Optical Access Network Architecture that Enables Prompt Construction to Meet Growing Demand

Tamotsu Yonemoto†, Masahiro Sonobe, Hiroshi Kigami, Yukio Hasegawa, and Shigehiro Miura

Abstract

This article introduces the optical access network design technologies we are using to achieve NTT's target of 30 million optical subscribers by FY 2010. It also describes our investigation of how to expand optical service coverage afterwards.

1. Current optical access networks

Optical access networks can be implemented with various topologies, including single star, passive double star, and active double star (**Fig. 1**). In the passive double star, optical splitters are used to connect multiple subscribers via a single optical fiber, and passive optical elements are used to configure the optical access network. Hence, it is also referred to as a passive optical network (PON).

In the optical access network of the B-FLET'S service provided by NTT, we reduced the initial construction costs by using a PON configuration with four-branch optical splitters in NTT's central offices and eight-branch splitters outside. Since its launch in 2001, the B-FLET'S service has steadily gained subscribers, and the number reached 3.42 million by the end of FY 2005. In FY 2006, we aim to add a further 2.7 million subscribers in the regions handled by NTT East and West towards meeting our target of 30 million optical subscribers by FY 2010. To respond promptly to this growing demand for optical services (which resembles the large-scale growth of telephone services in the last century), it is becoming essential to establish optimum optical access network design technologies to ensure that the network is developed more efficiently based on economical planning.

2. Existing optical access network architecture

Here, architecture means the design technologies used to enable rising demand to be accommodated efficiently and economically in NTT's central offices. When optical cables are installed, it is cost-effective to establish individual connections between each customer and an NTT central office when there is low demand. However, as demand increases, this could lead to overcrowding of facilities, more difficult facility management, and the same engineering work being performed for each customer. We have achieved efficient construction, operation, and management of optical access network facilities by establishing optimum management units (**Fig. 2**).

2.1 Distribution area

The distribution area is the area covered by an 8-branch optical splitter outside an NTT central office. When demand is low, larger distribution areas yield a higher splitter utilization rate and allow the optical cables and equipment in NTT's central office to be used more efficiently. On the other hand, when demand is high, smaller distribution areas are more economical because they result in shorter lengths of drop fibers* between the optical splitters and customers' premises (**Fig. 3**).

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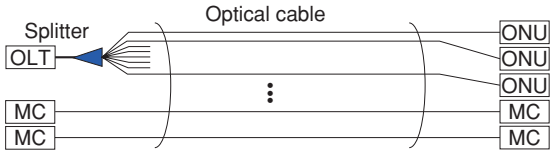
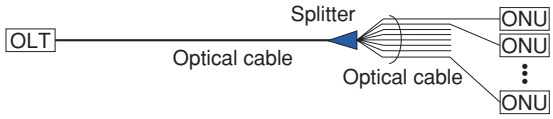
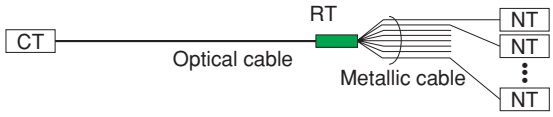
* Drop fiber: a single fiber, mainly used from an outside splitter to a customer's premises.

Topology	Optical access networks			Characteristics		
	Central office	Access section	Customer premises	Initial construction cost	Multiple services	Testing
Single star				Fair Optical fiber needed for each subscriber	Good Multiple services can be provided.	Good End-to-end testing is possible.
Passive double star				Excellent More efficient access sections and equipment in central office	Fair Splitter must be changed.	Fair Problems of testing and facility management between splitter and customer's premises
Active double star				Good More efficient access sections	Fair Can provide only low-speed services	Fair Nodes (O/E conversion) require maintenance.

OLT: optical line terminater
ONU: optical network unit
MC: media converter
CT: central terminal
RT: remote terminal
NT: network termination
O/E: optical-to-electrical

Fig. 1. Topology of optical access networks.

