4-2 Improvement of Reliability to the Network Composed of Optical fibers inside Sewerage Pipe

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ABSTRACT

The sewer system in Tokyo covers 100 % of the 23-wards area and Bureau of Sewerage, Tokyo Metropolitan Government entered its maintenance management era. We have been integrating operations of pumping stations and water reclamation plants by a remote-control system, so security and reliability of our facilities and back ground systems became a matter of great importance.
We lay optical fiber cable inside trunk sewers and it is used as information infrastructure for telecommunication of remote control and our office management (internet, e-mail and so on).
In this thesis, we introduce how we use our optical fiber network infrastructure which is constructed in trunk sewers and demonstrate our measures to raise its long-lasting reliability constantly including backup for disconnection fault.

KEYWORDS: network composed of optical fibers inside sewerage pipe, reliability of network, backup for disconnection fault

INTRODUCTION

Sewerage Maintenance of Tokyo

The sewerage in the Tokyo section began with the construction of “Kanda drainage” in 1884. We had spread our enterprise since 1958, and the sewer system in Tokyo covered 100% of the 23-wards area in 1995.There are 13 water reclamation plants and 84 pumping stations in the Tokyo area at the end of March in 2010. Now we maintain the public sewerage for 57,839 hectares of 23 wards, and about 82% of the sewer system in the Tokyo area is composed of the combined sewer system.
Also, after the spread of sewer system up to 100%, we increased the number of the pumping

stations and the facilities to improve the combined sewer system. Therefore, the amount of maintenance and management task has increased. On the other hand, we should improve the environment of workplace and working system because of staff's aging and the difficulty in securing manpower. Moreover, it will become important to process information adequately and promptly to the efficient management of the sewerage enterprise. Therefore, we attempted to advance the construction of the optical fiber network in trunk sewers for further efficient management. And we use it to unify the information which is used for office management and for the remote-control system. We construct the optical fiber cable inside trunk sewers and use it as the telecommunication network which communicates between the sewerage facilities. The plan to improve the operation and maintenance through the use of fiber network is called SOFTPLAN (Sewer Optical Fiber Teleway Network PLAN).

Outline of SOFTPLAN

SOFTPLAN introduces the latest information technology to our facilities which work as one of the public institutions in the metropolis. Uniformly managing our facilities such as pumping stations, water reclamation plants and management offices by constructing a highly reliable network, we can proceed with our enterprise smoothly. By constructing inside trunk sewers, we can construct strong network resistant to thunder and earthquakes.

Actually, 164 offices and plants will be connected by optical fiber cables which are up to 1200km in length in total. Fig1 shows network topology of SOFTPLAN.

We started laying optical fiber cables inside trunk sewers to measure water level in 1986 and up to now, the length of optical fiber cable reached 781 km, connecting 130 facilities and it is used for telecommunication for remote-control and gathering and distributing information for facility operation. The optical fiber cable which we use contains 24 glass fibers. The SOFTPLAN network divides optical fiber cable roughly into "remote-control system network" and "Information network", the latter of which is divided into "OA system network" and "FA system network."

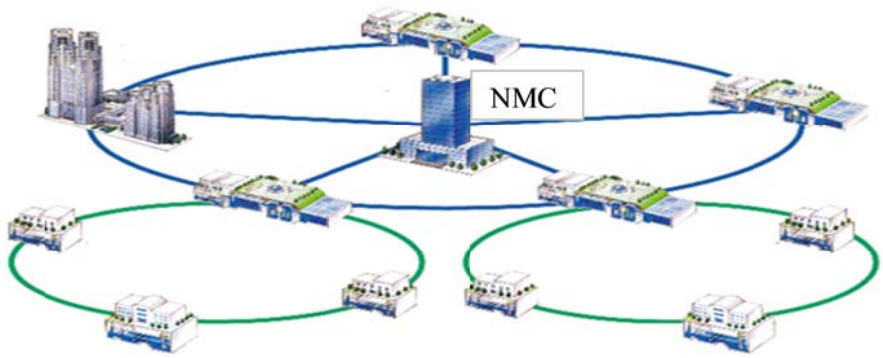

Figure 1. Network topology of SOFTPLAN

-Information Network
The network system which makes our office management more efficient is defined as “OA system network.” It is used for the Internet, E-mail and so on. On the other hand, the network which supports the operation and the management of our facilities is defined as “FA system network.” Information necessary to the management of the sewerage facilities: the water level information, the flowing quantity information, real-time information about Tokyo areas of precipitation, and so on.

