gore, who proposed the NII (National Information Infrastructure) plan in 1993. This plan centered on research and development of an ultrafast (Gpbs class) network, and worldwide it was to become the trigger for construction of information transmission infrastructures.

③ Increasingly powerful computers

So far most of the computers connected to the Internet had been UNIX workstations with the TCP/IP protocol as the standard. The reason was that the Internet from the beginning was developed for academic and research purposes, and these institutions tended to select workstations as the computers connected to the Internet because these offered higher performance and capabilities than personal computers.
In recent years, however, personal computers have also supported TCP/IP and have more processing power and become less expensive, leading to today's situation where the general public can easily connect to the Internet using an ordinary personal computer. This has contributed to making the use of the Internet even more common among the general public.

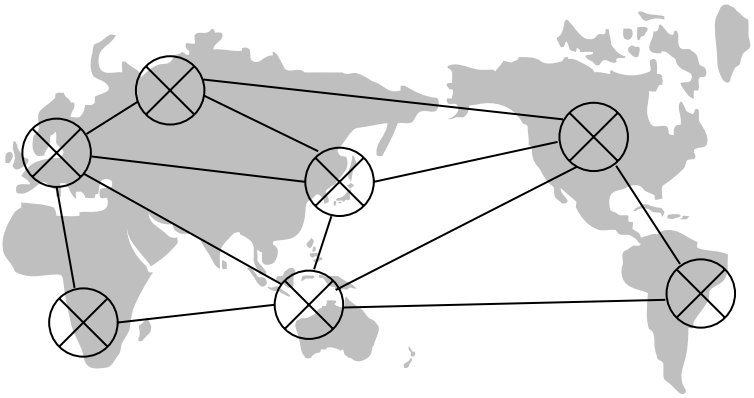
3.2.2 The Structure of the Internet

This section explains the basic structure of the Internet.

(1) A network of networks

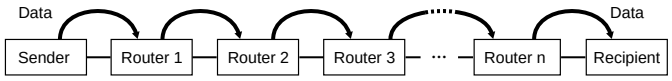
The Internet can be said to be "a network of networks." The Internet is a network on a worldwide scale that is made up of large and small interconnected networks (Figure 3-2-1).

Figure 3-2-1 The Internet = a network of networks



As Figure 3-2-2 shows, the Internet uses the bucket-relay like transmission to transfer data sent from a terminal connected to the Internet to the terminal at the destination via countless routers (relay devices).

Figure 3-2-2 Data transmission on the Internet (bucket relay)



Traveling through routers, data is sent from the sender to the recipient just like the bucket relay method.

(2) The difference between the Internet and personal computer communication

Network services labeled "personal computer communication" have existed from before the Internet became popular. Personal computer communication networks are run by companies (organizations) that have a host computer and offer various services founded on databases to members (Figure 3-2-3).
Both personal computer communication and the Internet use networks to provided services but basically differ in the following ways.

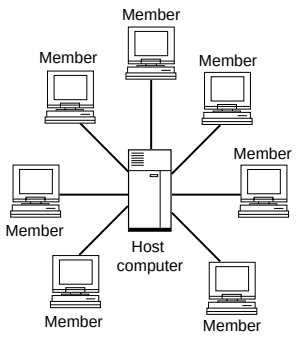
<Internet>

There is no mother organization running the Internet, and anybody can receive services provided that they are connected to the net.

<Personal computer communication>

The company (organization) that owns the host computer manages everything, and service is only available to its members.

Figure 3-2-3
Personal computer communication



In recent years, however, personal computer communication providers have also been providing connection to the Internet making it possible to exchange E-mail between personal computer communication networks and the Internet.

(3) The Internet and TCP/IP

The Internet is interspersed with countless computers of different types and performances, and their manufacturers are also different. In order for any manufacturer's computer to be able to connect to the Internet and receive services, all the computers must employ the same protocol. In other words, anybody can receive services by connecting his/her computer to the Internet provided that the TCP/IP protocol is employed as the communication protocol.
TCP/IP was developed for the ARPANET in 1974 and began being used as a superior network protocol for LAN in the later part of the 1970s. The beginning of the 1980s saw a jump in its proliferation as it was implemented as the protocol in the BSD UNIX (Berkeley Software Distribution UNIX). When the military purpose network was separated from ARPANET in 1983, DARPA replaced the communication protocol with the TCP/IP. The origin of the TCP/IP being the standard protocol of the Internet goes back to these factors.
However, it must be kept in mind that while the TCP/IP is not a protocol that is swayed by particular vendor interests it is not managed by any international organization like the ISO. It is a de facto standard protocol.

3.2.3 Internet Technology

As mentioned earlier, the Internet is a "network of networks." To put it differently, the Internet is a giant network in which all the computers connected to the network can exchange information. It is thanks to the realization of this idea that it has become easy to exchange information among all computers all over the world.
The technologies that have made this possible are:

- IP routing
- DNS

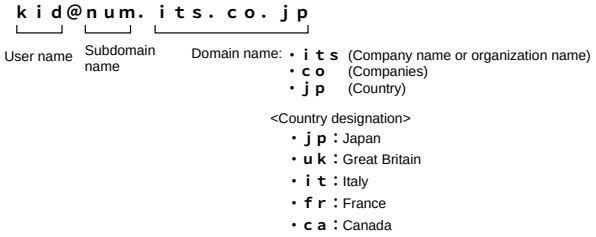
(1) IP routing

On the Internet, each computer connected to the network is given and managed by an IP address. IP addresses are unique addresses that are used all over the world. IP routing is the technique that determines the transmission route from the sender to the destination.

(2) DNS (Domain Name System)

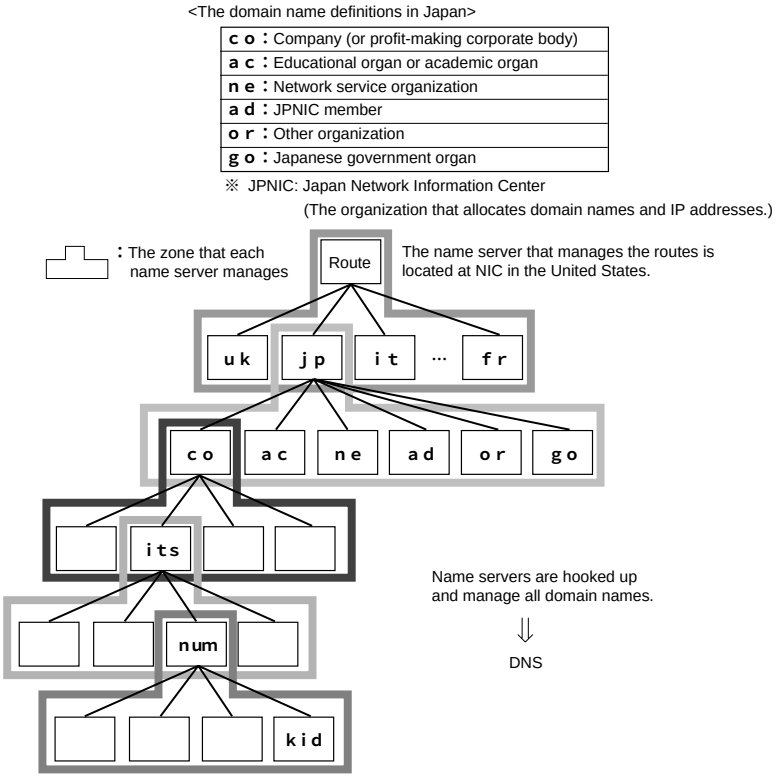
Each computer connected to the Internet is given an IP address but the format of this is very difficult to understand by humans. The "domain name" was therefore invented as a name that should be readily understandable.
There is a one-to-one coordination between a domain name and the IP address, and the DNS (Domain Name System) manages this coordination. In practice, name servers (DNS server) all over the world are working in unison to carry out the DNS function.
Figure 3-2-4 shows an example of a possible domain name.

Figure 3-2-4
Domain name example



The meaning of the identifiers comprising the domain name is indicated in Figure 3-2-5. As the birthplace of the Internet, the United States is the only country where domain names do not contain the country identifier.
A domain name is very easy to handle as it is understandable at a glace since it tells you "which country," "what kind of organization," "who." An increasing number of the name servers that make DNS possible are clustered o be fault-tolerant against any possible failures.

Figure 3-2-5
The hierarchical structure of domain names and name server zones



3.2.4 Types of Servers

There are a number of servers performing different roles on the Internet. Simple explanations of the representative servers are as follows.

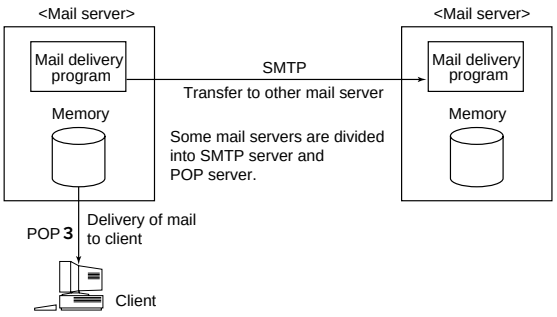
(1) Mail servers

Mail servers are servers that transmit the E-mail sent from the mailer (mail software) installed in the user's machine to the mail server of the destination (Figure 3-2-6).
Mail servers controls the e-mail in accordance with the following two protocols:

- SMTP (Simple Mail Transfer Protocol)
- POP 3 (Post Office Protocol Version 3)

For details on E-mail, see Section 3.2.5 (1) E-mail.

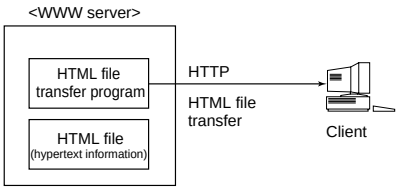
Figure 3-2-6
Mail server



(2) WWW server

WWW servers are also called HTTP (Hyper Text Transfer Protocol) servers or web servers. These servers consist of programs used to transfer hyperlinked text, video, audio, etc. (also called hypertext information) and HTML (Hyper Text Markup Language) files.
For details on WWW, see Section 3.2.5 (2) WWW.

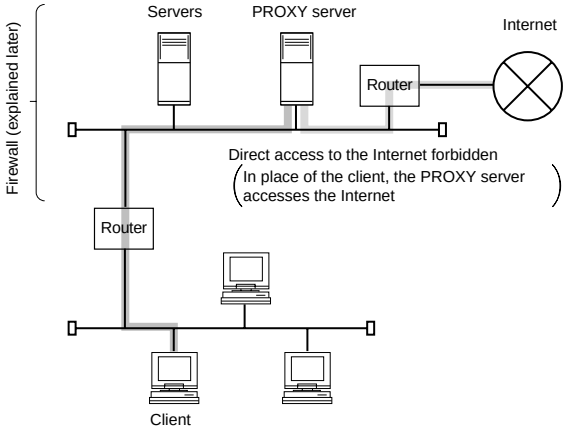
Figure 3-2-7
WWW server



(3) PROXY server

A PROXY server is a server that allows access to the Internet for computers that are forbidden to access the Internet directly (Figure 3-2-8). A PROXY server also has the functionality to temporarily store (caching) accessed information, designed to reduce the traffic load and faster access.

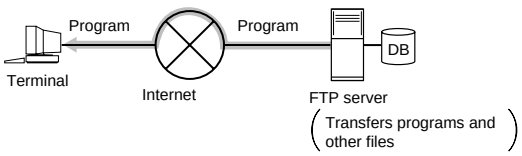
Figure 3-2-8
PROXY server



(4) FTP (File Transfer Protocol) server

FTP (File Transfer Protocol) servers deliver files, programs, etc, to the user over the Internet.
For details on FTP, see Section 3.2.5 (3) FTP.

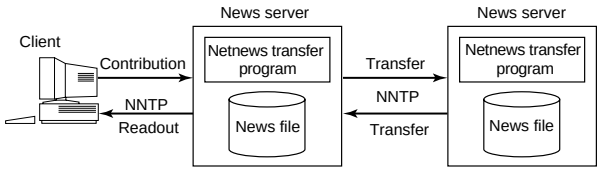
Figure 3-2-9
FTP server



(5) News server

News servers, also called NNTP (Network News Transfer Protocol) servers, transfer news from other news servers and control the readout of news and news contributions from users.

Figure 3-2-10
News server



NNTP: Network News Transfer Protocol

(6) Name server

Name servers, also called DNS (Domain Name System) servers, are servers that can answer domain name inquiries from users with IP addresses. This function is one of those that have facilitated use of the Internet. To ensure high reliability, name servers usually have the following redundant configuration.

- Primary name server: A server that has the management rights for a specified zone.
- Secondary name server: Server that holds the information of the primary server.

3.2.5 Internet Services

Various services are provided via the Internet. The following representative services are explained in this section:

- E-mail
- WWW
- FTP

(1) E-mail

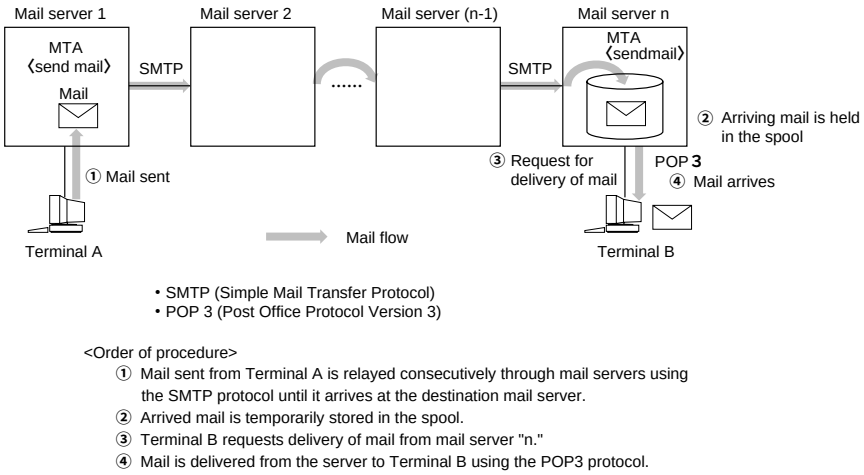
E-mail is one of the communication methods over the Internet or other networks (personal computer communications, LAN, etc.). It has become a widely used communication means in place of telephones and fax.
The features of E-mail are:

- Allows all sorts of data to be sent in large amounts and at high speed.
  Due to improvements in compression technologies and bandwidth expansion, large amounts of data can be transmitted at high speed. In addition to text (characters), video and audio can also be transmitted.
- Regardless of whether or not the recipient is at home, the mail arrives in the mailbox inside the mail server.
- Running costs are low.
  Apart from the fee to be paid to the provider, the cost of sending or receiving E-mail only amounts to the telephone charge for the connection between the user and the provider (in the case of a dial-up IP connection), and this applies both to domestic E-mail and E-mail sent to other countries.

The mechanisms behind E-mail are shown in Figure 3-2-11.
The mail server exchanges and transfers mail using a program called MTA (Mail Transfer Agent) (the far most common software is called "sendmail").
The mail server sends and receives mail according to the following two protocols:

- SMTP (Simple Mail Transfer Protocol)
- POP 3 (Post Office Protocol Version 3)

Figure 3-2-11 The mechanisms behind E-mail

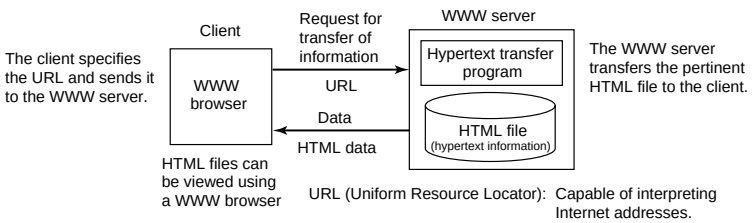


The SMTP protocol is used for transferring mail between mail servers, and POP 3 is the protocol used for transferring mail from the mail server to the user's terminal. Sometimes mail servers are thought of as being divided into a SMPT server and a POP 3 server in accordance with these protocols.
When sending other items than text as E-mail, such as video or audio, these data is compressed and converted into character information and transferred using a method called MIME (Multipurpose Internet Mail Extensions).
Mailing lists can be mentioned as an example of how E-mail can be utilized. Originally, this was a function for sending mail to the members of a specific group using the broadcasting method. However, these days it is often taken to refer to the activities of a group (groups of friends sharing the same interests, etc.) on the Internet that uses this distribution function.

(2) WWW (World Wide Web)

The most important reason for the explosive growth in Internet users was the development of the WWW. The WWW interlinks all the WWW servers all over the world to allow search for information by surfing through the links. This is referred to as "net surfing."
The World Wide Web was developed at the European Laboratory for Particle Physics (CERN) in 1989. The number of WWW users increased rapidly after the National Center for Super-computing Applications (NCSA) at the University of Illinois developed and released the first popular WWW browser, called Mosaic, which could handle not only text but also images and audio.
Figure 3-2-12 illustrates the structure of the WWW.

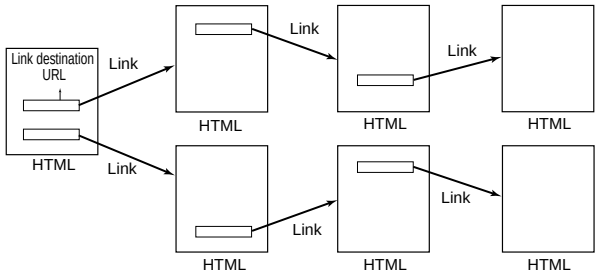
Figure 3-2-12 The structure of the WWW



Most of the data housed in WWW servers is in the HTML format. Recently, Java (object-oriented language suitable for use on networks), VRML (Virtual Reality Modeling Language; language that can express 3-D), XML (eXtensible Markup Language; language that extends HTML and can be used on the Web), etc. have also become widely used, promoting more visual and advanced use of the Internet.

Figure 3-2-13 Hyperlink structure and HTML

Hyperlink structure : The desired information can be viewed by jumping from one linked piece of information to another.



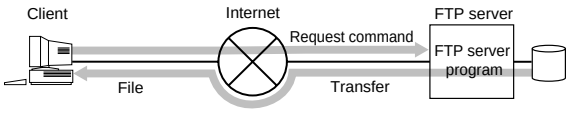

```
<HTML example>
<IMG SRC="img/smallblueball.gif"><font size=+0><a href="html/syuppan/press01.html">press release
</a><BR>
<IMG SRC="img/smallblueball.gif"><font size=+0><a href="html/kenshu/shiken.html">Information on examination
for information technology engineers</a><BR>
<font size=+0><a href="html/kenshu/shiken.html">(Central Academy of Information Technology for Japan Information
Processing Development Corporation  Japan Information-Technology Engineers Examination Center)</a><BR>
<IMG SRC="img/smallblueball.gif"><a href="html/nintei/index.html">List of schools with authorized curriculum
for education of IT personnel (Authorized by the Minister of Economy, Trade and Industry) </a><BR></font></ul>
<hr size=5>
<center>
```

Underlined parts: Linked information
(From CAIT's homepage)

(3) FTP (File Transfer Protocol)

Figure 3-2-14 shows the structure of FTP (File Transfer Protocol).

Figure 3-2-14
FTP structure



The file transfer sequence of FTP is as follows:

1. As the FTP delivery request command differ with the user's OS, the command is converted to a standard command by the FTP client program, and then sent to the FTP server.
2. The FTP server converts the standard command by the FTP server program into a command conforming to the server's OS and interprets the command and transfers the file. For the transfer, the FTP server program also converts the object file into a standardized form before it is transferred.

Some FTP servers require an "account" (authorization for use) to enable use and others can be used as "anonymous" FTP.

3.2.6 Search Engines

There is countless data (homepages) registered in countless WWW servers on the Internet. In principle, users can freely get their hands on all these data. However, finding the data you are searching for among all these many data is very cumbersome. Therefore search engines are used for this purpose. A search engine is an information retrieval tool (system) found on the Internet. It can be thought of as site specialized for information search.

Search engines are divided into the following groups:

- Search engine type: Directory type, robot type
- Search method: Keyword search, directory search

(1) Search engine types

① Directory type search engines

Directory type search engines search indices in which homepage titles and contents (comments) are registered to find the target homepage. Humans perform the indexing. These engines yield good search results and are highly reliable but they do not necessarily support the latest information. Another shortcoming is that the total amount of data to be searched is somewhat small. "Yahoo!" is one of the representative search engines belonging to the directory type.

② Robot type search engine

Robot type search engines employ search robots (programs) that automatically search WWW servers and collect information for indexing. These search engines regularly search all the WWW servers throughout the world and can thus gather large amounts of the newest information. However, since automatic judgments are left to programs, the search results and reliability are somewhat low (homepages that are almost irrelevant will often be shown).
Among the representative robot type search engines is "goo."

(2) Search methods

① Keyword search

Keyword search is a method in which search is performed based on keywords specified by the user. There are many inconvenient points in connection with the keyword search method as it can be very difficult to find the desired information. The method is probably most useful to advanced users.

② Directory search

Directory search is a method in which you find the desired information by gradually narrowing the search object to fields or genres, etc. Since the search is performed in stages, it can be bothersome but it is a search method that is easy to use by beginners.
There are also full-text retrieval systems that work in ways similar to search engines. While search engines search through indexes with registered information, full-text retrieval systems search the entire text of homepages. Because the full text is searched, the application area is wide but there are many technological challenges involved, as a large amount of data has to be searched.

3.2.7 Internet Related Knowledge

(1) QoS (Quality of Service)

Based on transmission delay and lowest guaranteed speed, etc., QoS is used as an indicator to show the quality of the service provided by the network layer of the OSI basic reference model. Recently, QoS standards for offering Internet services have been laid down by the IETF (Internet Engineering Task Force).

(2) xDSL (x Digital Subscriber Line)

xDSL is the general term for technologies for high-speed transmission using telephone lines. The x is substituted to indicate the various types, e.g., ADSL (Asymmetric DSL), HDSL (High-speed DSL), SDSL (Symmetric DSL), VDSL (Very-high-speed DSL). Figure 3-2-15 shows various methods and the limitations in terms of transmission distance and transmission speed.

Figure 3-2-15
xDSL transmission speeds

Designation	Upstream	Downstream
ADSL	Max. approx. 1 Mbps	Max. approx. 8 Mbps
HDSL	Max. approx. 2 Mbps	
SDSL	Max. approx. 2 Mbps	
VDSL	Max. approx. 6 Mbps	Max. approx. 52 Mbps

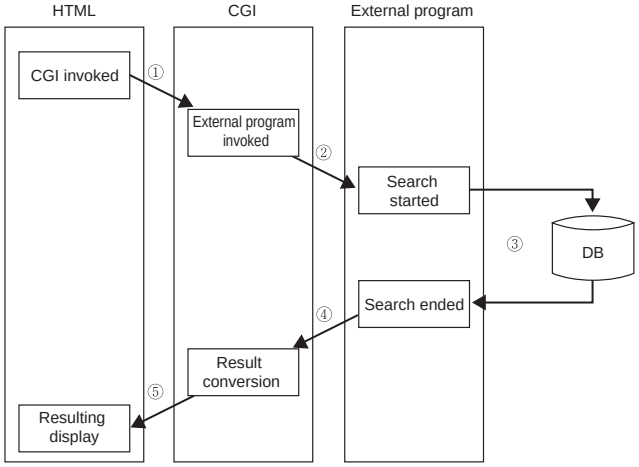
(3) Best Effort Service

Best effort services are services that give no guarantee for the transmission bandwidth that can be used on the network at times of congestion. In lieu of guarantees, charges are normally lower. In contrast to best effort services, services that offer guarantees even in times of congestion are called "guaranteed services."

(4) CGI (Common Gateway Interface)

CGI is an interface between a WWW server and programs. The CGI is invoked by commands included in HTML documents held in the WWW server and it can issue commands to external programs. Employing CGI makes it possible to create conversational homepages in which processing is carried out in accordance with the inputs made by the user.

Figure 3-2-16
The workings of CGI

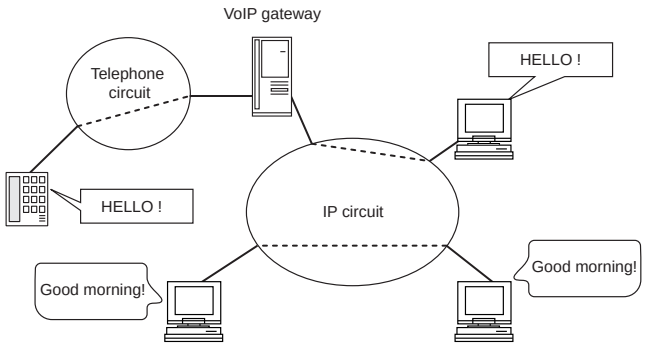


① CGI is invoked by commands contained in the HTML document.
② CGI organizes the search conditions and invokes the external program used for DB retrieval.
③ The external program organizes the search conditions passed to it and retrieves the database(s).
④ The search result is transferred to the CGI program used for converting the results of the DB retrieval.
⑤ The CGI program integrates the search results into the HTML document for display.

(5) VoIP (Voice over IP)

VoIP is a voice data transmission technology employing the IP protocol. VoIP is used to carry out voice communication over the Internet by using a personal computer as an Internet phone (Figure 3-2-17).
By using VoIP gateways it is possible to connect public switched telephone network and IP networks. For this purpose the MGCP (Media Gateway Control Protocol) is used to control the VoIP gateway. Standardization is under way by the IETF.

Figure 3-2-17
Voice network using VoIP



Currently, the quality of Internet telephones is lower than that of public switched telephone networks. However, research into how to prevent delays or fallout of the sound is progressing, and it can be

envisioned that Internet telephones will make up a high-quality and low-cost telephone network in the future.

3.3 Network Security

The development of networks has expanded the areas of computer applications and networks have become the foundation of today's information society. Together with the spread of networks these have also been exposed to the various threats.
Some of the threats facing networks are:

- Eavesdropping of the contents of communications by third parties.
- Falsification with the contents of communications by third parties.
- Illegitimate intrusion into networks by persons without authorization.

Network security refers to the overall term to embrace the ideas and efforts trying to counter these threats and make networks safe to use.

3.3.1 Confidentiality Protection and Falsification Prevention

The first aspect that must be considered in terms of network security is the protection of information (data). Eavesdropping and falsification with information is a serious problem to both companies and individuals.
The following are some of the methods available to prevent eavesdropping or falsification of information:

- Encryption of information
- Authentication of user identities
- Control of access rights

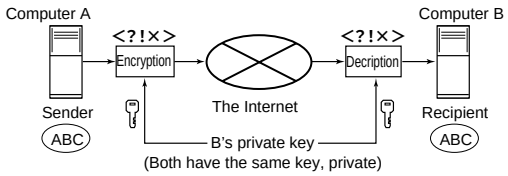
(1) Cryptography technology

With the spread of the Internet, the social structures (distribution structures and pricing structures) are likely to undergo major changes. One of the representative themes is EC (Electronic Commerce). Simply expressed, EC is the conduct of various commercial transactions on the Internet. This involves important data flowing on the communications lines. However, there is a risk that the data may be bugged or falsified, since these are not private lines. Technology to counter these threats is required and technology to carry out "data encryption" preventing the contents of any stolen data from being read is indispensable.
Private key cryptography and public key cryptography are the two representative encryption technologies.

① Private key cryptosystem

In private key cryptosystem a set of symmetric keys is used by the sender for encryption and by the recipient for decryption. A representative example of this method is the DES (Data Encryption Standard), created by the U.S. National Bureau of Standards.

Figure 3-3-1
Private key cryptosystem

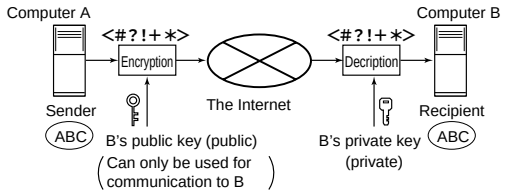


As the key is private, only specified parties will know the key and the other party can thus be identified but thorough management and arrangements are necessary to prevent theft of the key. Since a number of keys corresponding to the number of users are required, the number of keys can swell dramatically.

② Public key cryptosystem

In public key cryptosystem the sender uses a public key to encrypt data, and the recipient uses a dedicated private key to decrypt it. A representative example of this method is RSA (Rivest, Shamir, Adleman, the names of the three inventors).

Figure 3-3-2
Public key cryptosystem



Public key cryptosystem differs from private key cryptosystem in the way that there is no need for management of the public key. The private key cannot be found from the public key. However, since the key for encryption is public it is impossible to confirm the identity of the sender, which means that there is a risk of "impersonation."
Recently, PGP (Pretty Good Privacy) has become widely used in e-mail encryption software. This software was developed by Philip Zimmermann of the PGP Corporation in the United States and it combines both the functions of encryption and authentication (explained later).

③ Encryption algorithms

Representative encryption algorithms are: Substitution ciphers, transposition ciphers, insertion ciphers, etc.

a. Substitution ciphers

The substitution cipher is an encoding technique that replaces the original characters with other characters or symbols according to a rule. A representative substitution cipher is the Caesar cipher. In the Caesar cipher a character is replaced with another character placed at a specified interval from the original character. This method was used by Julius Caesar and is said to be the world's oldest encryption method.

Example Caesar cipher (shift interval: 2 characters)
Text to be sent: "Tomorrow" → Encrypted text: "Vqoqttqy"

b. Transposition ciphers

The transposition cipher is an encoding technique in which the order of the original characters is changed to create a separate character string. This technique enables more complicated ciphertext as the order can be changed not only in the direction of the line but also vertically.

Example Order changed for every 4 characters (ABCD → BDAC)
Text to be sent: "tomorrow" → Encrypted text: "ootmrwro"

c. Insertion ciphers

The insertion cipher method is an encryption technique in which an extra character is inserted after a specified interval. Because the original order of the characters is not jumbled, this encryption method is somewhat weak.

Example Extra character inserted for every two characters.
Text to be sent: "Tomorrow" → Encrypted text: "Toqmosrrgowa"

The DES private key encryption is a combination of the substitution cipher and transposition cipher methods. This method divides the message into fixed lengths and repeats substitution and transposition cipher encryption several times for each block.
The RSA public key encryption is a substitution cipher that relies on second power residue calculation. The security of this encryption is guaranteed by the fact that huge calculations are necessary to solve the prime factorization.

Other methods, such as the ECC (Elliptic Curve Cryptography), which is a public key encryption method that relies on calculations of curves, are also attracting attention.

(2) Authentication

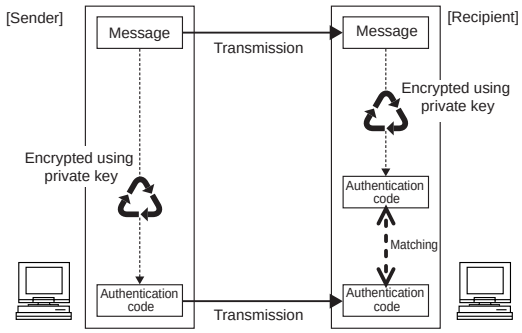
Following the countermeasures to eavesdropping, prevention of falsification of data and impersonation has to be considered.
Commercial transactions cannot be conducted on the network if it is easy to falsify the data. If, for example, the number of ordered items can be rewritten, the transaction cannot be concluded as it should be. If impersonation is possible, it will be possible for third parties to pretend that they are ordering for others.
The following are some of the technologies employed to prevent this:

- Message authentication
- Digital signature

① Message authentication

Message authentication is a technology for checking whether the sent data has been altered during the transmission. Error detection methods (parity check, CRC, etc.) that detect whether or not errors are generated and executed when the message is transmitted, can also be said to be a type of message authentication.
However, more than this, attention has to be paid to whether or not the message has been falsified. To prevent falsification of the message, private key encryption, etc. can be used. When this technique is used, the sender sends the message together with an authentication code encrypted using a private key. Based on the received message, the recipient uses the same private key as that used for the encryption to create an authentication code, and by matching this with the received authentication code it can be checked whether or not the message has been falsified.

