Trends in Optical Access Network Technologies Toward "30 Million Optical Subscribers by 2010"

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Abstract

With NTT group's medium-term management strategy calling for 30 million optical subscribers by 2010, NTT Laboratories is pushing forward to meet this goal. Before that date, an efficient optical access network will have to be constructed, and afterwards, when the era of mass optical communications finally arrives, the facilities and equipment supporting the network will have to be operated and maintained appropriately. This paper gives an overview of new technologies that are being developed to address these issues and provides the overall context for these technologies, which have been described separately in detail in previous issues of NTT Technical Review.

1. Background

As the development of optical fibers and optical cables continues to progress and practical optical facilities are deployed in rapid succession, the demand for B-FLET'S broadband services has been increasing rapidly. Dealing effectively with the installation work that this entails and reducing associated costs have become major issues.

The number of subscribers to B-FLET'S and other fiber to the home (FTTH) services has been increasing dramatically and now stands at more than 3.4 million (as of June 2005), which means that most of the FTTH subscribers in the world are in Japan. Looking at FTTH use by region, the Tokyo, Nagoya, and Osaka areas stand out in terms of subscriber numbers. Subscribers to the B-FLET'S "Mansion Type" service option for multi-dwelling apartment buildings make up a large percentage of FTTH use in large metropolitan areas, while B-FLET'S for individual houses tend to be prevalent in suburban and rural areas. In general, the percentage of Internet-connection services made up of broadband services has a high correlation with population size, as shown in **Fig. 1** and broadband has a higher penetration in municipalities with higher populations. This trend is particularly noticeable with FTTH, which is already being provided in more than 90% of municipalities with 50,000 people or more, but in only 3% of rural areas with populations of less than 5000 people. From the viewpoint of eliminating the digital divide, these figures represent a serious problem.

Looking back at policies on the national level, the "e-Japan Strategy" initiated in 2001 focused on the construction of a broadband infrastructure, while the "e-Japan Strategy II" promoted effective and practical use of broadband services. The aim was first to catch up and then provide a world-leading communications infrastructure by 2005. This was actually accomplished faster than expected, so in 2004, the government proposed the "u-Japan Strategy" advocating movement toward high-value services including ubiquitous networks with the goal of Japan becoming a world leader in this field by 2010. This new strategy represented a significant shift from a country in catch-up mode to one intent on becoming a frontrunner.

At present, however, there are still many regions in Japan without broadband access, and even in those areas where broadband services is claimed to be

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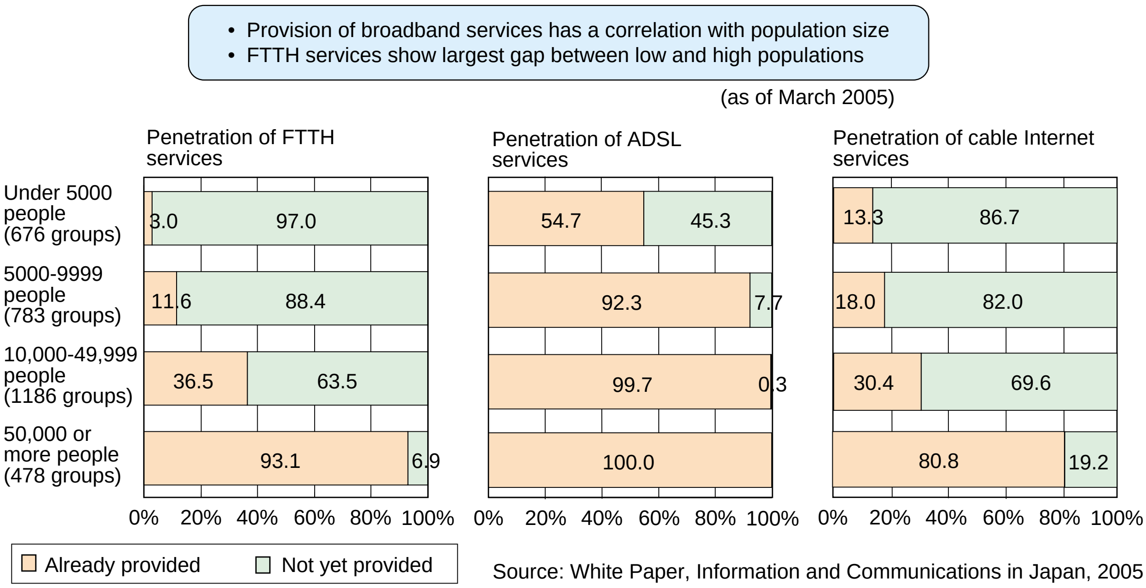

Fig. 1. Provision of broadband services by population size.

already provided, a high percentage of users are able to use only relatively low-speed broadband. In response to this situation, Japan's Ministry of Internal Affairs and Communications (MIC) has proposed the following goals in the form of the "Next-Generation Broadband Concept 2010".