-Remote-control System Network
We maintain 13 water reclamation plants, 84 pumping stations, 2 sludge plants, and 15,700km sewer culvert. We have been integrating operations of pumping stations and water reclamation plants by remote-control system. As a result, 69 pumping stations and 2 water reclamation plants are remote-controlled now. Integrating operations of pumping stations and water reclamation plants leads to more effective management. However, since torrential rain happens frequently in recent years, we need more prompt and more adequate operation. Therefore, it is necessary to secure the reliability of entire network including the optical fiber cable and data link control equipment because we must drain rainwater properly. For this reason, we duplicate data link control equipment and make the topology of the network looped.

-Operation and Maintenance of SOFTPLAN Network
The SOFTPLAN network requires high reliability because it is used for the remote-control system and information network. For finding troubles immediately, we monitor SOFTPLAN by using an observational system for optical fibers and an observational system for network 24/7 at network management center (NMC) (Figure 1). The observational system for optical fibers uses 2 glass fibers to detect disconnection fault. When the shape of measured waves is overlapped with the initial shape of waves every hour, if there is a change more than the constant value, it is regarded as “Disorder”, but if not, “Positive”. The observational system for network manages the status of systems including layer 3 switching by Simple Network Management Protocol. It is a UDP-based network protocol and used mostly in network management systems to monitor network-attached devices for conditions that warrant administrative attention.

CAUSES OF LOWERING NETWORK RELIABILITY

We have accumulated a great deal of knowledge of network composed of optical fibers inside trunk sewers because we have operated and maintained SOFTPLAN for more than 20 years. Recently we have recognized some problems which they lower reliability of the network. We show problems below.

Structural Imperfection of Loop Network

Ordinarily, the topology of transmission line is looped. However, in certain circumstances of setting up trunk sewer, we cannot avoid setting up more than one part of the loop in one trunk sewer (Figure2). We term this case “structural imperfection of loop network”. On the spot, there is possibility that more than one optical fiber cable will cut off at the same time owing to works of construction or inflow. In case of optical fiber cables used for remote-control system, it has risk with which we cannot remote-control a pumping station.

