Development of Network System Based on Fiber-To-The-Desktop (FTTD) in a National University Hospital

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Abstract— **The authors have developed a network system in a national university hospital based on Fiber-To-The-Desktop (FTTD), which is a network architecture that has a star network topology. This paper describes backgrounds from which the hospital required the FTTD-based network system and issues that the authors faced in development of the network system. Moreover, this paper evaluates effects of their FTTD-based system and discusses advantages and disadvantages of FTTD, based on the authors' experiences of both development and administration of the network system.**

Keywords-FTTD; network system; national university hospital.

I. INTRODUCTION

Recently, a lot of large hospitals including university hospitals introduce various information systems to assist medical care services ranging from administration of patients' healthcare records to accounting service [1][2]. Consequently, network systems, which are base of the hospital information systems, have become large and complex. The reason why the network systems have grown is not only the growth of the server systems of hospital informations systems but also diversification of devices that medical staffs employ. Today medical staffs use multiple information terminal devices ranging from desktop computers to smart phone everywhere in hospitals to input and view information for medical services. Since this tendency continues for the foreseeable future, network systems of hospitals will grow increasingly large.

The growth of scale and complexity of a network system increases in not only the cost of the system development, but also the burden of both operation and maintenance of the system. Therefore, it is important to keep performance of the network system without making the system complex.

Fiber-To-The-Desktop (FTTD) is known as a network system architecture to reduce risks and costs of maintenance by simplifying the structure of the network system itself by eliminating intermediate network switches. However, it seems that FTTD has seldom been publicly evaluated its advantages and disadvantages from practical viewpoints, with real development of FTTD-based network systems. Therefore, this paper describes backgrounds from which a university hospital required a FTTD-based network system, issues that the authors faced in development of the network system, effects of the FTTD-based system, and advantages and disadvantages of FTTD from practical viewpoints, based on the authors' experiences of development and administration of the FTTD-based large scale network system in the university hospital.

In order to develop the FTTD-based network system, the authors employed the standard development framework of information systems in software engineering. The framework consists of (i) requirements analysis for the FTTD-based system, (ii) specification of the system based on the requirements, (iii) implementation of the system based on the specification and (iv) evaluation of the system based on the original requirements.

The remainder of this paper is structured as follows. Section II briefly explains FTTD. Section III takes for example a university hospital, and describes backgrounds from which the hospital required FTTD. Section IV takes the development of a FTTD-based large-scale network system in the university hospital, and describes issues that the authors faced in the development of the network system and how they addressed the issues. Section V evaluates effects of the FTTD-based network system and describes advantages and disadvantages of FTTD based on both development and administration of the system. The last section presents conclusions.

II. BRIEF EXPLANATION OF FTTD

Fiber-To-The-Desktop (FTTD) is a network system architecture that has a star network topology [3][4] (Fig. 1). A star network topology has the central part that controls data (packets or datagrams) and multiple terminals which are attached to servers, client computers and so forth. In this paper, the central part above is called “the central control part”, and the terminals above are called “terminal parts”. In FTTD, each terminal part is connected to the central control part by a fiber cable (in many cases, an optical fiber cable).

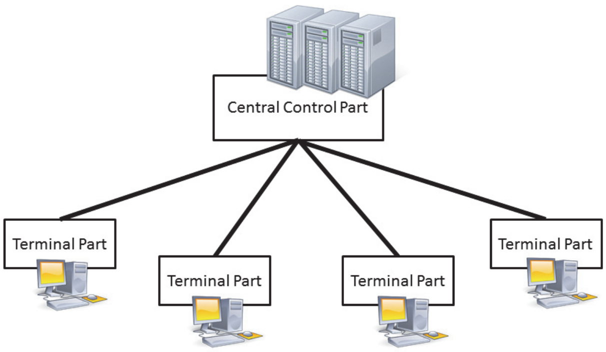

Figure 1. Network topology of FTTD

The main feature of FTTD is that an FTTD-based network system has no network switch that relays data between the central control part and a terminal part, and hence, the structure of FTTD is very simple. Typical advantages of FTTD by virtue of its simple structure are reliability and expandability. The feature that FTTD has no intermediate switches and simple structure reduces opportunities where failure risks occur in the network system. This enhances reliability of an FTTD-based network system. On the other hand, in many cases, the fiber cable between the central control part and each terminal part is made to have not lower than 1Gbps data rate, which makes it possible to connect computers or devices which require more traffic data to the network system. This indicates that FTTD has high expandability.

As a typical disadvantage of FTTD, this network architecture requires higher development costs [4]. The issue will be again described in Section IV.