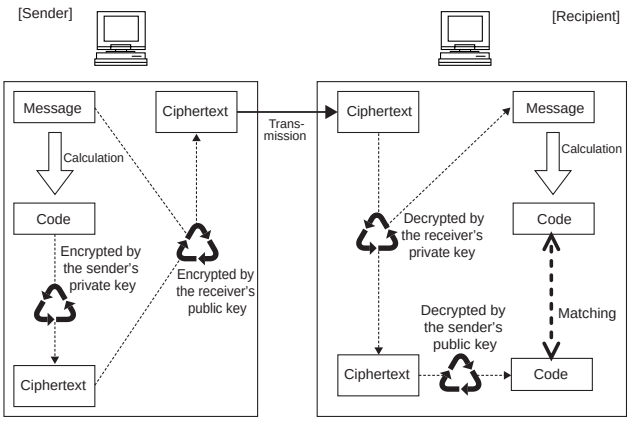
Figure 3-3-3 Message authentication mechanism



② Digital signature

Digital signature is a user authentication method to prevent impersonations. Using the public key, this authentication method identifies the sender's authenticity as well as certifies that the data has not been falsified.

Figure 3-3-4 Digital signature mechanism



The digital signature is a technique in which the data "encrypted" by the sender's private key is "decrypted" by the sender's public key on the receiver side. The public key and private key correspond one-to-one, meaning that the message "decrypted" correctly using the public key is made a person who possesses the private key corresponding to the public key. In this context, the Certification Authority (CA) certifies the authenticity of the public key itself.

Whether the contents of the message have been altered can be detected by the code embedded into the transmitted message. In the digital signature, this embedded code is the "encrypted" data by the sender's private key. Also, by encrypting the message and code with the recipient's public key before transmission, eavesdropping of the data can be prevented.

In general public key encryption, it is called "encrypting" when the public key is used and "decrypting" when the private key is used. Accordingly, it can be said that digital signature is "a method in which the data "decrypted" by the sender's private key is "encrypted" by the sender's public key on the receiver side."

(3) Security protocols

Security protocols are protocols providing security measure to prevent interception of information, etc. SLL is one of the representative security protocols.

① SSL (Secure Sockets Layer)

SSL provides security measure for the upper level protocols like HTTP, SMTP, FTP, etc. It is a protocol located midway between the application layer and the transport layer, and it performs the role of encrypting the information received from the upper level protocols and passing it to the lower level protocol (TCP).

By employing the SSL eavesdropping of information can be prevented, as encrypted data will be transmitted on the communication channel. However, the safety of SSL is somewhat low because it offers common security measure for all the upper level protocols. Consequently, several separate methods have been proposed for use according to purpose. Representative of these are SHTTP and SET.

② SHTTP (Secure HyperText Transfer Protocol)

SHTTP is a protocol that adds function for encryption of HTML documents to the HTTP protocol and is used when data should be encrypted for transmission between a WWW browser and a WWW server.

③ SET (Secure Electronic Transaction)

SET is used for conducting secure electronic commerce transactions on networks, and it provides a series of security measures such as encryption of transaction data, issue of digital certificate from a Certification Authority.

(4) Access control

Encryption of data can reduce the risk of data flowing on the communications lines from being bugged (eavesdropping or falsification of information). However, eavesdropping or falsification of information can also be done directly from databases or files if an intruder gains illegal access to the network.

To prevent this kind of threat, it is of utmost importance to prevent illegal access to the network. Nevertheless, it is also possible to envision that a user who has legal access to the network could steal or falsify files belonging to other people or confidential company information. To prevent this, access control to prevent unauthorized access to data on the network is required.
Access control is implemented by the use of such measures as:

- Access right
- Password

① Access right

This is one of the aspects of access control that sets access right for each user in relation to files and databases. Access rights comprise the right to read, write, delete and execute, etc. It is not possible for a user to perform other processing than he/she has the right to. For example, a user that only has the right to read can view the contents but cannot change the contents.
Often access rights are not defined for each individual user in practical access control. Instead users are divided into several layers, and access rights are defined for each layer. The three common user divisions are:

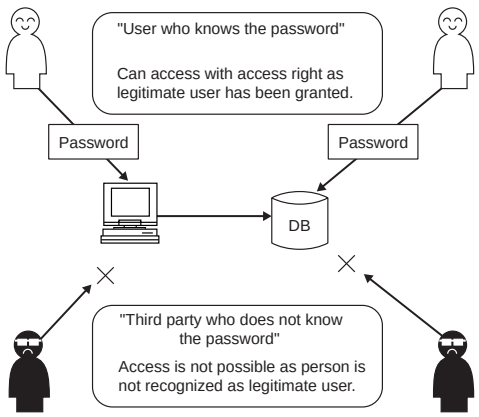
- Network system administrator
- The group to which the creator (owner) of the file belongs, such as department or project.
- Other users that are legitimate network users.

For a file created by A, for example, A himself/herself and the administrator may have full access rights. Members of the department to which A belongs may be granted the right to read the file together with the right to execute it. Other users may only be given the right to read the file.
Setting access rights in this way can help prevent theft and unauthorized alteration of information. However, the access right is not enough to prevent illegal access if a third party impersonalizes as a user who has legitimate access right. To minimize this risk, it is desirable to limit access right to the minimum required.

② Password

A password is a predetermined keyword that the user types in. The password is used to confirm that the person knows the keyword and is a legitimate user.
In access management, the password is used in two ways (Figure 3-3-5).
In one method, it is used on the level where the user is required to prove that he/she is a legitimate user who has been granted access right. As a means to control access, this will be ineffective if an illegitimate person impersonalizes as a legitimate user with access right. To prevent impostors from gaining access to the network, it is necessary to have persons enter a password when using the network in order to confirm that they are legitimate users.
Another way to use passwords is to set a password for files and databases. In other words, the user must enter a password in order to gain access to files and databases. By ensuring that only persons with legitimate access right know the password, illegitimate access can be prevented.

Figure 3-3-5
Use of passwords



The most important thing to ensure when using passwords is that the password itself is not disclosed to

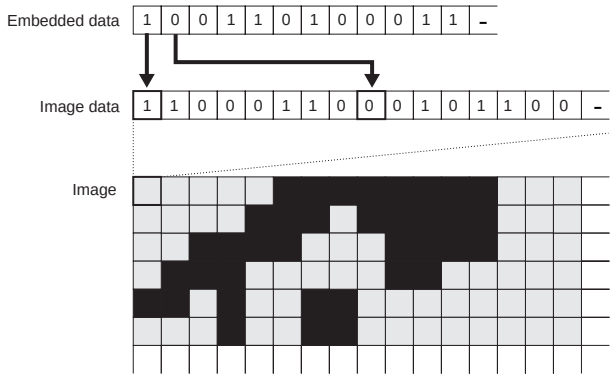
third parties.
Full attention must be paid to the following in association with the use of passwords:

- Other people must not be told the password.
- Passwords must be difficult to guess (birthdays, etc. must not be used).
- Passwords must be changed periodically.
- Password files must be encrypted.

(5) Electronic watermarking

Electronic watermarking is a technology for embedding special information, which is not discernable to the human eye, in image information, etc. It is often used to prevent piracy of image data, etc. by embedding information on copyrights. Electronic watermarks cannot be erased by normal operations (copy, compression/decompression, enlargement/reduction, etc.). Unless special software is used, the watermarks cannot be removed or modified which makes this technology highly efficient for countering illegitimate use of image information.
There are several methods for implementing electronic watermarking. An easily understandable example is the method that embeds special information bits in the bit strings that express image information (Figure 3-3-6). For example, when each of the colors red, blue and green for one image dot are saved as 8 bits, an information bit is included as the most significant bit for each of the colors. In this case, the gradation of each color falls from 256 colors to 128 colors but this degree of difference in color is very difficult to detect by the human eye.

Figure 3-3-6 Mechanism of electronic watermarking



Another method disassembles the data into frequency bands and only embeds a special signal in specified frequency bands. While this electronic watermarking demands work and efforts, safety is higher than in the case of the simple embedding method and currently this method is the most widely used.

(6) Confidentiality management

Confidentiality management aims to prevent disclosure of confidential company information, etc. Disclosure of confidential information is often associated with illegitimate behavior of third parties while in fact it is often leaked by people inside the company.
To prevent employees from disclosing information, it is necessary to arrange things so that it is not easy to get close to valuable and sensible information – even for people working inside the company. There is no sense in enhancing network security if it remains easy to enter and leave the computer room. Consequently, entrance control of people is required in association with computer rooms where sensible information is kept.
Some of the conceivable techniques for entrance control are:

- Identification by means of ID card with photo.
- Identification by PIN (personal identification number) and password.
- Identification by means of IC card.
- Identification by special physical features (fingerprints, voiceprint, etc.).

By implementing strict entrance control, illegitimate entry and exit can be prevented. However, this does not prevent people entering legitimately from disclosing information. That is the reason why laws and regulations related to prevention of disclosure of information have become necessary.
Fundamentally, the Japanese Civil Code and criminal law protect confidential company information. The Civil Code stipulates that by exchanging confidentiality agreement with an employee at the time of employment, an employee can be dismissed if found guilty in disclosing information. Furthermore, if the company suffers unnecessary damage due to the disclosure of the information it can demand compensation from the employee and from any company that may have used the information. In the context of criminal law, embezzlement and breach of trust may apply. The Unfair Competition Prevention Law can also be applied to halt illegitimate use of trade secrets.
As the information society is developing, one bill after another is being enacted to curb illegal disclosure of information. However, the real way to prevent leakage of information is not by punishment by means of bills and laws, but by enacting intra-company education and creating an environment inside the company so as to raise the consciousness of each employee.

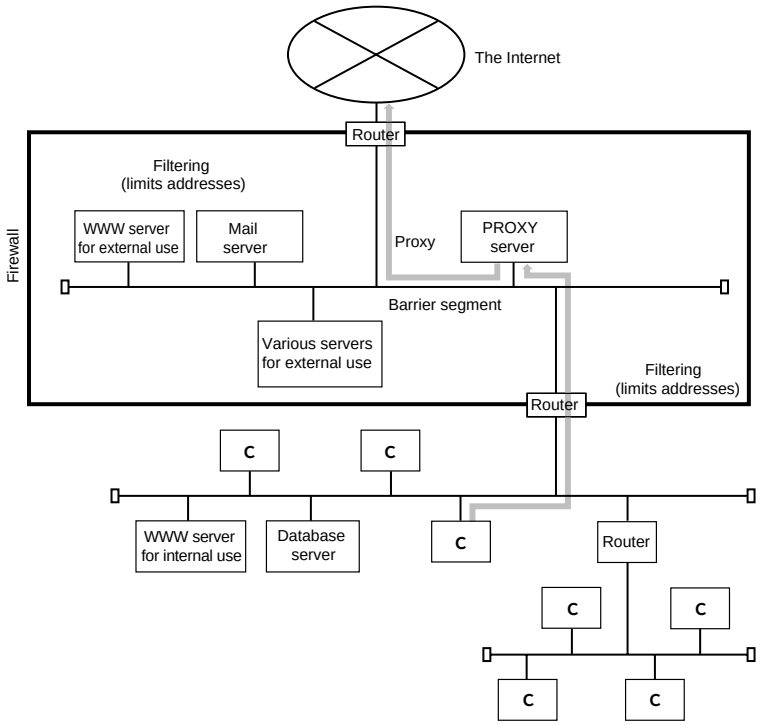
3.3.2 Illegal Intrusion and Protection against Computer Viruses

Connecting a network inside a company (LAN) to an external network (WAN) accelerates exchange of information, and brings great benefit to the company. However, this requires the company to deal with risk of attacks on the company's intranet (in the form of illegal intrusion, computer viruses, etc.).
This section explains firewalls enacted to prevent illegal intrusion into intranets, RAS, and precautions against computer viruses, etc.

(1) Firewall

A firewall is a security system set up between the Internet and the intranet and it is comprised of a network (called "barrier segment") of connected servers (WWW servers, mail servers, etc.) (Figure 3-3-7).
The fundamental role of the firewall is to control the passage of data (packets) and allow or deny the passage of data by means of the filtering performed by a router. Also, transactions between the intranet and the Internet are relayed through a PROXY server to prevent computers inside the company from accessing the Internet directly.

Figure 3-3-7
Firewall

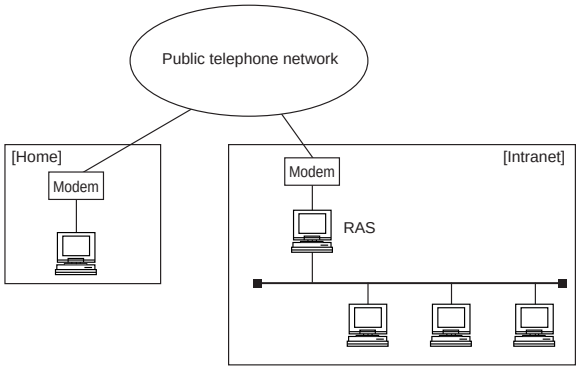


(2) RAS

A RAS (Remote Access Server) is a server that enables users to access the intranet over telephone lines. Installing such a server makes it easy to connect to the intranet from a remote location so that a user can obtain the same kind of service when he/she is at home or on a business trip as when in the office (Figure 3-3-8).

When a RAS is used, a "callback" is performed to prevent illegal intrusion. The callback works in the way that when a request for connection to the RAS is received from the remote location, the line is disconnected once before the RAS server dials the remote location and connects the line. This process prevents illegal intrusion even if user IDs or passwords have been stolen because only telephone numbers registered in advance are allowed to be connected to the intranet.

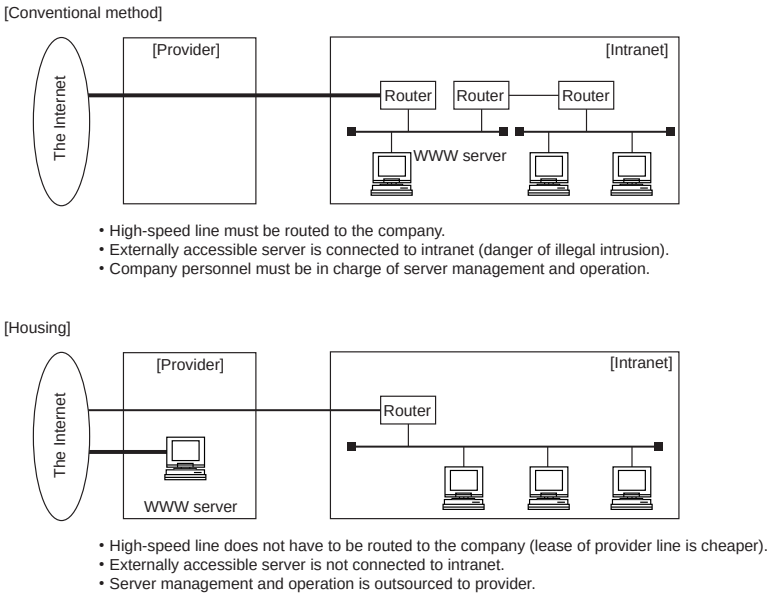
Figure 3-3-8
RAS



(3) Housing

Housing is method where the user places servers on the premises of the provider and leaves management to the provider.

Figure 3-3-9
Housing



When you use a server supplied by the provider, you call it "hosting." In this case, a user can borrow one server, or several users may share one server.
The benefits of housing and hosting are:

- Direct use of the provider's high-speed line.
- Separation between intranet and externally accessible server.
- Security service is provided.

(4) Computer virus

Computer viruses are programs that intrude into computers and can destroy the contents of the computer's hard disk or memory or alter programs. Often the infection route or the time of infection cannot be determined, and the virus may lay dormant for a while following intrusion before it starts working after a certain period of time has elapsed. Representative effects of viruses are:

- Destruction of programs.
- Destruction of data in files.
- Images or characters may suddenly appear on the monitor screen.

- Damage occurs on specific dates (for example Friday the 13th).

In many instances it is too late to do anything after the computer has become infected. Accordingly, it is a wise police to always inspect floppy diskettes, etc., brought in from the outside by running them through a virus check program (vaccine program) before inserting them into computers, and refrain from using media whose origin is unknown, etc. The Ministry of Economy, Trade and Industry has published guidelines on this in the form of the notice "Standards for Countering Computer Viruses."

3.3.3 Availability Measures

When considering network security, safety in terms of hardware must also be considered. It is necessary to make arrangements so that databases, etc. can be quickly restored if affected by computer viruses, and it must be ensured that the network does not go down if a line malfunctions, etc.
Security measures concerning hardware are referred to as "availability measures" or "hardware security."

(1) File backup

File backup is the most fundamental availability measures, and it refers to the act of taking copies of important data for backup. Representative methods comprise:

- Full backup
- Incremental backup
- Difference backup

① Full backup

Full backup is a method for backing up all the files, including OS and software. In case of failure, the system can quickly be restored. However, long time is required for the backup.

② Incremental backup

Incremental backup is a method that only makes a backup of the items that have changed since the last backup. Backup can be accomplished in relatively short time but recovery in case of failure takes a little longer time.

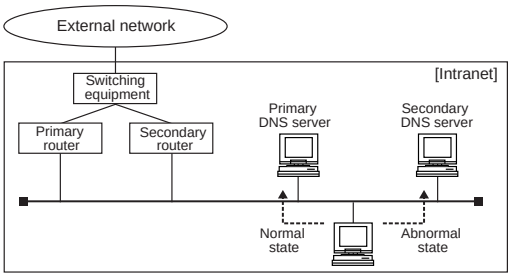
③ Difference backup

Difference backup is a method that backs up the items that have been newly added since the last full backup was performed. It takes longer to perform than the incremental backup but the time required for restoring is shorter.
Data recovery service is another file recovery method. This is a service provided by certain vendors where data is extracted from a damaged file and then recovered as a file. Using a special technique, data is extracted from data that the user cannot read. This allows 60 to 80% of the old data to be restored. However, currently this is a very expensive service and 100% recovery is not achievable, meaning that some data has to be inputted again.

(2) Redundant system configuration

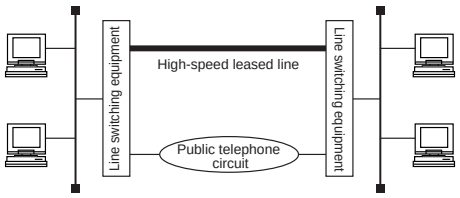
It must be ensured that all the functionalities of an intranet do not come to a stop in case of failure of any of the devices that make up the network. Consequently, it is necessary to arrange redundant system configuration for the most important equipment and devices, such as the communications lines and transmission control devices.
By preparing two or more of the same devices, it is possible to switch from the primary device to the secondary device if failures occur in the primary device so that the functionalities of the network can be retained. This redundant configuration is also applied to servers such as DNS and database servers.

Figure 3-3-10
Redundant system configuration



In the case of a network that connects two locations, a backup route, such as a public telephone line, should be prepared in advance for emergency situations, in addition to the high-speed leased line used under normal circumstances.

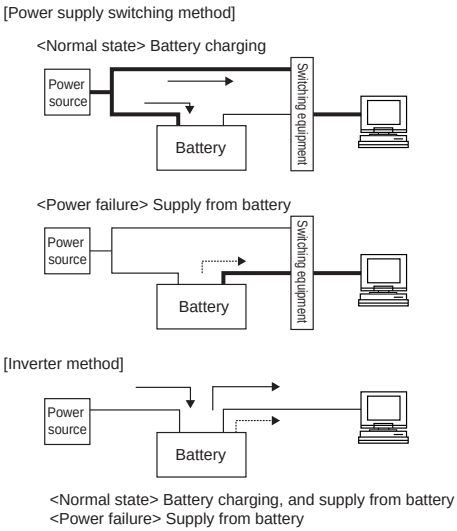
Figure 3-3-11
Duplication of communications lines



(3) Countermeasures against natural calamities

In the context of network security it is not sufficient to take precautions against human threats such as leakage of information or illegal intrusion. Preparations must also be made for natural calamities such as typhoons or earthquakes.
Most damage to networks stemming from natural calamities comes from the interruption of power. Countermeasures against power interruption include installation of UPS (Uninterruptible Power Supply). A UPS is a system that switches to operate on battery in case of a power interruption and supplies power for a certain period of time. One type of UPS only switches to battery in cases of abnormalities, and another inverter type supplies power via the battery under normal circumstances. In the case of the power supply switching method, the power supply might possibly be momentarily interrupted (short break), and thus the inverter type is more reliable even though it is more expensive.

Figure 3-3-12
UPS methods



CVCF (Constant Voltage Constant Frequency) equipment that combines a home generator with an uninterruptible power supply is used for large-scale computers.
Some of the countermeasures required for earthquakes are:

- Network equipment must be fixed in place so that it cannot fall down
- Backup media should be stored in a room away from the computer room.

3.3.4 Privacy Protection

Through sales activities, private enterprises amass a variety of personal information from the order slips and application forms received from consumers. In many cases the obtained information is entered into databases to support the company's sales activities. A great amount of information ranging from address and gender, date of birth, family structure to states of financial and property, can thus be collected. Much personal information, such as resident registration, taxpayer register, drivers license, social insurance, etc., is also registered by many public organizations.
This personal information involves the right to privacy, and the security of the information ought to be guaranteed. However, if this information is made public by some kind of mistake, the right to privacy may be violated. Free access to information and the right to privacy are often mutually contradictory, and organizations that possess personal information must consider safety precautions to ensure that information is not improperly disclosed.

(1) Personal information management

As a guideline on personal information, the OECD (Organization for Economic Cooperation and Development) proposed "Committee Recommendation on Guidelines for Protection of Privacy and International Circulation of Personal Information" in 1980. This recommendation provided the following 8 basic rules concerning personal information.

① Restrictions on collection
Unrestricted collection of personal information must not take place.
② Clarified purpose
The purpose must be clearly stated when data is collected.
③ Contents of data
Only information conforming to the purpose of the information gathering must be collected.
④ Restrictions on use
The information must not be used for other purposes than those for which it was collected.
⑤ Safety guarantee
Measures must be taken to guarantee the safety of the collected data.
⑥ Announcement of the purpose of use
How the data is used must be made public.
⑦ Participation by individuals
Individuals can confirm the existence of data. Furthermore, correction, deletion, etc. of data must take place upon request by an individual.
⑧ The collector's responsibility
The collector of the data must be responsible for the items described above.

Based on this guideline, most countries have enacted laws to protect personal information.

(2) Anonymity

On the Internet, it is possible to release information anonymously (under a pen name). This means that the Internet is a network that does not allow tracking and prevents identification of the source of the information.
Among the benefits of anonymity are:

- Personal information can be kept secret.
- Ensures freedom of expression.

Some of the demerits, on the other hand, are:

- Irresponsible release of information.
- Can promote illegal behavior (criminal acts, etc.).

When used in the normal way, an IP address is known even if the transaction is conducted anonymously. However, by using a certain type of mail forwarding service the mail can be sent from a completely different IP address.
In this case, the IP address can be investigated if a crime has been committed. If, for example, a mail forwarding service has been used to send a threatening letter, the IP address can be investigated by viewing

the log of the provider offering the service. However, it is possible that a false name and address were used when the IP address was obtained.

To prevent this and similar kinds of crimes, some are in favor of eliminating anonymity from the Internet. This is a very complicated problem, and some hold the opinion that eliminating the right to anonymity will also remove the right to free speech. There is also a way of thinking that says that because private information is leaked, the right to anonymity must be protected.

As this is an ongoing discussion and problem, no conclusion can be drawn, but considerations of actual laws to prevent crimes committed under the cover of anonymity are under way.

Ultimately, whether or not to use anonymity and under what circumstances are questions that are probably best left to the moral of the user.

Exercises

Q1 **Which of the following classifies the LAN according to the configuration (topology) of the communication network?**

a. 10BASE 5, 10BASE 2, 10BASE-T
b. CSMA/CD, token passing
c. Twisted-pair, coaxial, optical fiber
d. Bus, star, ring/loop
e. Router, bridge, repeater

Q2 **Which is the correct description of the special features of peer-to-peer LAN systems?**

a. Discs can be shared between computers but printers cannot be shared.
b. Suitable for large-scale LAN systems because this type is superior in terms of capabilities for scalability and reliability.
c. Suitable for construction of transaction processing systems with much traffic.
d. Each computer is equal in the connection.
e. LAN systems cannot be interconnected using bridge or router.

Q3 **Which of the LAN communication line standards possesses the following characteristics?**

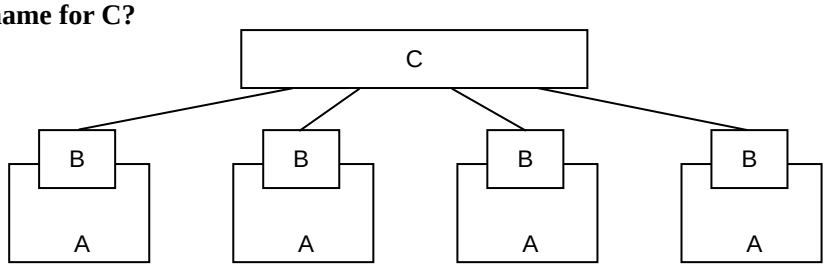
Transmission media	Coaxial cable
Topology	Bus
Transmission speed	10M bit/sec
Max. length of one segment	500 m
Max. number of stations for each segment	100

a. 10BASE 2 b. 10BASE 5 c. 10BASE-T d. 100BASE-T

Q4 **Which is the most appropriate description of the LAN access control method CSMA/CD?**

a. When collision of sent data is detected, retransmission is attempted following the elapse of a random time interval.
b. The node that has seized the message (free token) granting the right to transmit can send data.
c. Transmits after converting (by modulation) the digital signal into an analog signal.
d. Divides the information to be sent into blocks (called cells) of a fixed length before transmission.

Q5 **The figure shows an outline of a network with computers connected by means of 10BASE-T. If A in the figure is a computer and B is a network interface card, what is the appropriate device name for C?**



a. Terminator b. Transceiver c. Hub d. Modem

Q6 What is the appropriate description of a router?

a. Connects at the data-link layer and has traffic separating function.
b. Converts protocols, including protocols of levels higher than the transport layer, and allows interconnection of networks having different network architectures.
c. Connects at the network layer and is used for interconnecting LAN systems to wide area network.
d. Connects at the physical layer and is used to extend the connection distance.

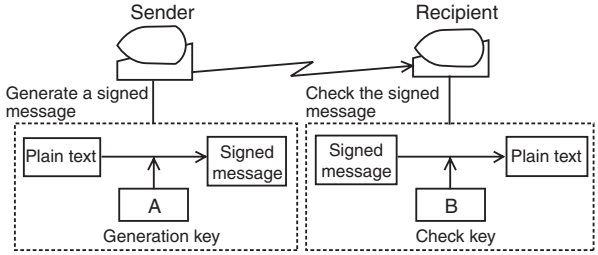
Q7 Which is the correct explanation of the role played by a DNS server?

a. Dynamically allocates the IP address to the client.
b. Relates the IP address to the domain name and host name.
c. Carries out communication processing on behalf of the client.
d. Enables remote access to intranets.

Q8 To use E-mail on the Internet, the two protocols SMTP and POP3 are used on mail servers. Which is the appropriate explanation of this?

a. The SMTP is a protocol used when one side is client, and POP 3 is a protocol used when both sides to transmit are mail servers.
b. SMTP is the protocol for the Internet, and POP3 is the protocol for LAN.
c. SMTP is the protocol used under normal circumstances when reception is possible, and POP3 is the protocol for fetching mail from the mailbox when connected.
d. SMTP is a protocol for receiving, and POP3 is a protocol for sending.

Q9 The illustration shows the structure of an electronic signature made by public key encryption. Which is the appropriate combination for "A" and "B"?



	A	B
a	Recipient's public key	Recipient's private key
b	Sender's public key	Sender's private key
c	Sender's private key	Recipient's public key
d	Sender's private key	Sender's public key

Q10 The Caesar cipher system is an encryption method in which an alphabetic letter is substituted by a letter located "N" places away. If "abcd" is encrypted with N=2, we get "cdef." What is the value of N, if we receive the Caesar encrypted "gewl" and decode it as "cash"?

a. 2 b. 3 c. 4 d. 5

Q11 **Which of the following operation methods is NOT appropriate for use with a computer system used with public telephone network?**

a. If a password is not modified within a previously specified period of time, it will no longer be possible to connect using this password.
b. When there is a request for connection, a callback will be made to a specific telephone number to establish the connection.
c. To ensure that the user does not forget the password, it is displayed on the terminal at the time of log on.
d. If the password is entered wrongly for a number of times determined in advanced, the line will be disconnected.

Q12 **What is the item used for detection and extermination of virus infections in connection with already-known computer viruses?**

a. Hidden file b. Screen saver c. Trojan horse
d. Michelangelo e. Vaccine

4 Communication Equipment and Network Software

Chapter Objectives

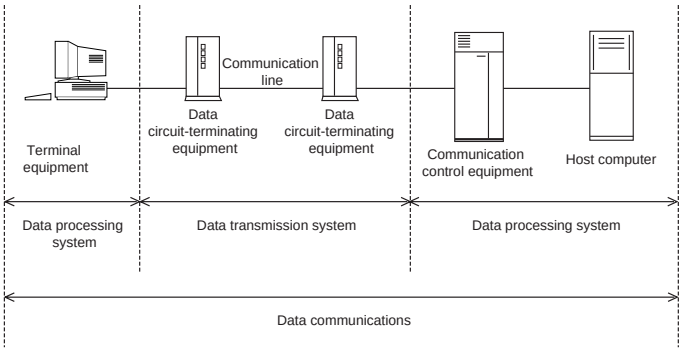
The elements making up network systems are broadly divided into hardware and software. The hardware elements are the communication equipment and devices comprising the network system, and the software elements are the network software that controls the network.
In this chapter you will learn about the elements that comprise a network.

① Understanding transmission media, and the types and roles played by communication equipment, such as DTE, DCE.
② Understanding the types and roles played by network software, such as network operating systems.

4.1 Communication Equipment

In today's information society exchange of information (data transmission) is supported by communications networks. Communication networks enables exchange of information between computers placed in remote locations. The devices making up these networks is called communications equipment. It is also true to say that the development of today's networks would not have been possible without the development of communications equipment.
Figure 4-1-1 shows the basic structure of a communication network.

Figure 4-1-1 Basic structure of a communication network

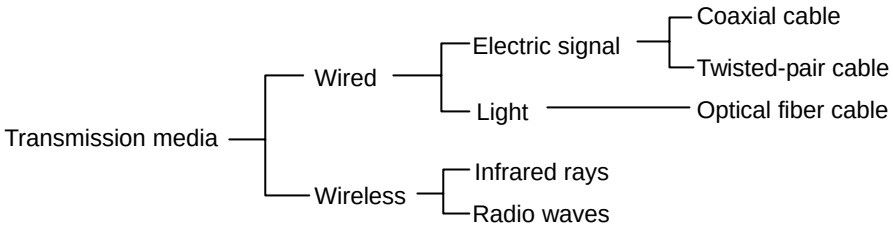


Communication cables used for the communication lines, data circuit-terminating equipment, transmission control equipment, and other peripheral equipment are explained in the following.

4.1.1 Transmission Media (Communication Cables)

Transmission media is indispensable for the conduct of data communication. This section explains transmission media and the physical transmission lines (communication cables) employed for communications using transmission media.
Transmission media is broadly divided into wired and wireless types depending on whether or not physical transmission lines (communications cables) are used.

Figure 4-1-2 Types of transmission media



(1) Wired

Some of the representative transmission media used in wired communication are:

- Twisted-pair cable
- Coaxial cable
- Optical fiber cable

The construction and characteristics of these are explained in the following:

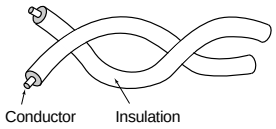
<Characteristics of wired communication>

- This is communication using communication cables, and it is used in a wide range of fields covering telephones, facsimile, communication networks, etc.
- The transmission capability is limited by the transmission media.
- In general, cables are resistant to noise.

① Twisted-pair cable

Twisted-pair cable is composed of two insulated conductors twisted around each other, and this structure prevents crosstalk.

Figure 4-1-3 Twisted-pair cable



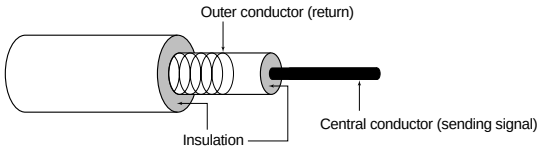
<Characteristics>

- Is less resistant to electromagnetic induction than coaxial cables and crosstalk or attenuation may occur
- Installation of cables is extremely easy
- The maximum transmission speed is several 10 Mbps (recently, types allowing about 100 Mbps have been introduced)
- Can be used with telephone subscribers' lines and LAN

② Coaxial cable

A coaxial cable consists of a central conductor inside an insulation tube surrounded by an outer conductor. The central conductor is for sending signals, and the outer conductor acts as a return path for signals carried by current. A coaxial cable may be used as a single cable, and sometimes several or several tens of cables are used together.