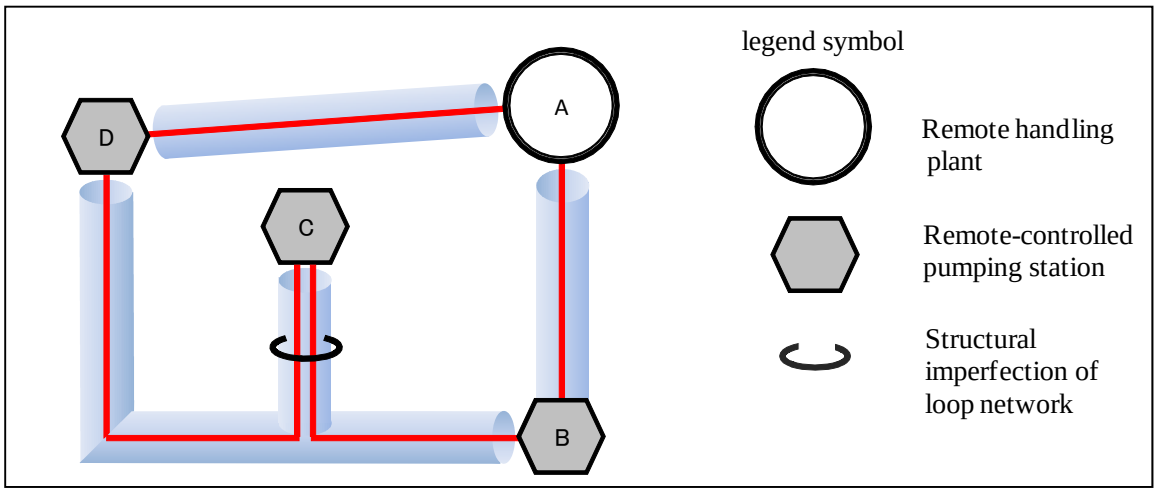

Figure 2. Network including structural imperfection of loop network

In Fig3, pumping stations (B, C, D) are remote-controlled by the remote handling plant (A). In case of one optical fiber cable cuts off, we can remote-control the remote-controlled pumping stations by backup line. For example, if the optical fiber cable between A-B cuts off, we can remote-control the remote-controlled pumping stations by backup line (A-D-C-B). However, in case of the spot of structural imperfection of loop network cut off, there is some possibility that we cannot use the either of the transmission lines at the same time by works of construction or inflow. As a result, we cannot remote-control a remote-controlled pumping station (C). For this reason, if lots of optical fiber cables are laid in the same pipe, it will be high-risk.

In certain circumstances of setting up trunk sewer, we cannot avoid setting up more than one part of the loop in one trunk sewer. Thus, it is almost certain that structural imperfection of loop network exists as weak spots in the network composed of optical fiber cables inside trunk sewer. A structural imperfection of loop network has the possibility that active and backup transmission lines may cut off at once.

