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# Some Aspects of Future Knowledge-Communication Networks as Infrastructure for Fifth Generation Computers

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## ABSTRACT

We have now a new problem to study: What will the requirements of a future communication network be as the infrastructure supporting intelligent computers, such as so-called fifth generation computers or AI (Artificial Intelligence) computers? As an office automation environment can be realized by personal computers and various types of local area networks, these intelligent computers of the future will possibly require new network environments, their own nervous systems.

This paper discusses some aspects of future knowledge-communication networks, including some requirements of future intelligent networks, multi-media, and network operating systems.

## 1. INTRODUCTION

We have now a new problem to study: What will the requirements of a future communication network be as the infrastructure supporting intelligent computers, such as fifth generation computers ?

As an office automation system can be established with personal computers and various types of local area networks, these future intelligent computers will require new network environments. For example, mobile communication is vital for developing mobile information systems (such as mobile-office-facilities), one of the R&D themes in the UK's Alvey fifth generation computer programme.

This paper discusses some aspects of future communication networks as the infrastructure for intelligent computers (e.g., Fifth Generation Computers). They include some requirements of such future networks, multi-communication media, intelligent network managements, and network operating systems.

In future, many computer applications (especially, large scale, open ended, geographically distributed, concurrent systems) will be based on communication between systems which will have been developed separately and independently [Hew1]. So, at the final stage of the Japan's Fifth Generation Computer Systems (FGCS) project, the investigation of new communication network technology will be required for realizing an integrated intelligent knowledge processing system, called a "co-operative problem solving system".

## 2. FIFTH GENERATION COMPUTERS

### (1) The Aim of the Fifth Generation Computer Systems Project

Today, more natural intelligent computer-human interfaces and more intelligent processing are needed. In the near future, computers will be applied not only in data processing but also in knowledge information processing. On the other hand, rapidly developing VLSI technology is available for implementing more sophisticated parallel computer-architectures, essential for supporting such intelligent knowledge processing. To satisfy such a need, the Japan's Fifth Generation Computer Systems (FGCS) project is aimed at establishing the basic technology required for developing various kinds of applications of Knowledge Information Processing System (KIPS).

### (2) Knowledge and Knowledge Processing

In KIPS, the conventional concepts of "program" (or "procedure") and "data" (or "database") will be integrated into one higher or broader concept called "knowledge", and be manipulated uniformly; the retrieval of data and the computation of programs are also integrated into the higher concept of inferential problem-solving through knowledge bases. Programs and data differ in representation rather than in semantics. Program and data are respectively regarded as intensional and extensional representations of the same knowledge. The following are examples:

- Trigonometric function SIN(x) can be represented either as a program (e.g. in Taylor expansion) or as data (e.g. in a trigonometric function table).

.A PROLOG program can be viewed both as a program and as a database.

Knowledge representation models would, however, vary with their application fields. Various techniques of knowledge representations have been studied, as exemplified below. Knowledge can generally be viewed as a set of data having some structure. For example, the parsing tree of a given sentence is more than a sequence of words (that is, just data): a parsing tree, in itself, contains results of interpretation.

.Relational model

.Parsing tree

.Frame

.Semantic network, and so on.

Various researches into Artificial Intelligence have shown that symbol processing (especially, list processing) is useful for computer-based simulation of human intellectual behavior or activities. For example, a parsing tree can naturally be represented in a list structure as shown Fig.2-1. This means that symbol processing (e.g., pattern-matching) may also be useful in knowledge processing.

Knowledge processing may include various operations, such as judging the equality or hierarchical relation of two knowledges (that is, two structured sets of data), unifying them, reducing (or partially evaluating) some knowledge and so on, in addition to knowledge-based inference. It should be pointed out that future high-level intelligent applications would be easier to develop based on knowledge (knowledge processing) rather than based on data (data processing). Analogically speaking, knowledge processing corresponds to solving a problem specified in one's native language; data processing to solving a problem in a foreign language. The native language itself directly conveys some meaning; a foreign language can be accepted only after translation.