Figure 4-1-4 Coaxial cable



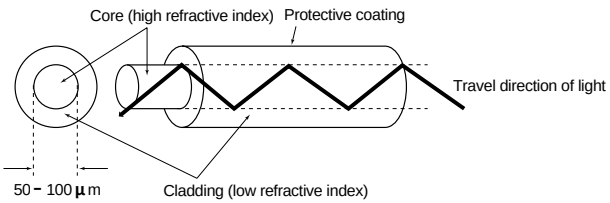
<Characteristics>

- Slightly susceptible to crosstalk and attenuation, and shows superior characteristics for high frequency signal transmission
- Installation of cables requires time and effort
- Maximum transmission speed is 100 Mbps.
- Used for trunk networks, CATV, LAN (Ethernet), etc.

③ Optical fiber cable

An optical fiber cable is made up of optical fibers each of which consists of two common-axis glass fibers (core and cladding) having different refractive indexes. Laser light pulse introduced into the fiber travels down the length of the fiber reflecting off to zig-zag along the inner surfaces.
An optical fiber cable consists of a bundle of optical fibers having the structure shown in Figure 4-1-5.

Figure 4-1-5 Optical fiber



<Characteristics>

- Information is transmitted in the form of light pulse instead of conventional electric signals.
- Compared to conventional telephone lines, optical fibers have a transmission capacity about 6000 times higher.
- Fiber is immune to electromagnetic interference and crosstalk.
- Lightweight and compact.
- Cable installation is easy but technicians must undergo technical training.
- Very resistant to thunder and noise
- Transmission speed is 100 Mbps or higher.
- Used in nationwide trunk networks (ISDN, etc.) and trunk LAN (FDDI, etc.), and the use of fiber cables is expected to become even more prevalent.

(2) Wireless

Wireless communication is employed where it is difficult to install cables (e.g., on remote islands) and in office environments.

<Characteristics of wireless communication>

- Comprise communication using radio waves and light, and is divided into satellite communications and terrestrial wireless communications.
- Installation of cables is not required, so wide-area communication is possible.
- Susceptible to electromagnetic interference and threat of tapping and bugging
- In the case of satellite communications, a relatively large transmission delay (about 250 milliseconds) occurs due to the distances involved. (For details, see Section 3.6.2 Telecommunications services in WAN.)
- Long waves, short waves, microwaves, infrared waves, etc. are used.
- Employed in mobile telephone systems and satellite communications, and wireless LAN using infrared rays, etc.

4.1.2 Peripheral Communication Equipment

Peripheral communication equipment is the general term for equipment and devices used for data transmission employing transmission media. Using these devices in the right places enables fast and reliable data transmission.

Peripheral communication equipment includes:

- Data terminal equipment
- Data circuit-terminating equipment
- Multiplexing equipment
- Switching equipment
- Branching equipment
- Distributing equipment

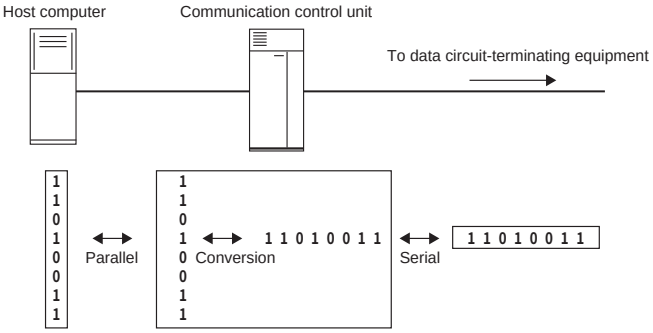
(1) Data terminal equipment (DTE)

Data terminal equipment is the general term for host computers, terminal equipment, and transmission control equipment that make up the data processing system with communication capabilities.

① Communication control unit (CCU)

A communication control unit performs serial-parallel conversion of data (assembly/disassembly of characters) at the time of transmission or reception. CCU is a data communications system using general-purpose computers, and also performs data error control, controls multiple lines, etc.

Figure 4-1-6 Data assembly and disassembly in a communication control unit (CCU)



(2) Data circuit-terminating equipment (DCE)

Data circuit-terminating equipment is the general term for equipment that connects data terminal equipment with communication lines. It has the function of converting the signals sent from the data terminal equipment into signals suitable for transmission.

① Modem (Modulator/DEModulator: MODEM)

A modem is a data circuit-terminating device used when data transmission is conducted with an analog line. This device modulates digital signals into analog signals, and demodulates analog signals into digital signals.

② DSU (Digital Service Unit)

A DSU is a data circuit-terminating device used when data transmission is conducted with a digital line. This device converts the digital signals used internally in the computer into digital signals suitable for transmission.

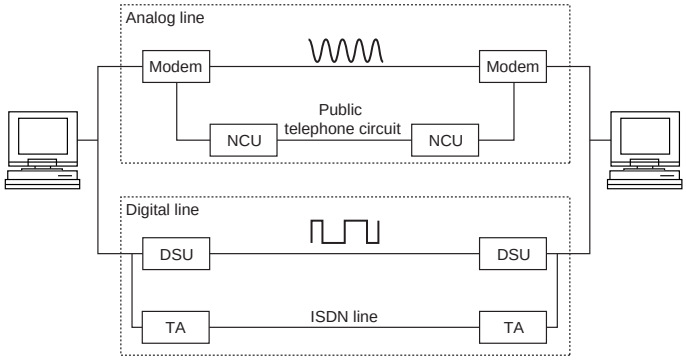
③ NCU (Network Control Unit)

A NCU is a data circuit-terminating device used when data transmission is conducted using a public telephone circuit. The NCU has dial functions for connecting to the line and the other party. Recently, the NSU is often found built into the modem and TA.

④ TA (Terminal Adapter)

A TA is a data circuit-terminating device used when data transmission is conducted using ISDN lines. The TA converts the signals of devices not compliant with ISDN lines into signals suitable for ISDN lines. Recently, the DSU is often built into the TA.

Figure 4-1-7 Data circuit-terminating equipment



(3) Other peripheral communication equipment

① Multiplexing equipment

Multiplexing equipment combines several low-speed communication lines into one high-speed communication line or divides one high-speed communication line into several low-speed communication lines. It is also called MUX (MUltipleXer).
Frequency division multiplexing (FDM) equipment and time division multiplexing (TDM) equipment are representative multiplexing equipment.

② Switching equipment

Switching equipment is equipment placed inside company buildings, etc. and it is used for switching lines. It is also called PBX (Private Branch eXchange) and has conventionally been used with public telephone circuits (to distribute calls received from outside lines, and switch extension lines, etc.). Recently, digital PBX equipment handling digital information are widely used.

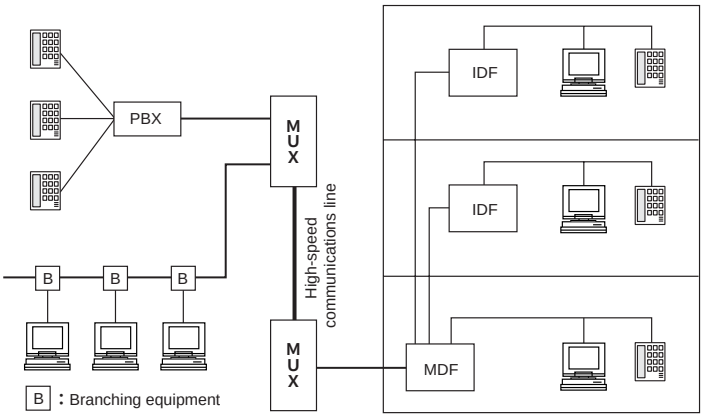
③ Branching equipment

Branching equipment is used when connecting multiple terminals to the same communications line in the multi-point configuration. Transceivers, etc. used for bus-topology LAN configuration belong to this category of equipment.

④ Distributing equipment

Distributing equipment is used to concentrate wiring of each floor when constructing networks inside buildings. The network is constructed by distributing cables from the MDF (Main Distributing Frame) to the IDF (Intermediate Distributing Frame) located on each floor.
Figure 4-1-8 shows a layout example with the various peripheral equipment employed.

Figure 4-1-8 Peripheral communications equipment



4.2 Network Software

A network need to be managed in an integrated manner from both hardware and software viewpoints. Network software is the general term for applications for networks management.
Network software is divided into:

- Network management systems
- Network OS

4.2.1 Network Management

The five functions required for network management are defined as:

- Configuration management
  Collection and management of information on current network resources as well as on changes in network configuration.
- Fault management
  Monitoring system errors to perform automated recovery process as well as to notify to prevent possible failure so as to make proactive remedy possible.
- Security management
  Monitoring the state of access to the network to protect against illegitimate access to the resources (eavesdropping, illegal use, impersonalization, etc.).
- Performance management
  Monitoring response time and traffic load to manage and maintain the performance of the network.
- Service charge management
  Monitoring and analysis of information indicating the use of network resources and help management of deciding service charges to users.

A network management software is installed to take advantage of these functionalities.

(1) Network management software

Network management systems encompass systems using the SNMP (Simple Network Management Protocol) and proprietary management systems developed by software vendors.
Representative network management systems are:

- Sun Net Manager
- Net View
- NMS
- HP OpenView

① Sun Net Manager

Sun Net Manager is a network management system developed by Sun Microsystems, Inc. in the USA. It uses SNMP and is mainly used on TCP/IP networks. Network is managed by UNIX workstations and third party products based on this technology have also been developed.

② Net View

Net View was developed by IBM in the USA and is a vendor-developed network management system that is mainly used on a host computer-centric networks. As an integrated system for management by a host computer, it provides a variety of functionalities.

③ NMS (Network Management System)

NMS is a vendor-developed network management system developed by Novell, Inc. in the USA that is mainly used for personal computer LAN. It is used for management of the company's network OS called Netware (explained later).

④ HP OpenView

HP OpenView is a network management system developed by Hewlett-Packard in the USA. It visualizes network environment by automatically creating and updating network maps, in different detailed levels. This eases network operators' tasks with such functionalities as failure detection, operation data collection etc.

(2) Network management tools

Network management tools are tools used for collection and analysis of information used for network management.
Network management tools are divided into:

- SNMP management tools
- Vendor-specific management tools

SNMP management tools are compliant with the standard protocol SNMP. These systems use LAN analyzers, etc. to measure traffic, evaluate the performance of equipment by sending pseudo packets, and identify the cause of errors by using ping commands.
Vendor-specific management tools are tools developed by individual vendors. There is little compatibility between these tools and they are not suitable for networks in which the products of several vendors are mixed. However, in the case of networks built around one vendor, these tools are often more efficient than SNMP compliant tools.

4.2.2 Network OS (NOS)

Network OS (Network Operating System (NOS)) is basic software that already contains the basic functionalities required for building effective network.
The basic NOS functions are:

- Data sharing: Allow sharing of external storage devices such as hard disks on a LAN.
- Printer sharing: Allow sharing of printers on a LAN.
- Security management: Management of users' access right and usage, etc.

Which NOS to introduce must be decided based on considerations of the scale of the LAN to be built, the performance level demanded for the network system, etc.

(1) Functions and characteristics of network OS

The two representative network operating systems are:

- Netware
- Windows NT/Windows 2000

① Netware

Netware is a network operating system that was developed by Novell, Inc., and it is the most commonly used system for sharing of data and printers on personal computer LAN systems. In relation to security it offers functions such as disc mirroring, transaction tracking, etc.
In addition to the dedicated Netware protocols, such as IPX, SPX, the NOS also supports standard protocols like TCP/IP and OSI, and vendor-specific protocols such as SNA (IBM Corporation), AppleTalk (Apple Computers, Inc.), etc.

② Windows NT/Windows 2000

Windows NT/Windows2000 are network operating systems that were developed by Microsoft Corporation in the USA. To be exact, those are operating systems designed for use in network environments. These NOS inherit the Windows operating environment and enable preemptive multitasking and protected memory for safety and reliability.
Representative functions comprise:

- Virtual memory
  By allocating virtual memory space to each application, system errors of one application will not affect other applications.
- NTFS (NT File System)
  In addition to the capability for setting security for each file, the file management system also has functions for recovering damaged files.

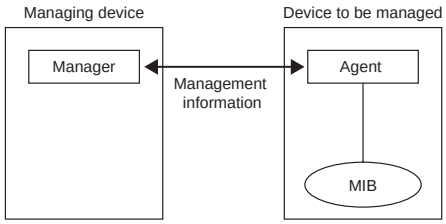
Windows NT/Windows 2000 use the NetBEUI (IBM Corporation) network protocol.

(2) Network management protocol (SNMP)

SNMP (Simple Network Management Protocol) is the most typical network management protocol. SNMP is used on TCP/IP network, but many systems conform to this protocol.
SNMP is comprised of:

- Manager
  Management program operating on the managing device.
- Agent
  Program operating on the device to be managed.
- MIB (Management Information Base)
  Defines the structure of the database with the information to be managed.

Figure 4-2-1
SNMP image model



Management by SNMP is performed by the exchange of information between the manager and the agent (the UDP protocol is used for this exchange).
There are three types of exchanges taking place between the manager and the agent.

- Information collection
  To collect the information for management, the manager sends the "Get Request" packet. In response to this, the agent provides the information by the "Get Response" packet.
- Setting information
  To set the information for management, the manager sends the "Set Request" packet. In response to this instruction, the agent modifies the setting and confirms the setting by the "Set Response" packet.
- Interruption from object under management
  By sending the "Trap" packet, the agent can request an interruption to the manager.

Exercises

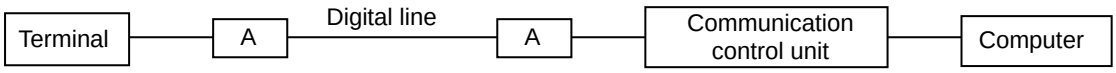
Q1 **Which of the following explanations of devices used in data communications systems covers DTE?**

a. It is a switching device used in line switching technique.
b. It is a computer or terminal having communications capabilities.
c. It is a device that performs multiplexing slow speed or medium speed signals, and transmits to the other party using a high-speed digital line.
d. It is a device that coordinates signal format between a data transmission line and a terminal. It is also called a circuit-terminating device.
e. It is a device that disassembles packet data into non-packet data, and vice versa, using the packet switching.

Q2 **Which of the following explanations of devices comprising networks describes communication control unit (CCU)?**

a. Connects data terminal equipment (such as a computer) to a digital circuit to allow fully digital communications
b. Dials the telephone number of the terminal in order to call up the terminal.
c. Performs modulation of digital signals into analog signals and vice versa.
d. Performs assembly and disassembly of transmission data and error control of the data.

Q3 **What is the name of the circuit-terminating device A in the following diagram of a digital line?**



a. DSU b. DTE c. NCU d. PAD

Q4 **Which is the device for connecting public telephone circuits with extension telephones and interconnecting extension telephones?**

a. IDF b. MDF c. MUX d. PBX

Q5 **Which is the network management protocol widely used on TCP/IP network environments?**

a. ARP b. MIB c. PPP d. SNMP

Part 2

DATABASE TECHNOLOGY

Introduction

This series of textbooks has been developed based on the Information Technology Engineers Skill Standards made public in July 2000. The following four volumes cover the whole contents of fundamental knowledge and skills required for development, operation and maintenance of information systems:

No. 1: Introduction to Computer Systems
No. 2: System Development and Operations
No. 3: Internal Design and Programming--Practical and Core Bodies of Knowledge--
No. 4: Network and Database Technologies
No. 5: Current IT Topics

This part gives easy explanations systematically so that those who are learning database technology for the first time can easily acquire knowledge in these fields. This part consists of the following chapters:

1 Overview of Database

Chapter Objectives

The concept of databases came into being in the second half of 1960s, and since then numerous improvements have been made for more efficient processing of larger amounts of data.
In this chapter, we get an overall picture of databases.

① Grasping the concept of databases by comparing files and databases, and understanding the structures and characteristics of data models to build databases.
② Understanding data normalization and ERD which are the most important things in database design.
③ Understanding the set and relational operations necessary for database manipulations.

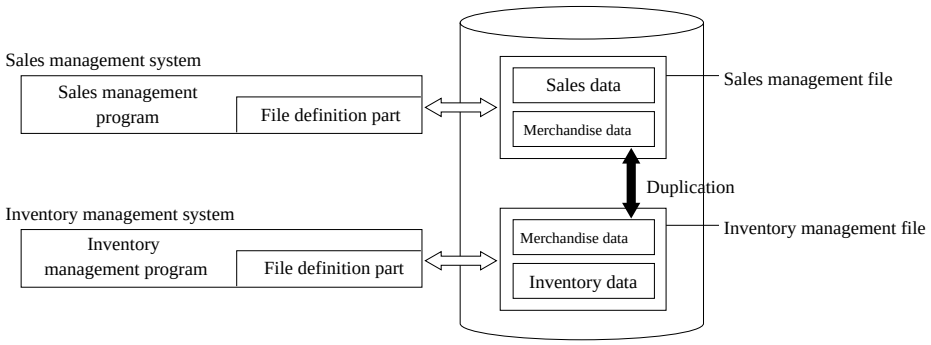
1.1 Purpose of Database

Although we now call a collection of data a database in our daily lives, the word 'database' first appeared in the second half of 1960's.
This section, we'll present the overview and functionalities of the databases which have come to be utilized for efficient processing as the computer application area has expanded.

(1) Problems of file-based systems

In the past file-based systems were created to process large amounts of data efficiently. In such systems, data processing was performed by creating files on magnetic tapes and disks.

Figure 1-1-1 File-Based System



However, as the scale of business and the need to process and operate data for various purposes in various formats increased, some serious problems arised.
The diversification of the purposes and formats of data processing and operation also caused problems.
File-based systems developed for particular uses, for example, have the following problems:

- Because files are created for each application system, a set of same data are recorded in each system, and hardware resources such as magnetic disks are wasted.
- As the data recorded in files is independently changed by the corresponding system, the contents of some data items can be inconsistent with those of the same data items in a different system.
- Because the file definition is included in the program, if file contents and record formats need to be modified, the program also has to be modified.

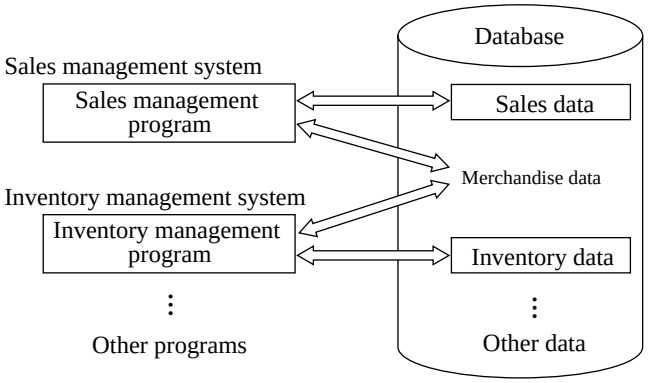
To solve these problems, an idea of database was conceived.

(2) Purposes and functions of database

To solve problems of file-based systems, the following measures are required:

- To eliminate duplication of data items in the related files
- To maintain strict consistency of file contents
- To make programs independent of files

Figure 1-1-2
Concept of Database



More specifically, the following functions and controls are required:

- Data sharing
  By centrally managing files used in an organization data maintenance workload is reduced and data consistency can be maintained.
- Data independent of programs
  By making programs independent of centrally managed databases, program maintenance and modification are become easier.
- Data integrity and failure recovery
  Data integrity must be guaranteed even in the case of supporting a large number of user access, and fast recovery must be made in case of failures.
- Data confidentiality
  Depending on the data contents, access right control is required to allow access only by authorized users.

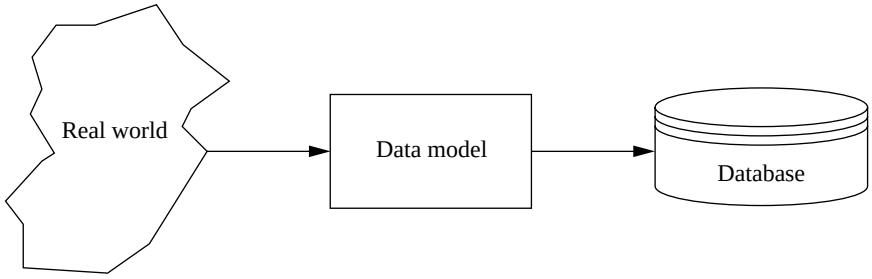
Taking these factors into consideration, databases are built on large-scale direct access storage devices (DASD) such as magnetic disk devices with large storage capacity.

1.2 Database Model

To build a database, a framework which defines the complex real world information and the operations on it is required. This framework is called a "data model." The purposes of data model are as follows:

- To provide conventions for describing data and its structure.
- To define a set of operations for the data represented based on the conventions.
- To provide a framework to describe semantic constraints to correctly represent the information in the real world.

Figure 1-2-1
Data Model



The major roles of a data model can be summarized in the following two items:

- An interface between a database management system (Database Management System software to manage databases: the details explained in Chapter 3) and users. This enables data description and manipulations at the logical level, independent of the physical data storage formats and data retrieval procedures. With this, people can use database without knowing physical-level contents.
- The tool to model the real world
  This provides the framework to represent the data structure and semantics, reflecting the information used in the targeted world as naturally as possible.

1.2.1 Data Modeling

To build a database, the following procedures are carried out to decide its contents:

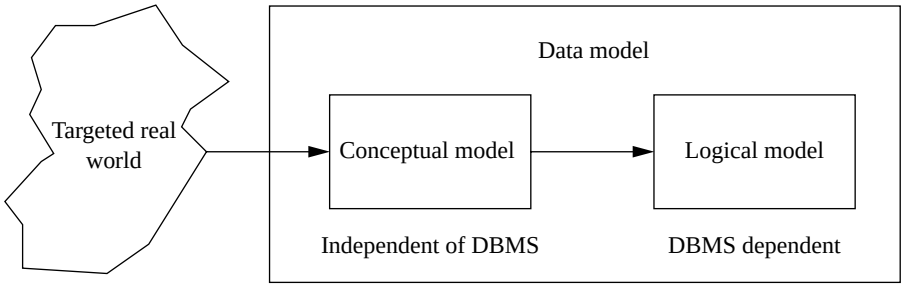
1. Investigate and analyze the complicated information structure, various applications and requirements of the real world.
2. Select information to be arranged into a database.
3. Appropriately structuralize selected data.

These procedures are called "database design." As a result, a mini-world is constructed by modeling and abstracting the targeted world. A series of these processes is generally called "data modeling."
In a database system, data must be described with the manageable data model provided by DBMS. However, describing directly the complex data structure in the real world with the data model provided by DBMS may limit the degree of freedom in representation.

1.2.2 Conceptual Data Model

Even after the completion of a database, natural expressions without constraints imposed by DBMS are necessary to understand the structure and the meaning of data in a database. For this reason, data modeling is generally conducted through at least two steps (Figure 1-2-2).
First, how the target data look like is depicted independently from the data model provided by the DBMS. This is called a "conceptual model." Next, convert this conceptual model into the data model provided by DBMS. This converted model is called a "logical model." This corresponds to the conceptual schema of the three-layer schema mentioned later. A DBMS currently corresponds to either the hierarchical data model, the network data model, or the relational data model.

Figure 1-2-2 Creation Process of Data Model

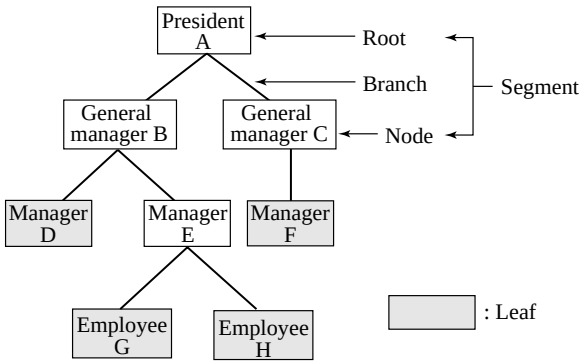


1.2.3 Logical Data Model

(1) Hierarchical data model

The hierarchical data model is a data model employed in IMS (Information Management Systems) which was made public by IBM in 1968. A data set structured based on the hierarchical data model is called the hierarchical database.

Figure 1-2-3
Structure of Hierarchical Data Model



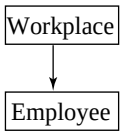
The hierarchical data model consists of the following three kinds of elements:

- Root
  This is the highest-level data, and data retrieval basically begins from the "root."
- Node
  This is the middle-level data. It always has its parent and child (children).
- Leaf
  This is the terminal data, and no data exists below the "leaf" level.

Root and node are sometimes referred to as "segment."
Data are connected by the pointer called branch. The relationship of "root" - "node" and "node" - "leaf" is

parent and child. A parent can have more than one child, but each child cannot have more than one parent. This is called a parent-child relationship. Therefore, only a single path exists to reach a certain data item.
The Bachman diagram is used to express a hierarchical data model. As shown in Figure 1-2-4, a rectangular box shows a record, and the parent-child relationship is shown by connecting the records with an arrow.

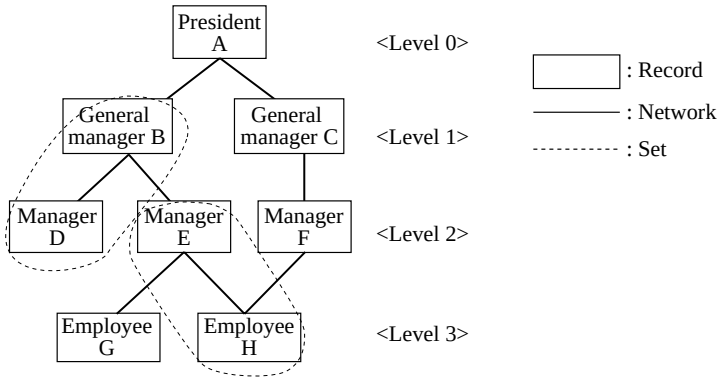
Figure 1-2-4
Bachman Diagram



(2) Network Data Model

A network data model is the one which was employed for IDS (Integrated Data Store) developed by GE in 1963. A data set integrated and based on the network data model is called a network database. Since a network database is designed in accordance with the specifications proposed by CODASYL (Conference on Data Systems Languages), it is also called a CODASYL-type database.
In the network data model, the part corresponding to the segment in the hierarchical data model is called a "record" and records are connected by "network." As records are defined as a parent-child set called "set," a child can have more than one parent. Each hierarchy is called a "level." The levels are defined as level 0, level 1, level 2, ..., and level n, from the highest level towards the lower levels.

Figure 1-2-5 Data Structure of Network Data Model

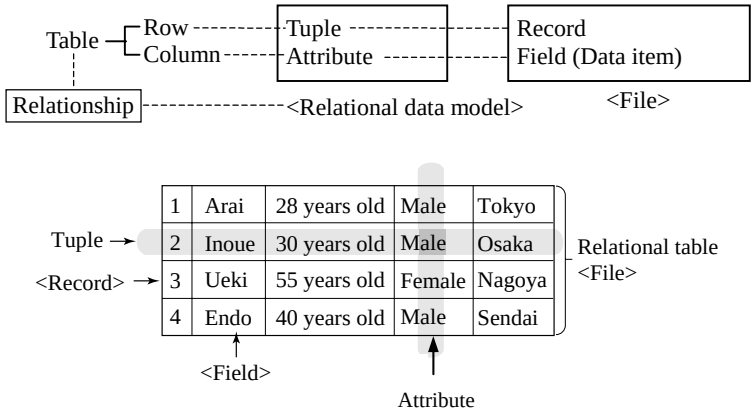


While only one access path to the data exists in the hierarchical data model, multiple access paths can be set in the network data model.

(3) Relational data model

The relational data model is a data model which was proposed by E. F. Codd of IBM in 1970. A data set structured based on the relational data model is called the relational database.
While segments and records are connected by branches and networks in the hierarchical data model and network data model, tables are used in the relational data model. A table consists of rows and columns. A "row" corresponds to a record and a "column" corresponds to a field in a file. In the relational data model, a table is called a "relation," a row a "tuple," and a column an "attribute."

Figure 1-2-6 Structure of Relational Data Model

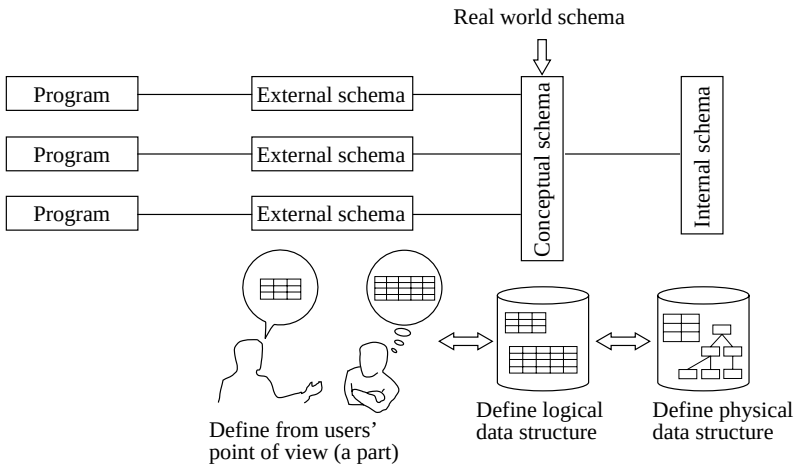


As the structure of the relational data model is simple, data can be freely combined and the operation method is simple enough for end users. The relational data model, therefore, is widely used in various systems ranging from mainframes to personal computers.

1.2.4 3-Tier Schema

As for data modeling, ANSI-SPARC (American National Standard Institute/Systems Planning And Requirements Committee) proposed the 3-tier schema (Figure 1-2-7) in 1978, and it is widely accepted at present.

Figure 1-2-7
3-Tier Schema



In the 3-tier schema, the basic structure of the database system is layered into the following three schemata:

① Conceptual schema

The conceptual schema logically defines the data of the whole real world necessary for the computer system to process. It defines data from its own viewpoint, without taking into consideration the characteristics of computers and programs. One conceptual schema corresponds to one database.

② External schema

The external schema defines the database from the viewpoint of the program using the database. The external schema is considered as part of the data structure defined by the conceptual schema.

③ Internal schema

The internal schema defines how to store physically on storage devices the database defined by the conceptual schema. One internal schema corresponds to one conceptual schema.

The word "schema" as used here means "database description."

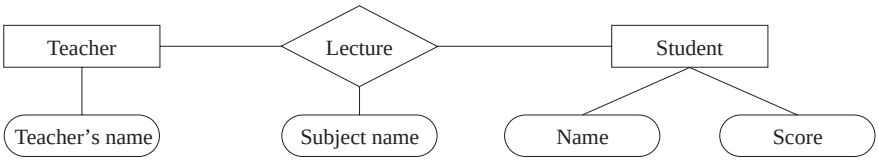
1.3 Data Analysis

1.3.1 ERD

The "Entity-Relationship model (E-R model)" is a diagram expressing the conceptual model, independent of DBMS. The entity-relationship diagram (ERD) is used here. ERD represents the world to be modeled in terms of entities, their relationships and their attributes.
The E-R model consists of the following three elements:

- Entities
  Entities are objects to be managed as depicted by rectangles.
- Relationships
  A relationship indicates a relation between an entity and another entity or a relationship between an entity and a relationship, and is depicted by diamonds.
- Attributes
  Attributes are characteristics of entities and of relationships, and are depicted by ovals.

Figure 1-3-1
E-R Model



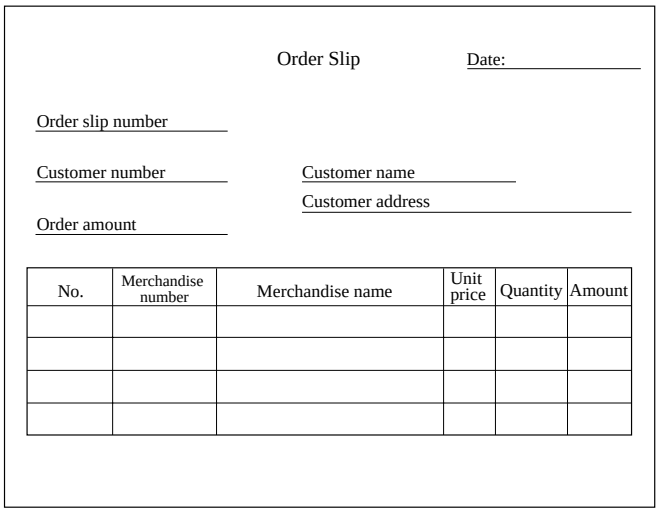
The E-R model in Figure 1-3-1 shows the following:
- "Teacher" and "Student" are connected by "Lecture."
- "Teacher" has "Teacher's name."
- "Student" has "Name" and "Score."
- "Lecture" has "Subject name."