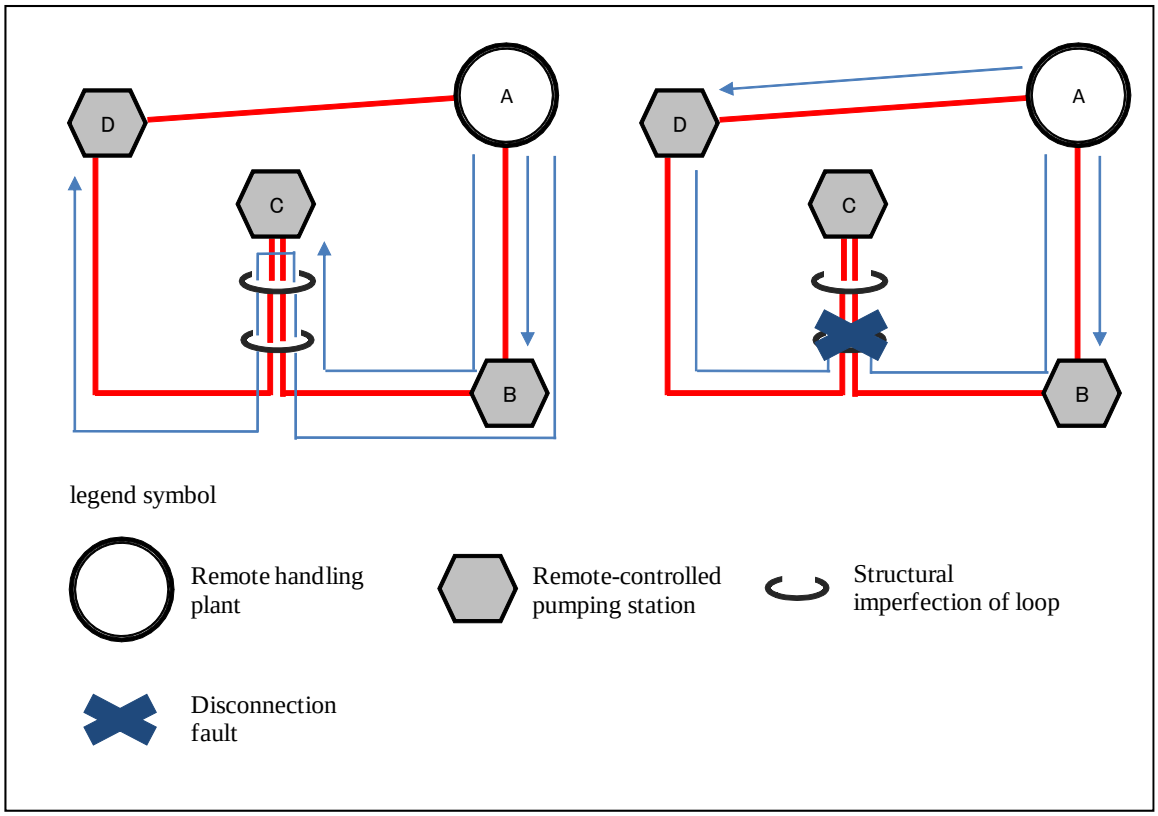

Figure 3. Remote-control system network including structural imperfection of loop network

Difficulty in Detecting Partial Disconnection Fault

So far, we have described our operation and maintenance of the SOFTPLAN network. Through these activities, we have encountered problems with detecting partial disconnection faults in the optical fiber cable. The optical fiber cable which we use ordinarily contains 24 glass fibers, and our observational system for an optical fiber uses 2 glass fibers to detect disconnection fault (Figure 4). Disconnection faults are detected by checking the 2 glass fibers that are connected to observational system. If the 2 glass fibers connected to the observational system are damaged, an alert will be sent. If any of the remaining 22 fibers are damaged (Figure 5), then no alert will be sent. In the latter case, we cannot recognize disconnection fault with the observational system which we currently use. We term the latter case “partial disconnection fault.” A system connected through those damaged glass fibers may not work properly, but in some cases, we cannot detect this type of disconnection fault.

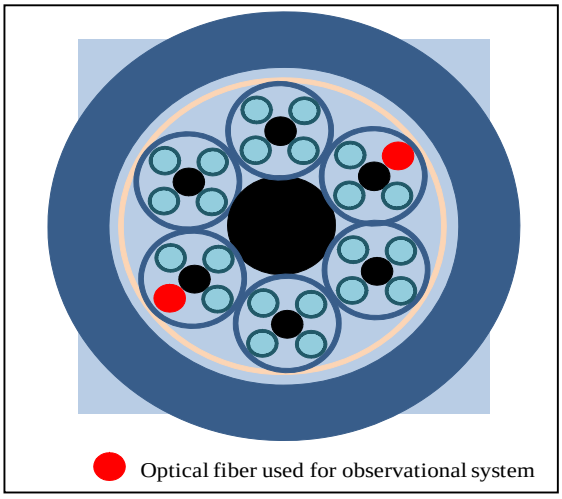

Figure 4. Cross-section view of optical fiber cable

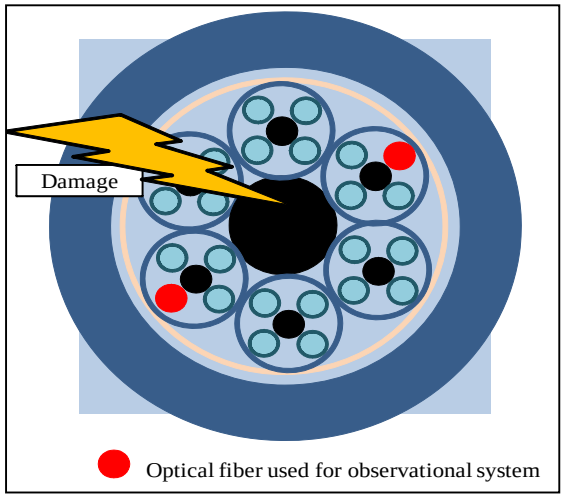

Figure 5. Cross-section view of optical fiber cable(Partial disconnection fault)

Table 1 shows the types of disconnection faults from 2005-2008. The number of partial disconnection faults is larger than that of entire disconnection faults. Therefore, to improve this situation, it is important to make transition to a system which can detect partial disconnection faults.

