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Evolutional Flexible Network

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In this paper, we propose an architecture of the global communication networks with evolution functions based on the concept of Flexible Network. The evolution function enhances the capability of communication networks to deal with various changes detected in both human users and networked environment. In our architecture, a new functional layer called Flexible Network Layer is introduced between the application layer and the IP-network layer of the global communication networks. To elaborate the functions of the Flexible Network Layer, we demonstrate an agent-based model of Flexible Network Layer for a multimedia communication application and discuss the properties of the proposed architecture.

進化型やわらかいネットワーク

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やわらかいネットワークの概念に基づいて、進化機能を備えた広域ネットワーク環境のアーキテクチャを提案する。進化機能は、広域ネットワークとその利用者の双方に生起する様々な変動に対処するネットワーク環境自身の能力を強化するものである。提案するアーキテクチャでは、広域ネットワーク環境におけるアプリケーション層とIPネットワーク層との中間に、やわらかいネットワーク層と呼ぶ位置する新たな機能層を導入している。やわらかいネットワーク層が具備すべき機能を探るために、本稿では、マルチメディア通信アプリケーションを例としたやわらかいネットワーク層のエージェント指向モデルを示し、提案するアーキテクチャの特徴について議論する。

1. Introduction

In recent years, many useful communication services have been provided for users in the global communication networks such as Internet. Using high-speed personal computers together with those services, people can deal with many kinds of tasks efficiently. However, as the services of both computers and communication networks get more high and complex, non-expert users have to learn many additional things to utilize these services according to their requests. Moreover, due to the changes of the operational situations of the networked environment, the quality of services provided for users can easily be changed and degraded in many cases. The users may confuse such best-effort nature of global networked environment especially when they confront with the operational problems/troubles raised from both the users and the networked environment.

Hence, the global networked environment have to have the capabilities to help the naive users as well as the expert users and maintain the quality of services for the users against the various troubles observed within the environment. To do so, a concept of *flexible network* is proposed together with the basic framework of *flexible system* [1]. Under the flexible network concept, the prototypical applications of multimedia communication have been built to demonstrate the effect of this concept. Although we can take several ways of realizing the flexible network concept into consideration, it is essential how to

design the important functions to manage, control and adapt the system's operational environment in order to provide the required quality of service for users. In our applications, such functions have been designed and implemented as the organization of agents that work as part of the applications by using the agent-based computing environment, i.e., *ADIPS framework* [2]. In this sense, at present, the flexible network concept had been realized at the application level.

The next step is to establish a systematic way to realize the flexible network at the middleware level in order to suit the applications to the existing global communication networks effectively. Hence, in this paper, we propose an architecture of global communication networks in which the functions of flexible network will be realized as a new functional layer called *Flexible Network Layer* installed between an application/service layer and an IP-network layer of a global networked environment.

2. Concept of Flexible Network

First, we explain a concept of flexible system as a basic model of flexible network. A flexible system is a system S that can deal with the changes of both the system S and the external environment E in a system world W(S) by using an evolution mechanism EM. The changes can be classified into three kinds of changes, i.e., a change of S, ΔS, a change of E, ΔE, and a change of interaction between S and E, ΔINT. The evolution mechanism is responsible to recognize a change and make a counter action δS against the change in order to maintain the system's functionality and the required quality of service for users, as shown in Fig.1.

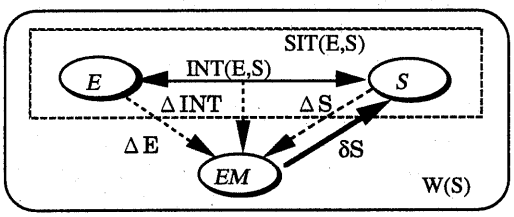


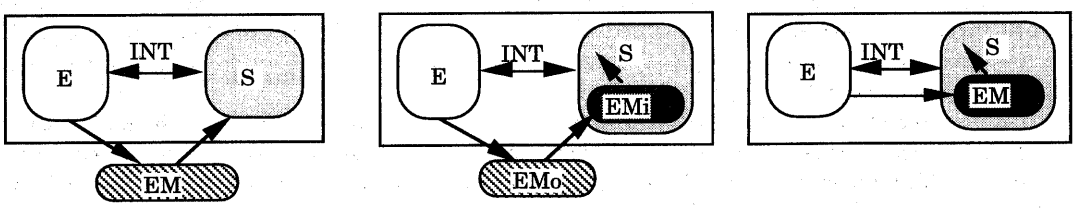
Fig.1 Model of Flexible System

According to the above model, a flexible network is defined by the networked environment Net and its evolution mechanism EM(Net), and the change in a system world of Net is expressed as follows, i.e.,

FN = < Net, EM(Net) >,

W(Net)+ ΔW(Net) = < Net+ ΔNet+δNet, Users+ ΔUsers >,

here, the Users corresponds to the external environments which represents a set of users' requests regarding the services and their quality. The evolution mechanism EM(Net) will interact with Net and modify Net optimally by making a counter change δNet. For instance, the EM takes an action in which a service function of Net is replaced with a new function. To do so, the W(Net) remains satisfactory even if there is the changes of both the ΔNet and the ΔUsers.