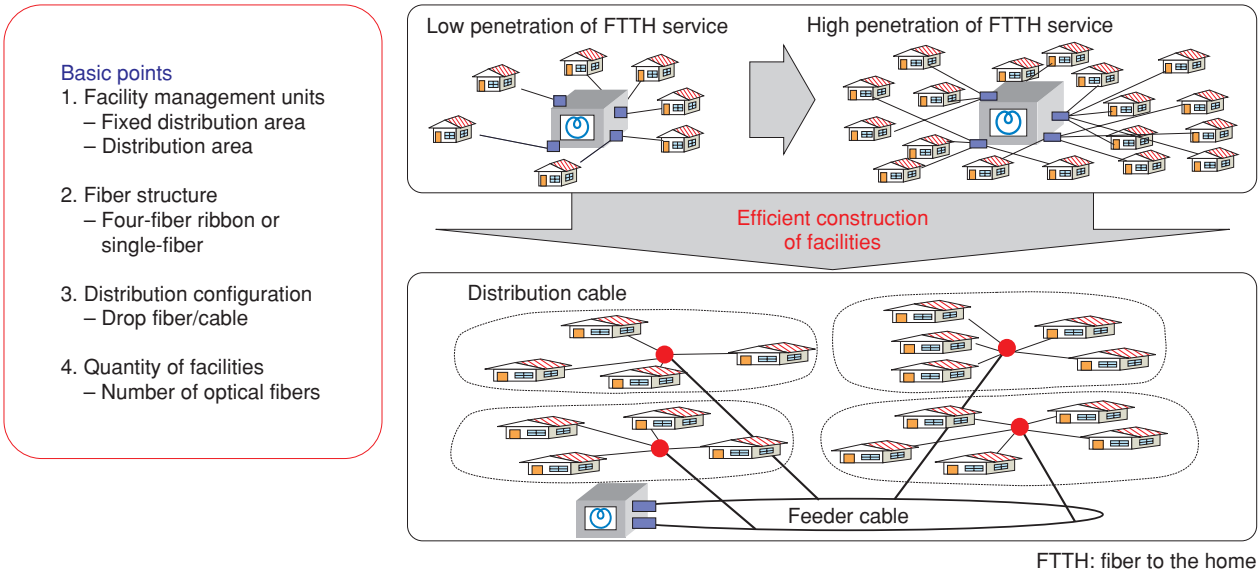


Fig. 2. Optical access network architecture.

2.2 Fiber structure

Aerial optical cables include four-fiber ribbon cables and single-fiber cables. When we use a four-fiber ribbon cable, we need to separate the ribbon's fibers at the point where a fiber is needed. The remaining fibers in the ribbon can be used only to serve homes in that immediate area. So when demand is low, it is inefficient to use four-fiber ribbon cables. However, four-fiber ribbon cables have the advantage of simpler multi-fiber connections. When demand is