Table1. Kind of disconnection fault (number of cases)

Kind of disconnection fault	2005	2006	2007	2008
Partial disconnection fault	1	1	0	3
Entire disconnection fault	1	1	1	0

METHODOLOGY

To improve reliability requires enhancement of composition of network, strengthening on the maintenance and management are needed. We show our measures below.

Method of Solving Structural Imperfection of Loop Network

By constructing inside trunk sewer, we can construct strong network resistant to thunder, earthquakes and windstorms. However, in certain circumstances of setting up trunk sewer, we cannot avoid structural imperfection of loop network. It is almost impossible to avoid structural imperfection of loop network. A structural imperfection of loop network has the possibility that

active and backup transmission lines cut off at once, and therefore, it lowers the network reliability. When one optical fiber cable cuts off, we can find out where failure occurs with the observational system for optical fiber. However, it is expected that it may take a long time to complete recovery work because the location of recovery work is inside trunk sewer. Therefore, as for optical fiber cables which are used for remote-control, we definitely need to avert any accident because in case that we cannot remote-control pumping stations, that will cause flooding. If we cannot control our facility for a long time, it can be a menace to our duty. To prevent this type of the worst scenario, we use telecommunications carrier's lines as adjunctive lines for the emergency that both of the transmission lines cut off at once. We will show the composition in which signals can go through in a roundabout route (Figure 6). We use telecommunications carrier's lines only as adjunctive lines for the remote-control line. We target only control signals because our purpose is to avoid the risk that we cannot remote-control pumping stations. We do not target the other signals including remote ITV cameras for plant management, although, in the ordinary situation, ITV cameras, which transmit large volumes of data are indispensable. We can use telecommunications carrier's lines at a low price if it is used for control signals only.

