Issues of Network Reliability Design toward IoT Society

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***Abstract*-- Telecommunication networks with high reliability and high performance are indispensable for realizing the Iot society. The authors have been engaged in the research and development of reliability design of telephone network (PSTN), which is one of nationwide backbone network. This paper summarizes the methodology of reliability design of PSTN and points out the future issues of network reliability design toward IoT society.**

I. INTRODUCTION

Reliability is the important attribute of telecommunication networks. There are various countermeasures for achieving high reliability. However, as any countermeasure takes cost, the methods to determine the appropriate reliability objective for every parts of network have been developed[1] for balancing cost and reliability. Although these methods have been established mainly for telephone network in Japan, it is thought that the methodology should be useful for the networks supporting IoT society.

II. 2. METHODOLOGY FOR PSTN

The reliability design of PSTN is carried out according to the following steps. At first the network configuration is described as the model of reliability block diagram, secondly the reliability objectives, which is the target reliability to be achieved, of telecommunication services are determined, and third the desirable redundant structure of network or failure rate of equipment are determined so as to satisfy these objectives.

A. Modeling of networks and reliability objectives

Any service degradation form of a network with N users can be described by an $N \times N$ matrix F, in which the element $f_{ij} = 0$ denotes that the communication between user i and j is available and 1 denotes unavailable. Therefore, the reliability objective of service degradation can be defined as a function of F.

$$F = \begin{matrix} \text{Originating users} \\ \overleftrightarrow{} \end{matrix} \quad \begin{matrix} \left[\begin{array}{cccccc} 0 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 0 \\ & & \cdots & & & \\ 0 & 0 & 1 & 1 & 0 & 1 \end{array}\right] \\ \text{Incoming users} \end{matrix} \qquad (1)$$

This means that objectives are defined as the probability that each form of degradation occurs. However, this is too generalized words and too complex. The actual reliability objective requires more realistic and general thinking about the actual structures of networks. The actual and almost nationwide backbone networks have the structure as shown in Fig. 1, which connects the access areas with the structure of tree configurations mutually by a transit network.

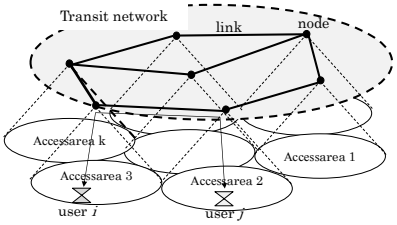

Fig.1 Model of Backbone Networks

Therefore, expressing network reliability by the following three points of view is a solution. The first is the end-end reliability, the second is the access area reliability taking account of the number of service outage users, and the third is the reliability of transition network taking account of the degradation of communication performance between subscriber areas. Because the end-end reliability is the probability that a certain user can communicate to the other user in the network, to keep end-end unavailability for all combination of communication under a certain value can be a possible objective. The unavailability is used as the measure of reliability.

B. Reliability objective of access network

The unavailability of access networks can be described as the probability that a certain number of users lose their communication capabilities at the same time (Fig. 2(a)). Therefore, the actual value of reliability of systems like as Fig. 2(a) are described as functions of the number of users. And the objective $U(x)$ is defined as a function of the number of users.

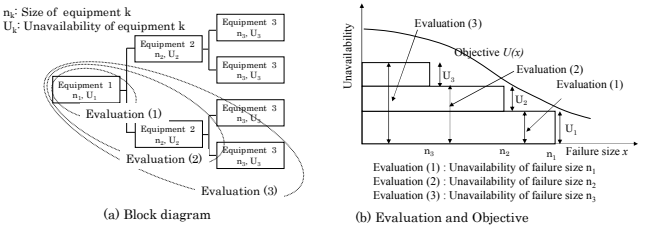

Fig.2 Model and Reliability of Access Networks

These objectives are yielded by using the concept of social loss [2]. Let $L(x)$ denote the loss per unit time caused by service outage of x users, and consider the two cases of system configuration (Fig.3(a) and (b)). As the expected value of the total loss per unit time must be equal in both cases, the following formula is obtained [3]. The actual form of L(x) is $a+bx^{1.5}$, here a and b are constants. This has been yielded

form the field data of PSTN failures [2].

$$U(x) = kx/L(x) \qquad (2)$$

where k is a constant.