(3) Knowledge Base

A logic program (e.g., a PROLOG program) consisting of a set of facts (relations) and rules, can be considered to be a first approximation to the knowledge base. It is more powerful and flexible to construct models organically connecting individual relations than conventional relational databases.

Formerly, the meaning of "data" or "database" has been known only to the user (i.e., a program); a database or a data-file only contains "something" unknown. On the contrary, a knowledge base is like an organism: it knows the meaning of the stored information.

Roughly speaking, a knowledge base system is analogous to an excellent library: while the latter has not only a large collection of books but also professional librarians, the former needs to be equipped with some knowledge in addition to data or knowledge themselves. As librarians have knowledge about the books in their library, a knowledge base system must have knowledge of the knowledge stored in its own database. Such knowledge is called meta-knowledge; inference that uses meta-knowledge is called meta-inference.

```
Parsing Tree:        (sentence)
                      --------
                       /   \
                      /     \
                     /     / \
                    /     /   \
                   /     /     \
                  /     / \   / \
                He     /   \  a  song
                      /     \
                     is   singing
```

```
List:   [He, [is, singing], [a, song]]
        ------------------------------
```

Fig.2-1   Parsing Tree and Its List Representation

## 3. PROSPECT for SOME ASPECTS of FUTURE INTELLIGENT NETWORK

### 3.1 FGCS IMPACT on COMMUNICATION NETWORK TECHNOLOGY

The same philosophy and technology as those for the FGCS project will be adopted in the communication network field, as well as in other information-processing fields.

Future intelligent networks should have the capability of autonomic intelligent self-control, including adaptive routing and adaptive flow-control. These intelligent network controls will be performed by KIPSs installed in networks.

These intelligent networks will support knowledge communication instead of conventional data communication, while fifth generation computers will perform knowledge processing instead of data processing. In other words, they will transmit not "representations" but "semantics". Knowledge communication implies, firstly, intelligent services provided by intelligent servers and knowledge bases, and secondly, the conversion of knowledge representations, including protocol translation and media conversion (e.g., text-voice conversion). Such knowledge conversions will be far more difficult and diverse than conventional capabilities, such as speed conversion, code conversion and data compression: it will also be performed by KIPSs installed within the network itself. Various techniques of knowledge representation have been proposed. Knowledge representation models would vary with their application fields. So, the conversion of knowledge representations will be more important in future intelligent networks.

### 3.2 BASIC REQUIREMENTS of FUTURE COMMUNICATION NETWORKS

In this section, some basic requirements of future intelligent networks will be discussed briefly, though most of them are still obscure and indefinite.

(1) Capability of Interactively Transmitting Large Volume Information

Generally, KIPSs or fifth generation computers will be capable of high-speed processing of a large volume of data/knowledge, while accessing large knowledge bases locally or through communication networks; e.g., for realizing intelligent interactive human interfaces. So, first of all, knowledge communications will require the capability of interactively transmitting a large volume of information.

(2) Low-level Network Load

In addition to the future use of high-transmission-capacity communication media (e.g., optical fibre), the load level of future networks will need to be held far below the saturation point in order to guarantee reasonable throughput and transfer-delay. The low-level network load will be claimed not only for real-time applications (e.g., voice communications and tele-conference), but also for expedited transmission of network control information and statistics required for intelligent network management.

(3) Broadcasting Facility

Before long, various broadcasting physical communication media will be available; e.g. satellite communication and wireless communication. Broadcasting facility is generally appropriate for executing simultaneous queries to distributed databases and for developing distributed problem solving systems, including intelligent network management systems. The group communication facility, a kind of multi-casting protocol in the logical-level layer of the INI (Internal Network in ICOT) local area network ([Tag2]), is also useful for the same purpose, e.g., for gathering and propagating network-management information and statistics from/to various network nodes.

(4) Various Transmission Service Grades

In [Lan1], Langseth discusses the significance of various grades of services and the synergies of technology and services in future integrated service networks.