There are three types of relationships: "one-to-one," "one-to-many," and "many-to-many." In Figure 1-3-1, if one teacher gives a lecture to more than one student, and a student receives lectures from more than one teacher, the relationship between "Teacher" and "Student" is "many-to-many."

1.3.2 Normalization

To design a database that fits the users' purposes, the database structure must be thoroughly examined. If not fully examined, users may make demands for other ways to use the database after loading the actual data. Such modifications tend to be very time-consuming and inefficient.
Company A, for example, is a distributor of office automation equipment and uses the order slip shown in Figure 1-3-2.

Figure 1-3-2
Order Slip of Company A



Order Slip Date:

Order slip number

Customer number Customer name

Customer address

Order amount

No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount

The characteristics of the merchandises, customers, and order-receiving data of Company A are as follows:

- "Customers" are lasting clients and each customer has its own "customer number."
- Each "merchandise" has its "merchandise number" and "unit price."
- "No." is a sequential number for order received for "merchandises."
- "Amount" is calculated by "unit price" × "quantity."
- "Order amount" is the total of "amounts."

Company A plans to design a database of these order slips and related data for efficient order management. For example, when designing a database by the relational data model after deciding the purpose of applications, tables are created by classifying necessary data items to manage. Normalization of data is necessary in this phase. The purpose of normalization is to eliminate the redundancy from data and achieve integrity and consistency of data.

There are five stages for the normalization of a relational database:

- The 1st normalization
- The 2nd normalization
- The 3rd normalization
- The 4th normalization
- The 5th normalization

However, since a relational database requires only the 1st to the 3rd normalization, explanations up to the 3rd normalization are given here.

In the example of Company A, the data items in the order slip can be arranged in a table as shown in Figure 1-3-3.

Figure 1-3-3 Table of Order Slip of Company A (order detail table)

Order slip number	Customer number	Customer name	Customer address	Date	Order amount	No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
						No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
						No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount

The database in this phase is called the unnormalized form (non-1st normal form).

The underlined items here are key items. Key items means the items used to identify records. Thus, if a certain data item is identified, other data items are uniquely determined. This is called "functional dependency (FD)."

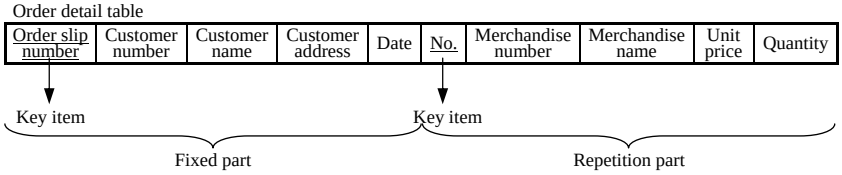
(1) The 1st normalization

There are fixed parts and repetition parts in the unnormalized data as follows:

- Fixed part
  Order slip number, customer number, customer name, customer address, date, and order amount
- Repetition part
  No., merchandise number, merchandise name, unit price, quantity, and amount

In the 1st normalization, data is divided into the fixed part and the repetition part, and the fixed part is overlapped with the repetition part. In this stage, both amount and order amount are excluded because they are decided by calculation of other items, and do not have to be included in the database.
As a result of the 1st normalization, the order slip of Company A is arranged as shown in Figure 1-3-4. This is called the 1st normal form.

Figure 1-3-4
The 1st Normal Form



In the order slip of Company A (unnormalized form), only the slip number was specified as a key item. However, in the 1st normal form, the order slip number and No. are specified as key items because the order slip number cannot specify the repetition items (No., merchandise number, merchandise name, unit price, and quantity). Therefore, combinations of multiple data items such as "slip number + No." are used as concatenated keys.

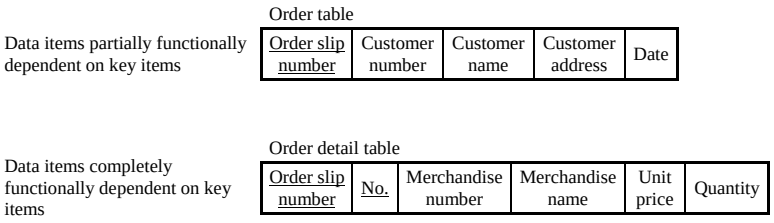
(2) The 2nd normalization

In the 2nd normalization, data items are divided into those data items completely functionally dependent on the key items ("slip number" + "No.") and the data items partially dependent on the key items (functionally dependent on either of the "slip number" or "No.").

- Data items completely functionally dependent on key items
  Merchandise number, merchandise name, unit price, quantity
- Data items partially functionally dependent on key items ("order slip number")
  Customer number, customer name, customer address, date

The result of the 2nd normalization is shown in Figure 1-3-5. This is called the 2nd normal form.

Figure 1-3-5
The 2nd
Normal Form



(3) The 3rd normalization

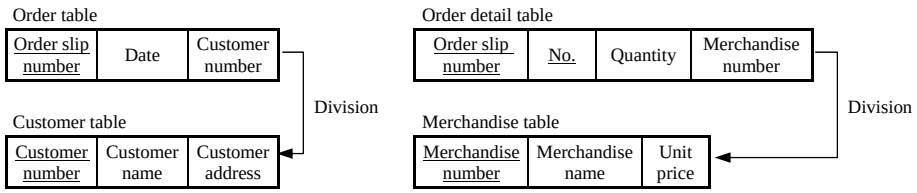
In the 3rd normalization, data items functionally dependent on the data items other than key items, are divided from the data in the 2nd normal form.
The 3rd normalization procedure is as follows:

1. If the customer number is identified, the customer name and the customer address are uniquely determined. So, the order table is divided into the groups of "order slip number and date" and "customer number, customer name, and customer address." "Customer number" is included in the order table to coordinate it to have relationship with the customer table.

2. If the merchandise number is identified, the merchandise name and the unit price are uniquely determined. So, the order table is divided into the groups of "order slip number, No., and quantity" and "merchandise number, merchandise name, and unit price." "Merchandise number" is included in the order table to coordinate it to have relationship with the merchandise table.

The result of the 3rd normalization is shown in Figure 1-3-6. This is called the 3rd normal form.

Figure 1-3-6
The 3rd Normal Form



As the above example, the redundancy of the data can be eliminated by data normalization. Divided tables can be reproduced in the original table in the unnormalized form by means of key items.

Concrete data examples in line with the steps of normalization are shown below. By reference to these examples, we can firmly grasp the image of normalization.

Page 1

November 10, 2000

Order Slip

Order slip number 120131
Customer number 9321
Customer name: Office Ginza Co., Ltd.
Customer address: 1-2-3 Ginza, Chuo-ku

OA Sales Co., Ltd.
138 Soto-kanda, Chiyoda-ku, Tokyo

Order amount: ¥2,782,000-

No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
1	H1010	Notebook-size personal computer	250,000	4	1,000,000
2	H2010	Laser printer	300,000	2	600,000
3	S1040	Integrated software	100,000	1	100,000
4	SP002	A-4 size paper	3,000	2	6,000
5	SP003	B-5 size paper	2,500	4	10,000
6	H0030	Mouse	4,000	4	16,000
7	H1020	Desktop personal computer	180,000	5	900,000
8	S1010	Word processing software	30,000	5	150,000
9		The space below is left blank.			
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Page 2

November 18, 2000

Order Slip

Order slip number 120132
Customer number 8109
Customer name: Daiba Sangyo Co., Ltd.
Customer address: 3-2-1 Daiba, Minato-ku

OA Sales Co., Ltd.
138 Soto-kanda, Chiyoda-ku, Tokyo

Order amount: ¥2,773,000-

No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
1	H1010	Notebook-size personal computer	250,000	6	1,500,000
2	H2010	Laser printer	300,000	2	600,000
3	N1030	Terminal adapter	20,000	1	20,000
4	S1040	Integrated software	100,000	4	400,000
5	N0010	LAN cable	1,500	6	9,000
6	N0020	LAN card	5,000	6	30,000
7	S1020	Spreadsheet software	50,000	2	100,000
8	S1010	Word processing software	30,000	2	60,000
9	SP002	A-4 size paper	3,000	10	30,000
10	H0030	Mouse	4,000	6	24,000

Page 3

December 12, 2000

Order Slip

Order slip number 120133
Customer number 9321
Customer name: Office Ginza Co., Ltd.
Customer address: 1-2-3 Ginza, Chuo-ku

OA Sales Co., Ltd.
138 Soto-kanda, Chiyoda-ku, Tokyo

Order amount: ¥310,500-

No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
1	H1020	Desktop personal computer	180,000	1	180,000
2	N1030	Terminal adapter	20,000	1	20,000
3	N0010	LAN cable	1,500	1	1,500
4	N0020	LAN card	5,000	1	5,000
5	S1040	Integrated software	100,000	1	100,000
6	H0030	Mouse	4,000	1	4,000
7		The space below is left blank.			
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Page 4

December 12, 2000

Order Slip

Order slip number 120134
Customer number 9321
Customer name: Office Ginza Co., Ltd.
Customer address: 1-2-3 Ginza, Chuo-ku

OA Sales Co., Ltd.
138 Soto-kanda, Chiyoda-ku, Tokyo

Order amount: ¥1,028,500-

No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
1	H1010	Notebook-size personal computer	250,000	2	500,000
2	S1040	Integrated software	100,000	1	100,000
3	H0030	Mouse	4,000	2	8,000
4	SP002	A-4 size paper	3,000	5	15,000
5	SP003	B-5 size paper	2,500	5	12,500
6	N0010	LAN cable	1,500	2	3,000
7	N0020	LAN card	5,000	2	10,000
8	H2010	Laser printer	300,000	1	300,000
9	S1010	Word processing software	30,000	1	30,000
10	S1020	Spreadsheet software	50,000	1	50,000

Order slip/Page 1

Order slip number	Customer number	Customer name	Customer address	Date	Order amount	No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	2,782,000	1	H1010	Notebook-size personal computer	250,000	4	1,000,000
						2	H2010	Laser printer	300,000	2	600,000
						3	S1040	Integrated software	100,000	1	100,000
						4	SP002	A-4 size paper	3,000	2	6,000
						5	SP003	B-5 size paper	2,500	4	10,000
						6	H0030	Mouse	4,000	4	16,000
						7	H1020	Desktop personal computer	180,000	5	900,000
						8	S1010	Word processing software	30,000	5	150,000

Order slip/Page 2

Order slip number	Customer number	Customer name	Customer address	Date	Order amount	No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	2,773,000	1	H1010	Notebook-size personal computer	250,000	6	1,500,000
						2	H2010	Laser printer	300,000	2	600,000
						3	N1030	Terminal adapter	20,000	1	20,000
						4	S1040	Integrated software	100,000	4	400,000
						5	N0010	LAN cable	1,500	6	9,000
						6	N0020	LAN card	5,000	6	30,000
						7	S1020	Spreadsheet software	50,000	2	100,000
						8	S1010	Word processing software	30,000	2	60,000
						9	SP002	A-4 size paper	3,000	10	30,000
						10	H0030	Mouse	4,000	6	24,000

Order slip/Page 3

Order slip number	Customer number	Customer name	Customer address	Date	Order amount	No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	310,500	1	H1020	Desktop personal computer	180,000	1	180,000
						2	N1030	Terminal adapter	20,000	1	20,000
						3	N0010	LAN cable	1,500	1	1,500
						4	N0020	LAN card	5,000	1	5,000
						5	S1040	Integrated software	100,000	1	100,000
						6	H0030	Mouse	4,000	1	4,000

Order slip/Page 4

Order slip number	Customer number	Customer name	Customer address	Date	Order amount	No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	1,028,500	1	H1010	Notebook-size personal computer	250,000	2	500,000
						2	S1040	Integrated software	100,000	1	100,000
						3	H0030	Mouse	4,000	2	8,000
						4	SP002	A-4 size paper	3,000	5	15,000
						5	SP003	B-5 size paper	2,500	5	12,500
						6	N0010	LAN cable	1,500	2	3,000
						7	N0020	LAN card	5,000	2	10,000
						8	H2010	Laser printer	300,000	1	300,000
						9	S1010	Word processing software	30,000	1	30,000
						10	S1020	Spreadsheet software	50,000	1	50,000

The 1st Normal Form

Order detail table

	Order slip number	Customer number	Customer name	Customer address	Date	No.	Merchandise number	Merchandise name	Unit price	Quantity
Page 1	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	1	H1010	Notebook-size personal computer	250,000	4
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	2	H2010	Laser printer	300,000	2
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	3	S1040	Integrated software	100,000	1
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	4	SP002	A-4 size paper	3,000	2
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	5	SP003	B-5 size paper	2,500	4
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	6	H0030	Mouse	4,000	4
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	7	H1020	Desktop personal computer	180,000	5
	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000	8	S1010	Word processing software	30,000	5
Page 2	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	1	H1010	Notebook-size personal computer	250,000	6
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	2	H2010	Laser printer	300,000	2
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	3	N1030	Terminal adapter	20,000	1
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	4	S1040	Integrated software	100,000	4
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	5	N0010	LAN cable	1,500	6
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	6	N0020	LAN card	5,000	6
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	7	S1020	Spreadsheet software	50,000	2
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	8	S1010	Word processing software	30,000	2
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	9	SP002	A-4 size paper	3,000	10
	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000	10	H0030	Mouse	4,000	6
Page 3	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	1	H1020	Desktop personal computer	180,000	1
	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	2	N1030	Terminal adapter	20,000	1
	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	3	N0010	LAN cable	1,500	1
	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	4	N0020	LAN card	5,000	1
	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	5	S1040	Integrated software	100,000	1
	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	6	H0030	Mouse	4,000	1
Page 4	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	1	H1010	Notebook-size personal computer	250,000	2
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	2	S1040	Integrated software	100,000	1
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	3	H0030	Mouse	4,000	2
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	4	SP002	A-4 size paper	3,000	5
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	5	SP003	B-5 size paper	2,500	5
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	6	N0010	LAN cable	1,500	2
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	7	N0020	LAN card	5,000	2
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	8	H2010	Laser printer	300,000	1
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	9	S1010	Word processing software	30,000	1
	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000	10	S1020	Spreadsheet software	50,000	1

The 2nd Normal Form

Order table

	Order slip number	Customer number	Customer name	Customer address	Date
Page 1	120131	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	11/10/2000
Page 2	120132	8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku	11/18/2000
Page 3	120133	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000
Page 4	120134	9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku	12/12/2000

Order detail table

	Order slip number	No.	Merchandise number	Merchandise name	Unit price	Quantity
Page 1	120131	1	H1010	Notebook-size personal computer	250,000	4
	120131	2	H2010	Laser printer	300,000	2
	120131	3	S1040	Integrated software	100,000	1
	120131	4	SP002	A-4 size paper	3,000	2
	120131	5	SP003	B-5 size paper	2,500	4
	120131	6	H0030	Mouse	4,000	4
	120131	7	H1020	Desktop personal computer	180,000	5
	120131	8	S1010	Word processing software	30,000	5
Page 2	120132	1	H1010	Notebook-size personal computer	250,000	6
	120132	2	H2010	Laser printer	300,000	2
	120132	3	N1030	Terminal adapter	20,000	1
	120132	4	S1040	Integrated software	100,000	4
	120132	5	N0010	LAN cable	1,500	6
	120132	6	N0020	LAN card	5,000	6
	120132	7	S1020	Spreadsheet software	50,000	2
	120132	8	S1010	Word processing software	30,000	2
	120132	9	SP002	A-4 size paper	3,000	10
	120132	10	H0030	Mouse	4,000	6
Page 3	120133	1	H1020	Desktop personal computer	180,000	1
	120133	2	N1030	Terminal adapter	20,000	1
	120133	3	N0010	LAN cable	1,500	1
	120133	4	N0020	LAN card	5,000	1
	120133	5	S1040	Integrated software	100,000	1
	120133	6	H0030	Mouse	4,000	1
Page 4	120134	1	H1010	Notebook-size personal computer	250,000	2
	120134	2	S1040	Integrated software	100,000	1
	120134	3	H0030	Mouse	4,000	2
	120134	4	SP002	A-4 size paper	3,000	5
	120134	5	SP003	B-5 size paper	2,500	5
	120134	6	N0010	LAN cable	1,500	2
	120134	7	N0020	LAN card	5,000	2
	120134	8	H2010	Laser printer	300,000	1
	120134	9	S1010	Word processing software	30,000	1
	120134	10	S1020	Spreadsheet software	50,000	1

The 3rd Normal Form

Order table

	Order slip number	Date	Customer number
Page 1	120131	2000/11/10	9321
Page 2	120132	2000/11/18	8109
Page 3	120133	2000/12/12	9321
Page 4	120134	2000/12/12	9321

Customer table

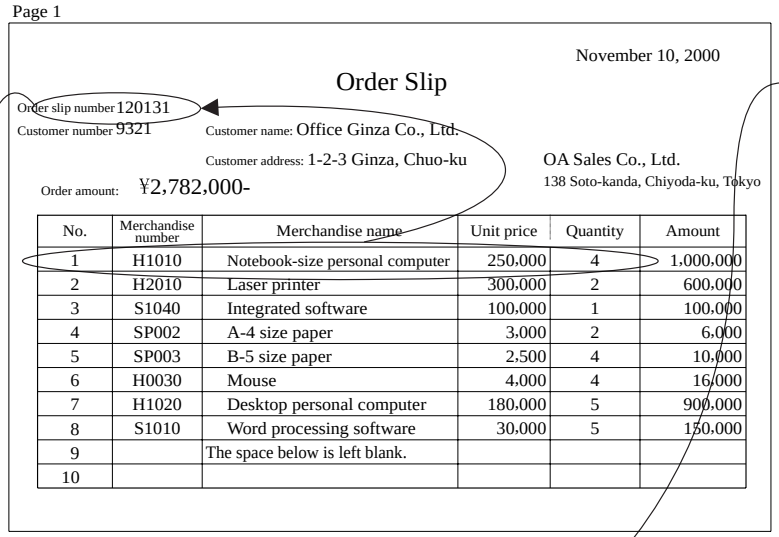
Customer number	Customer name	Customer address
9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku
8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku

Order detail table

	Order slip number	No.	Quantity	Merchandise number
Page 1	120131	1	4	H1010
	120131	2	2	H2010
	120131	3	1	S1040
	120131	4	2	SP002
	120131	5	4	SP003
	120131	6	4	H0030
	120131	7	5	H1020
	120131	8	5	S1010
Page 2	120132	1	6	H1010
	120132	2	2	H2010
	120132	3	1	N1030
	120132	4	4	S1040
	120132	5	6	N0010
	120132	6	6	N0020
	120132	7	2	S1020
	120132	8	2	S1010
	120132	9	10	SP002
	120132	10	6	H0030
Page 3	120133	1	1	H1020
	120133	2	1	N1030
	120133	3	1	N0010
	120133	4	1	N0020
	120133	5	1	S1040
	120133	6	1	H0030
Page 4	120134	1	2	H1010
	120134	2	1	S1040
	120134	3	2	H0030
	120134	4	5	SP002
	120134	5	5	SP003
	120134	6	2	N0010
	120134	7	2	N0020
	120134	8	1	H2010
	120134	9	1	S1010
	120134	10	1	S1020

Merchandise table

Merchandise number	Merchandise name	Unit price
H0030	Mouse	4,000
H1010	Notebook-size personal computer	250,000
H1020	Desktop personal computer	180,000
H2010	Laser printer	300,000
N0010	LAN cable	1,500
N0020	LAN card	5,000
N1030	Terminal adapter	20,000
S1010	Word processing software	30,000
S1020	Spreadsheet software	50,000
S1040	Integrated software	100,000
SP002	A-4 size paper	3,000
SP003	B-5 size paper	2,500



No.	Merchandise number	Merchandise name	Unit price	Quantity	Amount
1	H1010	Notebook-size personal computer	250,000	4	1,000,000
2	H2010	Laser printer	300,000	2	600,000
3	S1040	Integrated software	100,000	1	100,000
4	SP002	A-4 size paper	3,000	2	6,000
5	SP003	B-5 size paper	2,500	4	10,000
6	H0030	Mouse	4,000	4	16,000
7	H1020	Desktop personal computer	180,000	5	900,000
8	S1010	Word processing software	30,000	5	150,000
9		The space below is left blank.			
10					

Order table

Order slip number	Date	Customer number
120131	2000/11/10	9321
120132	2000/11/18	8109
120133	2000/12/12	9321
120134	2000/12/12	9321

Customer table

Customer number	Customer name	Customer address
9321	Office Ginza Co., Ltd.	1-2-3 Ginza, Chuo-ku
8109	Daiba Sangyo Co., Ltd.	3-2-1 Daiba, Minato-ku

Order detail table

Order slip number	No.	Quantity	Merchandise number
120131	1	4	H1010
120131	2	2	H2010
120131	3	1	S1040
120131	4	2	SP002
120131	5	4	SP003
120131	6	4	H0030
120131	7	5	H1020
120131	8	5	S1010
120132	1	6	H1010
120132	2	2	H2010
120132	3	1	N1030
120132	4	4	S1040
120132	5	6	N0010
120132	6	6	N0020
120132	7	2	S1020
120132	8	2	S1010
120132	9	10	SP002
120132	10	6	H0030
120133	1	1	H1020
120133	2	1	N1030
120133	3	1	N0010
120133	4	1	N0020
120133	5	1	S1040
120133	6	1	H0030
120134	1	2	H1010
120134	2	1	S1040
120134	3	2	H0030
120134	4	5	SP002
120134	5	5	SP003
120134	6	2	N0010
120134	7	2	N0020
120134	8	1	H2010
120134	9	1	S1010
120134	10	1	S1020

Merchandise table

Merchandise number	Merchandise name	Unit price
H0030	Mouse	4,000
H1010	Notebook-size personal computer	250,000
H1020	Desktop personal computer	180,000
H2010	Laser printer	300,000
N0010	LAN cable	1,500
N0020	LAN card	5,000
N1030	Terminal adapter	20,000
S1010	Word processing software	30,000
S1020	Spreadsheet software	50,000
S1040	Integrated software	100,000
SP002	A-4 size paper	3,000
SP003	B-5 size paper	2,500

1.4 Data Manipulation

This chapter explains data manipulation of relational databases by using concrete examples. Data manipulation in information processing consists of four representative set operations (union, difference, intersection, and Cartesian product) and four relational operations (selection, projection, join, and divide) for the relational model.

1.4.1 Set Operation

The following is an explanation of set operations (data manipulation) of union, difference, and intersection using Tables A and B.

Table A: Participants in the Database Course

Employee name	Gender	Extension
Ichiro Higashino	Male	2136
Takako Minamida	Female	2142
Shuhei Nishikawa	Male	2144
Akira Kitayama	Male	2145

Table B: Participants in the Network Course

Employee name	Gender	Extension
Tadanobu Ueno	Male	2134
Ichiro Higashino	Male	2136
Michiko Shimoda	Female	2137
Shuhei Nishikawa	Male	2144
Akira Kitayama	Male	2145
Takao Migita	Male	2146

Of the four set operations, Cartesian product is explained by using Tables C and D on the next page.

(1) Union (A∪B)

Union is also called sum.
For example, union is used for the data manipulation to extract employees who took either of the database courses, or the network course, or both.
When union is used, duplicate tuples (rows) do not exist in the result. Domains of columns corresponding to the two tables must be the same, but column names can be different.

<Operation result>

Employee name	Gender	Extension
Ichiro Higashino	Male	2136
Takako Minamida	Female	2142
Shuhei Nishikawa	Male	2144
Akira Kitayama	Male	2145
Tadanobu Ueno	Male	2134
Michiko Shimoda	Female	2137
Takao Migita	Male	2146

(2) Difference (A−B)

Difference is used to extract employees who did not take the network course, from the participants in the database course.
In the case of difference, as in the case of union, domains of columns corresponding to the two tables must be the same, but column names can be different.

<Operation result>

Employee name	Gender	Extension
Takako Minamida	Female	2142

(3) Intersection (A∩B)

Intersection is also called product.
Intersection is used to extract the employees who took both the database course and the network course.
In the case of intersection, like the above two cases, domains of columns corresponding to the two tables must be the same, but column names can be different.

<Operation result>

Employee name	Gender	Extension
Ichiro Higashino	Male	2136
Shuhei Nishikawa	Male	2144
Akira Kitayama	Male	2145

(4) Cartesian product (C×D)

Cartesian product is used to create a table by combining tuples in the two tables. This operation, however, is transparent to users because it is used for intermediate processing to increase the efficiency of database manipulation.
In Cartesian product, the table name is added before the column name to avoid the duplication of column names, and the number of rows is decided by multiplying the numbers of rows in the two tables.
Table E shows the result of Cartesian product performed on Tables C and D.

Table C: Participant

Employee name	Course code
Masaharu Yamamoto	NE208
Yoko Kawano	DB200

Table D: Course

Course code	Course name
NE208	Network course
DB200	Database course
DB202	SQL course

<Table E: Operation result>

Participant/ Employee name	Participant/ Course code	Course/ Course code	Course/Course name
Masaharu Yamamoto	NE208	NE208	Network course
Masaharu Yamamoto	NE208	DB200	Database course
Masaharu Yamamoto	NE208	DB202	SQL course
Yoko Kawano	DB200	NE208	Network course
Yoko Kawano	DB200	DB200	Database course
Yoko Kawano	DB200	DB202	SQL course

1.4.2 Relational Operation

The following is an explanation of relational operations (data manipulation) of selection, projection, and join using Tables E and F.

Table E: Employee

Employee name	Gender	Extension
Tadanobu Ueno	Male	2134
Ichiro Higashino	Male	2136
Michiko Shimoda	Female	2137
Takako Miyamida	Female	2142
Shuhei Nishikawa	Male	2144
Akira Kitayama	Male	2145
Takao Migita	Male	2146

Table F: Employee Information

Employee name	Native place	Date of employment
Tadanobu Ueno	Tokyo	1993
Ichiro Higashino	Chiba Pref.	1999
Michiko Shimoda	Shizuoka Pref.	1995
Takako Miyamida	Saitama Pref.	1998
Shuhei Nishikawa	Kanagawa Pref.	1995
Akira Kitayama	Fukushima Pref.	1996
Takao Migita	Tochigi Pref.	1994

Of the four relational operations, divide is explained by using Tables G to J on the next page.

(1) Selection

Selection extracts only the rows satisfying the conditions from the specified table.
The following is the result gained by extracting the rows of females from Table E: Employee by selection.

<Operation result>

Employee name	Gender	Extension
Michiko Shimoda	Female	2137
Takako Minamida	Female	2142

(2) Projection

Projection extracts only those columns satisfying conditions from the specified table.
The following is the result gained by extracting the column of gender from Table E: Employee by projection.

<Operation result>

Gender
Male
Female

(3) Join

Join is used to create a new table by extracting the necessary columns from the multiple tables.
The table below is an employee list created by extracting all column names from Table E: Employee and Table F: Employee Information by join.

Operation Result: Employee List

Employee name	Gender	Extension	Native place	Date of employment
Tadanobu Ueno	Male	2134	Tokyo	1993
Ichiro Higashino	Male	2136	Chiba Pref.	1999
Michiko Shimoda	Female	2137	Shizuoka Pref.	1995
Takako Miyamida	Female	2142	Saitama Pref.	1998
Shuhei Nishikawa	Male	2144	Kanagawa Pref.	1995
Akira Kitayama	Male	2145	Fukushima Pref.	1996
Takao Migita	Male	2146	Tochigi Pref.	1994

(4) Divide

Divide is used to examine whether the one table completely includes all elements in the other table, by comparing column elements of two tables.
Example 1 below is the divide operation used to extract the distributor that deals in all products in Table I: Company's Products. Example 2 is the divide operation used to extract the distributors that deal in all products in Table J: Production.

Table G: Distributor List

Distributor	Merchandise
A	Pencil
C	Pencil
A	Eraser
B	Eraser
A	Paint-stick
B	Paint-stick
A	Ballpoint pen
B	Ballpoint pen

Sort

Table H: Distributor List

Distributor	Merchandise
A	Pencil
A	Eraser
A	Paint-stick
A	Ballpoint pen
B	Eraser
B	Paint-stick
B	Ballpoint pen
C	Pencil

Table I: Company's Products

Production
Pencil
Paint-stick
Ballpoint pen

<Operation result>

Distributor
A

Example 1) Merchandise in the table H ÷ Products in the table I

Table J: Production

Company	Production
X	Eraser
Y	Ballpoint pen

<Operation result>

Distributor
A
B

Example 2) Merchandise in the table H ÷ Products in the table I

Some set and relational operations can be expressed by combining other operations. By combining six operations: union, difference, selection, projection, join, and attribute renaming, all other operations can be expressed. Intersection, for example, can be expressed by using difference as follows:
$A \cap B = A-(A-B)$
In data manipulation of relational databases, at least six operations are necessary.

Exercises

Q1 Choose two effects that can be expected by installing database systems.

a. Reduction of code design works
b. Reduction of duplicate data
c. Increase in the data transfer rate
d. Realization of dynamic access
e. Improvement of independence of programs and data

Q2 Which of the data models shows the relationship between nodes by tree structure?

a. E-R model
b. Hierarchical data model
c. Relational data model
d. Network data model

Q3 Which of the following statements correctly explains relational database?

a. Data are treated as a two-dimensional table from the users' point of view. Relationships between records are defined by the value of fields in each record
b. Relationships between records are expressed by parent-child relationship.
c. Relationships between records are expressed by network structure.
d. Data fields composing a record are stored in the index format by data type. Access to the record is made through the data gathering in these index values.

Q4 Which of the following describes the storage method of databases in storage devices?

a. Conceptual schema
b. External schema
c. Subschema
d. Internal schema

Q5 Which of the following statements correctly explains the 3-tier schema structure of a database?

a. The conceptual schema expresses physical relationships of data.
b. The external schema expresses the data view required by users.
c. The internal schema expresses logical relationships of data.
d. Physical schema expresses physical relationships of data.

Q6 Which of the following data models is used for the conceptual design of a database, expressing the targeted world by two concepts of entities and relationships between entities?

a. E-R model
b. Hierarchical data model
c. Relational data model
d. Network data model

Q7 In the ERD diagram, the one-to-many relationship, "a company has multiple employees," is expressed as follows:

Then,

Which of the following statements correctly explains the above diagram?

a. There are multiple companies, and each company has a shareholder.
b. There are multiple companies, and each company has multiple shareholders.
c. One company has one shareholder.
d. One company has multiple shareholders.

Q8 A database was designed to store the data of the following sales slip. The database is planned to be separated into two tables: the basic part and detail part of the sales slip. The items in the detail part are inputted by reading bar codes on merchandise. Depending on the input method, the same merchandise can appear multiple times in the same sales slip.
Which of the following combinations is appropriate as key items for the basic part and the detail part? Key values of both parts cannot be duplicated.

* * Sales Slip * *

Basic part
Sales slip number: A001
Customer code: 0001 Customer name: Taro Nihon
Sales date: 01-01-15

Detail part

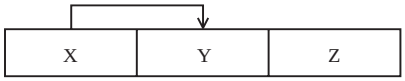
Item no.	Merchandise name code	Merchandise name	Unit price	Quantity	Amount
01	0001	Shampoo	100	10	1,000
02	0002	Soap	50	5	250
03	0001	Shampoo	100	5	500
				Total	1,750

	Basic part	Detail part
a.	Sales slip number	Sales slip number + Item no.
b.	Sales slip number	Sales slip number + Merchandise name code
c.	Customer code	Item no. + Merchandise name code
d.	Customer code	Customer code + Item no.

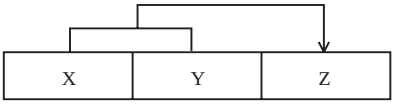
Q9 **Which of the following table structures correctly describes the record consisting of data fields a to e in the 3rd normal form in accordance with the relationships between fields described below?**

[Relationships between fields]

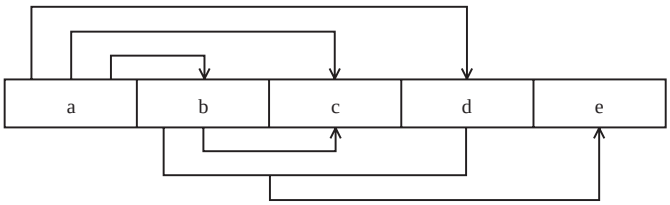
(1) When the value of the field X is given, the value of the field Y can be uniquely identified.