(a) Cooperative EM (b) Cooperative Distributed EM (c) Embedded EM

Fig.2 Implementation of Evolution Mechanism

The evolution mechanism EM of flexible network can be realized in several ways, as shown in Fig.2. Although the detailed discussion is omitted in this paper, we have designed and implemented an evolution mechanism of type (c) in Fig.2 by using agent-based computing technologies. The capability of flexible network is realized as various agents of the application system that have knowledge to detect the changes, and to manage and control the system's services/functions. In this case, the functions of communication networks can only be managed and controlled in an indirect manner. However, another types of evolution mechanisms should be possible to make a global networked environment flexible in order to provide the ease-of-use communication services for users/applications. Hence we propose a new architecture of building flexible network for the global networked environment.

3. Flexible Network for Global Networked Environment

Recently, many research and development of global networked environment have been done mainly from a view point of designers. However, an important aspect of global networked environment should be considered from a view point of users based on the concept of flexible network. For instance, the following kinds of flexible networks can be identified, i.e.,

(Level I) a network which provides the facilities to detect the changes of its operational conditions and tune its functions for users/applications (**AFN: Application-embedded Flexible Network**)

(Level II) a network which can manage and control its services/functions autonomously to adapt the temporary changes of its operational conditions (**CFN: Core Flexible Network**)

(Level III) a network which can reorganize and enhance its services/functions to adapt the permanent changes of the networked environment (**EFN: Evolutional Flexible Network**)

Our previous work have been done focussing on the Level I flexible network, i.e., Application-oriented Flexible Network. Now, we have to proceed to the Level II and III flexible networks, i.e., Core flexible network and Evolutional flexible network. Since the EFN includes functions of the CFN, we will discuss an architecture of the EFN in this paper. The EFN should have the following capabilities to maintain and improve the quality of service required by users/applications.

(C1) collect and accumulate knowledge regarding the global networked environment such as information of users, user's requirements, functional specifications of applications/services, configuration of both platforms and networks and so on.

(C2) monitor the qualities of services at the user's requirement level (Req-QoS) and the application level (Ap-QoS) to grasp the operational conditions of the networked environment from a view point of users/applications.

(C3) manage and control the quality of service of the network functions (NF-Qos).

(C4) coordinate the interactions between the application functions and the network functions to organize and reorganize the services provided for users.

(C5) provide an integrated way of access to the functions of heterogeneous networks.

(C6) assimilate and utilize new services/functions of both the applications and the networks to enhance the capability of global networked environment.

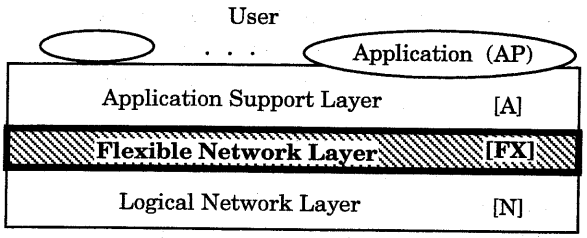


Fig.3 Flexible Network Layer

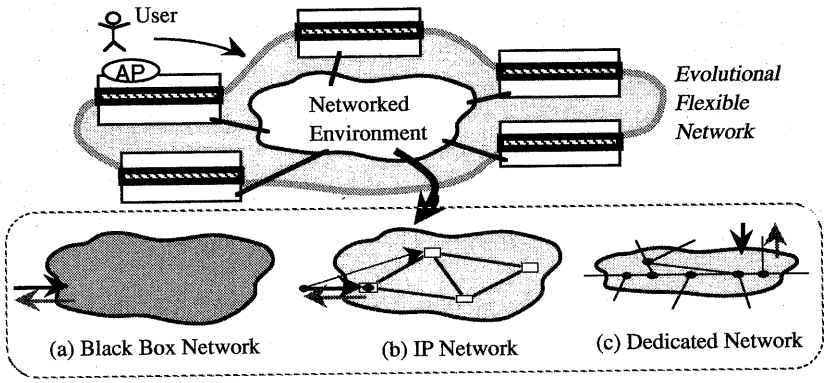


Fig.4 Evolutional Flexible Network over the global networked environment

To realize the EFN with above capabilities, we introduce a new functional layer called ***Flexible Network Layer (FX)***, over the global networked environment. The FX layer operates between the applications/users (**Application Support Layer**) and a logical network such as a conventional IP-network (**Logical Network Layer**), as shown in Fig.3.

