Novel Optical-Fiber Network Management System in Central Office Using RFID and LED Navigation Technologies

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Abstract. Optical IP services such as FTTH have been growing rapidly, leading to an urgent need to manage the optical fiber network from the central office. We have developed an optical-fiber distribution facility called an IDM. However, the changing FTTH environment means we need further efficiency and cost-effectiveness for network construction and operation work. This paper proposes a novel optical-fiber network management system for the IDM that realizes reducing working time, less skilled work and eliminating human error. This system consists of two technologies with control software, namely optical distribution identification technology using RFID, and automatic navigation technology using an LED and DB. In this paper, we describe optimized work flows for installation and removal work. Moreover, we achieved a reduction of up to 48 % in working time with less skilled workers and accurate DB management by using our proposed system.

Keywords: FTTH, human error, RFID, automatic navigation system.

1 Introduction

Optical IP services such as fiber to the home (FTTH) have been growing rapidly throughout the world. In Japan, the number of FTTH customers has increased tenfold in the last 5 years [1]. In addition, NTT plans to achieve 20 million customers by 2010 [2]. In this kind of environment, we have to reduce optical fiber network costs related to construction, maintenance and operation. At the same time, our goal is to spread the use of FTTH services and related components that link an optical line terminal (OLT) in an NTT central office to optical network units (ONU) in a customer's home. Therefore, we have developed optical fiber network facilities for central offices that consist of an integrated distribution module (IDM), optical fiber cables and a management system [3][4]. These facilities realize increased work efficiency and high-density connectors.

Figure 1 shows the optical access network topology for typical FTTH services in Japan. There are many kinds of access network line and the type depends on the FTTH service being provided. In recent years, FTTH in Japan has provided an access network bandwidth of 100 Mb/s. Figure 1 (a) shows the basic FTTH service with a

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gigabit Ethernet-passive optical network (GE-PON) [5]. This network serves a maximum of 32 customers per optical fiber by using two kinds of splitter in the central office and near the customer's house. The other access network topology shown in Fig. 1 (b) is a single star (SS) topology, which is used for businesses and common carrier leased lines. To manage these services in the access network, there is a strong need to be able to change a service easily and rapidly, and to realize further efficiency and cost-effectiveness as regards network construction and operation.

In this paper, we propose a novel optical-fiber network management system for the IDM that reduces working time, requires less skilled work and prevents human error. This system consists of two technologies with control software, namely optical distribution identification technology using radio frequency identification (RFID), and automatic navigation technology using a light emitting diode (LED) and a database (DB). We describe optimized work flows for installation and removal work. As a result, we achieved a working time reduction of up to 48 % with less skilled workers, and accurate DB management by using a novel system.

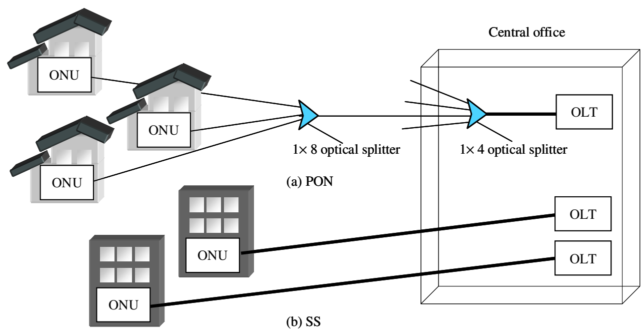


Fig. 1. Access network topology

2 Installation and Removal Work on IDM

In this section, we describe actual distribution facilities with a management system in a central office and the service order flow.

2.1 Distribution Facilities in Central Office

The progress made on such aspects of the optical access service as operation and maintenance technologies has been inadequate compared with the growth in service demand and the development of optical line and transmission technologies [6]. We have developed an IDM to increase the work efficiency and to solve the problem of optical fiber cable congestion. In addition, it is likely that there will be a shortage of available floor space. We realized a high-density connector and a space-saving module by optimizing the architecture and design of the module. Figure 2 shows the optical fiber distribution facility in a central office using the IDM. The IDM realizes simple optical fiber distribution, and integrates the following functions; the accommodation of splitters for splitting optical signals, the termination and the connection of feeder and central office cables, the selection of an optical fiber to be tested and the launching of a maintenance signal. The IDM consists of IDM-A, which terminates and connects feeder cables from outside the central office, and IDM-B, which terminates and connects all the optical fiber cables that run from the OLTs.