(2) When the values of fields X and Y are given, the value of field Z can be uniquely identified.



[The record to be normalized]



a) a b c d a d e

b) a b c d a d e b c

c) a b c a d e b c d

d) a b d b c b d e

Q10 **A school has recorded information on classes taken by students in the following record format. To create a database from these records, each record must be divided into several parts to avoid the problems of duplicated data. A student takes multiple classes, and multiple students can take one class at the same time. Every student can take a class only once. Which of the following is the most appropriate division pattern?**

Student code	Student name	Class code	Class name	Class finishing year	Score

a.

Student code	Class code

Student name	Class name	Class finishing year	Score

b.

Student code	Student name	Score

Class code	Class name	Class finishing year

c.

Student code	Student name	Class finishing year	Score

Class code	Class name	Student code

d.

Student code	Student name

Class code	Class name

Class finishing year	Score

e.

Student code	Student name

Class code	Class name

Student code	Class code	Class finishing year	Score

Q11 **A culture center examined three types of schemata (data structures) of A to C to manage the customers by using a database. Which of the following statements is correct?**

[Explanation]
A member can take multiple courses.
One course accepts applications from multiple members. Some courses receive no application.
One lecturer takes charge of one course.

Schema A

Member name	Member address	Telephone number	Course name	Lecturer in charge	Lecture fee	Application date

Schema B

Member name	Member address	Telephone number	Course name	Application date

Course name	Lecturer in charge	Lecture fee

Schema C

Member name	Member address	Telephone number

Application date	Member name	Course name

Course name	Member name	Lecture fee

a. In any of the three schemata, when there is any change in the lecturer in charge, you only have to correct the lecturer in charge recorded in the specific row on the database.
b. In any of the three schemata, when you delete the row including the application date to cancel the application for the course, the information on the course related to the cancellation can be removed from the database.
c. In Schemata A and B, when you delete the row including the application date to cancel the application for the course, the information on the member related to the cancellation can be removed from the database.
d. In Schemata B and C, when there is any change in the member address, you only have to correct the member address recorded in the specific row on the database.
e. In Schema C, to delete the information on the member applying for the course, you only have to delete the specific row including the member address.

Q12 **Regarding relational database manipulation, which of the following statements correctly explains projection?**

a. Create a table by combining inquiry results from one table and the ones of the other table.
b. Extract the rows satisfying specific conditions from the table.
c. Extract the specific columns from the table.
d. Create a new table by combining tuples satisfying conditions from tuples in more than two tables.

Q13 Which of the following combinations of manipulations is correct to gain Tables b and c from Table a of the relational database?

Table a

Mountain name	Region
Mt. Fuji	Honshu
Mt. Tarumae	Hokkaido
Yarigatake	Honshu
Yatsugatake	Honshu
Mt. Ishizuchi	Shikoku
Mt. Aso	Kyushu
Nasudake	Honshu
Mt. Kuju	Kyushu
Mt. Daisetsu	Hokkaido

Table b

Mountain name	Region
Mt. Fuji	Honshu
Yarigatake	Honshu
Yatsugatake	Honshu
Nasudake	Honshu

Table c

Region
Honshu
Hokkaido
Shikoku
Kyushu

	Table b	Table c
a.	Projection	Join
b.	Projection	Selection
c.	Selection	Join
d.	Selection	Projection

2 Database Language

Chapter Objectives

Database languages are necessary to use databases. SQL was developed for the use of relational databases, and has been standardized by ISO and JIS, and is currently in wide use.
In this chapter, we learn the method of using SQL to define tables and databases and to manipulate databases.

① Understanding the outline of database languages such as NDL and SQL.
② Understanding SQL structure, definitions of 'database,' 'schema,' 'table,' and 'view,' as well as database creation procedures including data control and entry.
③ Understanding data manipulation using SQL to be able to express the required processing using SQL.
④ Understanding the process of embedding SQL statements in application programs and cursor manipulation.

2.1 What are Database Languages?

A database language is used to define database schemata and refer to the actual data. SQL (Structured Query Language) and NDL are representative database languages.

- SQL : A database language for relational databases. Its standard specifications were established by ISO (International Organization for Standardization). SQL was also standardized as JIS X 3005 in Japan.
- NDL : A database language for CODASYL (network) databases. It was introduced by CODASYL, and standardized as JIS X 3004 in Japan.

Database languages are classified into the following three groups according to the users' standpoint and the purposes:

- Data Definition Language (DDL)
- Data Manipulation Language (DML)
- End User Language (EUL)

2.1.1 Data Definition Language

The Data Definition Language, as its name signifies, is a language that defines databases. "Database definition" means the definition of the schema. Data Definition Language is broadly classified into two languages: the schema definition language used by a database administrator (DBA) to define the whole picture of the database (conceptual schema), and the subschema definition language that defines external schemata by the user.

2.1.2 Data Manipulation Language

The Data Manipulation Language is used to actually operate databases. This language is used on the creation side of the database system (programmers, etc.).

2.1.3 End User Language

The End User Language is a simple query language designed for general database users (end users). This language is generally used based on the interactive processing by using tables and simple commands.

2.2 SQL

2.2.1 SQL: Database Language

SQL (Structured Query Language) is a language to manipulate databases based on the relational data model.
SQL is designed to process relational databases (RDB) in which data are expressed in the table format, and can create, manipulate, update, and delete data in tables. Because SQL is a non-procedural language which does not require a description of every procedure in the programs, its statements are simple and easy to understand.
In addition to concrete statements on access to the tables, SQL can grant access authority to a specific person to define and manipulate the table.
The prototype of SQL was called SEQUEL (Structured English Query Language) originating as a language to access database "System R." It was developed as the relational database in 1979 at the San Jose Research Laboratory of IBM. After ISO established standard specifications for SQL in 1987, SQL was standardized by JIS as "JIS X3005-1995" in Japan.

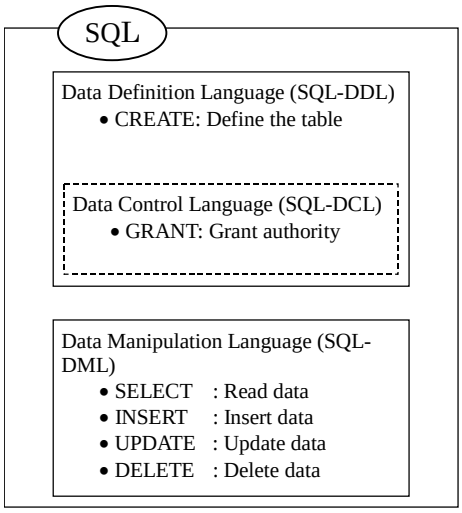
2.2.2 Structure of SQL

SQL is a complete database language to process relational databases, and can create, manipulate, update, and delete tables. It consists of the following languages (Figure 2-2-1):

- Data Definition Language (SQL-DDL)
- Data Control Language (SQL-DCL)
- Data Manipulation Language (SQL-DML)

The Data Control Language (DCL), a language to grant access authority to tables, is sometimes included in the category of the Data Definition Language.

Figure 2-2-1
What is SQL?



SQL can be used in a host language system (embedded SQL) and also as a self-contained system (interactive SQL).

- Host language system
  The host language system is a system to manipulate databases by programming languages. It performs processing by embedding SQL statements in programming languages such as COBOL and FORTRAN. → Embedded SQL
- Self-contained system
  The self-contained system is a system to manipulate databases only by the database manipulation language, independent of programming languages. Users perform interactive processing with terminals, using SQL. → Conversational SQL
  In the DBMS for personal computers, the instructions issued by users are converted into SQL statements (SQL - DML) and executed inside the DBMS by the query function (QBE: Query By Example).

2.3 Database Definition, Data Access Control and Loading

2.3.1 Definition of Database

To use a database, the database must be defined based on the database design. Specifically, the database can be defined by defining various schemata.
The following is an explanation of a database definition, taking Figure 2-3-1 as an example:

Figure 2-3-1 Normalized Data Tables

customer_table	customer_number	customer_name	customer_address
	C005	Tokyo Shoji	Kanda, Chiyoda-ku
	D010	Osaka Shokai	Doyama-cho, Kita-ku, Osaka-City
	G001	Chugoku Shoten	Moto-machi, Naka-ku, Hiroshima-City
	(4-digit character string) CHAR (4)	(10-digit kanji string) NCHAR (10)	(20-digit kanji string) NCHAR (20)

order_table	customer_number	order_slip_number	order_receiving_date
	C005	2001	08/07/1999
	C005	2002	09/01/1999
	D010	2101	07/28/1999
	G001	2201	09/10/1999
	(4-digit character string) CHAR (4)	(4-digit numeric value) INT	(Year/Month/Date (Christian era)) DATE

order_detail_table	customer_number	order_slip_number	raw_number	merchandise_number	quantity
	C005	2001	01	PR1	20
	C005	2001	02	PX0	15
	C005	2002	01	Q91	10
	C005	2002	02	S00	5
	D010	2101	01	PX0	30
	D010	2101	02	S00	6
	(4-digit character string) CHAR (4)	(4-digit numeric value) INT	(2-digit numeric value) SMALLINT	(3-digit character string) CHAR (3)	(3-digit numeric value) DEC (3)

merchandise_table	merchandise_number	merchandise_name	unit_price
	PR1	Printer 1-type	300
	PX0	Printer X-type	550
	Q91	Disk 1-type	910
	S00	System 0-type	4500
	(3-digit character string) CHAR (3)	(10-digit kanji string) NCHAR (10)	(5-digit numeric value) DEC (5)

2.3.2 Definition of Schema

(1) What is a schema?

Database definition information is called a schema. A schema is specified by the schema definition statement of the data definition language (SQL-DDL). The definition of the schema consists of the definitions of the table, view, and authorization.
The definition information related to the schemata is automatically registered in DD/D (Database Dictionary/Directory) by the DBMS.

(2) Authorization identifier

When defining a schema, it is necessary to know the person who defines the schema, so that the person can be identified. The schema authorization identifier is used for that purpose. The user who has the authorization identifier is granted authorization to process the tables and views created in the schema. As a user who does not have the authorization identifier cannot gain access to the database, the authorization identifier also serves as a protection of the database. In interactive processing in network systems, in many cases, the authorization identifier also serves as a user ID.
The schema authorization identifier is specified by the CREATE SCHEMA statement of SQL-DDL.

Definition of the schema (authorization identifier)

```
CREATE  SCHEMA
        AUTHORIZATION authorization_identifier
```

When the authorization identifier is specified as DRY, for example, the definition is as follows:

```
CREATE    SCHEMA
          AUTHORIZATION   DRY
```

2.3.3 Definition of Table

(1) Table_name

The actual data are stored in a table. A table has a two-dimensional structure consisting of rows and columns. In contrast to a view (virtual table) described later, a table is also called an "actual table." Although multiple tables can exist, the same table_name must be avoided because each table is identified by the table_name.
The definition of the table is specified by the CREATE TABLE statement of SQL-DDL.

Definition of the table

```
CREATE  TABLE   table_name
```

(2) Data type

A table consists of rows (tuples) and columns (attributes). To define the table, attributes (data type) must be defined.

Definition of the data type

```
column_name   data_type
```

Figure 2-3-2 shows the data types that can be defined by SQL. Note the extended functionalities of the SQL language provided by each vendor.

Figure 2-3-2
Data type

Data type	Definition	Contents
Character string type	CHARACTER	Also described as CHAR. A fixed-length character string with a specified length. Up to 255 characters.
Numeric value type	INTEGER	Also described as INT. An integer with a specified number of digits. 4-byte binary numeric value
	SMALLINT	A short integer with a specified number of digits. The precision contains fewer digits than INT. 2-byte binary numeric value
	NUMERIC	A numeric value with the decimal part and the integer part with a specified number of digits.
	DECIMAL	Also described as DEC. A numeric value with the decimal part and the integer part with a specified number of digits. A decimal number with up to 15-digit precision.
	FLOAT	A numeric value expressed by a binary number with a specified number of digits or smaller. Floating-point binary number
	REAL	Single-precision floating-point number
	DOUBLE PRECISION	Double-precision floating-point number
Kanji string type	NATIONAL CHARACTER	Also described as NCHAR. A kanji string with a specified length. Up to 128 characters.
Date type	DATE	Described in the format of Year/Month/Day (Christian Era)

In the definition of the data type of a database, "null values" can be set. A null value means "no value" or "the undecided value." When defining the data type, decide whether the use of null values is allowed or not. If the use of null values is not allowed for fields that contain data such as key items, specify "NOT NULL." As described later, the null value can be used as a query condition.

(3) PRIMARY KEY

In a table, the attribute to be a record key item is specified as a primary key. The primary key is defined by PRIMARY KEY clause in the SQL language.
When the record key is a concatenated key, column names are successively combined.

Definition of the primary key

```
PRIMARY KEY column_name
```

(4) FOREIGN KEY

The foreign key is a data item not used as a record key in a table, but used as a record key (primary key) in other tables. In the SQL language, the foreign key is defined by FOREIGN KEY clause and the tables in which the foreign key is used as a record key (primary key) are specified.

Definition of the foreign key

```
FOREIGN KEY   column_name
        REFERENCES   table_name
```

The definitions of the four tables in Figure 2-3-1 are as follows:

- Customer_table

```
CREATE  TABLE   customer_table
        (customer_number      CHAR (4)      NOT NULL,
        customer_name         NCHAR (10)    NOT NULL,
        customer_address      NCHAR (20)    NOT NULL,
        PRIMARY KEY (customer_number))
```

- Order_table

```
CREATE  TABLE   order_table
        (customer_number      CHAR (4)      NOT NULL,
        order_slip_number     INT           NOT NULL,
        order_receiving_date  DATE          NOT NULL,
        PRIMARY KEY (customer_number, order_slip_number),
        FOREIGN KEY (customer_number) REFERENCES customer_table)
```

- Order_detail_table

```
CREATE  TABLE   order_detail_table
        (customer_number      CHAR (4)      NOT NULL,
        order_slip_number     INT           NOT NULL,
        row_number            SMALLINT      NOT NULL,
        merchandise_number    CHAR (3)      NOT NULL,
        quantity              DEC (3),
        PRIMARY KEY (customer_number, order_slip_number, row_number),
        FOREIGN KEY (customer_number, order_slip_number) REFERENCES order_table,
        FOREIGN KEY (merchandise_number) REFERENCES merchandise_table)
```

- Merchandise_table

```
CREATE  TABLE   merchandise_table
        (merchandise_number   CHAR (3)      NOT NULL,
        merchandise_name      NCHAR (10)    NOT NULL,
        unit_price            DEC (5)       NOT NULL,
        PRIMARY KEY (merchandise_number))
```

2.3.4 Characteristics and Definition of View

(1) Characteristics of a view

A view is a look at part of an actual table or a virtual table, which combines necessary data items from multiple tables. One of the advantages of the relational data model over other data models is that it uses views. As views can be freely created depending on the situation, they are adaptable to routine operations as well as ad hoc operations.

Under certain restrictions, you can perform various data operations such as query and update of data with a view like with a table. Update of data, however, cannot be performed for a view created from multiple tables. When there is any change in the data of the original table, the change results can be immediately reflected in the view.

Use of a view enables the following:

- Increase in usability
  By creating a new table (view) by extracting necessary columns from a table, the readability of the data in the table is improved. You can create a new table by combining multiple tables. SQL statements for these views become simpler than the ones for the original table.
- Security enhancement by limiting the data utilization range
  By creating a view from the specified rows or columns and granting access privileges to the view, the data utilization range is limited and security can be enhanced.
- Increased independence from data
  Even if the definition of the original table is changed (for example, addition of columns or division of a table), instructions to operate the view need not be changed.

(2) Definition of a view

When defining a view, a view name which is distinct from table_names and other view names in the same schema must be given to the view.
In the SQL language, a view is specified by the CREATE VIEW statement.

Definition of a view

```
CREATE  VIEW  view_name
        AS  SELECT  column_name  FROM  table_name
```

For example, the statement "define a view named 'customer_name table' consisting only of customer_numbers and customer_names from the customer_table" is given as follows:

```
CREATE  VIEW  customer_name_table
        AS SELECT  customer_number, customer_name  FROM  customer_table
```

2.3.5 Data Access Control

Data access control means limiting persons who can manipulate the database (table) by granting access privileges.
When a table is used frequently in a database, the data may be destroyed intentionally or by accident. To prevent such destruction, users of the table should be limited by granting access privileges.
There are five types of access privileges:

- SELECT privilege to read data
- INSERT privilege to insert data
- DELETE privilege to delete data
- UPDATE privilege to update data
- REFERENCE privilege to redefine the table

These five privileges are automatically granted to the creator of the table. Specifying ALL PRIVILEGES means granting all privileges. The REVOKE statement on the other hand, is used to cancel the granted privileges.
When granting privileges to specified persons, the GRANT statement is used in SQL.

Granting privileges

```
GRANT  privilege  ON  table_name  TO  authorization_identifier
```

For example, the statement "grant the ability (privilege) to read a customer_table to the person who has the authorization identifier WET" is given as follows:

```
GRANT  SELECT  ON  customer_table  TO  WET
```

2.3.6 Data Loading

After defining the database, data must be loaded into the table actually defined.
There are three data loading methods:

(1) Interactive system

In the interactive system, data are loaded line by line using the INSERT statement of SQL in the self-contained system. Details are described later.
Because the data are loaded line by line, this system is not suitable for loading of large amounts of data.

(2) Host language system

In this system, data prepared separately are loaded using embedded SQL. In this case, it is necessary to prepare a data loading program by embedding an SQL statement (INSERT) beforehand (the method to embed an SQL statement is described later).
The host language system is suitable for loading data while processing separately prepared data or selecting data under certain conditions.

(3) Utility program system

In the utility program system, data prepared separately are loaded using a utility program (load utility). This method is suitable for simply loading large amounts of data without manipulating the prepared data.

2.4 Database Manipulation

2.4.1 Query Processing

Users who have been granted privileges by the GRANT statement can gain access to the table within the permitted range. Query means reading the data in tables.

(1) Basic syntax

Reading the data in tables is the most frequently performed data manipulation in the relational database processing, and it is performed by using the SELECT statement.

Data retrieval

```
SELECT    column_name        : Specify the column to retrieve
  FROM    table_name         : Specify the table to read
```

For example, the statement "retrieve customer_numbers and customer_names from the customer_table" is expressed as follows:

```
SELECT    customer_number,    customer_name
  FROM    customer_table
```

<Display result>

customer_number	customer_name
C005	Tokyo Shoji
D010	Osaka Shokai
G001	Chugoku Shoten

The column_names in the SELECT statement must be separated by a comma, and specified in the preferred order of display.
Multiple table_names can be specified in the FROM clause. Details are described later.
If the SELECT statement is specified as follows, all the columns to be read are displayed in the order of columns specified in the table definition.

```
SELECT    *      FROM    customer_table
```

<Display result>

customer_number	customer_name	customer_address
C005	Tokyo Shoji	Kanda, Chiyoda-ku
D010	Osaka Shokai	Doyama-cho, Kita-ku, Osaka City
G001	Chugoku Shoten	Moto-machi, Naka-ku, Hiroshima City

"Retrieve customer_numbers from the order_table" is expressed as follows:

```
SELECT    customer_number    FROM    order_table
```

<Display result>

customer_number
C005
C005
D010
G001

The above display result does not include mistakes. However, if you want to avoid displaying the records of the same contents (C005), use DISTINCT to eliminate the duplicate data.

```
SELECT DISTINCT customer_number FROM order_table
```

<Display result>

customer_number
C005
D010
G001

Exercise 1. Write an SQL statement to extract the following display result from the merchandise_table.

<Display result>

merchandise_name	unit_price
Printer 1-type	300
Printer X-type	550
Disk 1-type	910
System 0-type	4500

(Answer 1)

```
SELECT merchandise_name, unit_price FROM merchandise_table
```

Exercise 2. What is the display result when the following SQL statement is executed?

```
SELECT DISTINCT customer_number, order_slip_number FROM order_detail_table
```

(Answer 2)

<Display result>

customer_number	order_slip_number
C005	2001
C005	2002
D010	2101

---

(2) Query using conditional expression

The conditional query is an inquiry retrieving the specified rows under certain conditions. The conditions used to retrieve the rows are defined using the WHERE clause.

Conditional query

```
SELECT column_name
  FROM table_name
 WHERE query_conditions (the conditional to specify the rows to be selected)
```

Query_conditions are described in the form of expression using operators. The following are the representative operators used in the conditional expression.

- Comparison_operator (relational operator)
- Logical operator
- Character string comparison operator
- Null value operator

① Comparison_operator (relational operator)

The comparison operator, also called the "relational operator", is used to compare numeric type and character type data. The following operators are used in SQL.

- Equal (=)
- Larger than (>)
- Smaller than (<)

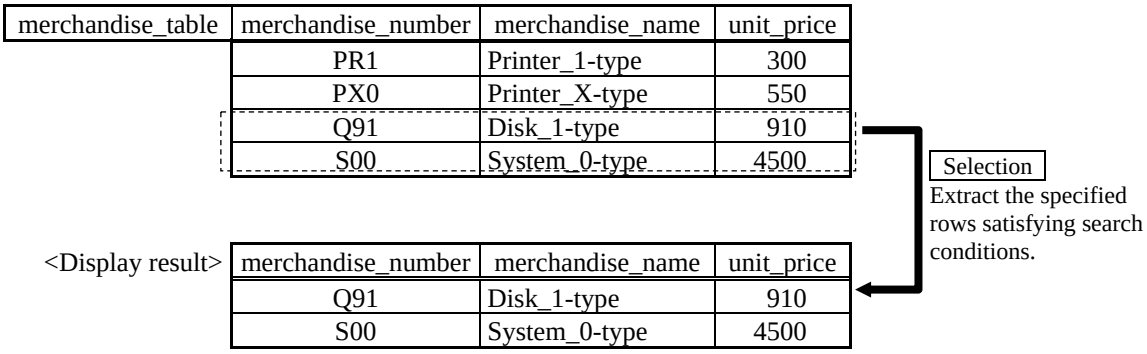
- Equal to or larger than (> =)
- Equal to or smaller than (< =)

In the SQL syntax, the form of "column_name comparison_operator value" is used in the WHERE clause. Selection and projection of relational algebra using comparison operators are written in the SQL as follows:

a. Selection

Selection is a manipulation to extract the rows satisfying query_conditions from the table.
For example, the statement "retrieve from merchandise_table the records whose unit_price is ¥800 or higher" is written as follows:

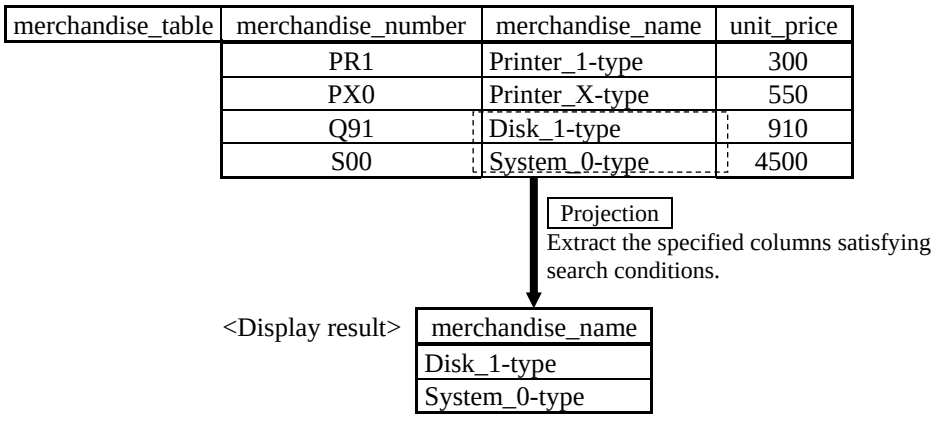
```
SELECT  *  FROM  merchandise_table
  WHERE  unit_price  > =  800
```



b. Projection

Projection is a manipulation to extract the columns satisfying query_conditions from the table.
For example, the statement "retrieve from merchandise_table the merchandise_names in the records whose unit_price is ¥800 or higher" is expressed as follows:

```
SELECT  merchandise_name  FROM  merchandise_table
  WHERE  unit_price  > =  800
```



Values in the conditional expression must agree with the data type of the column. Numeric type data are described only by numeric values, and character type data are surrounded by quotation marks (').
Kanji type data are surrounde

d by quotation marks, adding N (meaning national character) before the string.

[Character type (CHAR)]
For example, the statement "retrieve from the merchandise_table the merchandise_name and its price in the record whose merchandise_number is PR1" is expressed as follows:

```
SELECT  merchandise_name, unit_price  FROM  merchandise_table
```

```
WHERE  merchandise_number  =  'PR 1'
```

[Kanji type (NCHAR)]
For example, the statement "retrieve from the merchandise_table the records whose merchandise_number is printer_1-type" is expressed as follows:

```
SELECT  *  FROM  merchandise_table
  WHERE  merchandise_number  =  Printer_1-type'
```

Exercise 3. Write an SQL statement meaning "retrieve from the order_detail_table the customer_numbers and the merchandise_numbers in the records whose quantity is less than 20."

<Display result>

customer_number	merchandise_number
C005	PX0
C005	Q91
C005	S00
D010	S00

(Answer 3)

```
SELECT  customer_number,  merchandise_number  FROM  order_detail_table
  WHERE  quantity  <  20
```

Exercise 4. As a result of the execution of an SQL statement, the following result was displayed. Write the executed SQL statement.

<Display result>

customer_number	order_slip_number
C005	2002
G001	2201

(Answer 4)
The tables including both the "customer_number" and "order_slip_number" are the "order_table" and the "order_detail_table." Of these two tables, only the "order_table" includes the customer_number 'G001'. Therefore, the SELECT statement is executed for the "order_table."
The condition common to the selected two records is that the order_receiving_date is 'after January 1999'. Therefore, the SQL statement is as follows:

```
SELECT  customer_number,  order_slip_number  FROM  order_table
  WHERE  order_receiving_date  > =  '99/01/01'
```

---

② Logical operator

The logical operator, also called the "Boolean operators," is used to combine conditional expressions consisting of the above-mentioned comparison operators. The following operators are used in SQL.

- AND
- OR
- NOT

For example, the statement "retrieve from the merchandise_table the merchandise_names and prices in the records whose unit_price is ¥500 to ¥1,000" is expressed as follows:

```
SELECT  merchandise_name,  unit_price  FROM  merchandise_table
WHERE  unit_price  >=  500  AND  unit_price  < =  1000
```

<Display result>

merchandise_name	unit_price
Printer_X-type	550
Disk_1-type	910

In the SQL, the SELECT statement shown above can also be expressed using the BETWEEN predicate.

column_name BETWEEN - AND - (equal to or larger than - and equal to or smaller than -)

Thus, a statement to "display the merchandise_names and prices in the records whose unit_price is ¥500 to ¥1,000" mentioned above can also be expressed as follows:

```
SELECT merchandise_name, unit_price FROM merchandise_table
  WHERE unit_price BETWEEN 500 AND 1000
```

Exercise 5. Write SQL statements for ① to ③ below, and display their results.

① "Retrieve from the customer_table the customer_names in the records whose customer_number is C005 or G001."

② "Retrieve from the order_detail_table the order_slip_numbers and the merchandise numbers in the records whose customer_number is C005 and whose quantity is 10 or larger."

③ " Retrieve from the order_table the customer_numbers in the records whose order_slip_number is 2100 to 2199."

(Answer 5)

①
```
SELECT customer_name FROM customer_table
  WHERE customer_number = 'C005' OR customer_number = 'G001'
```

<Display result>

customer_name
Tokyo Shoji
Chugoku Shoten

② SELECT order_slip_number merchandise number FROM order_detail_table
WHERE customer_number = 'C005' AND quantity >= 10

<Display result>

order_slip_number	merchandise_number
2001	PR1
2001	PX0
2002	Q91

③ SELECT customer_number FROM order_table
WHERE order_slip_number BETWEEN 2100 AND 2199

<Display result>

customer_number
D010

Exercise 6. Show the retrieved results when SQL statements ① to ⑥ are executed. If no result is obtained, answer "none."

①
```
SELECT * FROM order_detail_table
  WHERE customer_number = 'C005' AND row_number = 02 AND quantity > 10
```

② SELECT * FROM order_detail_table
WHERE customer_number = 'C005' OR row_number = 02 OR quantity > 10

③ SELECT * FROM order_detail_table
WHERE customer_number = 'C005' AND row_number = 02 OR quantity > 10

④ SELECT * FROM order_detail_table
WHERE customer_number = 'C005' AND (row_number = 02 OR quantity > 10)

⑤ SELECT * FROM order_detail_table
WHERE customer_number = 'C005' OR row_number = 02 AND quantity > 10

⑥ SELECT * FROM order_detail_table
WHERE (customer_number = 'C005' OR row_number = 02) AND quantity > 10

(Answer 6)

① <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	02	PX0	15

② <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	01	Q91	10
C005	2002	02	S00	5
D010	2101	01	PX0	30
D010	2101	02	S00	6

③ <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	02	S00	5
D010	2101	01	PX0	30

④ <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	02	S00	5

⑤ <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	01	Q91	10
C005	2002	02	S00	5

⑥ <Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15

③ Character string comparison operator

In SQL, the LIKE predicate is used to compare character strings such as "begin with …," "end with …," and "include … in the middle." For actual specifications, % (percent sign wildcard) or _ (underscore wildcard) are used. % matches any sequence of zero or more characters, and _ matches any single character.
For example, to express a character string code beginning with A, the following two specification methods can be used. However, you should note that these two methods have different meanings.

- A_ _ : A 3-character code beginning with A
- A% : A code beginning with A (any number of characters is acceptable)

The LIKE predicate can be used only for the character type (double-byte kanji, etc.).
For example, the statement "Retrieve from the customer_table the records whose customer_address is Nagoya City" is created as follows:

```
SELECT customer_number, customer_name, customer_address FROM customer_table
  WHERE customer_address LIKE 'Nagoya City %'
```

<Display result>

customer_number	customer_name	customer_address

* In this case, no record is displayed because the customer_table includes no customers whose address is Nagoya City.

For example, the statement "Retrieve from the merchandise_table the records whose merchandise_number begins with P" is written as follows:

```
SELECT * FROM merchandise_table
  WHERE merchandise_number LIKE 'P_ _'
```

<Display result>

Merchandise_number	merchandise_name	unit_price
PR1	Printer_1-type	300
PX0	Printer_X-type	550

Exercise 7. Write SQL statements for ① and ② below, and show the results.

① "Retrieve the merchandise_numbers and quantities in the records the second digit of whose merchandise_number is 0."

② "Retrieve the merchandise_numbers and unit_prices in the records whose merchandise_name includes '1'."

(Answer 7)

①
```
SELECT merchandise_number, quantity FROM order_detail_table
  WHERE merchandise number LIKE '_0_'
```

<Display result>

merchandise_number	quantity
S00	5
S00	6

②
```
SELECT merchandise_number, unit_price FROM merchandise_table
  WHERE merchandise_name LIKE N'%1%'
```

<Display result>

merchandise_number	unit_price
PR1	300
Q91	910

④ Null value operator

If a null value (NULL) is allowed in the table, the null value can be used as a query condition. In that case, the IS NULL statement is used in SQL.
For example, the statement "Retrieve from the order_detail_table the order_slip_numbers and the row_numbers in the records whose quantity is null" is created as follows:

```
SELECT  order_slip_number,  row_number  FROM  order_detail_table
  WHERE  quantity  IS  NULL
```

<Display result>

order_slip_number	row_number

When NULL is used as a query condition, it must be IS NULL instead of = NULL.
This is because it is impossible to compare a NULL value, and = NULL becomes an error.

(3) Aggregation and sorting of data

① Grouping and the aggregate functions (column functions)

The aggregate functions, also called "column functions," is used to process grouped column data. There are the following aggregate functions:

- SUM (column_name) : Return the sum in the numeric column
- AVG (column_name) : Return the average in the numeric column
- MIN (column_name) : Return the minimum value in the numeric column
- MAX (column_name) : Return the maximum value in the numeric column
- COUNT (*) : Count the number of rows satisfying the condition.
- COUNT (DISTINCT column_name) : Count the number of rows satisfying the condition, excluding duplication.