The EFN provides a global virtual networked environment for users/applications on the basis of the existing networked environment. Acquiring and using knowledge of the underlying networked environment, the FX can make them the communication infrastructure of the EFN, as shown in Fig.4.

4. Agent-based Architecture of Evolutional Flexible Network

(1) Flexible Network Layer

The essential functions of the flexible network layer (FX) can be summarized as follows.

Management of Application Support Layer (A)

- *monitor the changes of operational conditions of the required services (Req-QoS)*
- *monitor the changes of operational conditions of the applications (Ap-QoS)*
- *coordinate the operational parameters of the required services / applications*
- *collect and deliver the required information of services / applications*
- *define EFN components (wrappering of the required services / applications)*
- *management of information / knowledge of services / applications*

Management and Operation of Logical Network Layer (N)

- *monitor the change of operational conditions of the utilized network functions (NF-QoS)*
- *adjust the operational parameters of the utilized network functions*
- *monitor the change of operational parameters of networks (with respect to the specified applications)*
- *adjust the operational parameters of networks*
- *provide the required information of network functions to the applications*
- *define EFN components (wrappering of the network functions)*
- *management of information / knowledge of both networks and network functions*

Coordination of A and N

- *brokerage of operational information of both A and N*
- *management of information / knowledge of EFN*
- *management of EFN components*
- *organize and reorganize the required services for users / applications*
- *cooperative control of operations of both A and N*

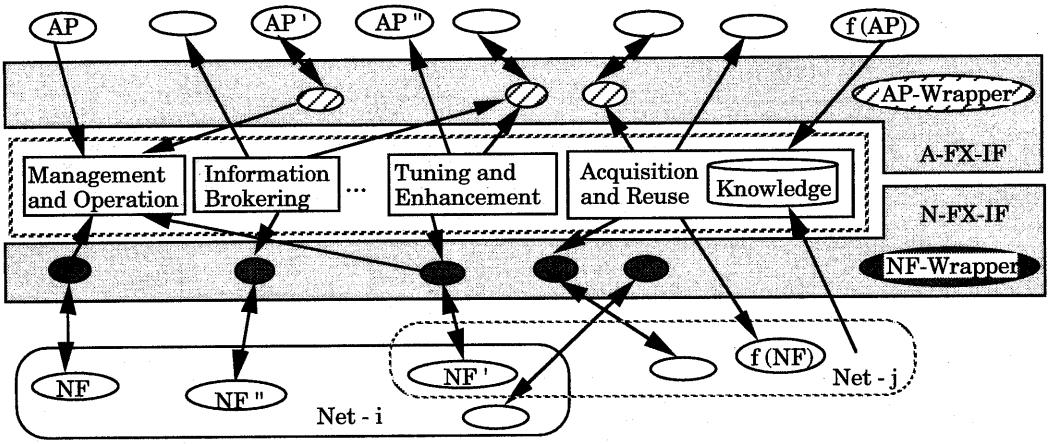


Fig.5 Agent-based Architecture of Flexible Network Layer

Since these functions of EFN have to work cooperatively to deal with various changes of the global networked environment, it is reasonable to design and implement these functions as the autonomous and intelligent functional components. Hence, we adopt the agent-based computing technology to realize these components as agents.

In Fig.5, a general architecture of FEN is depicted. A kernel module of EFN consists of agents which provide the most of essential functions of EFN. The kernel module operates together with two interface module, i.e., A-FX-IF and N-FX-IF. The interface modules are responsible to make the functions of both applications and networks the agents, and utilize them as components of EFN.

(2) Example of EFN

Although the detailed specifications of FX and EFN are under development, we demonstrate an example of EFN which provides a part of the office work support service for people by using a group meeting support service based on the videoconferencing functions as shown in Fig.6.

This example is an extended version of the flexible videoconference system based on the concept of flexible network [3]. The functions of the user-oriented multimedia communication services are realized as the organization of agents in the application support layer. The agents in the flexible network layer cooperate with the agents of A and N to manage, control and coordinate the functions of both the group meeting support service and the network functions provided by the IP-networks.

Using the NF broker agents in FX, the agents of the group meeting support are combined with the agents of FX and N to detect the changes and make the actions to deal with these changes.

To maintain the quality of the required service, the Req-QoS manager agents and AP-QoS manager agents in A, and the NF-QoS manager agents in FX are introduced in the system. They get information of the operational conditions from agents in A and FX such as Platform manager agents and Operation environment manager agents. And then, they determine and issue the control commands to the agents of the group meeting service and the network functions.

