Application of Network Knowledge

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The advances made in ubiquitous technology have more strongly linked the network world with the real world. By observing a network, we can practically perceive both the network conditions and real-world conditions. We are studying ways to change the information acquired from a network into social and business values in both the real world and virtual world. We call such information "network knowledge." Information that flows in a network is merely the data of bit strings consisting of 0 and 1. Such data is converted into network knowledge when such objects as switches and applications create specific meaning from the data by using the means of network technologies. This paper introduces two examples of these technologies. The first technology encompasses network fault diagnosis and quality monitoring technology used to identify the locations of faults and predict deteriorated performance. The second technology pertains to 4-dimensional traffic engineering (TE) used to optimize the allocation of network resources in consideration of future variations in traffic. Both technologies are useful in building a robust and easy-to-use information service environment.

1. Introduction

As a network society has grown in recent years, people have spent much time in network space. Various types of information flow in a network. Therefore, it can be said that a network has become a reflection of the real world.1) We consider this mapping relation between the network reflected on the real world and the real world reflected on the network. We are now studying the possibility of making social and business values from network knowledge. Here, we would like to define network knowledge as various types of information acquired via a network for a certain purpose. Network knowledge can be directly acquired with such ubiquitous devices as radio frequency ID (RFID) tags and sensors. In addition, network knowledge can also be acquired by observing actual data traffic in the network. For example, the technology used to check malicious use of a network by observing abnormal patterns of traffic has been already proposed and put to practical use.2)

This paper describes new observation technologies and cites examples of application for the safer use of networks.

2. Network knowledge

It can be predicted that networks will adhere more closely to the real world and become maps of the real world in the future. Then, real world status as well as virtual world status can be understood by observing a network. We assume that information acquired via a network for a certain intention is useful and call this information network knowledge. We are attempting to find values in such information.3) For example, access concentrated on content can be interpreted as people's high interest in informa-

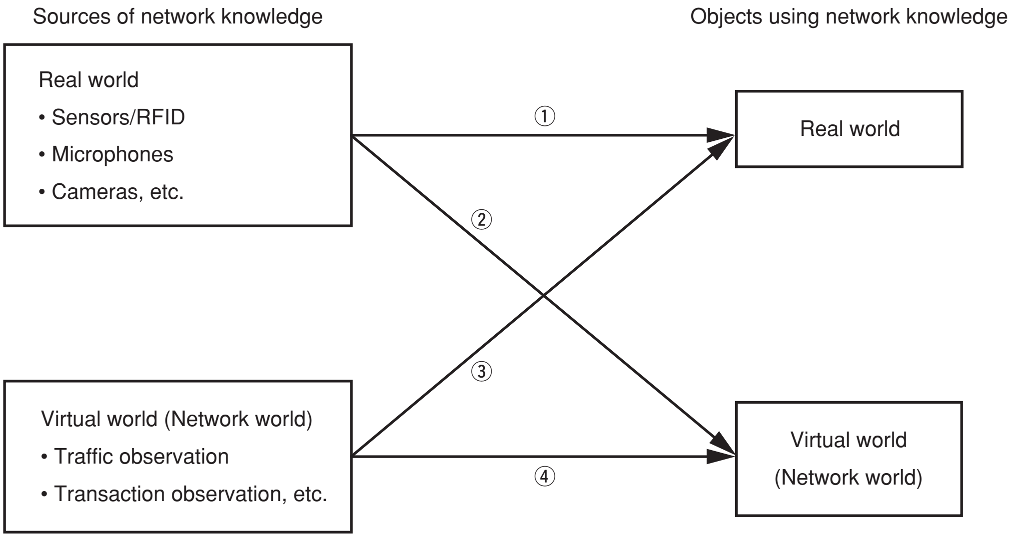

Figure 1
Relation between sources of network knowledge and objects using network knowledge.

tion acquired from the content. We attempt to change this knowledge into other values such as those used in demand forecasting.

Figure 1 shows the relation between the sources of network knowledge and objects using network knowledge. In this figure, arrow ① shows that real-world information is used for the real world. Arrow ④ shows that virtual-world (network) information is used for the network world. These relations are quite natural. For example, arrow ① applies to when a person returning home on foot during a hot day reduces the temperature setting of the air conditioner lower than usual. Arrow ④ applies to when transmission performance is maintained at a normal level by switching the transmission path in case transmission performance begins to deteriorate due to node trouble. In arrows ② and ③, conversely, information in the real or virtual world is respectively used for the other world. Arrow ② shows that real-world information is used as a trigger to control the network. For example, if an earthquake strikes a given district, it can be predicted that communications will be concentrated in that district. In such case, traffic to districts other than the afflicted district should be bypassed to avoid passing via that afflicted district. As a result, more communication requests to the afflicted district can be accepted. Arrow ③ shows action in the real world according to information acquired from a network. For example, a delay in commuter trains can be estimated due to excessively slow rising traffic in the morning. In this case, taxies may be dispatched to the stations.