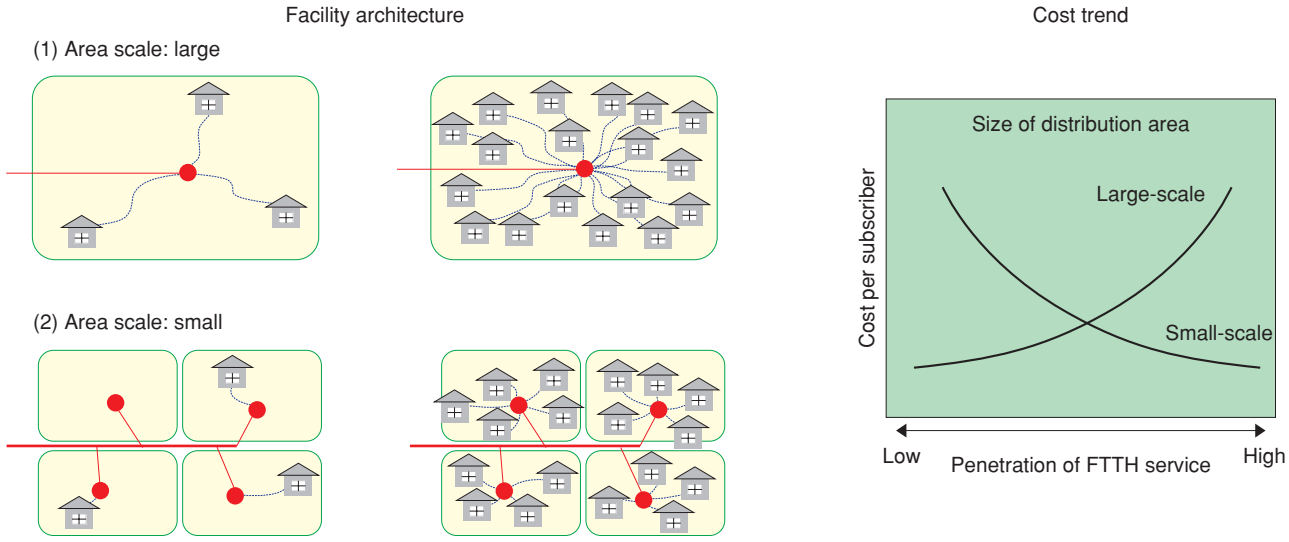


Fig. 3. Distribution area.

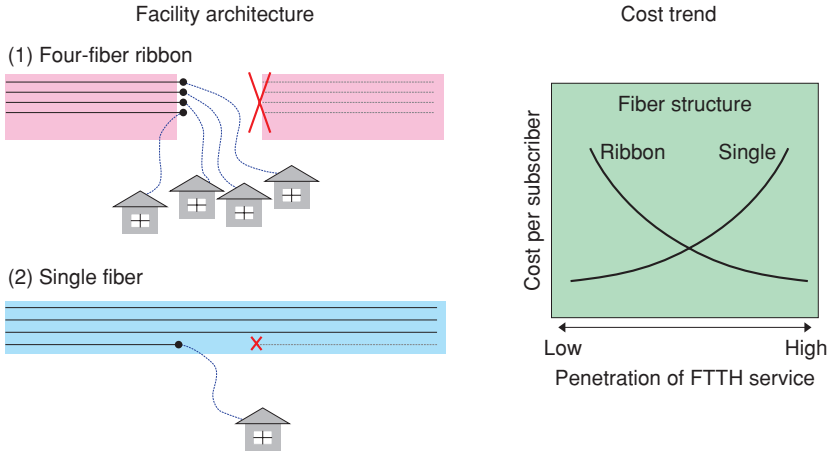


Fig. 4. Fiber structures: comparison of four-fiber ribbon and single-fiber.

high, four-fiber ribbon cables are economical because they do not need as many connections as single-fiber cables. Therefore, single-fiber cables are more economical in regions of low demand and four-fiber ribbon cables are more economical in regions of high demand (**Fig. 4**).

2.3 Distribution area configuration

Optical cables tend to cost less per fiber as the number of fibers in the cable increases. Accordingly, although it is more economical to distribute optical fibers individually from the optical splitter to each customer's premises when demand is low, it is more economical to distribute the optical fibers from the nearest telegraph pole via cables when demand is high (**Fig. 5**).

2.4 Number of fibers required in a fixed distribution area

The number of optical fibers to be constructed depends on the target penetration of FTTH (fiber to the home) and the complexity of the distribution network. As the distribution network becomes more complex, the number of fibers required becomes larger. When four-fiber ribbons are used, even more fibers are required; therefore, the utilization rate of