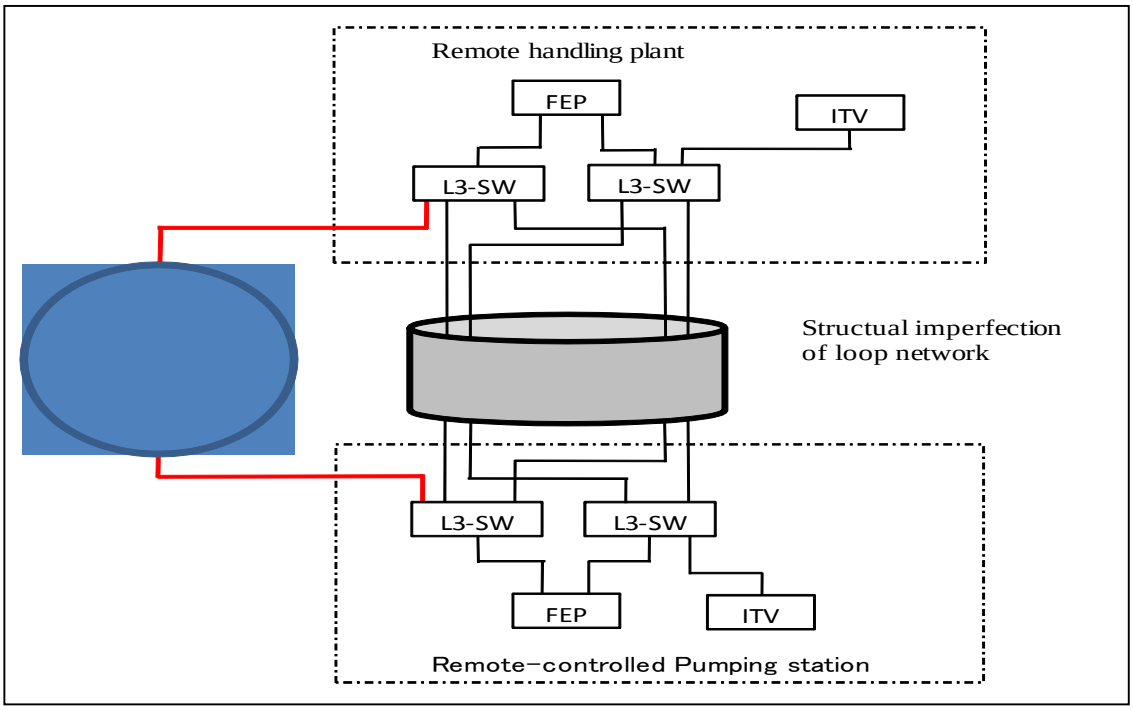

figure 6. Composition which the signals can go through a roundabout route

Method of Detection of Partial Disconnection Fault

We have described that our observational system cannot detect partial disconnection fault. Thus, when partial disconnection fault occurs, it is difficult and takes a long time to find the cause of

disconnection fault. For this reason, we are planning to switch the current observational system to new one, which uses WDM (Wave Division Multiplexing). WDM is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals. If we use WDM, we can detect partial disconnection fault, because we can use the active line to detect disconnection. By using WDM, we can strengthen the maintenance and management. And as a result, we can improve reliability of the network. We show the composition of observational system for optical fibers which uses WDM (Figure 7).

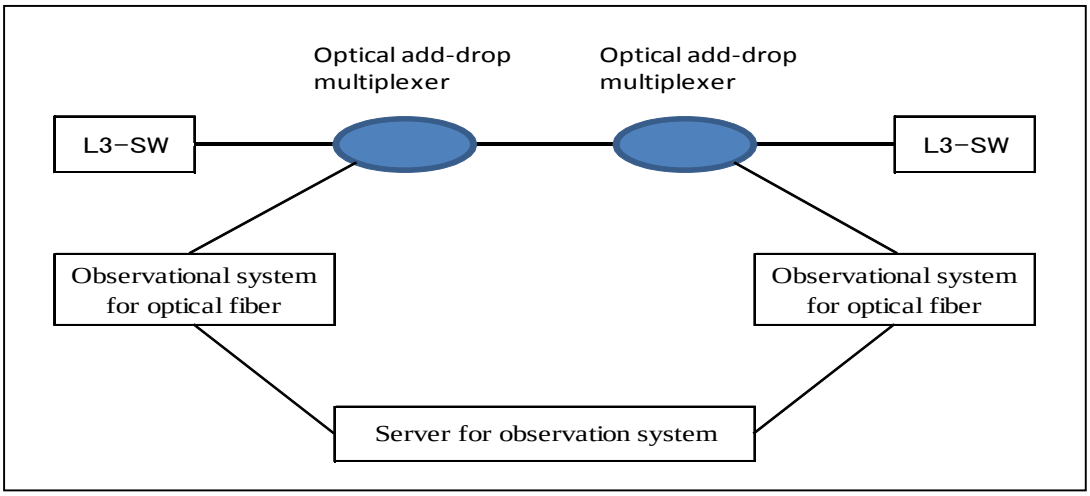

Figure 7. Observational system using WDM

CONCLUSION

-The problem caused by network composed of optical fibers inside trunk sewer is that whether loop network can be built depends on the location of our facilities and trunk sewer. Therefore, it may be difficult to build a network without loop-imperfection.
However, we can compensate for loop-imperfection by using telecommunication carrier's lines and we can avoid the risk of isolation of the remote controlled stations.
-As to wide area network such as SOFTPLAN, Network reliability depends on the quality of its maintenance. The introduction of WDM will enable the quality of maintenance to improve.
On the other hand, its cost will get higher as we increase the number of WDM. And the amount of information will get larger. Therefore, installing WDM requires circumspection.

Now that the use of fiber network is expanded, we measure the water level of trunk sewer by using optical water level gauge. Fiber network gets more cost-effective as we use more number of the glass fibers, but at the same time we need to care about its reliability. We should take

necessary measures about its reliability and efficiency, considering its characteristic condition like inside trunk sewer.
We should protect living conditions and the environment to make urban life more comfortable.
To provide people in Tokyo with comfortable urban life, we keep on preparing not only sewerage and storage pipes but also the fiber network which makes our facilities more effective and cost-effective.

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