III. BACKGROUND FROM WHICH A UNIVERSITY HOSPITAL REQUIRES FTTD

One of the authors' missions is development and administration of the network system in a national university hospital at which the authors work. When the authors designed a network system of the hospital that became fully operational on September 2015, they chose FTTD as the network architecture of the main part of the network system. In this section, in order to clarify significance of FTTD, the objectives that should be accomplished by developing the network system are described, as follows.

Integration of diversified network systems in the hospital: A university hospital consists of a lot of departments. Each department has a certain level of self-government or process which the staff in the department perform tasks according to. Moreover, each department has its own budget by which its own information systems are independently introduced, and some of which require additional network systems. Therefore, some small network systems are independently developed for a particular department in the hospital. However, when such small network systems are connected to the main network system of the whole hospital remaining the small systems not controlled by the administrators of the main network, various problems including network failure and decline of network performance sometimes happen. Therefore, such small network systems should be developed and operated in accordance with the guideline or governance of the whole hospital. To this ends, the main network should provide unified network environment to each department, on which the staffs in the department can develop their information systems.

Strengthening of fault tolerance: With increasing network devices to that client computers, instruments that need the network system, other network devices including small network hubs and so forth can be connected, the risk of network failure also increases by wrong connecting to the network devices. Moreover, as a network system becomes large, it becomes harder to specify the failure point and to address the point when a failure occurs. Therefore, it needs to develop the network system in that a failure seldom occurs and even if such a failure occurs one can specify the failure point and cope with it easily.

Strengthening of usability: In recent years, there have been increased opportunities that medical staffs use various devices and computers to input and/or view patients' healthcare records including vital data and ordering data for patients everywhere in the hospital. Thus, there is a growing need to assist users to access network systems from wherever in the hospital they need for their tasks.

In the following sections, the authors describe how the objectives are accomplished by FTTD.

IV. DEVELOPMENT OF FTTD-BASED NETWORK SYSTEM IN A UNIVERSITY HOSPITAL

In 2015, the authors developed a large-scale network system in our university hospital. The network system consists of three sub-network systems: the first sub-network system is the main part of the whole network system, which is based on FTTD-architecture; the second and third sub-network systems are developed on traditional tree architecture. The three sub-network systems are connected by a big L3-layer switch that we call the "core-switch" (Fig. 2).

This paper focuses on the first sub-network system, which the authors call "FTTD-system". In the following sub-sections, this paper describes main issues that the authors faced when they developed the sub-network system and how they addressed the issues.

A. Development of a Large-Scale FTTD-Based Network System

The FTTD-system is required to have about 1200 terminal parts and considerably large. Thus, from a financial viewpoint, it is not easy to develop the central control part of the FTTD-system by employing a single network switch directly. Therefore, the authors focused on a box-type network switch from Alaxala Networks Corporation, which is one of AX3800S series network switches. Here, the authors call it an "FTTD-switch".

This switch has advantages that it has 40 ports to which optical fiber cable can be attached despite its height with only 1U size, and it has sufficient switching capacity. Moreover, these switches can be connected to each other by 10Gbps cables that are called "directly attached cables" and that are relatively reasonable. The authors procured 35 FTTD-switches, and grouped them into 5 groups. Each group of FTTD-switches, which consists of 7 FTTD-switches, has a ring network topology in which each FTTD-switch connected to each other by four or two 10Gbps directly attached cables (Fig. 2). Moreover, each group of FTTD-switches is connected to the core-switch by four SR-cables that are 10Gbps optical fiber cables (Fig. 2). Thus, the authors constructed a large scale central control part that has 1260 downlink ports.

Moreover, the authors aggregated each pair of the 10Gpbs cables above and duplicated all parts of the core-switch. Thus, the central control part is constructed not to stop even if every part breaks down as far as the failure point is single.

B. Reduction of Development Cost and Space

It is a typical issue that the cost to develop a FTTD-based network system often becomes expensive. In the authors' case too, the issue to reduce the cost was not negligible. The cost issue of FTTD can be classified into the following three issues: (i) the cost of the central control part, (ii) the costs of parts and (iii) the cost of cable wiring. Here, a "part" above mainly denotes a media convertor, that is used to connect an optical fiber cable with a copper (metal) cable, or a small form-factor pluggable (SFP) transceiver, that is a module attached to a port in a network switch to connect fiber cable with the network switch. Moreover, the authors realized that it was also a considerable issue to reduce the size of the central control part. For example, if the authors chose media convertors to connect 1200 optical fiber cables with the central control part, they would need a space to set 1200 media convertors and their electric power supplies.