- Eliminate the digital divide and broadband-deficient regions and make broadband services available to 100% of the nation's people.
- Make ultrahigh-speed interactive broadband (UIBB) featuring upstream speeds of 30 Mbit/s or higher available to at least 90% of all households.

Against this background, NTT group's medium-term management strategy calls for "30 million optical subscribers by 2010" in line with the u-Japan Strategy. In short, NTT aims to provide optical services to 30 million users, which corresponds to about half of the current number of fixed-line subscribers. Thus, with its sights set on the coming of an era of mass optical communications, NTT views R&D efforts toward the construction of a highly efficient optical access network to be a matter of great urgency.

2. Configuration of the optical access network

We considered the following three types of optical-access network topologies.

- Single star (SS)

  This is the traditional format featuring 1-to-1 connections between the central office and users (the simplest structure of the three).

- Passive single star (PSS)

  This topology features the placement of an optical coupler (splitter) on the office side so that a single optical line terminal (OLT: terminating equipment on the office side in an optical-fiber subscriber communications network) can be shared by multiple users. In this system, fibers are still used in a 1-to-1 manner and each user pays for what he/she uses.

- Passive double star (PDS)

  In this format, a splitter is also placed on the user side so that a fiber running from the splitter to the office can also be shared by multiple users in addition to the OLT.

Of these three topologies, PDS allows both an OLT and a fiber to be shared by multiple users, so this system has the lowest initial costs. For this reason, PDS has become the main topology in use.

From the viewpoint of constructing efficient network facilities, it is important to select a "wiring method" for efficiently handling a wide variety of users at a central office. This wiring method should include specifications for:

- Unit of facility management (fixed distribution area, dropping area)
- Operation method of optical fiber (ribbon/single-fiber)
- Subscriber cable-drop-off method
- Number of fibers in the cable core

For example, if a fat cable is deployed all at once even though demand is still low, each user will have to bear a high initial cost. On the other hand, deploying slender cables as new subscribers are added even though demand is expected to be high is extremely inefficient. In short, the scale of facilities for optimizing cost depends on the number of users. Cost also varies with the size of the dropping area. If demand is small, a larger dropping area will lower the cost per user, but if demand is growing, a smaller dropping area will lower that cost. An optimal dropping area must therefore be decided upon by weighing the number of users against the scale of facilities and finding the minimum point for achieving that balance.

The main pieces of equipment composing an optical access network are shown in **Fig. 2**. To begin with, the equipment within the central office consists mainly of an integrated distribution module (IDM) capable of terminating 4000 optical fibers, a 4-branch optical splitter, and a system called AURORA (automatic optical fiber opeation support system) that includes an optical testing module. The AURORA system enables a maintenance center to test and monitor optical access paths remotely. It can be used to perform optical pulse tests and optical-path-loss tests when constructing a network, fault-isolation tests when performing maintenance, periodic testing to check for water penetration and other problems, and test light insertion to check the condition of optical fiber.

In the underground segment (ducts and cable tunnels), plastic-sleeve-type closures are used at cable jointing points, and water-blocking cables in which optical fiber ribbons are stacked in slots in the cable core are used to simplify maintenance.

In the aerial segment, an aerial optical closure is set up at the feeder point. In this segment, slotless slender cables are the most commonly used cable type because they lower costs and make cable deployment more efficient. At the end of this segment, an 8-branch optical splitter is installed for branching to individual user homes. Close to a user's house, there will be an aerial optical cable with a small number of fibers as well as an aerial optical closure for cable dropping, an optical drop cable, and an optical cabinet for running an optical fiber into a house [1].