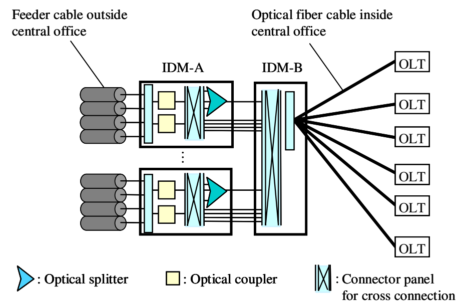


Fig. 2. Optical fiber distribution facilities in central office

This configuration makes it possible to minimize the additional distribution of optical fiber cables even if an IDM-A is newly installed. Therefore, the configuration reduces the number of cables and simplifies the cable configuration.

Figure 3 shows a photograph of the IDM-A. We use an MU connector with a 1.1 mm diameter optical fiber cord. Although the cord is temporarily housed in a plug holder, it can be extracted from the holder and connected if needed. The jumper unit connects the optical fiber cord and the feeder cable outside the central office and different types are used depending on the service.

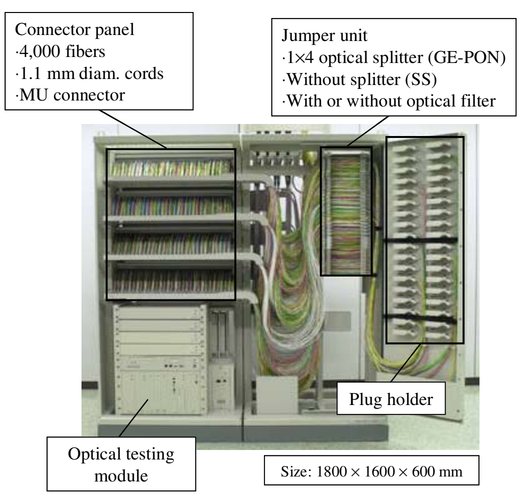


Fig. 3. Integrated distribution module (IDM-A)

2.2 Management System in Central Office Using QR Code

Figure 4 shows the configuration of a system designed to manage central office optical distribution facilities using a two-dimensional identification code, called a QR code (ISO/IEC 18004). The registration and accessing of fiber information are facilitated by attaching an information tag printed with the QR code to the optical fiber cord used in the IDM, and reading the QR code on the information tag with an identification code reader, called a QR code reader. The QR code includes information for facility identification. Moreover, the data read by the QR code reader can be output from a mobile terminal to the database server.

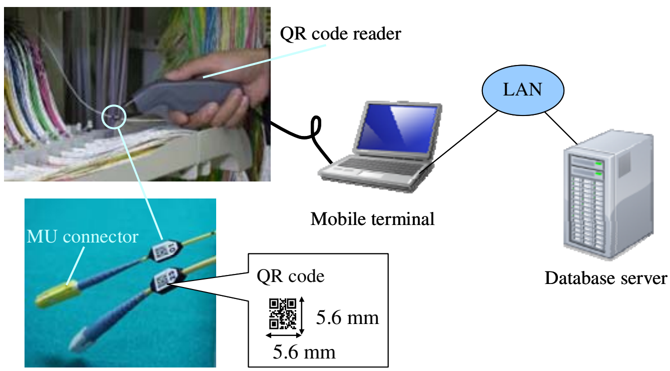
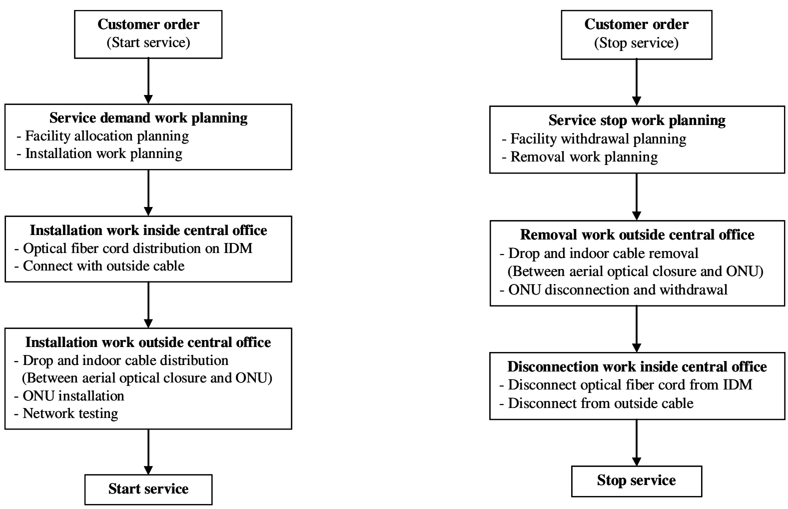