Voice need not be transmitted so accurately in face-to-face human communications. Fifth generation computers will be equipped with intelligence. This means that even fuzzy (or noisy) transmission facility may be convenient and efficient in certain special cases. The transmission cost will be much lower when only the exchange of acceptably accurate information is required. To reduce transmission volume, the situation or context of communication should be taken into consideration as in human communications; this technology will be far more sophisticated than that used now in tele-conference communications for the same purpose.

## 3.3 MULTI-MEDIA and KNOWLEDGE INFORMATION PROCESSING SYSTEM

### 3.3.1 SIGNIFICANCE of MULTI-MEDIA

The rapid evolution of communication network technology, such as optical fibre and multi-communication media, will provide greater possibilities in constructing both knowledge-communication networks and computer-network-based intelligent information systems. Future multi-communication media will provide diverse and integrated transmission services (e.g., voice, graphics, image, text, and so on), based on their extraordinarily large transmission capacity.

Research into intelligent human interfaces is one of the main R&D themes of the FGCS project. Multi-communication media will surely contribute to developing various kinds of intelligent human interfaces. It should be pointed out that the intelligent knowledge processing aimed at in the FGCS project is also essential for realizing such an intelligent human interface system, taking advantage of them. For instance, a database query system using voice/speech must be equipped with the capability of linguistic processing [Wil1]. That is, an intelligent human interface system itself can be regarded as a typical KIPS application.

### 3.3.2 MULTI-MEDIA and INTELLIGENT HUMAN INTERFACES

At first, fifth generation computers will possibly be used for intelligent office automation systems or office information systems, especially for providing more advanced human interfaces. More natural interface vehicles (e.g., natural languages, speech, and graphics) and more sophisticated interface models are both essential, taking advantage of new advanced interface hardware (including multi-interface media). It may be interesting to note the analogy between the human interface system and a three-layered network architecture: interface hardware, interface vehicle and interface model are analogous to physical-level, logical-level and application-level layers, respectively.

Taguchi discussed in [Tag4] some essential requirements of intelligent human interface models for intellectual work, such as programming, writing, and so on. These requirements are listed below. Among them, "visuality" and "mobility" would need support from network systems (especially, by multi-communication media).

.Quickness (Quick-response)

.User-initiative (Mode-lessness), based on a multi-window display

.Interactiveness

.Visuality

.Literate Terminology (Knowledge-based Dialogue)

.Mobility (Remote-accessibility)