All these aggregate functions perform calculations for the specified group in the specified column. In SQL, an aggregate function and a GROUP BY clause for grouping are combined.
For example, the statement "calculate the sum of order quantities by merchandise number from the order_detail_table, and display" is expressed as follows:

```
SELECT  merchandise_number,  SUM (quantity)  FROM  order_detail_table
  GROUP  BY  merchandise_number
```

Figure 2-4-1 Grouping

order_detail_table

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	01	Q91	10
C005	2002	02	S00	5
D010	2101	01	PX0	30
D010	2101	02	S00	6

Grouping
GROUP BY merchandise_number

merchandise_number	quantity
PR1	20
PX0	15
PX0	30
Q91	10
S00	5
S00	6

SUM (quantity)

<Display result>

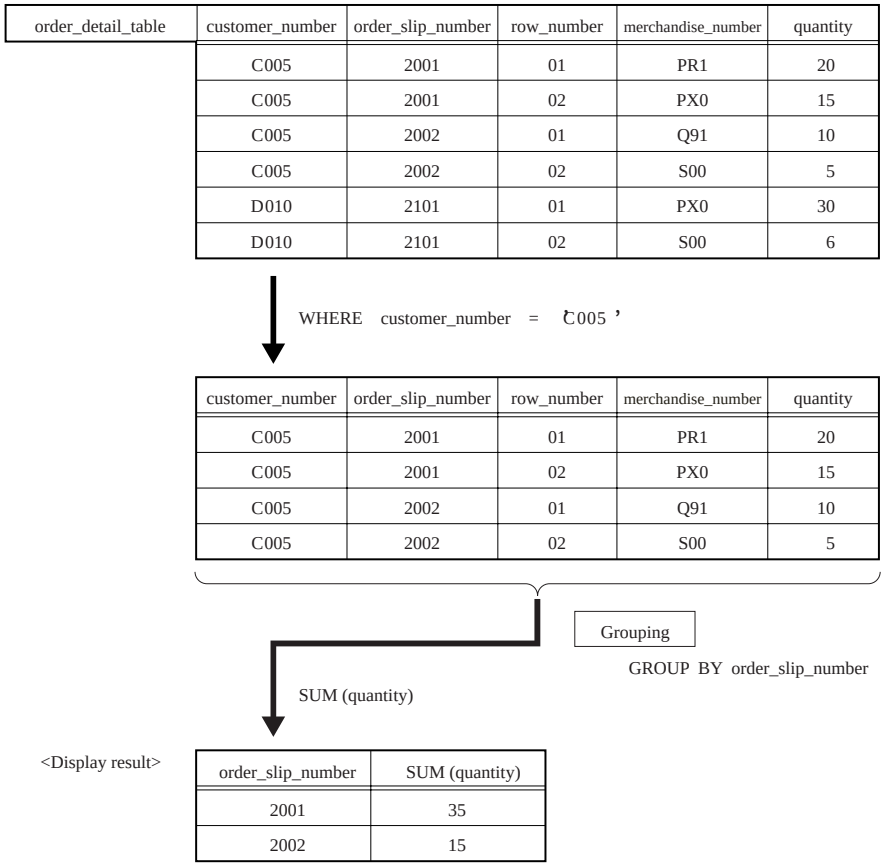
merchandise_number	sum (quantity)
PR1	20
PX0	45
Q91	10
S00	11

When the GROUP BY clause and the WHERE clause are written at the same time, the WHERE clause is

executed first, and then the GROUP BY clause is executed based on the execution result of WHERE clause.
For example, the statement "calculate the sum of order_quantities of customer_number C005 by order_slip_number from order_detail_table, and display" is expressed as follows:

```
SELECT   order_slip_number,   SUM (quantity)
  FROM   order_detail_table
  WHERE   customer_number   =   'C005'
  GROUP   BY   order_slip_number
```

Figure 2-4-2



To use the result extracted by the GROUP BY clause and the aggregate function as a condition, the HAVING clause is used.
For example, the statement "retrieve the merchandise numbers recorded twice or more, and display them with their number of records" is expressed as follows:

```
SELECT  merchandise_number,  COUNT (*)  FROM  order_detail_table
  GROUP  BY  merchandise_number
  HAVING  COUNT (*)  > =  2
```

Figure 2-4-3

order_detail_table

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR**1**	20
C005	2001	02	PX**0**	15
C005	2002	01	Q**91**	10
C005	2002	02	S**00**	5
D010	2101	01	PX**0**	30
D010	2101	02	S**00**	6

Grouping

GROUP BY merchandise_number

COUNT (*)

merchandise_number	COUNT (*)
PR**1**	1
PX**0**	2
Q**91**	1
S**00**	2

HAVING COUNT (*) > = 2

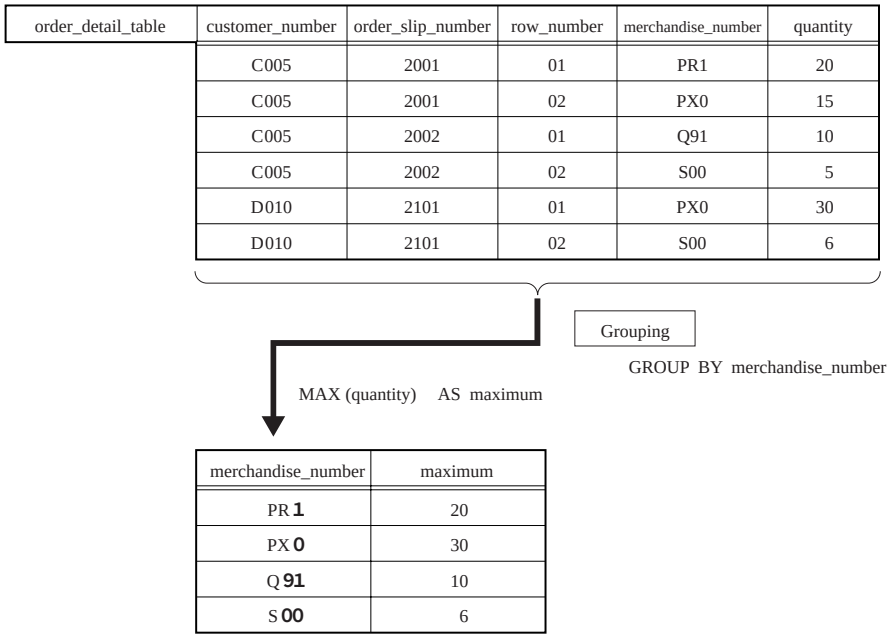
<Display result>

merchandise_number	COUNT (*)
PX**0**	2
S**00**	2

To give a new column_name to the column extracted by the aggregate function, the AS clause is used.
For example, the statement "retrieve the maximum order quantity by merchandise_number from the order_detail_table, and display the extracted order_quantities with the column_name <maximum>" is expressed as follows:

```
SELECT  merchandise_number,  MAX (quantity)  AS  maximum  FROM  order_detail_table
  GROUP  BY  merchandise_number
```

Figure 2-4-4



Exercise 8. Write SQL statements for ① to ③ below, and display the results.

① "Calculate the average order quantity by customer_number from the order_detail_table, and display the quantities with the customer_numbers, with the column_name <average>."

② "Calculate the number of records whose merchandise_number begins with 'P' by merchandise from the order_detail_table, and display the number_of_records with the merchandise_numbers, with the column_name <number_of_records>."

③ "Calculate the sum of quantities by order_slip_number from the order_detail_table, and display the order_slip_numbers whose total_quantity is 20 or larger with their total_quantity, with the column_name <total_quantity>."

(Answer 8)

① SELECT customer_number, AVG (quantity) AS average FROM order_detail_table
GROUP BY customer_number

<Display result>

customer_number	average
C005	13
D010	18

← 13 is displayed by rounding 12.5

② SELECT merchandise_number, COUN'T (*) AS number_of_records FROM order_detail_table
WHERE merchandise_number LIKE 'P%'
GROUP BY merchandise_number

<Display result>

merchandise_number	number_of_records
PR1	2
PX0	1

③ SELECT order_slip_number, SUM (quantity) AS total_quantity FROM order_detail_table
GROUP BY order_slip_number
HAVING SUM (quantity) > = 20

<Display result>

order_slip_number	total_quantity
2001	35
2101	36

---

② Sorting of data

Rows extracted from a table are not always sorted in the specified order. Therefore, rows are displayed after being rearranged in the order of values in a certain column to improve readability.
In SQL, the sorting is specified by the ORDER BY clause.

- When sorted in the ascending order : ASC (ascending)
- When sorted in the descending order : DESC (descending)

When there is no specification, ASC is used as the default. The numeric type data and the character type data are sorted in ascending/descending order by the size of the numeric values and character code values, respectively.
For example, the statement "display the order_slip_numbers and order_receiving_date from the order_table in the ascending order" is expressed as follows:

SELECT order_slip_number, order-receiving_date FROM order_table
ORDER BY order_receiving_date ASC …… ASC can be omitted.

<Display result>

order_slip_number	order_receiving_date
2101	07/28/1999
2001	08/07/1999
2002	09/01/1999
2201	09/10/1999

By specifying multiple columns, data can be sorted into major classifications, intermediate classifications, and minor classifications.
For example, the statement "display all data from the order_detail_table in the ascending order of the row_numbers and in the descending order of quantity" is written as follows:

SELECT * FROM order_detail_table
ORDER BY row_number ASC, quantity DESC

<Display result>

customer_number	order_slip_number	row_number	merchandise_number	quantity
D010	2101	01	PX0	30
C005	2001	01	PR1	20
C005	2002	01	Q91	10
C005	2001	02	PX0	15
D010	2101	02	S00	6
C005	2002	02	S00	5

The result gained by the aggregate function can be used as a sort key.
For example, the statement "calculate the sum of order quantities by the merchandise_number from the order_detail_table, and display the merchandise_numbers in the descending order of the total order quantities" is expressed as follows:

SELECT merchandise_number, SUM (quantity) FROM order_detail_table
GROUP BY merchandise_number
ORDER BY 2 DESC

Figure 2-4-5
Sort

order_detail_table

customer_number	order_slip_number	row_number	merchandise_number	quantity
C005	2001	01	PR1	20
C005	2001	02	PX0	15
C005	2002	01	Q91	10
C005	2002	02	S00	5
D010	2101	01	PX0	30
D010	2101	02	S00	6

Grouping
GROUP BY
merchandise_number

merchandise_number	quantity
PR1	20
PX0	15
PX0	30
Q91	10
S00	5
S00	6

Sort
SUM (quantity)
ORDER BY 2 DESC

<Display result>

merchandise_number	SUM (quantity)
PX0	45
PR1	20
S00	11
Q91	10

In this example, a "2" written after the ORDER BY clause shows the position of the corresponding column in the SELECT statement. In this case, as the data are sorted (in the descending order) based on "SUM (Quantity)" located in the second position in the SELECT statement, "2" is specified.
Depending on the DBMS type, "ORDER BY SUM (quantity) DESC" is acceptable. However, it is important to note that some types of DBMS accept only the column of the table or the position in the SELECT statement in the ORDER BY clause.

Exercise 9. Write SQL statements for ① to ③ below, and display the results.

① "Display merchandise_names and their unit_prices from the merchandise_table in the ascending order of merchandise_names."

② "Display merchandise_numbers and quantities from the order_detail_table in the ascending order of merchandise_numbers and in the descending order of the quantities."

③ "Calculate the sum of order_quantities by order_slip_number from the order_detail_table, and display order_slip_numbers in the descending order of the total_order_quantities."

(Answer 9)

① SELECT merchandise_name, unit_price FROM merchandise_table
ORDER BY merchandise_name ASC

<Display result>

merchandise_name	unit_price
System_0-type	4500
Disk_1-type	910
Printer_1-type	300
Printer_X-type	550

② SELECT merchandise_number, quantity FROM order_detail_table
ORDER BY merchandise_number ASC, quantity DESC

<Display result>

merchandise_number	quantity
PR1	20
PX0	30
PX0	15
Q91	10
S00	6
S00	5

③ SELECT order_slip_number, SUM (quantity) AS total_quantity FROM order_detail_table
GROUP BY order_slip_number
ORDER BY 2 DESC

<Display result>

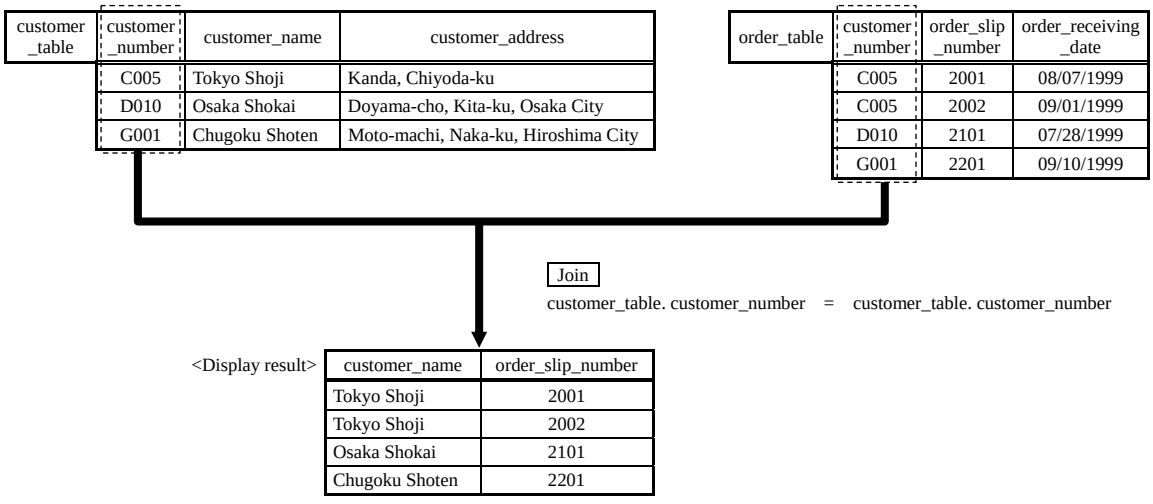
order_slip_number	total_quantity
2101	36
2001	35
2002	15

2.4.2 Join Processing

Join processing combines values in the specified columns in multiple tables. To perform this process, columns of the same data attribute must exist. Multiple tables are usually combined using the primary key and the external key.
For example, the statement "Combine the customer_table and the order_table, and retrieve customer_names and order_slip_numbers" is written as follows. In this case, to combine the customer_table and the order_table, customer_numbers are used as the (relational) key.

SELECT customer_name, order_slip_number FROM customer_table, order_table
WHERE customer_table. customer_number = order_table. customer_number

Figure 2-4-6 Join processing



Thus, in the SELECT statement to combine, two table_names are specified in the FROM clause, and columns to combine are connected by the equal sign in the WHERE clause. In most cases, the two column_names are the same. Therefore, the table_name and the column_name are connected by a period to distinguish between the two column_names.

The above SQL statement can also be written as follows:

```
SELECT customer_name, order_slip_number FROM customer_table X, order_table Y
  WHERE X .customer_number = Y .customer_number
```

In this SQL statement, the columns of the same name are distinguished by naming the customer_table X and the order_table Y, and specifying like "X.customer_number = Y.customer_number." X and Y, in this case, are called the "correlation name."

Exercise 10. Write SQL statements for ① to ④ below, and display the results.

① "Combine the customer_table and the order_detail_table, and display customer_names, merchandise_numbers, and quantities."

② "Combine the customer_table and the order_table, and display the names of the customers who placed orders in September 1999."

③ "Combine the order_detail_table and the merchandise_table, and calculate the sum of quantities by merchandise, and display the total_quantities with the merchandise_names, naming the column <total_quantity>."

④ "Combine the customer_table, the order_detail_table, and the merchandise_table, and calculate the sum of the amount by customer, and display the total amount with the customer_names, naming the column <total_amount>."
- The amount by merchandise is calculated by "quantity × unit_price."
- "total_amount" is the total by customer.

(Answer 10)

①
```
SELECT customer_name, merchandise_number, quantity FROM customer_table, order_detail_table
  WHERE customer_table. customer_number = order_detail_table. customer_number
```

<Display result>

customer_name	merchandise_number	quantity
Tokyo Shoji	PR1	20
Tokyo Shoji	PX0	15
Tokyo Shoji	Q91	10
Tokyo Shoji	S00	5
Osaka Shokai	PX0	30
Osaka Shokai	S00	6

②
```
SELECT customer_name FROM customer_table X, order_table Y
  WHERE X.customer_number = Y. customer_number
    AND order_receiving_date LIKE '99/09/_ _'
```

<Display result>

customer_name
Tokyo Shoji
Chugoku Shoten

③
```
SELECT merchandise_name, SUM (quantity) AS total_quantity
    FROM order_detail_table X, merchandise_table Y
  WHERE X. merchandise_number = Y. merchandise_number
  GROUP BY merchandise_name
```

<Display result>

merchandise_name	total_quantity
Printer_1-type	20
Printer_X-type	45
Disk_1-type	10
System_0-type	11

④ SELECT customer_name, SUM (quantity*unit_price) AS total_amount
FROM customer_table X, order_detail_table Y, order_table Z
WHERE X. customer_number = Y. customer_number
AND Y. merchandise_number = Z. merchandise_number
GROUP BY customer_name

<Display result>

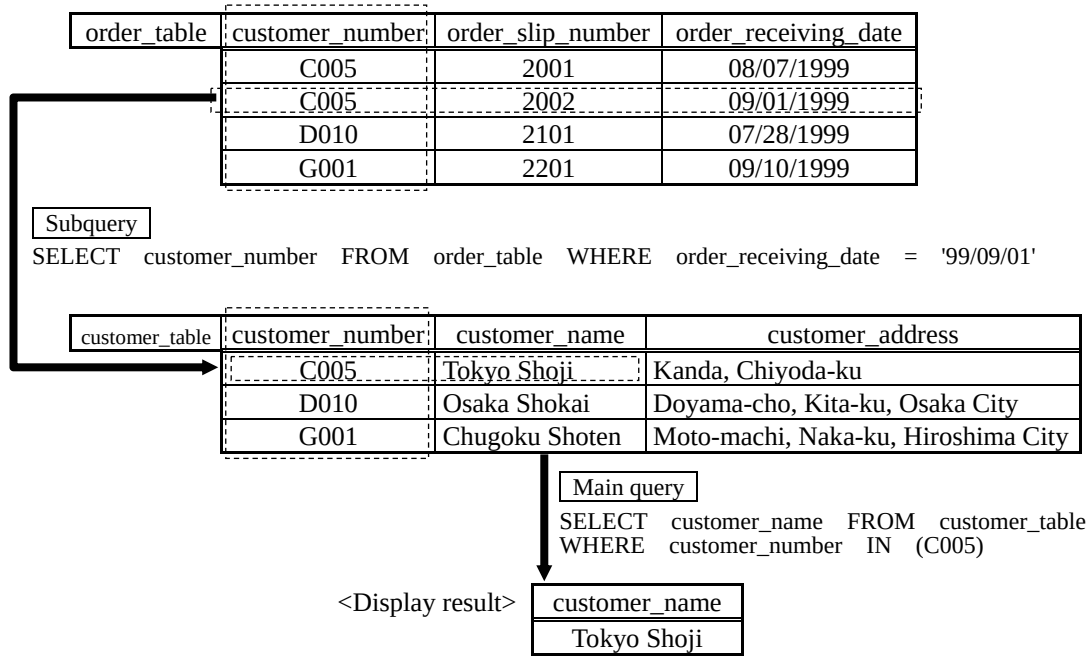
customer_name	total_amount
Tokyo Shoji	45850
Osaka Shokai	43500

2.4.3 Using Subqueries

A subquery is a query made for different tables or the same table, using a query result as a retrieval condition. In other words, subquery means making the next query (main query) based on the first query. To perform this process, specify the SELECT statement of the subquery by using the IN predicate in the SELECT statement.
For example, the statement "Extract the customer_names who placed orders in September 1st, 1999." is expressed as follows:

```
SELECT  customer_name
  FROM  customer_table  WHERE customer_number
      IN  (SELECT  customer_number  FROM  order_table
                WHERE  order_receiving_date  =  '99/09/01')
```

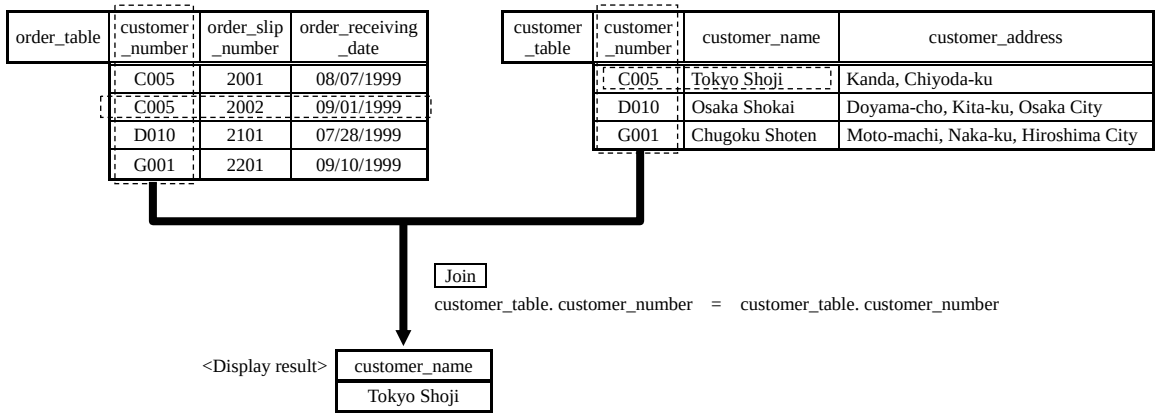
Figure 2-4-7 Subquery Processing Using the IN Predicate



The SQL statement using a subquery can be rewritten as the SQL statement of join processing as follows:

```
SELECT  customer_name  FROM  order_table,  customer_table
  WHERE  order_receiving_date  =  '99/09/01'
              AND  order_table. customer_number  =  order_table. customer_number
```

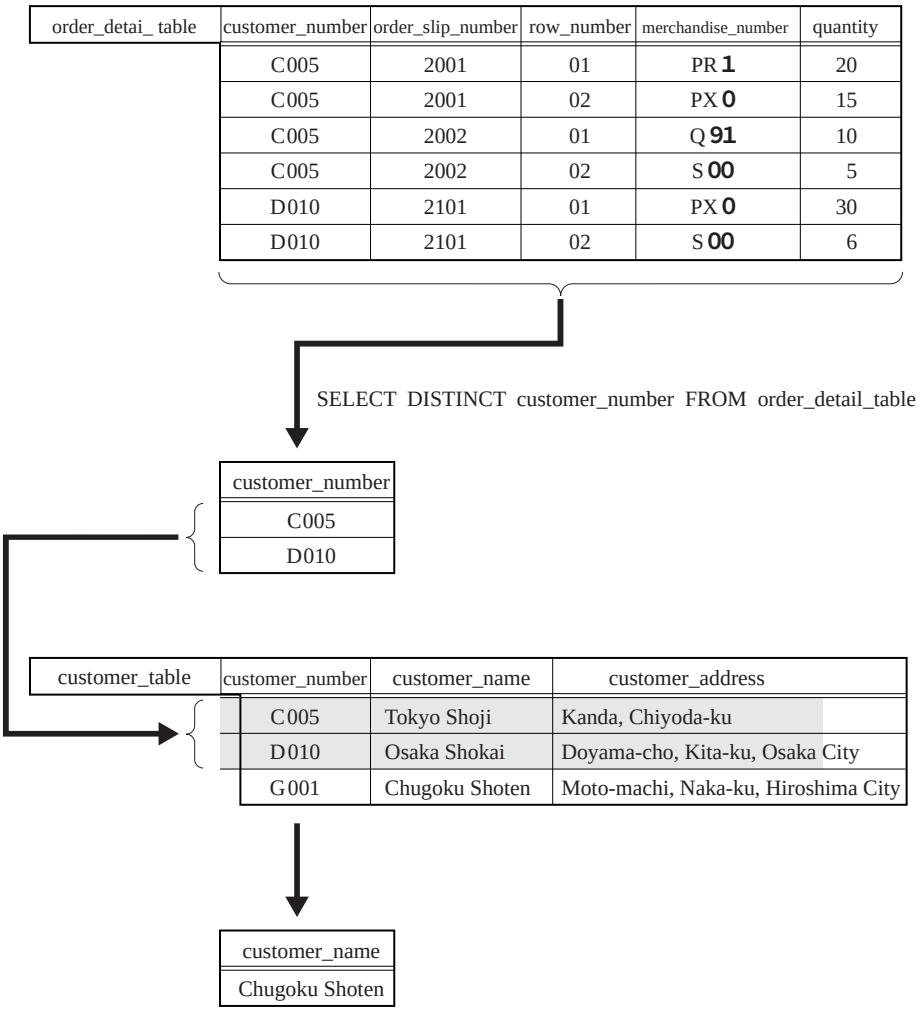
Figure 2-4-8 Subquery Processing Using Join Processing



Use the NOT IN predicate if you want to use a result other than the subquery result as a condition of the main query.
For example, the statement "display the customer_names not recorded in the order_detail_table" is expressed as follows:

```
SELECT customer_name FROM customer_table WHERE customer_number
  NOT IN (SELECT DISTINCT customer_number FROM order_detail_table)
```

Figure 2-4-9 Subquery Processing Using the NOT IN Predicate



Exercise 11. Write SQL statements for ① to ③ below, and display the results.

① "Display the names and addresses of customers who ordered the merchandise number 'PX 0'."

② "Display the merchandise numbers and quantities of merchandise ordered on other than September 1999."

③ "Display the names of customers who placed at least one order amounting to 10,000 or more per merchandise."
- The amount per merchandise is calculated by "quantity × unit_price."

(Answer 11)

```
① SELECT  customer_name,  customer_address  FROM  customer_table
    WHERE  customer_number
      IN  (SELECT  customer_number  FROM  order_detail_table
            WHERE  merchandise number  =  'PX0')
```

<Display result>

customer_name	customer_address
Tokyo Shoji	Kanda, Chiyoda-ku
Osaka Shokai	Doyama-cho, Kita-ku, Osaka City

```
② SELECT  merchandise_number,  quantity  FROM  order_detail_table
    WHERE  order_slip_number
      NOT  IN  (SELECT  order_slip_number  FROM  order_table
                WHERE  order_receiving_date  =  '99/09/_ _')
```

<Display result>

merchandise_number	quantity
PR1	20
PX0	15
PX0	30
S00	6

```
③ SELECT  customer_name  FROM  customer_table
    WHERE  customer_number
      IN  (SELECT  DISTINCT  customer_number
            FROM  order_detail_table  X,  merchandise_table  Y
            WHERE  X. merchandise_number  =  Y. merchandise_number
              AND  quantity  *  unit_price  > =  10000)
```

<Display result>

customer_name
Tokyo Shoji
Osaka Shokai

2.4.4 Use of View

As already stated, a view is defined by the data definition language (SQL-DDL). A view can be defined by extracting part of an actual table and by combining multiple tables. In this section, creating a view by combining multiple tables, is explained.
For example, the statement "combine the customer_table and the order_table, and extract customer_names and order_slip_numbers" used in join process can also be defined as "create a view consisting of customer_names and order_slip_numbers."

```
CREATE  VIEW  customer_order_slip_table
  AS  SELECT  customer_name,  order_slip_number  FROM  customer_table  X,  order_table
Y
      WHERE  X. customer_number  =  Y. customer_number
```

<Display result>

customer_order_slip_table	customer_name	order_slip_number
	Tokyo Shoji	2001
	Tokyo Shoji	2002
	Osaka Shokai	2101
	Chugoku Shoten	2201

As a result, a "customer_order_slip_table," created by joining the customer_table and order_table is defined as a view.
This is called a "query" in the DBMS used on personal computers. In the data manipulation by the DBMS on personal computers, only data satisfying certain conditions can be extracted from the database (actual table) by defining a query (view). A query can be defined by specifying the query name, target table/query name, field (column) name, and query conditions.
As explained in 2.3.4, once a view is defined, data in the view become accessible. This improves the usability of the view.
For example, the statement "display the customer_name whose order_slip_number is 2101" is defined by the SQL statement of join processing as follows:

```
SELECT  customer_name  FROM  customer_table,  order_table
  WHERE  customer_table. customer_number  =  order_table. customer_number
      AND  order_slip_number  =  2101
```

Using the previously defined view "customer_order_slip_table," the above example can be defined by the SQL statement as follows:

```
SELECT  customer_name  FROM  customer_order_slip_table
  WHERE  order_slip_number  =  2101
```

When the above two SQL statements are compared, the one using the view is simpler. If the view has been defined, the data in the view "customer_order_slip" are automatically updated when order records increase and actual tables, "customer_table" and "order_table," are updated.
Thus, when extracting required data from multiple tables, the method to create a view including the required data beforehand and extract the data form the view is more efficient.

2.4.5 Change Processing

In this section, as data change processing insert, update, and deletion of data are explained.

(1) Data insertion

Data insertion is performed for an actual table (data cannot be inserted into a view), and it is manipulated by "INSERT statement" in SQL.

Data insertion

```
INSERT  INTO   the name of the table in which the data are inserted (column names to be inserted)
        VALUES  values to be inserted
```

For example, the statement "add new customer information (A001, Yokohama Shokai, Nishi-shiba, Kanazawa-ku, Yokohama City) to the customer table" is written as follows:

```
INSERT INTO customer_table (customer_number, customer_name, customer_address)
    VALUES ('A001', N'Yokohama Shokai', N'Nishi-shiba, Kanazawa-ku, Yokohama City')
```

customer_table

customer_number	customer_name	customer_address
C005	Tokyo Shoji	Kanda, Chiyoda-ku
D010	Osaka Shokai	Doyama-cho, Kita-ku, Osaka City
G001	Chugoku Shoten	Moto-machi, Naka-ku, Hiroshima City
A001	Yokohama Shokai	Nishi-shiba, Kanazawa-ku, Yokohama City

← Insert

Data values after the VALUES clause correspond to the column_names after the table_name. When inserting data, if the column_names and their order correspond to those of the table in which the data are inserted, column_names following the table_name after INSERT INTO need not be specified.

(2) Data update

Data update means updating values in the specified rows in the actual table, and it is manipulated by "UPDATE statement" in SQL.

Data update

```
UPDATE table_name
    SET column_name = expression WHERE query_condition
```

For example, the statement "raise the price of printers in the merchandise_table by 10%" is expressed as follows:

```
UPDATE merchandise_table
    SET unit_price = unit_price * 1.1
 WHERE merchandise_name LIKE N' printer %'
```

merchandise_table

merchandise_number	merchandise_name	unit_price
PR1	Printer_1-type	300
PX0	Printer_X-type	550
Q91	Disk_1-type	910
S00	System_0-type	4500

Update

330
605

In the above definition, the specified rows are selected by the WHERE clause and the specified columns are updated by the SET clause.

(3) Data deletion

Data deletion means deleting the specified rows in the actual table, and it is controlled by "DELETE statement" in SQL.

Data deletion

```
DELETE FROM table_name WHERE query_condition
```

For example, the statement "delete the data of Chugoku Shoten from the customer_table" is expressed as follows:

```
DELETE FROM customer_table
    WHERE customer_name = 'Chugoku Shoten'
```

customer_table	customer_number	customer_name	customer_address	
	C005	Tokyo Shoji	Kanda, Chiyoda-ku	
	D010	Osaka Shokai	Doyama-cho, Kita-ku, Osaka City	
	G001	Chugoku Shoten	Moto-machi, Naka-ku, Hiroshima City	→ Delete

In the above definition, the specific rows selected by the WHERE clause are deleted. If the WHERE clause is omitted, the whole rows of the table is deleted.

2.4.6 Summary of SQL

In this section, the contents in the preceding sections are confirmed by creating SQL statements for Q1 to Q20 to execute a series of processes from the definition to the manipulation of tables.

Q1. Define the table ① to ③ below by SQL. These tables and data are also used in Q2 and later.