3. Future direction of R&D

Future NTT R&D in optical access network technologies will be divided into two phases. Phase 1 will consist of immediate support toward an era of mass optical construction. Phase 2 will cover medium- and long-term development work after the target of 30 million optical subscribers by 2010 has been reached. In Phase 1, the focus will be on prompt installation and cost reduction as urgent issues that must be dealt with prior to 2010. Specifically, there will be a need for a do-it-yourself (DIY) approach and simplified, easy-to-use systems. Next, in Phase 2, which will actually begin slightly before 2010, there will be a need to maintain a large user base efficiently as part of a period requiring the operation and maintenance of a large number of optical facilities. Targets in this phase will include the reduction of field operations by developing ways to perform installations work with-

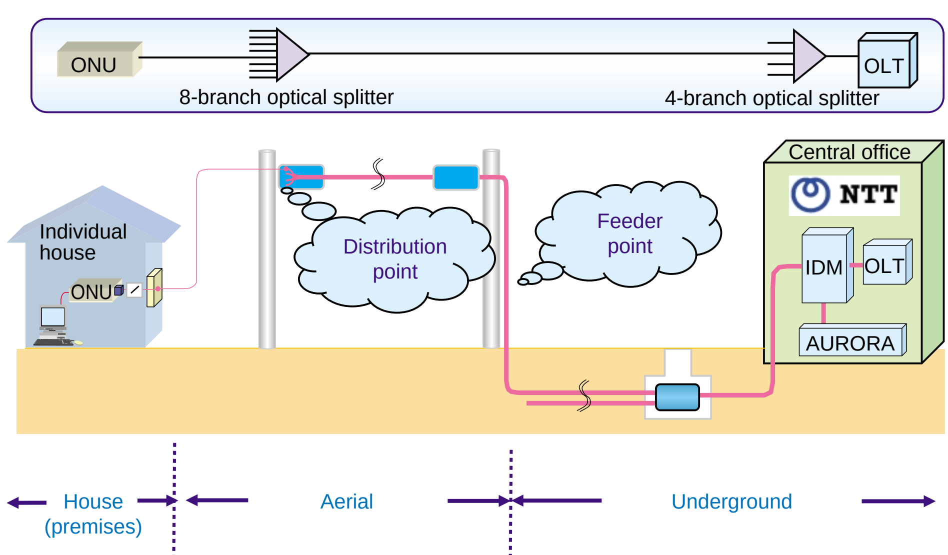

Fig. 2. Configuration of an optical access network.

out dispatching workers to the costomer's premises and the elimination of manual database input to increase the accuracy of facility databases, which are the foundation of network maintenance and operation.

3.1 Technologies for mass optical construction (Phase 1)

In recent years, it has frequently been said that fiber optic research has just about exhausted itself. Indeed, as shown in **Fig. 3**, various technologies have been steadily improving. For example, under fiber class, single-mode fiber has reached the completion stage, and under fiber/ribbon structure, the trend is toward more slender and thinner configurations. Likewise, for cable structure, cable waterproofing, and fiber connection, technology has been advancing significantly. Thus, in future R&D, instead of efforts to develop new elemental technologies, the emphasis will be on enhancing the practical application of existing technologies. It will be necessary to investigate ways of using the optical network more efficiently, reducing field operations, and making network operations more efficient.

Although the three pillars of development are high performance, low cost, and simplicity, the top priority was high-performance fiber when the existing optical trunk system was constructed. However, since the introduction of optical access equipment in the second half of the 1990s, the need for low-cost systems has been growing. The coming era of mass optical communications will no doubt require simplicity and even further cost reductions. One effective means to this end is a DIY approach because it brings two benefits: It simplifies installation work, so optical-cable installation time can be shortened and installation expenses can be reduced, and enables the work involved in wiring on premises to be done by the user himself, which decreases the cost to the user.

3.2 Technologies for mass operation and maintenance (Phase 2)

When the period of operating and maintaining numerous optical facilities actually arrives, we can expect to see an increase in tasks associated with service orders, optical-fiber cable removal work, and fault handling. Consequently, in addition to reducing the cost of product development and facility deployment as in the past, there will also be a great need to reduce the lifetime cost (operating cost) of the optical network.