3. Acquiring network knowledge

To acquire network knowledge, the base information must be collected and converted into knowledge that matches the purpose of use. Information that flows in a network is merely the data of bit strings consisting of 0 and 1. Thus, such data doesn't become network knowledge until meaning is assigned to the data by such objects as routers, switches, application software, and human beings. When bit strings that flow in the network are grasped by a packet capture and meaning is assigned to these bit strings according to the purpose of use, various new network services and applications become feasible. **Figure 2** shows application examples of network knowledge acquired via such a packet

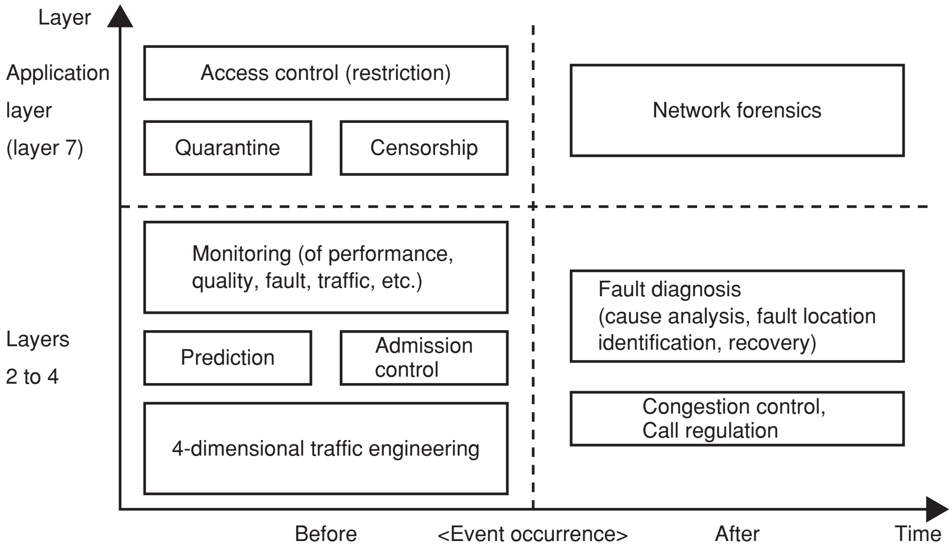

Figure 2
Application examples of network knowledge acquired via packet capture.

capture. In this figure, the X-axis denotes time; that is, the time before and after an event occurs. The Y-axis shows layers 2 to 4, and layer 7 (the application layer). For example, if network fault analysis is necessary, any packet loss, delay, and jitter are calculated from the packet header information according to the packet log obtained. Then the location and cause of fault are estimated. In network forensics[note)] (in the upper layer), electronic mail is recovered and Web access regenerated according to the same log, thus detecting evidence of such malpractices as leaking information. By extending this operation up to the stage of previous handling, a quarantine or censorship function can be realized. The communication status where connection setup is difficult due to excessive communication requests is called congestion. Congestion can be prevented by admission control and congestion control. Admission control checks whether communication requests can be accepted according to the current status. Congestion control takes an escape action from the congestion status caused. In addition, 4-dimensional traffic engineering is proposed as a higher-level form of traffic control. This 4-dimensional traffic engineering uses a time axis; that is, it controls traffic by considering future demand as well as current status.

4. Examples of application technologies

The above means of assigning meaning to packets according to the purpose of use can be considered technologies. This chapter explains two examples of these technologies: network fault diagnosis and quality monitoring technology, and 4-dimensional traffic engineering (TE).

4.1 Fault diagnosis and quality monitoring technology

The IP network fundamental to IT systems must be highly available and stable. If a fault occurs in the IP network, the location and cause of fault cannot be easily detected due to the autonomous decentralized characteristics of the IP network. The following describes examples of identifying the location of a fault when it occurs and monitoring quality to prevent faults.[4),5)]

Figure 3 shows an example of the technol-

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note) Network forensics provides a countermeasure against information leaks or illegal access on a network.