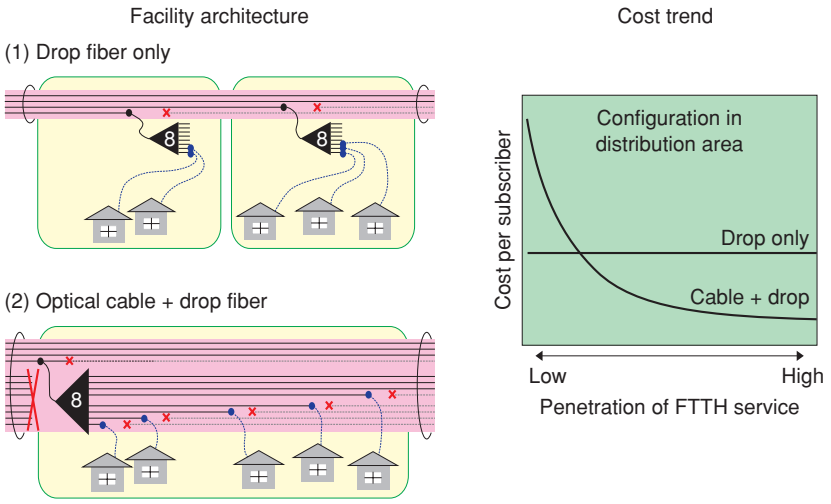


Fig. 5. Configuration in distribution area (drop/cable).

four-fiber ribbon is inefficient when demand is low.

3. New optical access network architecture

Since the demand for FTTH has reached a substantial level, we have developed a new optical network architecture that enables prompt construction to meet the growing demand by focusing on the following two ideas.

(1) Optical splitter utilization rate

When demand is low, the number of subscribers accommodated in an eight-branch optical splitter is also low, resulting in a low splitter utilization rate. In a PON configuration, the service's systems and optical splitters are closely related to each other, so new optical splitters have to be added separately when services are added or modified. Consequently, when new services are provided in a short period of time, the cost of the facilities becomes relatively high without any increase in the optical splitter utilization rate. An effective method of increasing the optical splitter utilization rate is to expand the area covered by the optical splitter, i.e., the scale of the distribution area. However, simply increasing the scale of the distribution area results in a longer length of drop fiber from the optical splitter to the customer's premises. That is, there is more engineering work involved in meeting the service demand.

(2) Service demand work

In the current distribution configuration, where direct drop fibers are distributed to customers' premises from the optical splitters, the drop fibers must span several telegraph poles, which means that service demand work will be a considerable burden in the future when demand grows. This service demand work can be reduced if the length of drop fibers is reduced by using an architecture where cables are pre-routed from the optical splitters so that drop fibers have to be installed only in the section between the telegraph pole nearest to the customer and the customer's premises.

To implement these two ideas, we conducted a comprehensive study of design parameters such as the structure of distribution areas and the fiber structures mentioned in section 2, and we developed and introduced a new distribution area configuration that combines cables and drop fibers, as shown in **Fig. 6**. We have also developed facility management methods and products (aerial optical closures for distribution/dropping points and optical cables) that are needed to introduce the new distribution configuration. For example, **Fig. 7** shows how the number of fibers required in aerial optical cables varies with the market penetration of FTTH and the distribution configuration from the optical splitter to the customer's premises. We developed optical cables with the optimum number of fibers based on this distribution of the required number of fibers.

4. Optical access network architecture for expanding optical service coverage

In the construction of optical access networks, it is also important to consider the characteristics of each