Fig. 4. Management system using QR code



(a) Service order flow for starting service (b) Service order flow for stopping service

Fig. 5. Service order flow from the customer's service demand

Figure 5 shows the service order flow from the customer's request for a service to its provision. When starting a service as shown in Fig. 5 (a), the order flow is as follows; after receiving the customer's service request, the operator undertakes service demand work planning, which consists of facility allocation and installation work planning. Next, a worker in a central office undertakes distribution work such as fiber cord distribution on the IDM according to the work plan. Finally, after completing the distribution work inside the central office, the worker undertakes distribution work outside the central office such as drop and indoor cable distribution, ONU installation and network testing. The FTTH service starts once all the distribution work and testing are finished. On the other hand, when stopping a service as shown in Fig. 5 (b), the order flow is as follows; after receiving the customer's order to discontinue the service, the operator undertakes service stop work planning, which comprises facility withdrawal and removal work planning. Next, a worker outside the central office performs removal work such as drop and indoor cable removal, ONU disconnection and withdrawal. Finally, after finishing the removal work outside the central office, the worker performs disconnection work such as disconnecting the fiber cord from the IDM. After all the removal and disconnection work is finished, the FTTH service is discontinued. When changing a service, the worker would perform the service stop and start procedures in turn.

3 Architecture Design of Novel Optical-Fiber Network Management System

In the previous section, we described actual distribution facilities with a management system in a central office and the service order flow. However, as mentioned above, increasing FTTH service demand, and the introduction of novel FTTH services allows us to further improve efficiency and cost-effectiveness. Therefore, we focused on work at the IDM, and investigated how to reduce both working time and the required level of skill, and to eliminate human error.

Figure 6 shows our novel optical-fiber network management system. It consists of optical distribution identification technology and an automatic navigation system, a connection tool optimized for this system, a PC with control software referred to as a control terminal, and a DB server that provides service and access network information. The features of this system are as follows:

(1) ID discrimination function

We mounted RFID chips on connectors and connector adaptors, and installed an RFID reader, an ID discrimination device and a solenoid as a controlling trigger in the connection tool. Each RFID-chip-mounted adaptor has a unique ID. An RFID-chip-mounted connector has a unique ID and stores customer information such as the services the customer uses. The ID discrimination device in the connection tool linked to a control terminal uses a USB cable that supplies DC power.

(2) DB autonomous installation

Once a connector has been connected or disconnected, control software immediately updates the DB. Moreover, it is possible to crosscheck the records in the DB when a worker needs to confirm the difference between order information and the current state of the optical fiber distribution.

(3) Alarm notification and connector holder locking in discriminating different IDs
If a worker selects the wrong connector when disconnecting an optical fiber cord, the control software activates an alarm tone and posts a message on the PC display. Moreover, the connection tool trigger that controls the on/off connector remains locked.

(4) Automatic navigation using LED
LEDs mounted on both sides of the connector adaptor are illuminated when a installation or removal order is input.