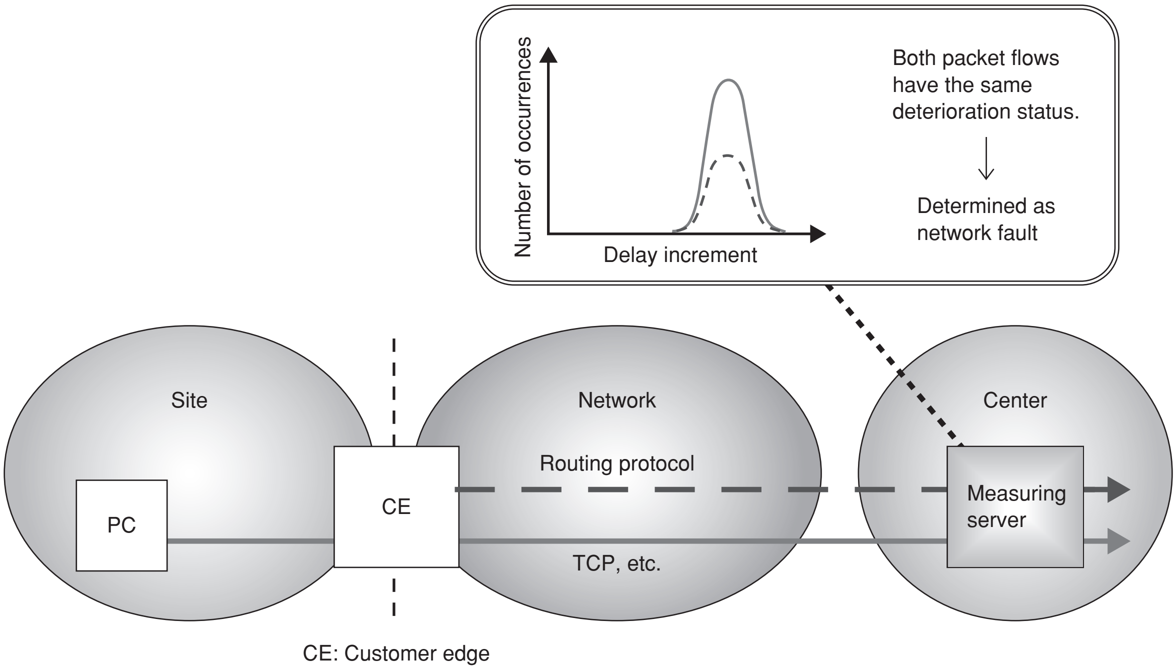

Figure 3
Locating deteriorated performance.

ogy used to identify the location of deteriorated performance when a performance problem occurs. If a performance problem occurs in communications between the sites in a company, it usually takes a long time to identify whether a site or the wide-area network is at fault. Assume that excessively low throughput is detected in a transmission control protocol (TCP) session as shown in Figure 3. In this case, a regular packet flow parallel to the defective TCP session in the wide-area network is measured, such as routing protocol performance. If the reduction in measured packet flow is roughly the same as in the defective TCP session, the wide-area network can be considered at fault.

Figure 4 shows an example of the technology used to monitor the speech quality of IP telephony. Our experience has shown that jitter occurs in packet arrival intervals in many cases before deteriorated speech quality becomes noticeable. Therefore, measuring the packet arrival intervals and checking the jitter in real time enables the prediction of deteriorated speech quality. However, packet jitter cannot be actually measured for all IP telephony sets. In Figure 4, probe packets used for measuring packet arrival intervals are installed in the section to be monitored. These probe packets are used to measure jitter in their arrival intervals. Thus, the communication quality of the entire link can be calculated and deterioration in communication predicted. The quality of all sessions on the link can be evenly measured without concentrating on the send/receive patterns of specific IP telephony packets by controlling the installation intervals of these probe packets.

4.2 4-dimensional traffic engineering

Conventional traffic engineering is used to select an optimal route among various alternative routes between the entry and exit switching nodes in a 2-dimensional (plane) network. By extending this technology, 3-dimensional traffic engineering for a 3-dimensional (spatial) network with multiple layers such as a generalized multi-protocol label switching (GMPLS) network