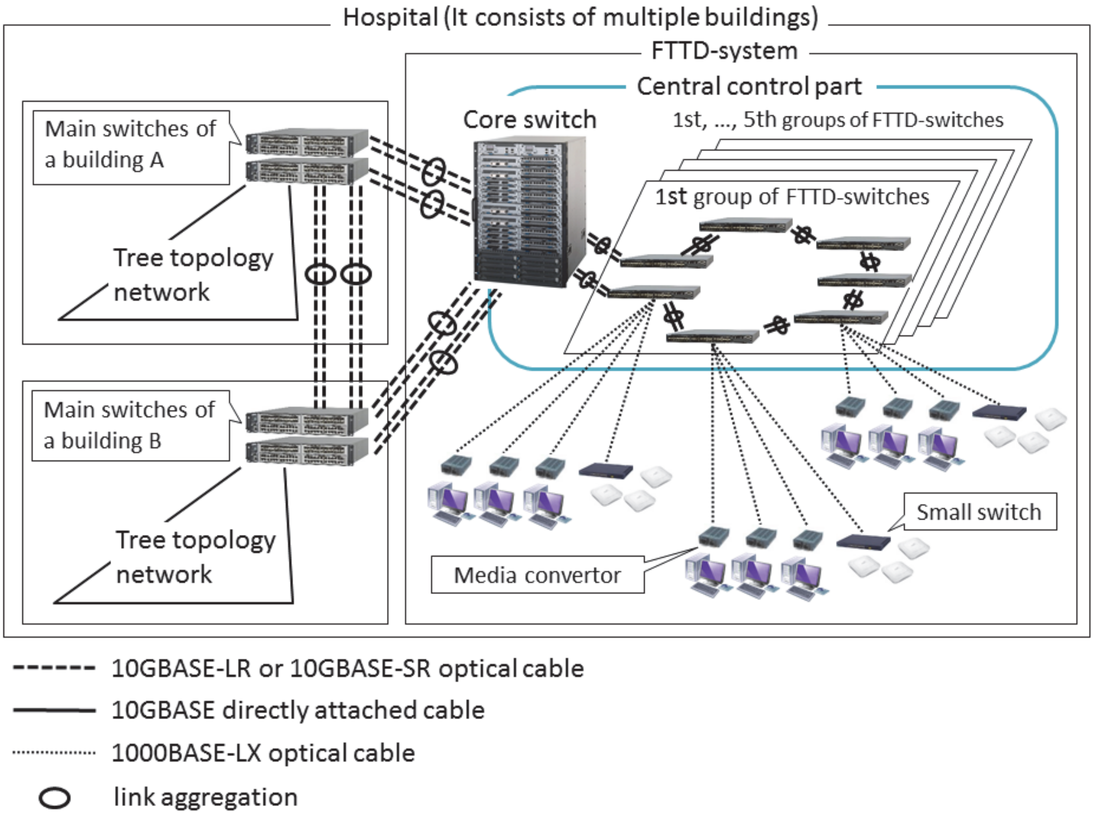

Figure 2. Architecture of FTTD-system

To reduce the cost of network switches that compose the central control part and to reduce the size of it, the authors chose network switches of AX3800S series from Alaxala network Corporation as FTTD-switches. The FTTD-switches have 40 ports to which optical fiber cables can be attached via SFP transceivers per 1U. Moreover, they are relatively reasonable, compared with chassis-type network switches that have the same density of ports as the FTTD-switches.

On the other hand, the authors could not reduce the costs of (ii) and (iii) in the first paragraph of this subsection. Especially, it took considerable cost to have optical fiber cables installed. However, it is partly legitimate that the cost of cable wiring is expensive, since optical fiber cables are longer-term resources than network equipments, and since sooner or later many hospitals will need fiber cables in the near future.

C. Development of Authentication Infrastructure

To realize integrated network systems, it is incomplete only to improve the network topology. That is, the network system also should have the capability to prevent users from adding their own network systems without permission or from attaching unexpected equipments to the network system. Therefore, the authors developed an authorization infrastructure in their FTTD-system. More specifically, they constructed a server that administers mac addresses of equipments that are admitted to be connected to the FTTD-system and VLAN identification numbers (VLAN-IDs) corresponding to the mac addresses. This server prevents any equipment with mac address unregistered from being connected to the FTTD-system. Moreover, when an equipment with mac address registered in the server is connected to the FTTD-system, the server configures the setting for VLAN for the equipment in accordance with the VLAN-ID corresponding to the mac address. Thus, the user of the equipment above can use it wherever in the area that is indicated by the VLAN-ID.

To ensure information security, it is quite insufficient to restrict equipments to connect to the network system only by their mac addresses. In fact, the way to collect mac addresses that are registered in the server and to fake them is well known (for example, see [5]). However, just for preventing staffs in the hospital from connecting non-admitted equipments with the network system, the restriction based on mac addresses is effective at least partly, since staffs should hesitate in explicitly violating information security guideline as well as faking mac addresses.

V. EVALUATION OF FTTD

This section describes effects of FTTD architecture from two viewpoints, and discusses advantages and disadvantages of FTTD based on the authors' experiences of development and administration of their FTTD-based network system.