① <student table> primary key: student number

student number	name	gender	address
1201	Shizuka Yamamoto	Female	Yokohama City
1221	Yuka Motoyama	Female	Kawasaki City
1231	Jiro Yamada	Male	Kawasaki City
1232	Shiro Yamamoto	Male	Yokohama City
1233	Karin Kida	Female	Yokosuka City
1235	Shinji Kimoto	Male	Yokohama City
4-character text	10-character kanji text	1-character kanji	5-character kanji text

② <score table> primary key: student_number + subject_code, foreign key: subject_code

student_number	subject_code	score	examination_date
1201	A01	60	10/10/1999
1201	B01	85	10/11/1999
1221	A01	70	10/10/1999
1221	B02	60	10/11/1999
1231	A02	90	10/10/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999
4-character text	3- character text	3- character numeric value	Date type

③ <subject_table> primary key: subject_code

subject_code	subject_name
A01	Mathematics I
A02	Mathematics II
B01	English I
B02	English II
3- character text	5- character kanji text

Q2. As the data of "student number" and "name" are frequently used, it is necessary to create a name table as shown below by extracting these two items from the student table. Write the SQL statement to set the new table.

<name table>

student_number	name
1201	Shizuka Yamamoto
1221	Yuka Motoyama
1231	Jiro Yamada
1232	Shiro Yamamoto
1233	Karin Kida
1235	Shinji Kimoto

Q3. The authority concerning the student table is defined as ① to ③ below. Write SQL statements for ① to ③. ( ) shows the authorization identifier (department or person given the authority).

① (The administrative department) has full authority.
② (The instruction department) has the authority to refer to and update the student table.
③ (Teachers) have the authority to refer to the student table.

Q4. Write the SQL statement to extract (project) names and addresses from the student table and display the results.

<Display result>

name	address
Shizuka Yamamoto	Yokohama City
Yuka Motoyama	Kawasaki City
Jiro Yamada	Kawasaki City
Shiro Yamamoto	Yokohama City
Karin Kida	Yokosuka City
Shinji Kimoto	Yokohama City

Q5. Write the SQL statement to extract (select) the students whose (gender is 'female') from the student table and display the results.

<Display result>

student_number	name	gender	address
1201	Shizuka Yamamoto	Female	Yokohama City
1221	Yuka Motoyama	Female	Kawasaki City
1233	Karin Kida	Female	Yokosuka City

Q6. Write the SQL statement to extract the records whose "student_number is not '1221'" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1201	A01	60	10/10/1999
1201	B01	85	10/11/1999
1231	A02	90	10/10/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999

Q7. Write the SQL statement to extract the records whose "examination date is '10/10/1999'" and "score is 80 or higher" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1231	A02	90	10/10/1999

Q8. Write the SQL statement to extract the records whose "examination date is '10/10/1999'" or "score is 80 or higher" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1201	A01	60	10/10/1999
1201	B01	85	10/11/1999
1221	A01	70	10/10/1999
1231	A02	90	10/10/1999
1231	B01	80	10/11/1999

Q9. Write the SQL statement to extract the records whose "score is 70 to 80" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1221	A01	70	10/10/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999

Q10. Write the SQL statement to extract the records whose "subject code begins with 'A'" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1201	A01	60	10/10/1999
1221	A01	70	10/10/1999
1231	A02	90	10/10/1999

Q11. Write the SQL statement to extract the records whose "student number's third position of characters is '2'" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1221	A01	70	10/10/1999
1221	B02	60	10/11/1999

Q12. Write the SQL statement to extract the records whose "score is 70 or higher," and "examination date is '10/11/1999"" or "subject code's last character is '1'" from the score table and display the results.

<Display result>

student_number	subject_code	score	examination_date
1201	B01	85	10/11/1999
1221	A01	70	10/10/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999

Q13. Write the SQL statement to calculate the total score of each student from the score table and display the results. Calculate the total score by grouping scores by student number.

<Display result>

student_number	SUM (score)
1201	145
1221	130
1231	245

Q14. Write the SQL statement to calculate the average score of each subject from the score table and display the results. Calculate the average score by grouping scores by subject code.

<Display result>

subject_code	average_score
A01	65
A02	90
B01	83
B02	68

Q15. Write the SQL statement to calculate the total number of examinees by examination date from the score table and display the results. Calculate the total number of examinees by grouping examinees by examination date.

[Duplication is counted]

<Display result>

examination_date	total_number_of_examinees
10/10/1999	3
10/11/1999	4

[Duplication is not counted (examinees of the same student number are counted as one examinee)]

<Display result>

examination_date	total_number_of_examinees
10/10/1999	3
10/11/1999	3

Q16. Write the SQL statement to sort scores in the score table in the descending order and display the results.

<Display result>

student_number	subject_code	score	examination_date
1231	A02	90	10/10/1999
1201	B01	85	10/11/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999
1221	A01	70	10/10/1999
1201	A01	60	10/10/1999
1221	B02	60	10/11/1999

Q17. Write the SQL statement to sort scores in the score table by subject code in descending order and display the results.

<Display result>

student_number	subject_code	score	examination_date
1221	A01	70	10/10/1999
1201	A01	60	10/10/1999
1231	A02	90	10/10/1999
1201	B01	85	10/11/1999
1231	B01	80	10/11/1999
1231	B02	75	10/11/1999
1221	B02	60	10/11/1999

Q18. Write the SQL statement to calculate the total score of each student from the score_table and sort them in descending order, and display the results.

<Display result>

student_number	SUM (score)
1231	245
1201	145
1221	130

Q19. Write the SQL statement to extract the student numbers, the subject names of the examinations, and the scores from the score table and the subject table, and display the results.

<Display result>

student_number	subject_name	score
1201	Mathematics I	60
1201	English I	85
1221	Mathematics I	70
1221	English II	60
1231	Mathematics II	90
1231	English I	80
1231	English II	75

Q20. Write the SQL statement to extract the name of the students whose score is 60 or lower from the student table and the score table, and display the results.

<Display result>

name
Shizuka Yamamoto
Yuka Motoyama

Answer 1.

```
① CREATE TABLE student_table
    (student_number   CHAR (4),
     name             NCHAR (10),
     gender           NCHAR (1),
     address          NCHAR (5),
     PRIMARY          KEY  student_number)
② CREATE TABLE score_table
    (student_number   CHAR (4),
     subject_code     CHAR (3),
     score            INT (3),
     examination_date DATE,
     PRIMARY          KEY  (student_number, subject_code),
     FOREIGN          KEY subject_code  REFERENCES  subject_table)
③ CREATE TABLE subject_table
    (subject_code     CHAR (3),
     subject_name     NCHAR (5),
     PRIMARY          KEY  subject_code)
```

Answer 2.

```
SELECT  VIEW  name_table
      AS  SELECT  student_number, name
            FROM  student_table
```

Answer 3.

```
① GRANT  ALL  PRIVILEGES  ON  student_table  TO  administration_department
② GRANT  SELECT  UPDATE   ON  student_table  TO  instruction_department
③ GRANT  SELECT           ON  student_table  TO  teacher
```

Answer 4.

```
SELECT  name,  address  FROM  student_table
```

Answer 5.

```
SELECT  *  FROM  student_table
  WHERE  gender  =  'female'
```

Answer 6.

```
SELECT  *  FROM  score_table
  WHERE  student_number  NOT  =  '1221'
```

Answer 7.

```
SELECT  *  FROM  score_table
  WHERE  examination_date  =  '10/10/1999"  AND  score  >=  80
```

Answer 8.

```
SELECT  *  FROM  score_table
  WHERE  examination_date  =  '10/10/1999"  OR  score  >=  80
```

Answer 9.

```
SELECT  *  FROM  score_table
  WHERE  score  BETWEEN  70  AND  80
```

Answer 10.

```
SELECT  *  FROM  score_table
  WHERE  subject_code  LIKE  'A%'
```

Answer 11.
```
SELECT * FROM score_table
  WHERE student_number LIKE '_ _2_ '
```

Answer 12.
```
SELECT * FROM score_table
  WHERE score > = 70
    AND (examination_date = '10/11/1999' OR subject_code LIKE '_ _1')
```

Answer 13.
```
SELECT student_number, SUM (score) FROM score_table
  GROUP BY student_number
```

Answer 14.
```
SELECT subject_code, AVG (score) AS average_score FROM score_table
  GROUP BY subject_code
```

Answer 15.
```
[Duplication is counted]
SELECT examination_date, COUNT (*) AS total_number_of_examinees FROM
   score_table
GROUP BY examination_date

[Duplication is not counted (examinees of the same student_number are counted as one
examinee)]
SELECT examination_date, COUNT (DISTINCT student_number) AS total_
   number_of_examinees FROM score_table
  GROUP BY examination_date
```

Answer 16.
```
SELECT * FROM score_table
  GROUP BY score DESC
```

Answer 17.
```
SELECT * FROM score_table
ORDER BY subject_code, score DESC
```

Answer 18.
```
SELECT student_number, SUM (score) FROM score_table
  GROUP BY student_number
  ORDER BY 2 DESC
```

Answer 19.
```
SELECT student_number, subject_name, score FROM score_table, subject_table
  WHERE score_table.subject_code = subject_table. subject_code
or
SELECT student_number, subject_name, score FROM score_table X,
    subject_table Y
  WHERE X. subject_code = Y. subject_code
```

Answer 20.
```
SELECT name FROM student_table
  WHERE student_number IN
     (SELECT student_number FROM score_table
       WHERE score <= 60)
or
SELECT name FROM student_table X, score_table Y
  WHERE X .student_number = Y. student_number
    AND score < = 60
```

2.5 Extended Use of SQL

Generally, SQL is used as a supplementary language (data sub language) to use databases, rather than used independently.
As a data sub-language, SQL is used in the following three ways:

- Embedded SQL
  Use SQL by embedding it in application programs written in high-level languages.
- Module language
  Use a module language developed to abstract the interface combining a high-level language and SQL.
- API (Application Programming Interface)
  Use API, the interface of functions, commands, etc., prepared for programmers to develop applications.

In this section, the use of the embedded SQL is described in detail.

2.5.1 Embedded SQL

By embedding SQL statements in application programs, routine operational processing, large amounts of data processing, and the processing of relational databases while processing files become more efficient.
In the embedded SQL, the cursor is used for operation. However, the operation of reading a row from a relational database can be performed without using the cursor (non-cursor operation).

2.5.2 Cursor Operation

When reading multiple rows from a table (relational database), the cursor is used. After instructing the reading of tables with the SELECT statement, rows are received one by one according by another instruction. The cursor is used to read one row at a time.
The following explain the cursor operations classified into the "program definition part" and the "program processing part."

(1) Program definition part

① Input/output work area

Processing of a relational database is instructed by the embedded SQL statement, and the process result is returned to the work area (variable) of the program definition part. The variable as a work area is called the "host variable."
The host variable as an input/output work area can be defined in the following format:

Definition of the host variable

```
EXEC SQL BEGIN DECLARE SECTION
    [host variable]
EXEC SQL END DECLARE SECTION
```

*One host variable is defined by one row.
*In SQL provided by vendors, a host variable is defined in the format defined by the normal programming.

It is important to define the host variable as an input/output work area to have the same attribute as the definition of the data type of the column in the table. If the defined data type is different, the value in the column may be truncated.

② SQLCODE

Definition of SQLCODE (SQLCOD in FORTRAN) is mandatory as a host variable. SQLCODE sets the return code showing whether every SQL statement is normally executed or not.
The contents of SQLCODE are mainly classified into the following three types:

- SQLCODE = 0 … Normal status
- SQLCODE = 100 … End status (end of the table and no corresponding row)
- SQLCODE < 0 … Error status

SQLCODE must be defined as having the same attributes as INTEGER (4-byte integer type), the data type of the column. Examples of the description in each language are shown below:

Definition of SQLCODE

```
<COBOL>
   01  SQLCODE  PIC  S9 (9)  COMP.
<PL/I>
   DCL  SQLCODE  BIN  FIXED  (31) ;
<FORTRAN>
   INTEGER  *  4  SQLCOD
<C>
   long  sqlcode;
```

③ Cursor

The cursor is defined in the program definition part using the SELECT statement. In the definition, the GROUP BY clause, the ORDER BY clause, and column functions can be included. Therefore, instructions of grouping and classification are not required in the program.
Avoid using duplicate cursor names in a program.

Cursor definition

```
EXEC  SQL  DECLARE  [cursor name]  CURSOR  FOR
    SELECT clause
      FROM [table_name]
    WHERE  [table_name. column_name]  =  [table_name. column_name]
```

(2) Program processing part

Cursor processing in the program processing part is performed in the order of the OPEN statement, the FETCH statement, and the CLOSE statement as shown below:

1. After the execution of the OPEN statement, the SELECT statement defined by the cursor is executed, and the cursor points to the first row of the corresponding table.
2. The FETCH statement fetches the row specified by the cursor, and returns the row to the host variable of the INTO clause. After fetching one row, the cursor points to the next row. And FETCH statement is repeated until no row is left in the table. That is, the termination condition of the FETCH statement is SQLCODE=100.
3. The CLOSE statement is used when there is no more row to be read in the table, and the cursor is closed.

Definition of the cursor processing statement

<OPEN> … Open the cursor
EXEC SQL OPEN [cursor name] END-EXEC

<FETCH> … Fetch the cursor
EXEC SQL FETCH [cursor name] INTO [host variable]
END-EXEC

<CLOSE> … Close the cursor
EXEC SQL CLOSE [cursor name] END-EXEC

Basically, the concept of the cursor operation is the same as that of the file operation.
First, open the file (or the cursor) and continue the processing of records one by one until the processing of all the records has finished, and then close the file (or the cursor). To read one record, the READ statement is used in the case of the file, while the FETCH statement is used in the case of the cursor.
For example, "print customer_numbers and customer_names in the customer_number order from the customer_table" is described by the embedded type SQL using COBOL as the host language as follows:

Program definition part

```
DATA DIVISION.
WORKING-STORAGE SECTION.
  EXEC SQL BEGIN DECLARE SECTION END-EXEC.
    01 CUSTNO PIC X (4).
    01 CUSTNAME PIC N (10).
    01 SQLCODE PIC S 9 (9) COMP.
  EXEC SQL END DECLARE SECTION EDN-EXEC.
  EXEC SQL DECLARE CUSTOMER CURSOR
           FOR SELECT customer_number, customer_name
                 FROM customer_table
               ORDER BY customer_number END-EXEC.
```

Program processing part

```
PROCEDURE DIVISION.
  EXEC SQL OPEN CUST END-EXEC.
  EXEC SQL FETCH CUST
           INTO :CUSTNO, :CUSTNAME END-EXEC.
  PERFORM UNTIL SQLCODE = 100
    IF SQLCODE < 0
       THEN PERFORM (Error processing)
       ELSE PERFORM (One-line print processing)
  END-PERFORM.

[Error processing]
       |
[One-line print processing]
       |
```

(3) Data changes

The FETCH statement is used to read data from the table. The methods to update and delete the read data are explained below.

① Update by cursor processing

When updating rows read by the FETCH statement under certain conditions in the program, an update instruction is given using the UPDATE statement after the FETCH statement.
In the UPDATE statement format, it is important to use

WHERE CURRENT OF [cursor_name]

instead of the WHERE clause.

Definition of cursor update processing

```
EXEC SQL UPDATE [table_name]
                SET [update_expression]
            WHERE CURRENT OF [cursor_name] END-EXEC.
```

For example, "update the customer number of Tokyo Shoji to C100" is described by the embedded SQL as follows:

[Program definition part]

```
EXEC SQL END DECLARE SECTION END-EXEC.
EXEC SQL DECLARE TOKYO CURSOR
        FOR SELECT customer_number, customer_name FROM customer_table
            WHERE customer_name = 'Tokyo Shoji' END-EXEC.
```

[Program processing part]

```
EXEC SQL OPEN TOKYO END-EXEC.
EXEC SQL FETCH TOKYO
        INTO :CUSTNO, :CUSTNAME END-EXEC.

PERFORM UNTIL SQLCODE = 100
   IF SQLCODE < 0
      THEN PERFORM (error processing)
      ELSE
         EXEC SQL UPDATE customer_table
                      SET customer_number = 'C100'
                  WHERE CURRENT OF TOKYO END-EXEC.
```

② Deletion by cursor processing

Deletion by cursor processing can also be performed by instructing the DELETE statement after the FETCH statement in the same way as the update. In the DELETE statement format, as in the UPDATE statement format,

```
WHERE CURRENT OF [cursor_name]
```

is used instead of the WHERE clause.

Definition of cursor deletion processing

```
EXEC SQL DELETE FROM [table_name]
WHERE CURRENT OF [cursor_name] END-EXEC.
```

For example, "delete the data of Tokyo Shoji" is described by the embedded SQL as follows:

[Program definition part]

```
EXEC SQL DECLARE TOKYO CURSOR
        FOR SELECT customer_number, customer_name FROM customer_table
            WHERE cursor_name = 'Tokyo Shoji' END-EXEC.
```

[Program processing part]

```
EXEC SQL OPEN TOKYO END-EXEC.
EXEC SQL FETCH TOKYO
        INTO :CUSTNO, :CUSTNAME END-EXEC.

PERFORM UNTIL SQLCODE = 100
   IF SQLCODE < 0
      THEN PERFORM (error processing)
      ELSE
         EXEC SQL DELETE FROM customer_table
             WHERE CURRENT OF TOKYO END-EXEC.
```

2.5.3 Non-Cursor Operation

The non-cursor operation is a method to embed SQL statements without making a cursor declaration. This operation, however, is available only when one data item is read from the table.
Although the method of specification of SQL statements is almost the same as conversational SQL, descriptions in the program definition part and program processing part are slightly different because no cursor declaration is made.
For example, "update the customer_number of Tokyo Shoji to C100" used in data update by cursor processing can be processed by the non-cursor operation as follows, because only one data item is read from the table (customer_table).

[Program definition part]

```
        |

    EXEC  SQL  END  DECLARE  SECTION  END-EXEC.
```

[Program processing part]

```
    EXEC  SQL  UPDATE  customer_table
                   SET  customer_number  =  'C100'
                 WHERE  customer_name  =  'Tokyo Shoji'  END-EXEC.
```

Exercises

Q1 Choose two correct answers from the following descriptions concerning characteristics of the CODASYL-type database.

a. The data structure is represented by a hierarchy.
b. The data structure is represented by a table format consisting of rows and columns.
c. The data structure is represented as a network.
d. NDL is used as its standard database language.
e. SQL is used as its standard database language.

Q2 Which of the following SQL statements defines a schema?

a. CREATE b. DELETE c. INSERT d. SELECT

Q3 Which of the following is not the SQL statement?

a. CREATE
b. DELETE
c. DIVIDE
d. INSERT
e. UPDATE

Q4 Which of the following SQL statements can extract employee_name s whose salary is ¥300,000 or higher from the table "human_resource?"

a.
```
SELECT salary FROM human_resource
    WHERE employee_name > = 300000
    GROUP BY salary
```
b.
```
SELECT employee_name COUNT (*) FROM human_resource
    WHERE salary > = 300000
    GROUP BY employee_name
```
c.
```
SELECT employee_name FROM human_resource
    WHERE salary > = 300000
```
d.
```
SELECT employee_name, salary FROM human_resource
    GROUP BY salary
    HAVING COUNT (*) > = 300000
```
e.
```
SELECT employee_name, salary FROM human_resource
    WHERE employee_name > = 300000
```

Q5 **In SQL, the SELECT statement is used to extract records from a two-dimensional table. If the following statement is executed for the leased apartments below, which data group is extracted?**

```
SELECT property FROM leased_apartment_table
  WHERE (district = 'Minami-cho' OR time_from_the_station
    < 15)
          AND floor_space > 60
```

Leased_Apartment_Table

property	district	floor_space	time_from_the_station
A	Kita-cho	66	10
B	Minami-cho	54	5
C	Minami-cho	98	15
D	Naka-cho	71	15
E	Kita-cho	63	20

a. A b. A, C c. A, C, D, E
d. B, D, E e. C

Q6 **Which of the following two descriptions on the operation of the customer_table is <u>wrong</u>?**

Customer_table

CUSTOMER_NO	CUSTOMER_NAME	ADDRESS
A0005	Tokyo Shoji	Toranomon, Minato-ku, Tokyo
D0010	Osaka Shokai	Kyo-cho, Tenmanbashi, Chuo-ku, Osaka-City
K0300	Chugoku Shokai	Teppo-cho, Naka-ku, Hiroshima-City
G0041	Kyushu Shoji	Hakataekimae, Hakata-ku, Fukuoka-City

Operation 1
```
SELECT CUSTOMER_NAME, ADDRESS FROM CUSTOMER
```

Operation 2
```
SELECT * FROM CUSTOMER
    WHERE CUSTOMER_NO = 'D0010'
```

a. The table extracted by operation 1 has four rows.
b. The table extracted by operation 1 has two columns.
c. Operation 1 is PROJECTION and operation 2 is SELECTION.
d. The table extracted by operation 2 has one row.
e. The table extracted by operation 2 has two columns.

Q7 Which of the following SQL statements for the table "Shipment Record" produces the largest value as a result of its execution?

shipment_record

merchandise_number	quantity	date
NP200	3	19991010
FP233	2	19991010
TP300	1	19991011
IP266	2	19991011

a. SELECT AVG (quantity) FROM shipment_record

b. SELECT COUNT (*) FROM shipment_record

c. SELECT MAX (quantity) FROM shipment_record

d. SELECT SUM (quantity) FROM shipment_record
WHERE date = '19991011'

Q8 In SQL, DISTINCT in the SELECT statement is used to "eliminate redundant duplicate rows" from the table gained by the SELECT statement. How many rows are included in the table gained as a result of execution of the following SELECT statement with DISTINCT?

[SELECT statement]

```
SELECT DISTINCT customer_name, merchandise_name, unit_price FROM
 order_table, merchandise_table
      WHERE order_table. Merchandise_number = merchandise_table.
      Merchandise_number
```

[order_table]

customer_name	merchandise_number
Oyama Shoten	TV28
Oyama Shoten	TV28W
Oyama Shoten	TV32
Ogawa Shokai	TV32
Ogawa Shokai	TV32W

[merchandise_table]

merchandise_number	merchandise_name	unit_price
TV28	28-inch television	250,000
TV28W	28-inch television	250,000
TV32	32-inch television	300,000
TV32W	32-inch television	300,000

a. 2 b. 3 c. 4 d. 5

Q9 Which of the following SQL statements can extract the average salary by department from tables A and B?

table_A

name	belonging_code	salary
Sachiko Ito	101	200,000
Eiichi Saito	201	300,000
Yuichi Suzuki	101	250,000
Kazuhiro Honda	102	350,000
Goro Yamada	102	300,000
Mari Wakayama	201	250,000

table_B

department_code	department_name
101	Sales department I
102	Sales department II
201	Administration department

a. SELECT department_code, department_name, AVG (salary) FROM table_A, table_B ORDER BY department_code

b. SELECT department_code, department_name, AVG (salary) FROM table_A, table_B WHERE table_A. belonging code = table_B. department_code

c. SELECT department_code, department_name, AVG (salary) FROM table_A, table_B WHERE table_A. belonging code = table_B. department_code GROUP BY department_code, department_name

d. SELECT department_code, department_name, AVG (salary) FROM table_A, table_B WHERE table_A. belonging_code = table_B. department_code ORDER BY department_code

Q10 In a relational database system, which of the following SQL statements is used to extract rows specified by the cursor after it has been defined?

a. DECLARE statement b. FETCH statement c. OPEN statement

d. READ statement e. SELECT statement

3 Database Management

Chapter Objectives

When actually using a database, administrative processes maintaining data integrity and security, recovery from failures, etc. are required. A database management system (DBMS) is software to perform these processes for the users.
In this chapter, we will learn about the overview, types, characteristics and functions of database management systems.

① Understanding functions and characteristics of database management systems to use databases efficiently.
② Understanding characteristics of various databases (DBMSs) such as RDB, OODB, ORDB and multimedia database.
③ Understanding differences between a centralized database and a distributed database and those functions such as commitment control necessary which are required to run a distributed database.

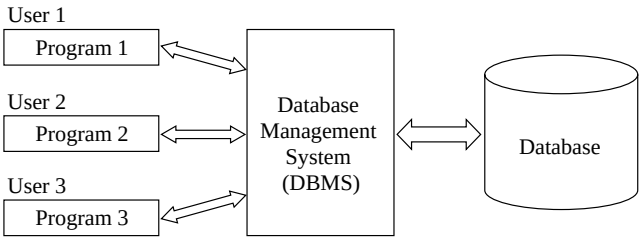
3.1 Functions and Characteristics of Database Management System (DBMS)

Even if data is integrated based on the hierarchical, network, or relational data model and stored in storage media such as magnetic disks as a database, it cannot be operated as a database system. To efficiently operate a database, which has complex data structures, dedicated database management software is needed.

3.1.1 Roles of DBMS

A database management system (DBMS) is software placed between users (programs) and a database to manage data.

Figure 3-1-1
Database Management System



(1) Roles required for a DBMS

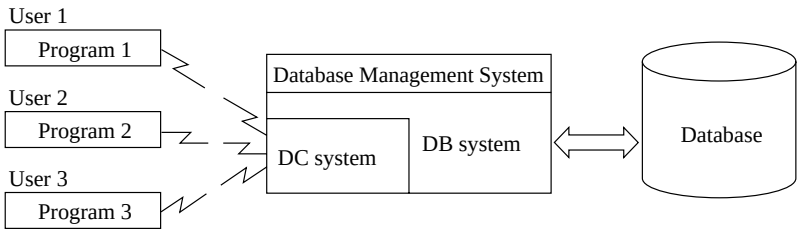
The following roles are required for a DBMS:

- Definition of databases
- Efficient use of data
- Sharing of databases
- Measures against database failures
- Protection of database security
- Provision of languages accessible to a database

(2) DB/DC system (database/data communication system)

Many terminals gain access to a database on a mainframe computer. To operate a database management system on an online system, the database (DB) and data communication (DC) must function in unity. This is called a DB/DC system (Figure 3-1-2). IMS (Information Management System) of IBM is a representative DB/DC system.

Figure 3-1-2 DB/DC System



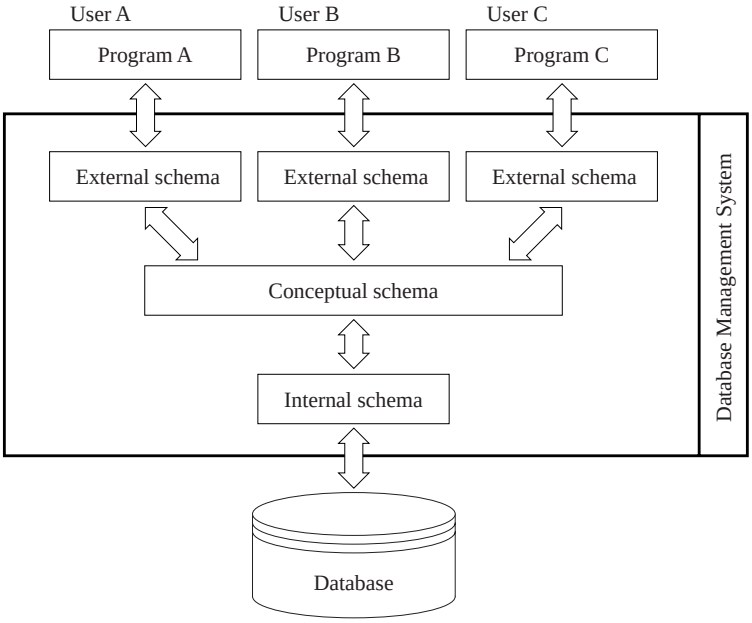
3.1.2 Functions of DBMS

Many DBMSs have been made public so far. In this section, taking a DBMS defined by ANSI-SPARC as an example, its functions are explained.

(1) Database definition functions

For a DBMS, the external schema, the conceptual schema and the internal schema are defined according to the 3-tier schema.

Figure 3-1-3
3-tier Schema of ANSI-SPARC



① Conceptual schema (in CODASYL, called 'schema')

In the conceptual schema, information on records, characteristics of fields, information on keys used to identify records and database names etc. are defined. The logical structure and contents of a database are described in this schema.

② External schema (in CODASYL, called 'subschema')

In the external schema, database information required by an individual user's program is defined. This contains definitions on only those records which are used in the program and their relationships extracted from the database defined in the conceptual schema.

③ Internal schema (in CODASYL, called 'storage schema')

In the internal schema, information concerning storage areas and data organization methods on the storage devices are defined.

Each of these schemata is defined in a database language, DDL (Data Definition Language). Data items such as attributes and names of the described data are called meta-data and meta-data described in each schema is managed by a data dictionary (Data Dictionary/Directory; DD/D). The DD/D consists of a data dictionary in the user-oriented information format and a data directory translated for use by computers.

(2) Database manipulation functions

The functions for users' manipulating databases are written in a DML (Data Manipulation Language), a database language. Concrete contents of database manipulation by users are described in DML and there are three description methods as follows:

① Host language system

The host language system is a system to describe and manipulate a database in a procedural programming language. In the host language system, by extending functions by adding database manipulation commands to the languages such as COBOL, FORTRAN, and PL/I, databases can be processed in the same system as by traditional programming. To operate databases in the host language system, comprehensive knowledge and engineering skill of programming languages and databases are required.

② Self-contained system

The self-contained system is a system using a language uniquely prepared for a specific DBMS. In this system, interactive database operations with the DBMS are performed. While procedures inherent in the system can be easily described, non-routine procedures cannot be described.

③ Query system

The query system is also called a command system and commands are inputted in this case. This system is designed for the non-procedural use of a database by end users.

(3) Database control functions

Among DBMS functions, aforementioned database definition functions and database manipulation functions are basic functions for application programs (as users of a database) to gain access to data and schemata. Furthermore, the following functions are required for a DBMS:

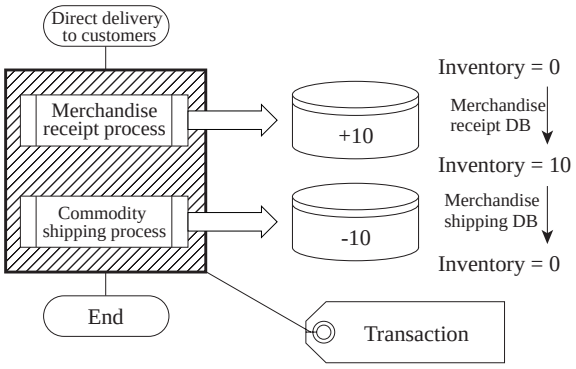
- A function to facilitate the development and maintenance of application programs
- A function to maintain data integrity
- A function to improve data reliability, availability, and security
- A function to maintain appropriate efficiency of processing

More specifically, the following functions are used to realize the above functions:

① Transaction management

A unit of processing from a user's point of view, including database reference and update processing is called a transaction. For example, some trading firms directly deliver some merchandise from suppliers to customers, without keeping in-house inventories. In this case, the receipt and the shipping of merchandise occur at the same time and the same operations are performed also in the inventory management system. If only one of the receipt/shipping operations is performed by a failure in the inventory management database, the actual number of merchandises and the number in the inventory management system will be inconsistent. The correct result can be gained only when both receipt/shipping processes are normally performed. Therefore, in this case, a combination of receipt and shipping processes is considered as a meaningful process, that is, a transaction.

Figure 3-1-4
Transaction Management



The update of a database is always managed by a transaction unit. When transaction processing is normally completed, receipt/shipping processing is also regarded as having been normally completed and the database update is executed. But, if transaction processing stops abnormally, it is not regarded as having been normally completed and the state before processing is restored. Ensuring update is called 'commit process,' and restoring the original state is called 'rollback process. '

② User view function

The external schema is also called a view. Therefore, as previously mentioned, a view is created by extracting a part of the conceptual schema. In a relational database, a view is defined by the SQL statement.
A table is an actual table, and it is stored in the auxiliary storage device. A view, however, is a virtual table created from the actual source table on a case-by-case basis by the execution of the SQL statement and is an abstract entity. Views, generally created by join operations, cannot be updated.
A view has the following roles in database control:

- To achieve logical data independence
- To improve security
- To increase efficiency in application program development

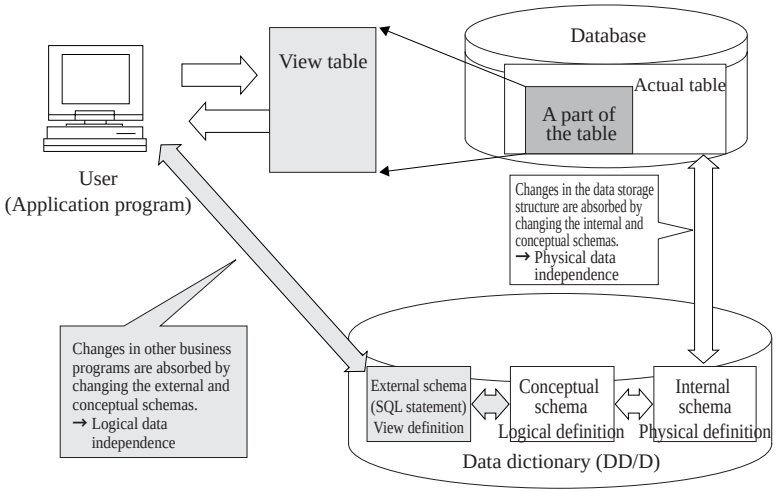
3.1.3 Characteristics of DBMS

By using a DBMS, users can use a database without paying much attention to its structure.
In this section, the characteristics of a DBMS are explained.