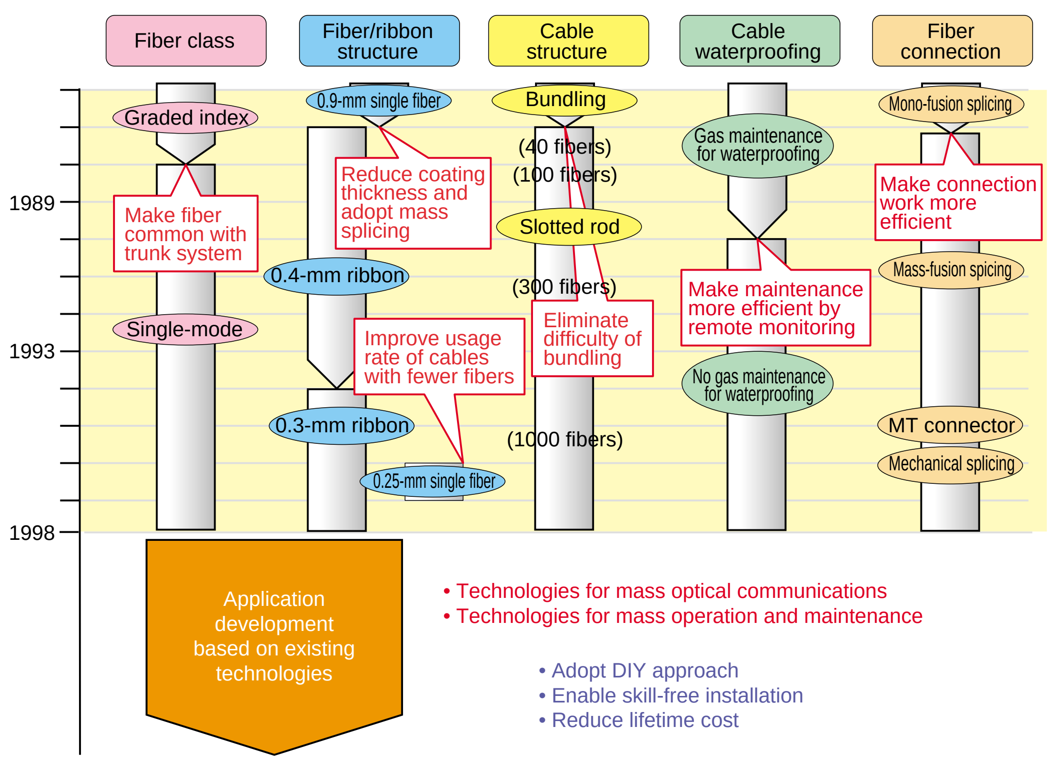

Fig. 3. Technology flow toward FTTH.

4. Recent development achievements

4.1 Developments toward coping with demand for optical access

To achieve a true era of mass optical communications, we must develop products and components that anyone can handle and must simplify construction and installation techniques. Several aspects of the current optical access network are inconvenient.

- Storing excess optical fiber in a cabinet and aerial optical closure is time consuming and troublesome
- Transferring fibers at a closure due to changes in service/carrier is time consuming and troublesome
- Troubleshooting at a cabinet is difficult
- Wiring inside a house is complicated

If the storage of excess optical fiber could be made unnecessary, problems associated with the housing of fiber could be eliminated. Likewise, if fiber connections could be achieved through the use of connectors, transfer operations could be simplified. In addition, the development of cables with a smaller bending radius that are consequently easier to use should make wiring easier to carry out. The development of various optics-related components to meet these needs is moving forward at NTT (**Fig. 4**).

Of particular interest here is a cable sheath holding connector, which can be directly attached to a cable. So there is no need to deal with excess lengths of optical fiber [2].

To assemble this field-assembly (FA) connector, we cut the optical fiber, insert the optical fiber into the connector, and pull out the wedge fixing the fiber.

The cable sheath holding connector is located in a newly developed optical cabinet. The use of this connector in conjunction with highly bendable optical cable enables the cabinet volume to be reduced by as much as 65% compared with the existing optical cabinet. This is because the existing optical cabinet, though also including a mechanical splice, may have to store up to 3 m of wound up excess optical fiber. The new optical cabinet, in contrast, has no need to store bare optical fiber making the previous storage space unnecessary and shortening installation time (**Fig. 5**). Similarly, for the aerial optical closure, application of cable sheath holding connectors and splitter modules eliminates the need to store excess optical fiber, which makes installation more efficient (**Fig. 6**).