(1) Visuality

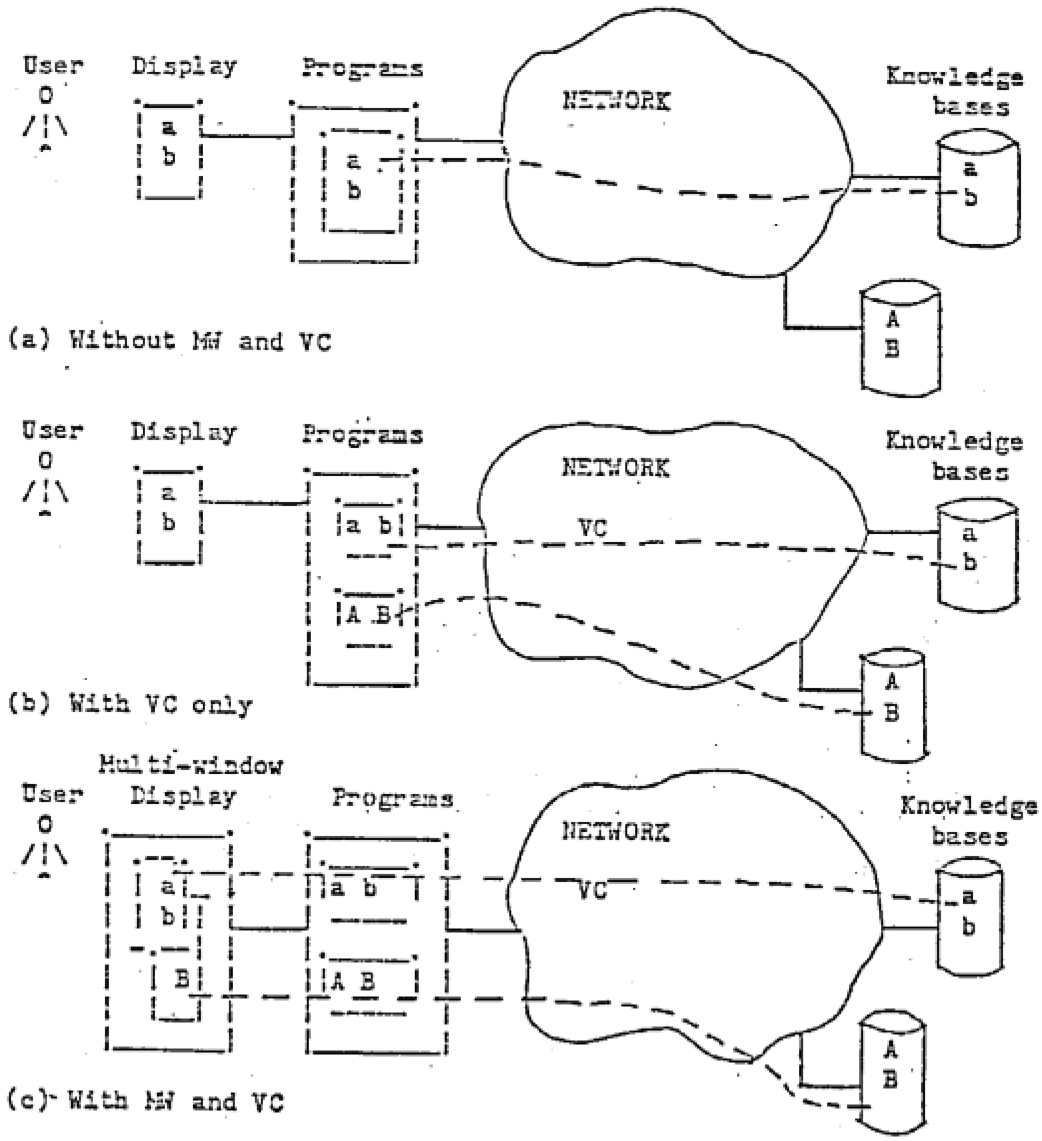
The visualization of the entire network, including knowledge bases distributed around networks, is significant for providing the network user with advanced interfaces. For network visualization, two multiplexing techniques, the multi-window display and the virtual circuit (or session), are primitive but essential materials. As shown in Fig.3-1 (c), the user can access several knowledge bases in the network at a time so as to facilitate his intellectual work.

Communication group ([Tag2]), which evolved from virtual circuits, is a more elegant advanced concept for realizing visual interfaces: it facilitates simultaneously accessing several knowledge bases through the network. In the near future, multi-communication media and more sophisticated multi-interface media will provide more ideal visual human interfaces. They will facilitate access to multi-media databases/knowledge-bases ([Chr1]), which, for example, contain text-graphics information or image-voice information.

(2) Mobility (Remote-accessibility)

It is desirable that various KIPS applications and knowledge bases can be accessed at any time and from any location.

For such a purpose, a more advanced infrastructure, based on mobile communication systems (e.g., satellite communication systems and wireless local area networks [Gfe1, Nak1]) and multi-communication media, will be vital as well as advanced portable or mobile interface devices. For example, a cellular radio network is intended to be used as the basis of mobile information systems (e.g., mobile office facilities), which are one of the R&D themes in the UK's Alvey fifth generation computer programme. This national cellular-radio network will comprise some 400 base stations (Electronics July 12, 1984).




VC: Virtual Circuit
MW: Multi-Window display

Fig.3-1 Visualization of Network Environment

### 3.4 NETWORK OPERATING SYSTEM and KNOWLEDGE-COMMUNICATION NETWORK

#### 3.4.1 SIGNIFICANCE of NETWORK OPERATING SYSTEM

Future personal intelligent computers, such as PSI (Personal Inference Machine) under development in the FGCS project ([Yok1]), should primarily act as intelligent agents of users and provide intelligent human interfaces. On the other hand, personal operating systems for them will be released from supporting main heavy functions that have been common in conventional large-scale operating systems. These include, for example, load-balancing, optimum resource allocation, so-called RASIS, and so on. Consequently, networks connecting various types of computing resources or knowledge bases should undertake these conventional operating system functions: they are called integrated network operating systems (NOSs). Roughly speaking, NOS is for the operation of an integrated network system, while a conventional operating system is for the operation of a computer system.