Furthermore, the FX knowledge manager collect and accumulate information/knowledge with respect to the office work applications and the network functions in order to provide such information to the agents of A, FX and N. For instance, the FX enhancing agents get knowledge of a new agent which can be available in the FX, make a plan to utilize the new agent and inform it to the broker agents in FX such as NF broker agents.

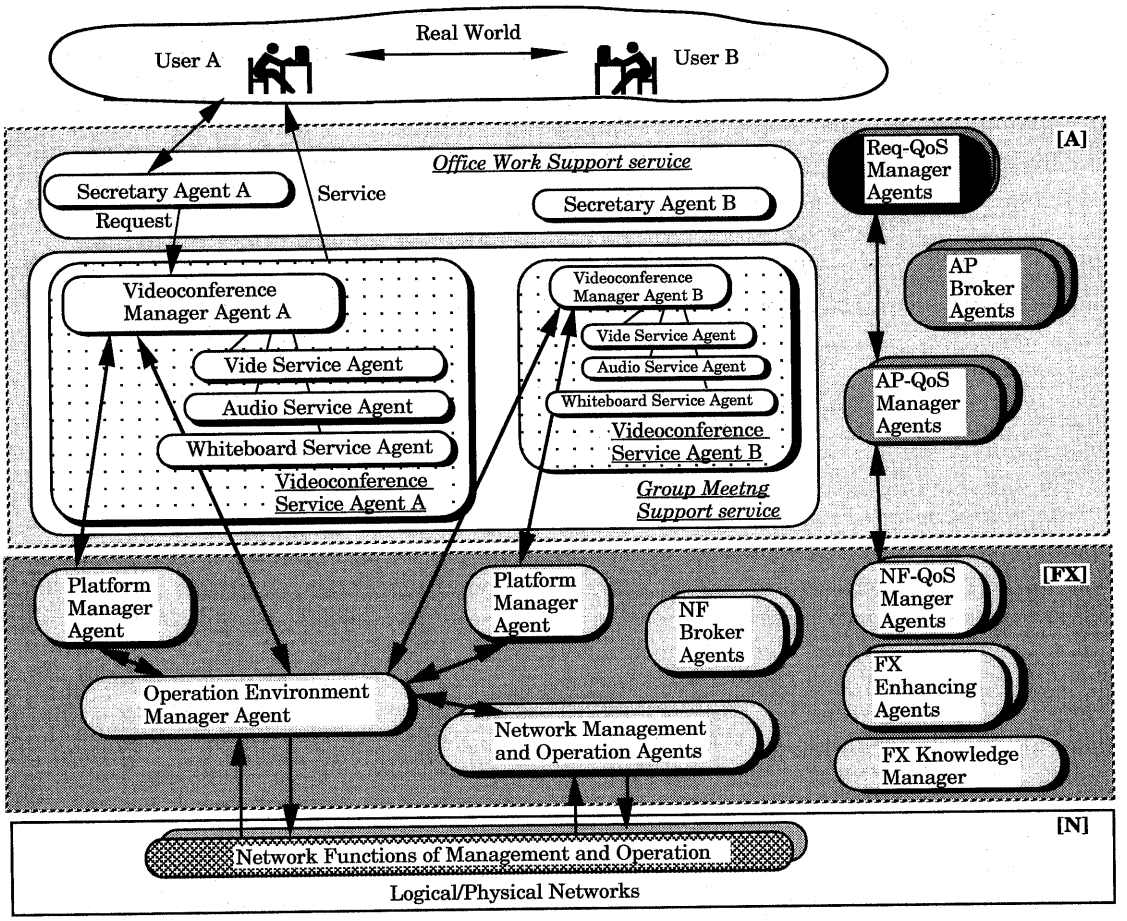


Fig.6 Example of Evolutional Flexible Network

5. Conclusion

We propose an architecture of Evolutional Flexible Network over the global communication networks based on the concept of flexible network, and also discuss the essential functions together with an example of evolutional flexible network in the multimedia application domain.

References

[1] Shiratori N., Sugawara K., Kinoshita T., Chakraborty G., "Flexible Networks: Basic Concept and Architecture", IEICE Trans. Commun., Vol.E77-B, No.11, pp.1287-1294, 1994.

[2] Kinoshita T., Sugawara K., "ADIPS Framework for Flexible Distributed Systems", Proc. Pacific Rim International Workshop on Multi-Agents (PRIMA'98), pp.161-175, 1998.

[3]Suganuma T., Kinoshita T., Sugawara K., Shiratori N., "Flexible Videoconference System based on ADIPS Framework", Proc. Third Int. Conf. on Practical Application of Intelligent Agent and Multi-agent Technology (PAAM98), pp.83-98, 1998.