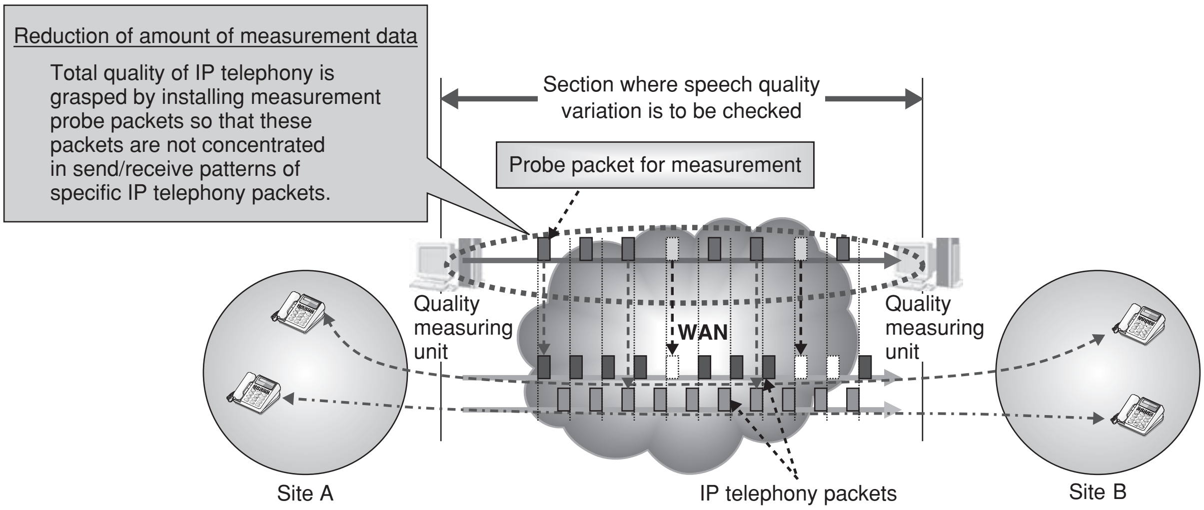

Figure 4
Speech quality monitoring of IP telephony.

is proposed.6) In these conventional technologies, such conditions as communication quality and cost for selecting an optimal route are checked based on the network status at path selection. Therefore, the network resources can be optimally assigned at that time, although optimization is not performed based on the prediction of later changes in network status.

We proposed the concept of 4-dimensional traffic engineering by adding the time axis to conventional traffic engineering.7) That is, the time transition of traffic is predicted and resources are assigned according to those prediction results. **Figure 5** shows a typical example of path assignment where a path with the minimum number of hops is assigned to a communication request requiring a short holding-time, followed immediately by a communication request requiring a long holding-time. In conventional systems, a bypath (a path with a larger number of hops) is assigned to the long-time communication request because the path with the minimum number of hops is already busy. Therefore, many resources are reserved for a long time and many communication requests made later must be rejected. However, such inefficient assignment of resources must be avoided. For this purpose, the arrival of a communication request with a long holding-time must be predicted. Then a bypath must be assigned to short-time communication, and a path with the minimum number of hops must be assigned to long-time communication. In this way, 4-dimensional traffic engineering considering the time axis provides such efficient assignment control. In order to develop 4-dimensional traffic engineering, traffic prediction technology and minimum-cost path search technology (for calculating cost based on prediction results) must be established. In the following descriptions, let's first consider traffic prediction technology. This technology is used to analyze the causes of past variations in actual traffic and predict the transition in future demand according to analysis results. Various causes of traffic variations can be considered.8) As shown in **Figure 6**, traffic variation consists of three components: periodic variation component, continuous variation component, and event variation component. The periodic variation component refers to periodic increases and decreases in traffic that are repeated in terms of days or years, etc. The continuous variation component refers to continuous increases or decreases in traffic. The event variation compo-