A. Evaluation of The FTTD-System Through Observing Its Structure

Before developing the FTTD-system, several departments that have their own information systems constructed their own network systems independently and often connected them to the main network system. When the authors developed the new FTTD-based network system, they clarified and integrated the small network systems as many as possible. They broadened the unified network system and simplified the structure based on FTTD architecture. As a result, they obtained a network system that has considerably good visibility.

Visibility of a network system is useful not only in learning the structure of the system, but also in determining the cause of the failure when a failure occurs in the network system. For example, the authors faced a network failure due to a malfunction of a control device of access points. Since any equipment did not present its malfunction explicitly, it was not easy to completely determine the cause of the failure though they predicted a malfunction of one of the control devises in an early stage. However, due to simplification of the network system, it did not take long time for the authors to eliminate the possibility of other equipments' malfunctions. As a result, they could focus on the control device and begin checking it in detail early on.

B. Evaluation Through Observing Log Data

One of the main objectives from which the authors developed the FTTD-system was to reduce the number of network failures due to connecting a non-admitted equipment to the network system. A typical problem of the failures above was a network loop problem, which is also called a switching loop problem. Thus, the authors looked at log data that FTTD-switches have output since the starting day of operating the FTTD-system. More specifically, they first inspected the number of records of network loop problems among log data of FTTD-switches for 242 days between the starting day of operating the FTTD-system and today. As a result, 4 loop problems were detected.

The authors next inspected how the problems were resolved. By inspecting log data, it was confirmed that, in every case in the four problems, the terminal part that contained the failure point of the loop was cut off by the FTTD-switch immediately after detecting the loop problem. Each terminal part is attached by a media convertor that is attached by a computer or a small switch that is attached by several access points (cf. Fig. 2). Every terminal part attached by a media convertor is set at a location that is easy for network administrators to check, while every terminal part attached by access points is isolated from users. Moreover, network administrators can immediately identify the location of every terminal part. Therefore, even if a user raises a loop problem, network administrators can detect the problem point and remove it immediately by checking log data from FTTD-switches. In fact, in any case in the four loop problems, it did not take long time to resolve the problem. Thus, it can be concluded that it enhanced fault tolerance of the network system to introduce FTTD as the base architecture of the system.

C. *Advantages and disadvantages of FTTD*

In this subsection, the authors discuss advantages and disadvantages of FTTD based on their experiences described in the previous sections. In Section II, they described reliability and expandability as typical advantages of FTTD. For reliability, the authors explained it as fault tolerance against network failures in Section IV. On the other hand, in the case of the authors' FTTD-system, every terminal part to which a user can attach his/her equipment is located at the place near the working place so that both of users and network administrators can easily check what is attached to the terminal part. Moreover, by administering mac addresses of equipments that are admitted to connect to the network system and VLAN-IDs corresponding to the mac addresses, the FTTD-system provides each admitted equipment an adequate network. Thus, while both of users and administrators recognizing conditions of the network system, they can connect their equipments to it. This implies that the FTTD-system enhances expandability as well as reliability.

As a typical disadvantage of FTTD, one can consider the development cost of an FTTD-based network system. Actually, as described in Section III.B, the FTTD-system required considerable costs of FTTD-switches, parts (media convertors and SFP modules) and wiring cables.

The authors learned another issue of FTTD from their experience of administration of the FTTD-switch. That is that SFP modules in FTTD-switches have malfunctions frequently. This is partly understandable because the central control part consists of a lot of FTTD-switches which have a lot of SFP modules in high density which are considerably accurate. Therefore, it will be required to develop a framework that includes a know-how or a guideline to effectively and promptly cope with a failure due to a malfunction of a parts in the FTTD-system.

VI. CONCLUSION AND FUTURE WORK

This paper described backgrounds from which a national university hospital required a large scale network system based on a network architecture called "Fiber-To-The-Desktop (FTTD)", and issues that the authors faced in development of a FTTD-based network system. Moreover, to evaluate the FTTD-based system, this paper inspected records of network loop problems in log data in the FTTD-system and how the authors resolved failures including the loop problems above, and discussed advantages and disadvantages of FTTD architecture based on the authors' experiences of both development and administration of the FTTD-based system. The evaluation shows that the FTTD-system partly enhanced reliability and expandability of the network system.

On the other hand, this paper described issues that the FTTD-system required high costs in development and maintenance of it. It will need to develop a framework to maintenance a lot of parts in the FTTD-system.

All data in a FTTD-based network system go through the central control part. It is useful to analyze such log data for investigation into the causes of network failure and security problem and for preparation for addressing such problems. Thus, the authors' next objective will be to develop a mechanism for the maintenance all log data collectively at the central control part.

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