(1) Achievement of data independence

One of the purposes of using a database is "independence of data from a program." This is achieved by the 3-tier schema. Data independence is classified into the physical data independence and the logical data independence.

Figure 3-1-5
Data independence



① Physical data independence

When data is not affected by changes of physical data structure and magnetic disk devices, this characteristic is called the physical data independence. In this case, even if the internal and conceptual schemata are modified, the modification of application programs is not required.

② Logical data independence

When logically extraneous data is not affected even if other application programs are changed, the characteristic is called the logical data independence. In this case, even if the external and conceptual schemata are modified, the modification of data is not required.

Thus, the independence of the data shared by users' application programs enables users to create programs without paying much attention to the data storage structures and increases flexibility in programming. Database administrators can also modify databases flexibly without taking users' programs into account.

(2) Database access

In a database system, programs do not directly gain access to the data, but all access operations are performed through a DBMS. In a relational database, for example, data access is performed by the execution of the SQL statement. A database system must respond to access from multiple users, including permission and denial of access. Because such actions are complicated, when a failure occurs, many users can be affected. Therefore, fast failure recovery is essential.
To satisfy these requirements, a DBMS provides the concurrent execution control for simultaneous access from multiple users, the failure recovery and the access privilege control for security.

① Concurrent execution control (exclusive lock management)

To respond to access from multiple users, simultaneous writing to and reading from the same database by multiple users must be reflected in the database without contradiction. The function to realize this is called the concurrent execution control or the exclusive control.

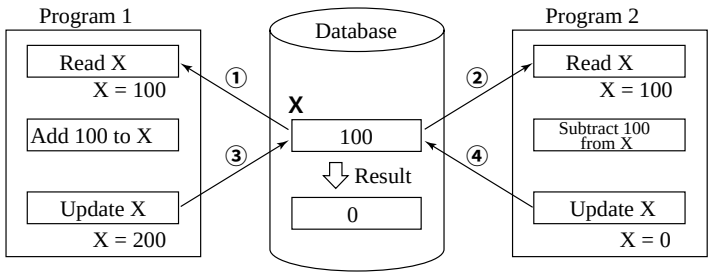
a. Mechanism of concurrent execution control (exclusive lock management)

Figure 3-1-6 shows the simultaneous access to the same data X in a database by programs 1 and 2.

① Program 1 reads data X in the database. The value of X is 100.
② Program 2 reads data X in the database. The value of X is also 100.
③ Program 1 adds 100 to the value of data X and writes the result 200 in the database.
④ Program 2 subtracts 100 from the value of data X, and writes the result 0 in the database.

If the processing is performed in the order of ①, ②, ③, and ④, the value of data X in the database becomes 0.

Figure 3-1-6
When the database does not have the concurrent execution control (exclusive control):



As stated above, when multiple programs gain access to one data item almost at the same time and try to update its contents, they may not be able to gain the correct results. The mechanism to prevent this phenomenon is the concurrent execution control (exclusive control).
In a DBMS, "lock" is used to perform this concurrent execution control (exclusive control). When multiple users gain access to the same data, the concurrent execution control (exclusive control) is performed in a DBMS as follows:

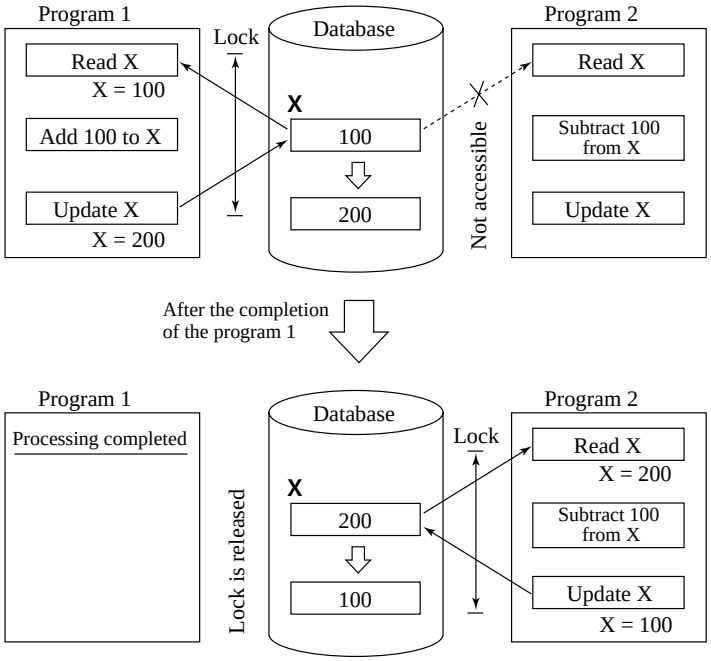
- Until the processing of the user who accessed the database first has been finished, hold the next user's access (this is called the lock).

- When the processing of the first user has been completed, release the lock.
- After confirming the release of the lock, accept the access from the next user.

Figure 3-1-7 shows an example of the concurrent execution control (exclusive lock management) function in a DBMS. The procedures are as follows:

① Program 1 gains access to data X and locks it at the same time to prevent access from program 2.
② After program 1 has completed its processing, program 2 gains access to data X to perform processing.
③ After the execution of programs, the result becomes 100.

Figure 3-1-7
When the database has the concurrent execution control (exclusive control):



This concurrent execution control (exclusive lock management), however, might produce another problem. That is the deadlock explained below.

b. Deadlock

In most DBMSs, the concurrent execution control (exclusive lock management) is performed for simultaneous access to a database. However, by using the lock of this control execution control (exclusive control), the phenomenon shown in Figure 3-1-8 may occur.

Figure 3-1-8
Deadlock

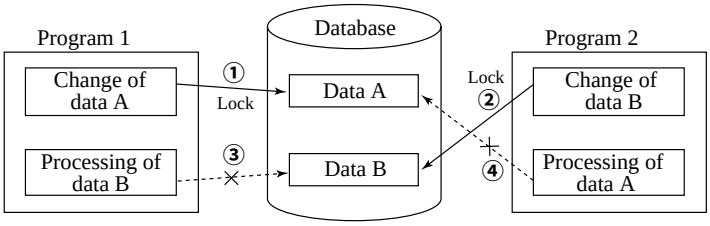


Figure 3-1-8 shows the simultaneous access to data A and B by programs 1 and 2.

① Program 1 gains access to data A.
② Program 2 gains access to data B.
③ Program 1 tried to access data B after accessing data A. But, data B is locked because it has already been accessed by program 2.
④ Program 2 tried to access data A after accessing data B. But, data A is locked because it has already been accessed by program 1.

Thus, the state in which both programs 1 and 2 cannot perform their processing and are locked in a waiting state of the completion of each other's processing is called the deadlock.

To prevent the deadlock, the following controls are performed in a DBMS:

- Regular monitoring of the occurrence of the waiting state of programs.
- When programs are in the deadlock state, the program that started processing later is forced to suspend its processing so that the program that first started processing can continue its processing by priority.
- After the program that first started processing has completed its processing, allow the program that started processing later to perform its processing.

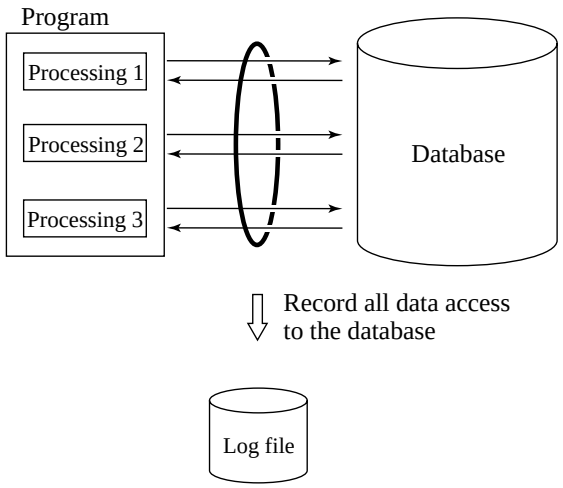
② Failure recovery

When a failure occurs in a database, the computer stops its processing and online transaction processing stops. Because important data indispensable to business activities are recorded in a database, failure prevention and fast failure recovery are essential for database availability.

a. Log file

A database management system prepares a log file to record processes including errors and each update of data in a time series. When a failure occurs in a database, the log file is used (Figure 3-1-9). A log file is also called a journal file or a journal log.

Figure 3-1-9
Log File



b. Rollback processing and roll forward processing

When a failure occurs in a database, there are two recovery methods: the rollback processing and the rollforward processing.

- Rollback processing

When a failure occurs in an operating system or a DBMS, restructure the database in the most recent recoverable state and restore the database before the point of failure by rewriting the contents using the images of the log file. Generally, this processing is automatically performed by the DBMS.

- Rollforward processing

If the disk storing the database is physically damaged, restore the contents of the database at the point of failure by reading the updated process images in the log file sequentially from the backup file.

③ Security

A database storing important and confidential data is accessed by many programs and interactive data manipulations, security to protect information is important.
Actually, security protection is performed not only by a DBMS, but also by software, hardware, and human efforts.
To protect disks on which a database is stored, a DBMS performs file access control and prevents unauthorized access to specific databases by users. It controls access privileges using user IDs, passwords, and their combinations, and encrypts data against data leakage to third parties.

(3) ACID characteristics

To protect a database, all database operations during transaction processing must have the following characteristics:

① Atomicity

A transaction must have the following characteristics:
- Normally complete all data operations included within a transaction processing.
- If only part of a transaction has been completed, the whole transaction processes have to be cancelled.

That means, a transaction has no option other than commit or rollback, and termination in the halfway state is not permitted.
The characteristic satisfying these requirements is the atomicity.

② Consistency

A transaction must be processed by the reliable program. Data manipulation by a transaction must be correctly performed without contradiction. After starting a transaction, the system must be maintained in the normal state.
The characteristic satisfying these requirements is the consistency.

③ Isolation

A transaction must not be affected by the processing results of other transactions. Even when being processed in parallel, transactions must not interfere with each other. In other words, the results of parallel processing and individual processing must be the same.
The characteristic satisfying these requirements is the isolation. The isolation is also called the independence.

④ Durability

When a transaction is normally completed, the state of the transaction must be maintained even if a failure occurs afterwards. That means, once a transaction has successfully ended, the state must be by all means maintained.
The characteristic satisfying these requirements is the durability. The durability is also called 'persistence.'

3.1.4 Types of DBMS

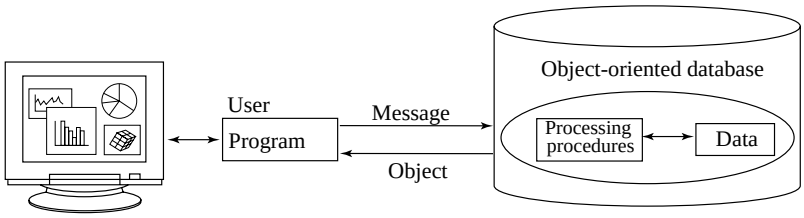
(1) RDB (Relational Database)

The database mentioned in 1.2 is called the relational database (RDB). Since the user of an RDB does not require a knowledge of specific computers, an RDB is employed for most of the current database software for personal computers.
The RDB is built on a mathematical foundation and its data structure, semantic constraints and data manipulation are logically systematized. An RDB consists of a set of simple two-dimensional tables and its smallest data unit is a character or a numeric value. Therefore, its structure is very simple and easy to understand. In addition, because its data manipulation is performed based on declarative manipulation using relational algebra, instead of the path-tracking method, it can provide high-level data control languages.

(2) OODB (Object Oriented Database)

While the relational database handles character data and numeric data, the object-oriented database (OODB) enables the efficient processing of complex data such as multimedia data (Figure 3-1-10). An integrated (encapsulated) set of data and processing procedures is called an object. In the OODB, objects are recorded and managed in magnetic disks.

Figure 3-1-10 OODB



In addition to basic manipulations such as query and update, persistent data integrity and failure recovery capabilities are included in processing procedures. Since objects are highly independent of each other, application programs can be built by assembling objects. User access to the object data is performed by sending messages in the predefined format.

(3) ORDB (Object Relational Database)

The object relational database (ORDB) is a database inheriting the data model and the data manipulation method of the RDB and including object-oriented features. An ORDB can handle abstract data type as well as numeric values and character strings handled in an RDB. The ORDB is a database adopting object-oriented features and inheriting the advantages of database management functions of the traditional RDB.
The ORDB employs SQL3, currently being standardized by ISO as the next version of SQL, as its database language. Some RDB products already put into practical use had begun to adopt object-oriented features before the announcement of SQL3.

(4) NDB (Network Database)

The network database mentioned in Section 1.2 is called NDB. Since knowledge about specific computers is required to use an NDB, it is mainly used for operational systems handling routine works. Compared to the hierarchical database, the NDB can create flexible structures such as cycles (closed paths) and loops (by setting itself as its parent) without being limited to vertical relations. However, the difficulty of having access beyond processing paths have been the challenging issue.

(5) Multimedia database

So far, the data mainly handled by databases are characters and numeric values. However, in response to the multimedia era, the multimedia database is designed to handle such data as video and audio in addition to characters and numeric values.
A multimedia database generally uses an object-oriented approach to provide a uniform user interface without making users conscious of the data structure of the media.
The following features are required for the multimedia database management system:

- Handling of a complex large data structure
  A DBMS can define the data structure by itself, and can perform queries and partial changes according to the structure.
- Time-related data operations and search
  A DBMS achieves such variable speed controls as fast-forwarding, slow-motion, and stop-motion in reproduction of video and audio data.

(6) Hypertext database

The hypertext database can handle complex data structures that cannot be expressed by the traditional structural databases and relational databases. A hypertext is a group of nodes that are linked together to express a set of related pieces of information. The hypertext database is designed by fitting these hypertexts into a database in the network data model structure.

The hypertext database enables the successive use of related databases such as searching for a new data item based on a search result. For example, it is suitable for the search of a homepage on the Internet.

In contrast to the hypertext database that can only search character information, the database that can search data including audio and video as well as characters is called the hypermedia database.

3.2 Distributed Database

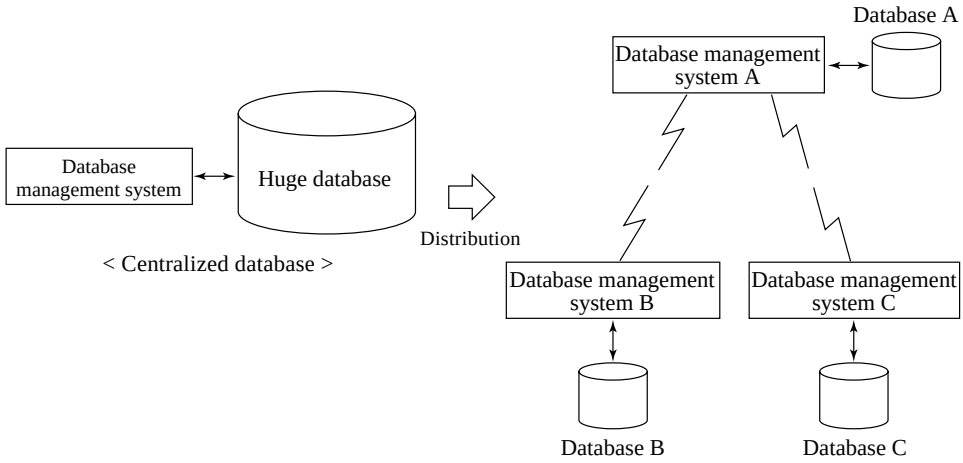
3.2.1 Characteristics of Distributed Database

Originally, the purpose of a database was to achieve a central control by centralizing data. Although the idea of distributed database seems to conflict with this original purpose, it is not true. Even when physically (geographically) distributed, if the data are logically centralized and under centralized control, the original purpose can be accomplished. Network technology has enabled this centralization. Using networks, a company headquarters can do centralized control of databases distributed to its branch offices. Therefore, network technology is indispensable to realize a distributed database. In this section, the advantages and problems of a distributed database are explained.
The centralized database created by gathering data used to be the major traditional database because it reduced the costs of system development, maintenance, and operation management.
The centralized database, however, has the following problems:

- A database failure affects the whole system
- Slow response to demands from a specific department
- High data communication costs due to central processing of data through communication lines
- Increase in costs and personnel to maintain a huge database

To solve these problems, a distributed database that enables the use of multiple databases as one database has been developed.

Figure 3-2-1
Distributed Database



<Advantages of a distributed database>

- Users in each department can perform query and editing of necessary information by themselves with simple operations.
- Better adaptability to changing business environments
- Due to independent processing by each department, the requirements of each department can be directly reflected into the system.
- Because databases are located in each work place, a quick response is possible.
- Even if a failure occurs in a database, other databases are available and the risks can be distributed.
- Users can access other databases without having to consider the location of the databases.

<Problems of a distributed database>

- Administrative management such as security and password controls is difficult.

- Because databases are distributed, duplicate data cannot be completely eliminated and databases can contradict each other.
- Due to the data distribution, programs can also be distributed.
- Due to the addition of department-specific functions, the version control of all the database programs becomes difficult.
- Because programs are developed on a department or individual basis, similar programs can be redundantly created.
- When company-wide processing is performed, larger amounts of time and cost are required for data communication.
- Batch processing is difficult.

In spite of the advantages and disadvantages mentioned above, the distributed database is rapidly becoming prevalent due to the increased performance and lower pricing of personal computers and development of communication networks.

3.2.2 Structure of Distributed Database

Figures 3-2-2 and 3-2-3 show the structures of a traditional centralized database and a general distributed database.

Figure 3-2-2 Centralized database

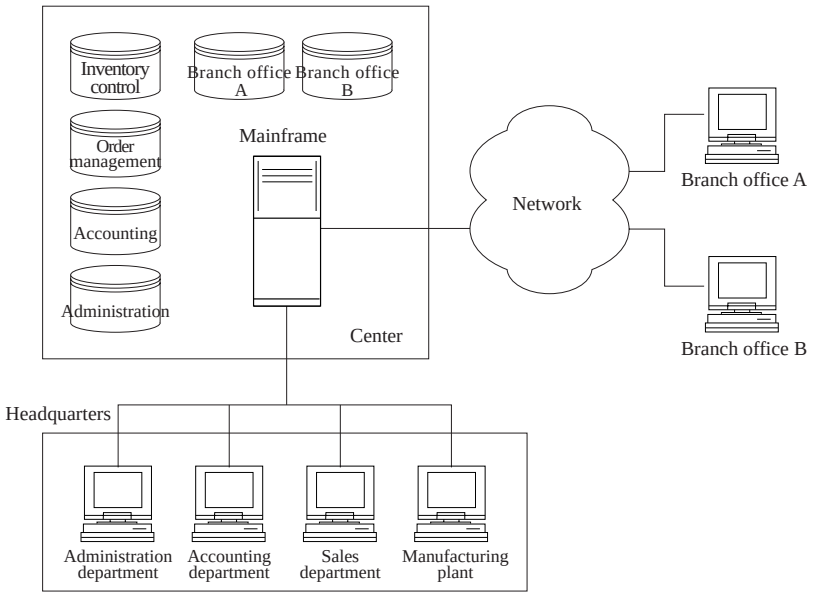
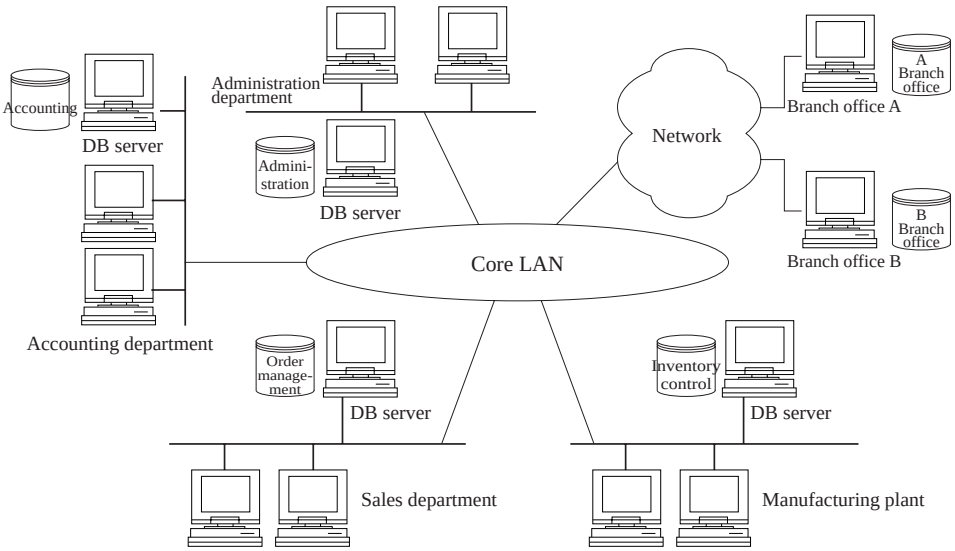


Figure 3-2-3 Distributed Database



These figures are examples using database servers (DB servers). The DB server is a computer that provides database functions for multiple clients (users). Due to the centralized control of database operations, it is possible to maintain the confidentiality of data.

3.2.3 Client Cache

In a distributed database, the amount of data transferred between DB servers and clients could be a problem. To solve this problem, the client cache is used.
In this system, when a client gains access to the database, the cache is used. If necessary data exist in the cache, data transfer from the DB server is not necessary and can reduce the amount of data traffic.
When using the client cache, note the following points:

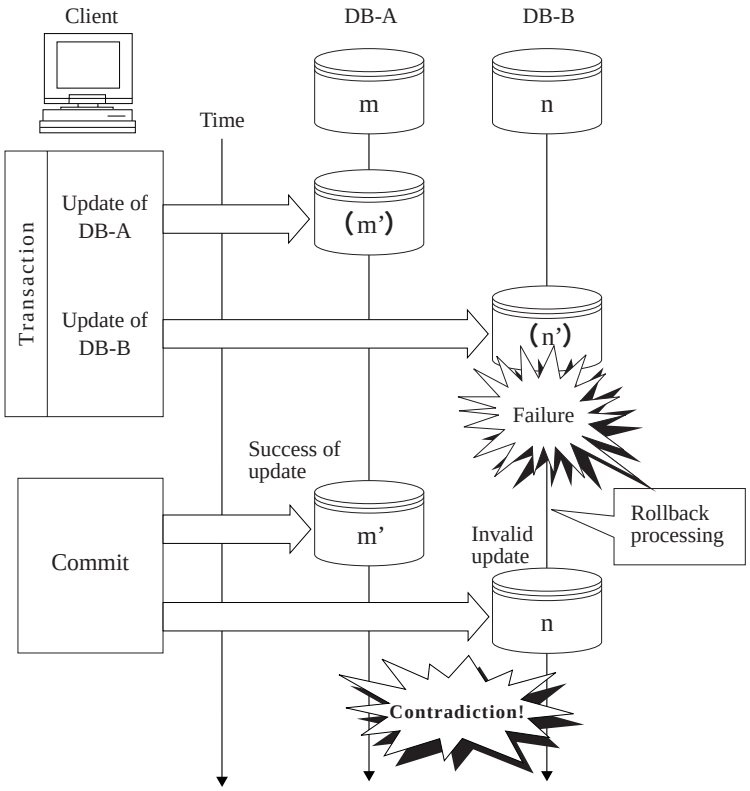
- Contents of the cache among multiple clients and DB servers must be automatically managed to maintain coherency.
- Concurrent execution control between transactions executed on different clients must be performed.

3.2.4 Commitment

(1) 2-phase commitment control

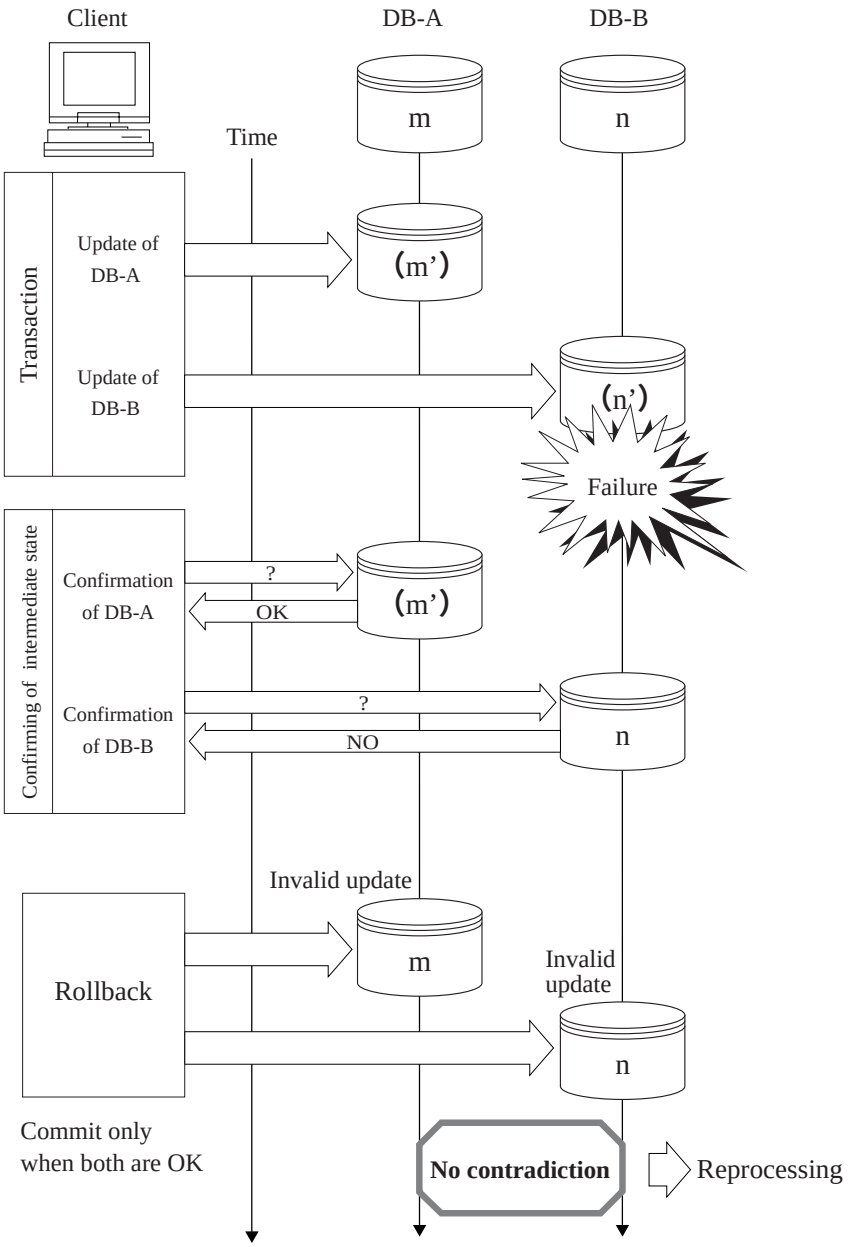
In a centralized database, the data integrity during transaction processing is maintained by controlling commitment and rollback. On the other hand, in a distributed database, because multiple databases are updated by transaction processing from the client, the following problems occur.
As Figure 3-2-4 shows, as a result of transaction processing from the client, commitment processing is performed against DB-A and DB-B based on the commitment request. When processing in DB-A is normally completed and processing in DB-B is abnormally terminated, the integrity of update processing is lost and the contents of the databases contradict each other.

Figure 3-2-4
1-Phase Commitment



Consequently, processing should be performed by the following two steps so as not to accept the results of transaction processing immediately. In the first step, secure an intermediate state (secure state) where both completion of process and rollback can be carried out and in the second step, perform commitment processing. This is called the 2-phase commitment control (Figure 3-2-5).

Figure 3-2-5
2-Phase Commitment



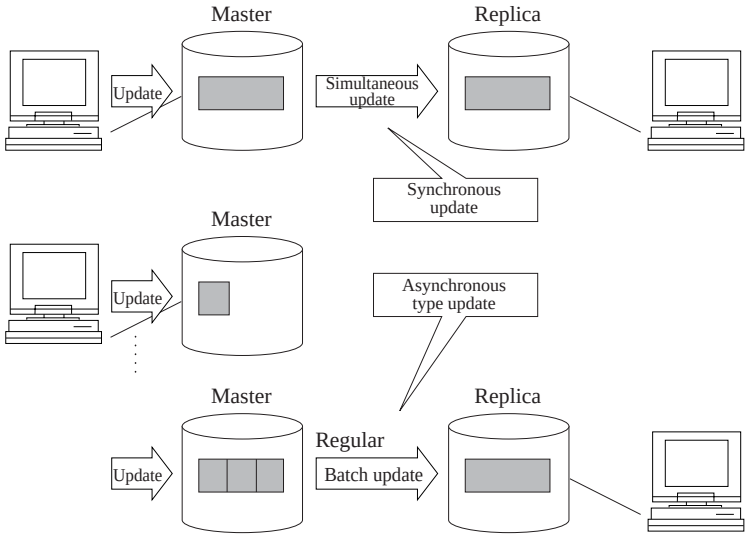
(2) 3-phase commitment control

In the case of 2-phase commitment control, failures are dealt with by having a secure state before commitment processing. However, this is not a complete measure because it cannot deal with failures that occurred during commitment processing.
In the 3-phase commitment control, another processing called pre-commitment processing is set between the secure and commitment states. If either of the databases fail in pre-commitment, rollback processing is conducted against all databases to maintain data integrity. Therefore, the 3-phase commitment control provides higher reliability than the 2-phase commitment control.

3.2.5 Replication

In a distributed database, transaction processing is performed by regarding multiple databases as one database. In the systems in which immediacy is required, real-time processing is performed by the above-mentioned 2-phase commitment control and 3-phase commitment control. On the contrary, in the systems in which immediacy is not so much required, replications of the database are made in the local servers at branch offices, departments, etc., and the burden of data traffic is lowered by using them. The replicated table is called a replica (duplicate table) and creation of a replica is called replication.
In replication, it is necessary to synchronize the contents of the master and those of the replica because the contents of the database are occasionally renewed. There are two methods of synchronization: the synchronization for real-time update and the asynchronous update based on periodical access to the master database.

Figure 3-2-6 Synchronization of Replication



3.3 Measures for Database Integrity

In the database system, processed results of multiple transactions are reflected in the database, and if necessary, the results are shown to users, or printed out. In this process, naturally, transactions themselves must be correct. In addition, in all manipulations such as requests for transaction processing, data manipulation, and result output, consistency of data and processing without contradiction are necessary. The feature is called integrity. As measures for database integrity, the previously mentioned items can be summarized as follows.

- Duplicate data → Data normalization
- Parallel processing of transactions → Concurrent execution control (Exclusive control)
- Update processing of distributed database → 2-phase commitment control
  → 3-phase commitment control

To achieve the database integrity, above all, correctness of the data is the most important factor.

Exercises

Q1 **Which of the DBMS features decides the schema?**

a) Security protection
b) Failure recovery
c) Definition
d) Maintenance

Q2 **In a database system, when multiple transaction processing programs simultaneously update the same database, which method is used to prevent logical contradiction?**

a) Normalization
b) Integrity constraints
c) Data-centric design
d) Exclusive control
e) Rollback

Q3 **There are mainly two files to be used for recovery of the database when a failure occurs in the media. One is a back-up file, and what is the other file?**

a) Transaction file
b) Master file
c) Rollback file
d) Log file

Q4 **Which is the correct data recovery procedure when the transaction processing program against the database has abnormally terminated while updating the data?**

a) Perform rollback processing using the information in the journal after update.
b) Perform rollforward processing using the information in the journal after update.
c) Perform rollback processing using the information in the journal before update.
d) Perform rollforward processing using the information in the journal before update.

Q5 **The ACID characteristic is required for application in the transaction processing. Which of the following features of ACID represents "the nature not producing contradiction by transaction processing?"**

a) Atomicity
b) Consistency
c) Isolation
d) Durability

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