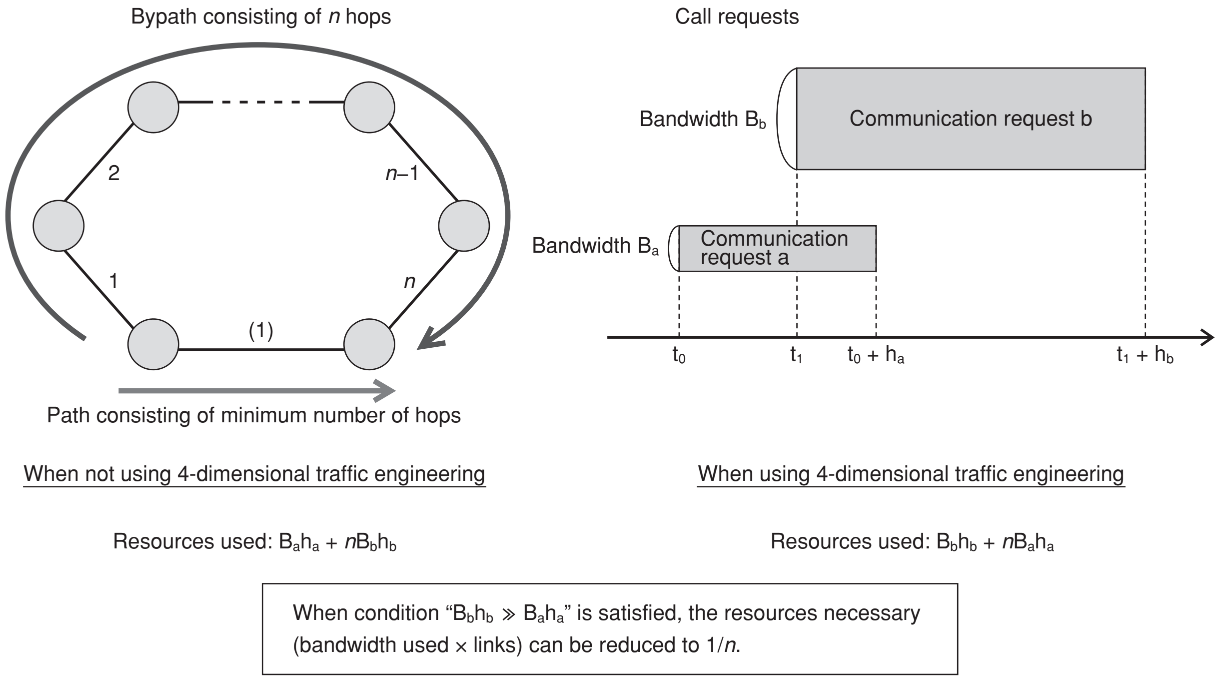

Figure 5
Concept of 4-dimensional traffic engineering.

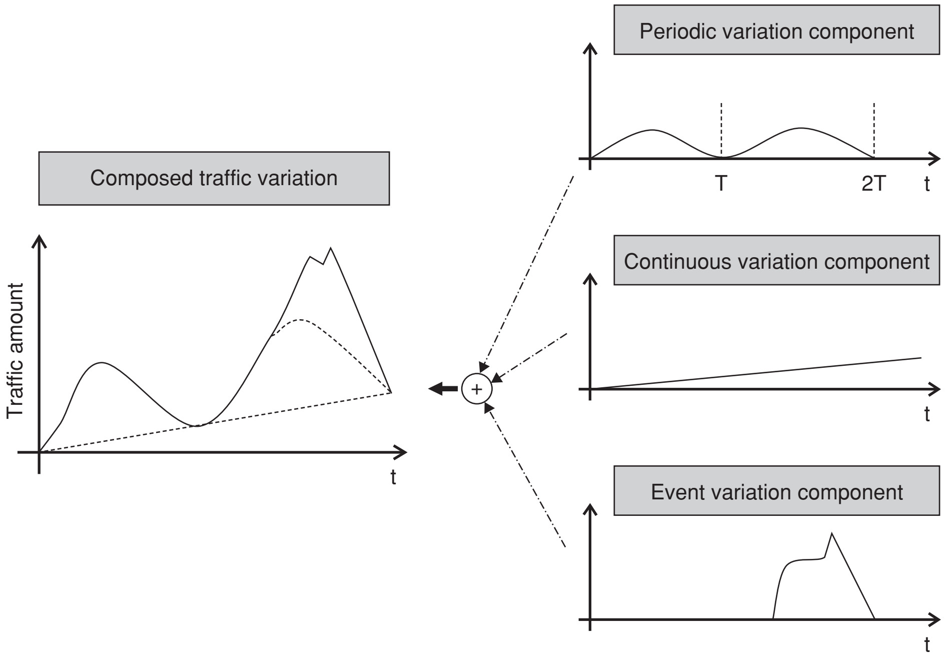

Figure 6
Components of traffic variation.

nent refers to a temporary or sudden increase or decrease in traffic due to a special event such as ticket sales or the occurrence of system failure. Thus, quantitative prediction can be simplified by combining these three components. Next, let's consider the minimum-cost path search technology. Upon the reception of a communication request not requiring minimum-cost path assignment, the topology graph is assumed where a communication request requiring minimum-cost path assignment is already made. In this status, this technology assigns the minimum-cost path.

5. Conclusion

Assuming that networks represent a map of the real world, this paper described the possibility of developing new applications by using knowledge ubiquitously distributed in a network. This paper also described the acquisition of network knowledge by using packet capture and cited examples of application. We believe that next generation networks (NGNs) will be constructed in many fields and ubiquitous society will grow, and thus result in an ever-expanding range of network knowledge applications. The application examples described in this paper are only some examples possible in the future. We will continue this research to generate new value-added applications.

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