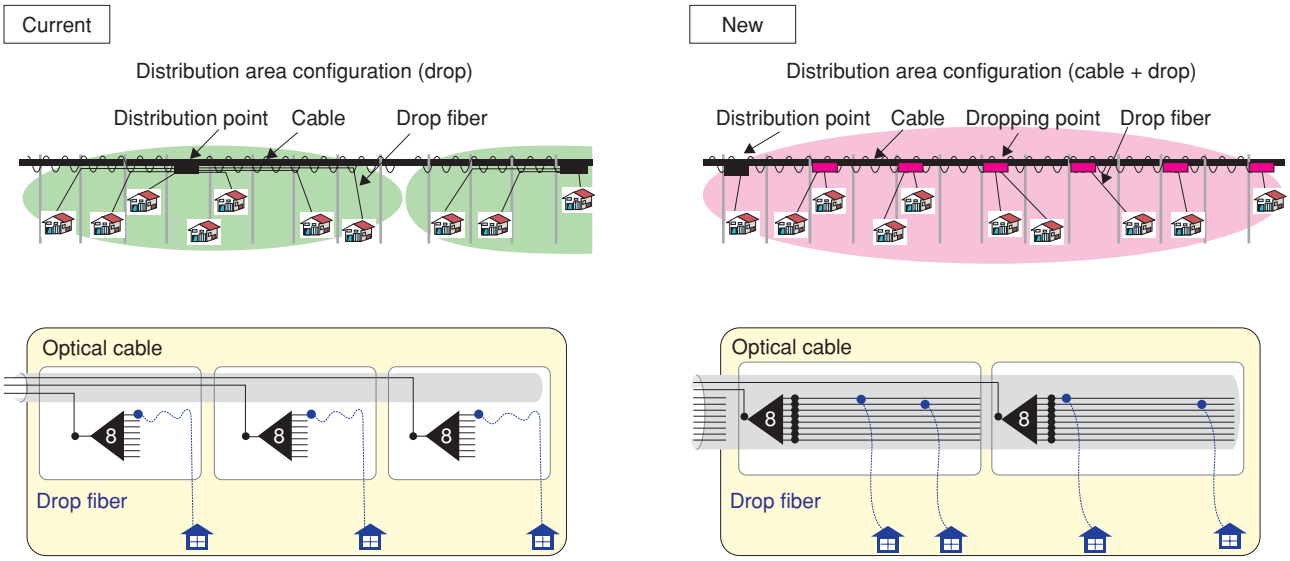


Fig. 6. Distribution area configuration.

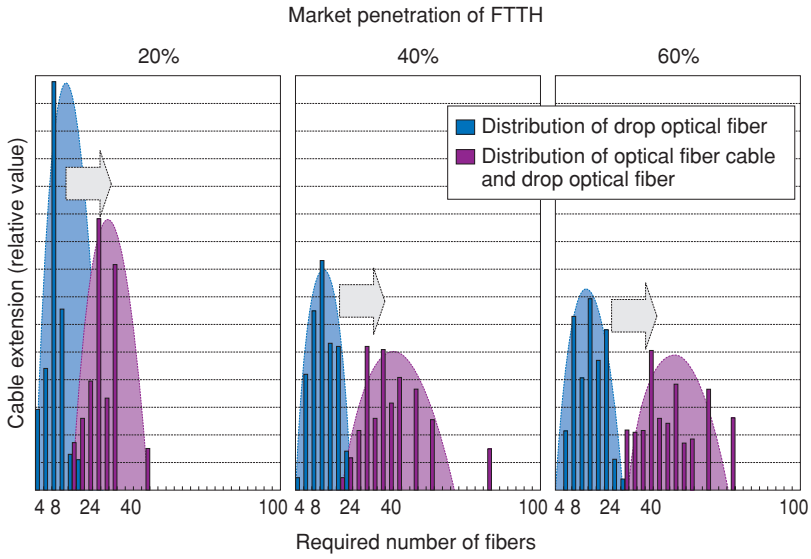


Fig. 7. Distribution of the number of fibers required in aerial optical cables.

area, such as the subscriber density and service coverage area. In practice, they differ widely among areas, as shown in **Fig. 8**. The B-FLET'S service has been preferentially provided in urban regions with a high density of subscribers, and by the end of FY 2005, approximately one quarter of all NTT's central offices were providing this service. To achieve an even greater spread of FTTH, we will have to investigate an optical access network architecture that can be applied to areas with a low subscriber density and to wide areas outside urban regions. In particular, the provision of FTTH services in rural areas where there is an extremely low subscriber density has been taken up as a target in NTT Group's Mid-Term Management Strategy (announced in November 2004), in the plan of the Ministry of Internal Affairs and Communications to introduce next-generation broadband by 2010 (announced in July 2005), and in the govern-