NOS will also be needed from the viewpoint of network management. Future knowledge-communication network systems will be constructed from various resources, such as inference machines, knowledge base machines and super-computers, scattered around the network. In order to manage them consistently as a total system, more sophisticated and powerful network management will be vital; so, these will be nearer to the capability of NOS. Moreover, NOS will be needed to provide the network user with reliable high-level services, let us say, for developing a distributed intelligent knowledge processing system or for the network-based integration of a fifth generation computer (for intelligent processing), a database machine and a super-computer, which is required for building a practical KIPS application (e.g., a nuclear-reactor diagnostic expert system).

It should be pointed out here that the large transmission capacity of future network media (such as optical fibre) would make possible the additional transmission of network control information in realizing NOS, while conventional operating systems are due to the surplus computing power of large-scale computers.

#### 3.4.2 MAIN FUNCTIONS of NETWORK OPERATING SYSTEM

The main functions of NOS can be classified as below (not exhaustively) from the experience in designing conventional operating systems and network management functions.

(1) User-directed Service Facilities

- .Virtualization
- .Security
- .Network transparency; e.g., name-server, where a symbolic name of a process can be viewed as an analogue to mnemonic codes in conventional operating systems
- .Network job (or job group), e.g., the "virtual network" concept introduced in the DCNA (Data Communication Network Architecture) network architecture ([Nae1, Kaw1])
- .Those analogous to supervisor macro or JCL of conventional

operating systems; e.g., the so-called remote procedure call

Network virtualization is the most basic concept. This means that network systems and various or heterogeneous resources over them should effectively be integrated and appear uniform to network users. The "logical network" concept of DCNA ([Nae1, Kaw1]) is a typical example of network system virtualization.

(2) Network-System Control Facilities

- Those corresponding to kernel functions in conventional operating systems; e.g., recovery facility, reconfiguration control, and so on

- Kernel functions proper to communication systems; e.g., adaptive routing or flow-control. These are similar to load-balancing or thrashing control in conventional operating systems

- Those corresponding to operational management functions in conventional operating systems; e.g., error information, statistics, accounting information, and so on

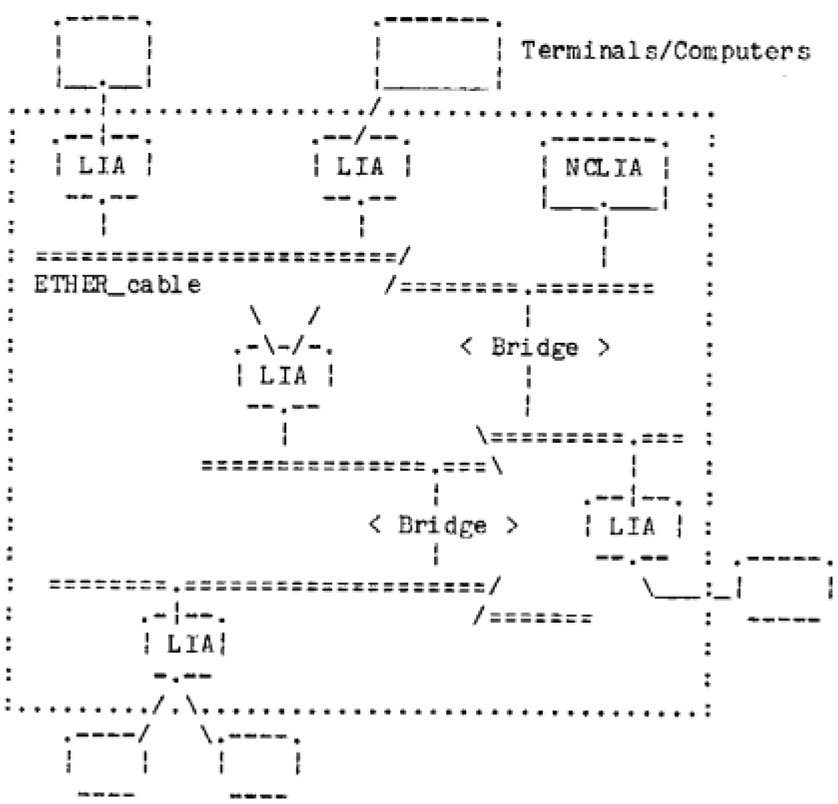
### 3.4.3 NETWORK MANAGEMENT FUNCTIONS in INI