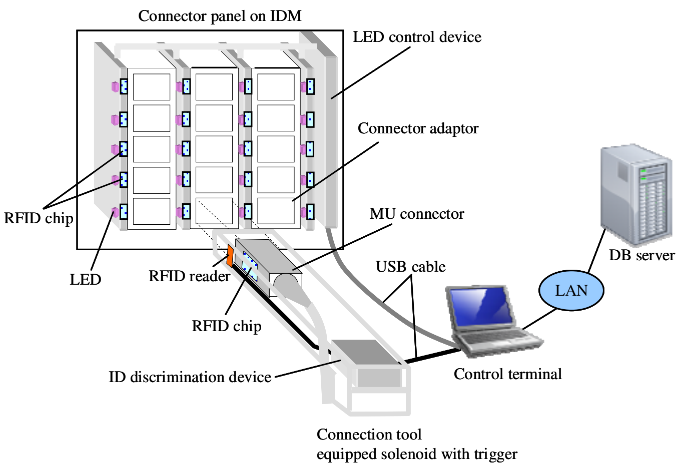


Fig. 6. IDM mounted proposed system

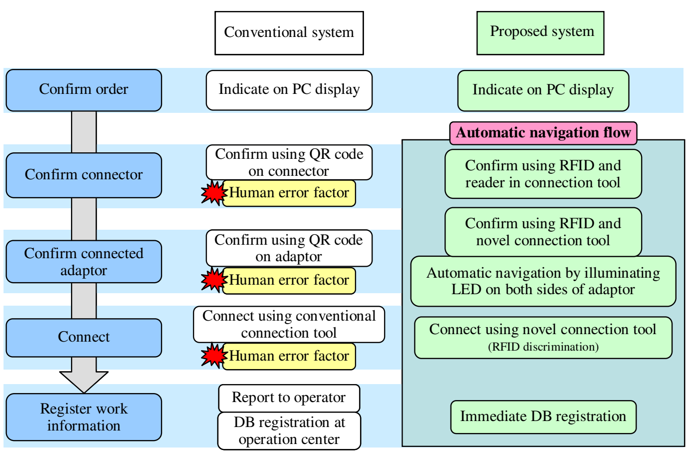


Fig. 7. Conventional and proposed installation work flow

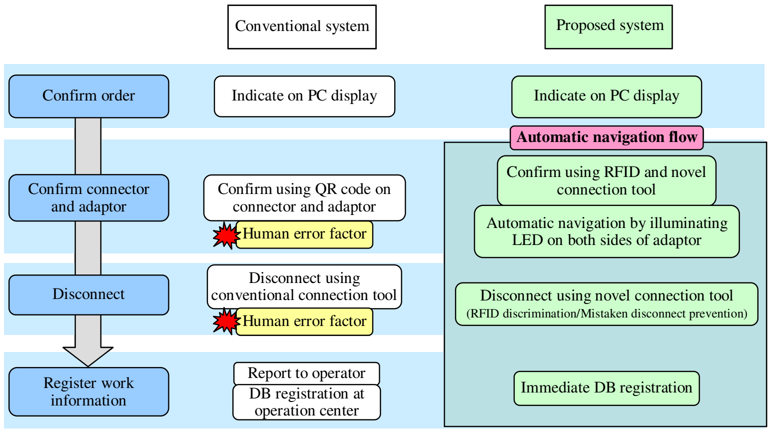


Fig. 8. Conventional and proposed removal work flow

Figures 7 and 8, respectively, show the conventional and proposed installation and removal work flow for an optical fiber network facility. It can be seen that a conventional IDM is subject to human error because it depends on manual work and visual confirmation. In addition, after confirming that the connector and connector adaptor are correct using the QR code, the worker must look away in order to remove the QR reader and attach the MU connector to the connection tool. For these reasons, it is possible for the worker to make a mistake. Therefore, a person working on an IDM with the currently used system must perform many crosschecks and this is time-consuming. To solve this problem, we investigated a way of eliminating human error from IDM work. Then, we developed an IDM work support system using the RFID and LED navigation technologies. This system employs an LED and sound navigation, and it enables the worker to continue concentrating on the target and thus prevents any errors as regards connector disconnection.

Figures 9 and 10 show the information flow when installing and removing a network. This flow involves four devices, namely a DB server in the management office, a control terminal with a connection tool, and an IDM equipped with an RFID and an LED navigation system. The information flow during installation is as follows; first, a worker in a central office downloads operation orders using the control terminal. Then, the worker selects the operation order using control software, and the details of the order including the adaptor number and connector information are input into the control software. Next, control software illuminates the appropriate LEDs that are mounted on both sides of connector adaptor on the IDM. The worker then places an appropriate connector in the connection tool, and the RFID reader in the connection tool confirms this by reading the RFID mounted connector. The control software determines whether the connector is correct, and informs the worker by both sound and display. Next, the worker connects the connector to the correct connector adaptor using the connection tool, and then the RFID reader in the connection tool confirms this by reading the RFID mounted connector adaptor. The control software makes a determination and informs the worker in the same way as that mentioned above. Finally, the control software uploads the installation data to the DB server.