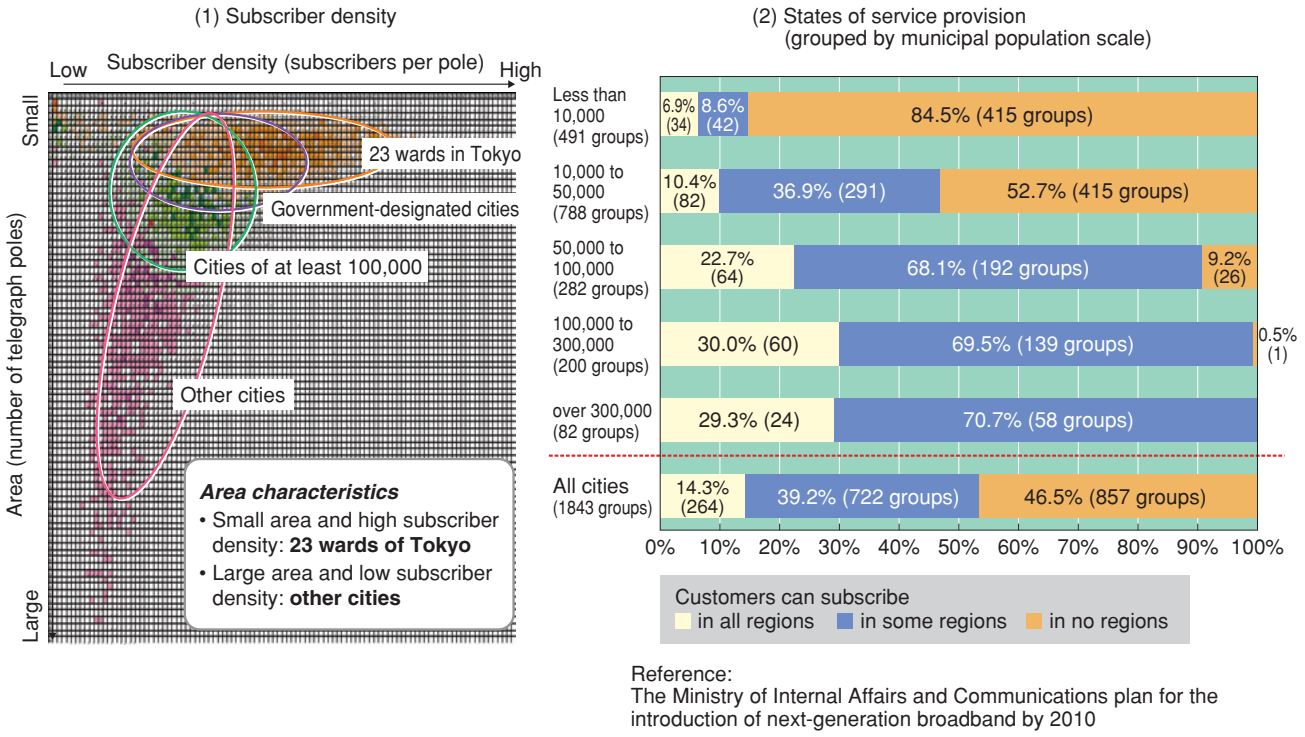


Fig. 8. Area characteristics.

ment's IT (information technology) strategy unit's IT New Reform Strategy (announced in January 2006). We are therefore engaged in the following studies for expanding optical service coverage.

(1) Further expansion of distribution areas

We are investigating methods of increasing the utilization rate of optical splitters by further expanding the distribution area in our new distribution configuration.

(2) Application of 2-branch optical splitters

We are investigating methods of sharing a single optical fiber between multiple customers by using cascaded 2-branch optical splitters in areas where demand is thinly distributed over a wide region.

For these two issues, we must study ways of optimizing the total capital expenditure and the operating expenditure, not only of the optical access network architecture but also of the optical access network as a whole, including the costs of products/construction, maintenance/operation, and facility management.

5. Future plans

In service demand work for B-FLET'S service, there have been concerns that the construction of drop fibers across multiple telegraph pole spans might hinder efforts to improve efficiency. However, the new optical access network architecture that we are developing to enable prompt construction to meet growing demand will substantially reduce the amount of construction work involved in network deployment. It will also enable us to increase the utilization rate of optical splitters relative to that in times of low demand. The ease of installation of related products has also been improved to make them more modular and easier to connect. The optical access network architecture forms the basis upon which optical access networks are constructed and operated. In the future, these networks will continue to play an important role as we make cooperative efforts in research and development to adapt to the needs of business and society.

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