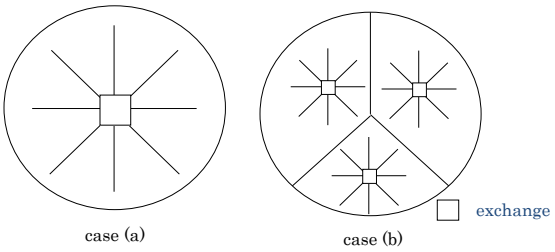

Fig.3 Service by Two different Systems

C. Reliability objective of transit networks

As the service degradation of transit network is the reduction of communication capacity between areas (Fig. 4(a)), the reliability of transition networks is defined as the probability that communication capacity is smaller than a certain value (Fig. 4(b)).

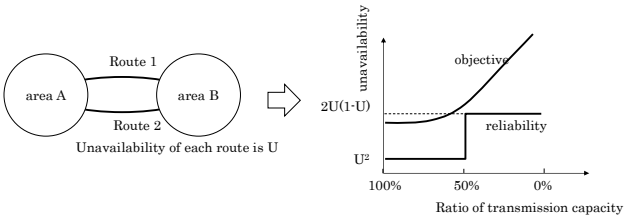

Fig.4 Reliability of Transit Networks

III. TOWARD IOT

For applying the methodology mentioned above to the future network in IoT society, there are some problems to be solved. This paper particularly pays attention to the collaboration of multiple networks. Collaborations can be classified into some kinds and the authors have been investigating the reliability design of these situations.

A. Support and supported networks

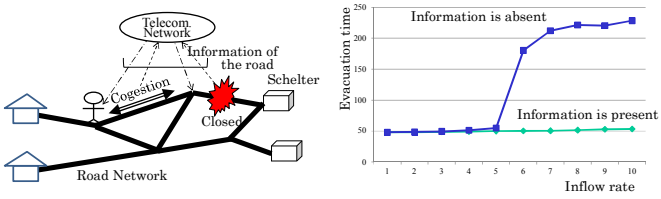

Fig.5 Evacuation Time and Information

Reducing the evacuation time is the important problem in disasters. The evacuation time depends on the presence or absence of information about road conditions. Therefore, it is recognized that the telecommunication network supports the road network. This is an example of support and supported networks. Fig. 5 shows an example of evaluation time [4]. These analyses clarify the required reliability of telecommunication networks in disaster conditions.

B. Reliability objectives considering signaling networks

Transmission and signaling are examples of collaborations of networks. Formula (2) gives the reliability objectives when the loss function is given. However, this formula can be applied only for the simple network as in Fig. 2. Therefore, the numerical method to determine the reliability objectives for networks with general structure containing signaling networks has been investigated (Fig. 6)[5]. This method has the possibility for designing reliability of large and complex networks with general structures.

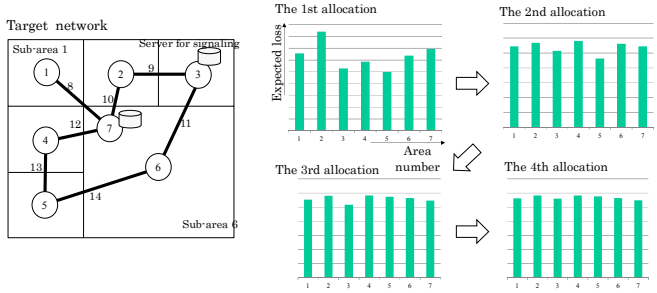

Fig.6 The Numerical Method to Determine Reliability Objectives

C. Reliability characteristics of overlay network

Many network applications run on the user networks overlaid on a backbone network. The reliability characteristics of overlay network depends on the reliability of the backbone network. Thus, formula (2) affects the reliability characteristics in both backbone network and user networks. To clarify the relationship of reliability characteristics of backbone and user networks as like as P2P is an important problem.

IV. CONCLUSION

The methods described above have contributed to construct the high reliability network in Japan and can be applicable for the reliability design of networks supporting IoT society. However, in that time, the expansion of definition of service outage may be required. This is because not only the fixed interruption but also the performance degradation may cause critical situation depending on the type of applications.

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