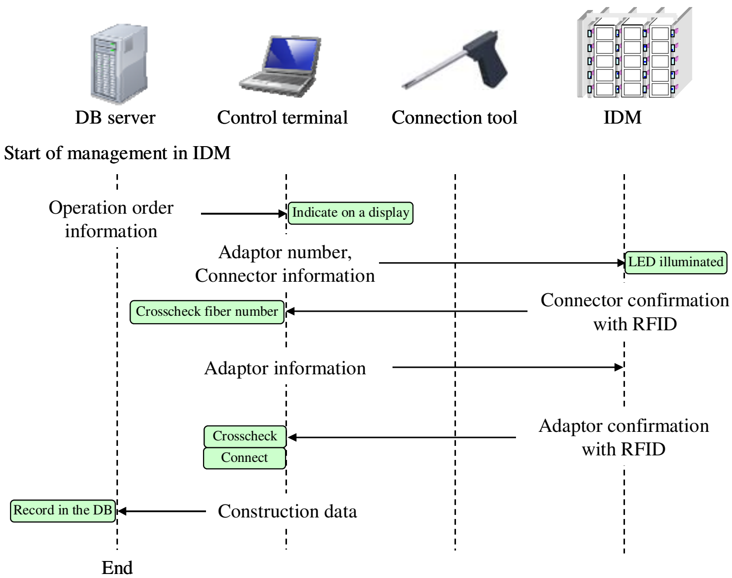


Fig. 9. Information flow when installing network

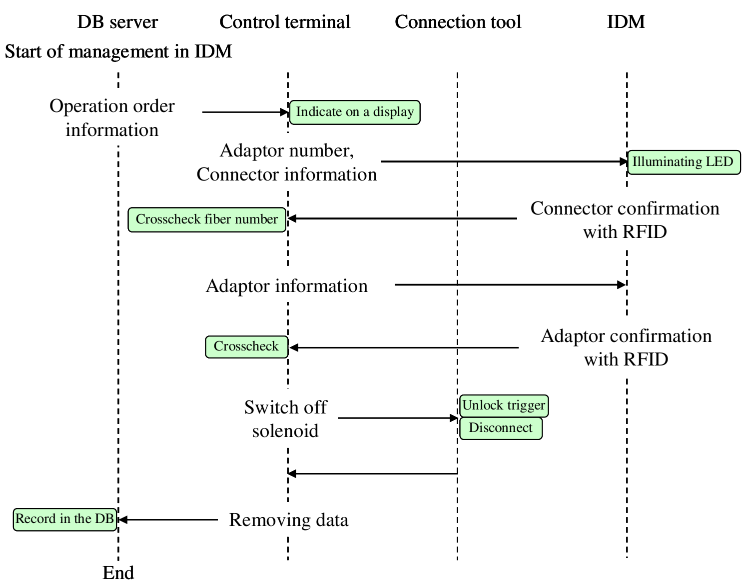


Fig. 10. Information flow when removing network

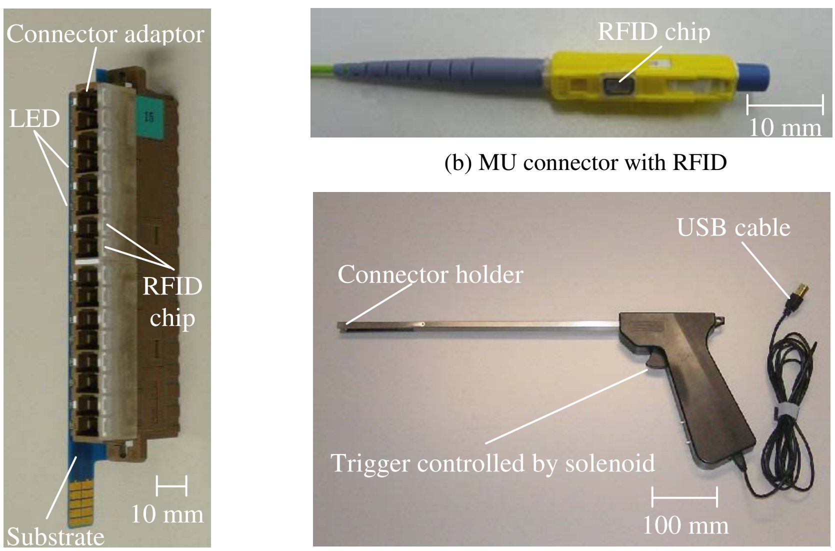
The information flow when removing a network is almost the same as the flow described above. However, the most important point in the work flow is to ensure that the wrong connector is not disconnected. If this were to happen, customers using

FTTH services would be cut off from the FTTH network. To prevent such a occurrence, we installed a solenoid beside the control trigger in the connection tool. Therefore, the connection tool trigger remains constantly locked. The trigger is released only if the control software determines that the connector adaptor is correct.