Some of the functional aspects of NOS can be viewed as an evolution of network management functions. In the following, examples from the INI (Internal Network in ICOT) local area network ([Tag2]) are briefly discussed.

Fig.3-2 shows the physical configuration of INI. An LIA (LAN Interface Adaptor) interfaces locally with several intelligent terminals, and executes communication protocols as their front-end communication processer. One or more LIAs, called Network-Control LIAs (NCLIAs), perform some network management functions as the master. LIAs, where network-management processes (as agents) are placed, perform the processing required for network management and, in the near future, they will doing this even for NOS.

INI has basically three layers: physical, logical and application. The application layer is in each terminal. The physical and logical layers are located in LIAs. The physical layer corresponds to OSI layers 1 and 2. Its protocol is based on ETHERNET. The logical layer corresponds to OSI layers 3, 4 and 5. For this layer, INI has a unique new group-communication protocol. A logical communication medium, called a "communication group", is formed among several processes: a message sent by any process is broadcast to all member processes of the communication group. For simultaneous gathering and propagation of information for network management, group communication is more appropriate than conventional session-oriented communications which are designed for one-to-one transmissions. Moreover, group communication is useful for implementing the basic functions of NOS, such as process synchronization and resource locking.

Application processes in terminals may use symbolic names to designate other processes, especially application-server processes. The LIA network-management process translates a symbolic process-name into the corresponding process-address by using the name-resolution protocol. (Otherwise, each LIA should know the correspondence between process names and process addresses of all the servers in INI.) Each LIA network management process knows only the correspondence between the process names and process addresses of servers in locally attached terminals. The network management process broadcasts the specified process names through a communication group among LIA network management processes with a NAME-RESOLUTION command in order to query their corresponding process addresses. The other network management processes return the process addresses with a NAME-RESOLUTION-REPLY command when one or more of the process names specified in the received NAME-RESOLUTION command are the same as those of server processes in their terminals. The status of server processes such as "busy" and "over-loaded" are also reported using NAME-RESOLUTION-REPLY commands. By making intelligent use of these status information, the network-management processes would contribute to network-wide load balancing; this is the first step towards NOS.




LIA : LAN Interface Adaptor
NCLIA: Network Control LIA

Fig.3-2 Physical Configuration of INI

4. CONCLUSION

In this paper, some aspects and requirements of future communication networks as the infrastructure for intelligent computers like fifth generation computers were briefly discussed.

At The final stage of the Japan's Fifth Generation Computer Systems (FGCS) project, the investigation of network-based total systems will also be necessary for realizing an integrated intelligent knowledge processing system, the so-called "co-operative problem solving system"; it will consist of several fifth generation computers (that is, Knowledge Information Processing Systems), cooperating through communication networks in order to accomplish their common purpose.

J. Alvey (British TELECOM), who is the chairman of the UK's Alvey fifth generation computer programme, mentioned in his keynote speech at ICCC'84, "And while perhaps we have yet to demonstrate more than 2GB through a fibre that speed of transmission still dumps the Encyclopedia Britannica in your in-tray in a very few seconds. Which poses the next question of what do you do with all that data-- the intelligent computer help you digest it and use it ?" This means that most of advantage of future network technology, such as optical fibre and multi-communication media, can be taken only in combination with intelligent knowledge processing. While fifth generation computers will be supported by the rapid evolution of VLSI technology, the intelligent knowledge-communication networks of the future generation will be made possible by FGCS technology in addition to optical fiber technology and VLSI technology.

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(Note) *: In Japanese