We believe that human error can be eliminated by using the proposed system including the solenoid-control connection tool, LED navigation and automatic cross-check functions. Moreover, IDM workers can perform without having to undertake many crosschecks. Therefore, all workers who have any level of skill can perform the above work accurately and quickly.

4 Prototype Manufacture and Evaluation Result

We have manufactured a prototype based on the design concept described in the previous section. Figure 11 (a) shows the connector adaptor mounted with 16 RFIDs and LEDs on both sides. Figure 11 (b) shows an MU connector equipped with an RFID, and Fig. 11 (c) shows a connection tool equipped with an RFID reader and a solenoid to control the locking of the connector holder.



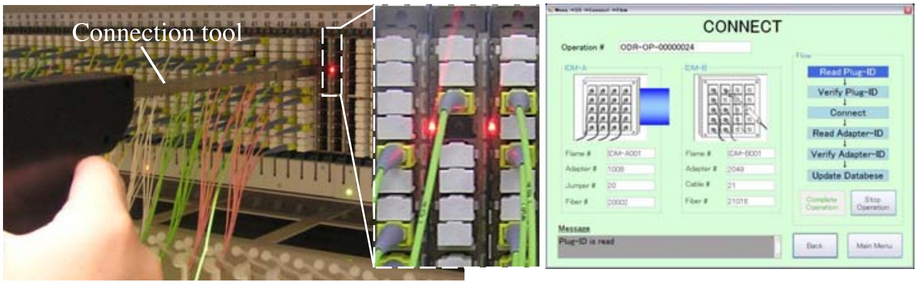
(a) Connector adaptor with RFIDs and LEDs

(b) MU connector with RFID

(c) Connection tool optimized for proposed system

Fig. 11. Prototype manufacture based on proposed system

Figure 12 shows the IDM equipped novel optical fiber network management system. Figure 12 (a) shows the appearance of the connector panel on an IDM and the connection tool and an enlarged view of connector adaptors with illuminated LEDs. Figure 12 (b) shows the control software window when a network is being installed.



(a) Enlarged view and appearance of IDM (b) Control software window

Fig. 12. Enlarged view and appearance of IDM, and control software window

This shows that the worker can confirm the operation order and the current work according to the work flow shown in fig.7 or 8.

Next, we investigated the workability of the IDM mounted in conventional and proposed management systems. We measured the time needed for installation and removal work. The participants were five people who were unfamiliar with IDM work. In this measurement, any human errors did not happen. Figure 13 shows the averaged working time dependence of the conventional and proposed systems. The figure shows that the times needed for installation and removal using the proposed system were respectively 28 and 48 % less than with the conventional system. Additionally, a connector panel with fiber cords on the IDM used for this measurement was exactly aligned. As the currently used IDM is providing the FTTH services and the fiber cords are congested, the worker spends more time crosschecking and looking for a connector and an adaptor. As a result, the actual working time when using an IDM with a conventional system will be longer than in this measurement.

As mentioned above, when using the proposed system, it is possible for all workers to perform this task accurately and quickly without frequent crosschecking.

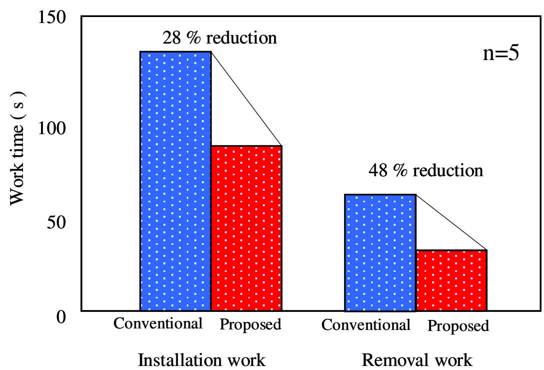


Fig. 13. Working time dependence of conventional and proposed systems

5 Conclusion

We investigated a novel optical fiber network management system designed to reduce working time and the required level of skill, and to eliminate human error. We achieved a working time reduction of up to 48 % with less skilled workers and accurate DB management by using our proposed system. These results show that the proposed system is a promising approach for achieving increased efficiency and cost-effectiveness for access networks.

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