Another new technology is hole-assisted fiber (HAF) [3]. This type of fiber has a number of holes arranged about the core, which produces a strong light-confinement effect. In conventional optical fiber, the optical loss factor increases rapidly once the fiber's bending radius drops below 20 mm. In HAF, however, almost no loss occurs even for small bending radii. The use of HAF-based free-bending optical fiber cord for optical wiring inside a house can make wiring so simple that even ordinary users will be able to do it by themselves. Free-bending optical fiber cord can withstand not only being bent, bundled, and

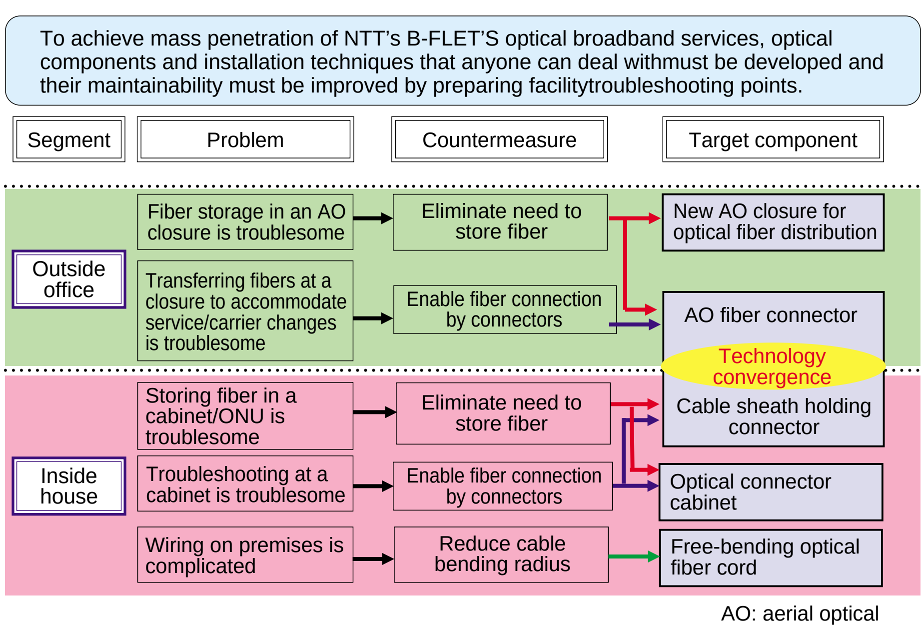

Fig. 4. Coping with demand for optical access: problems and solutions.

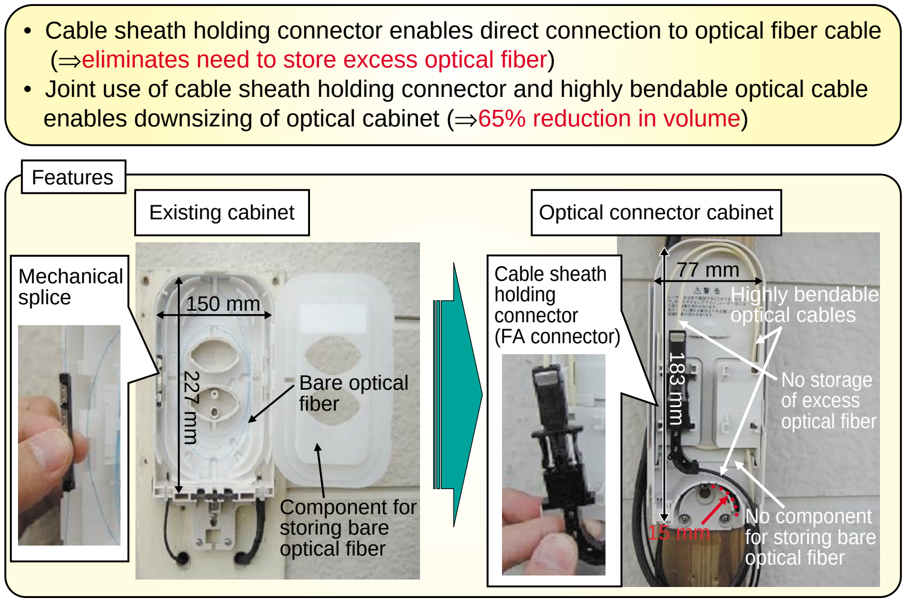

Fig. 5. FA connector and optical connector cabinet.

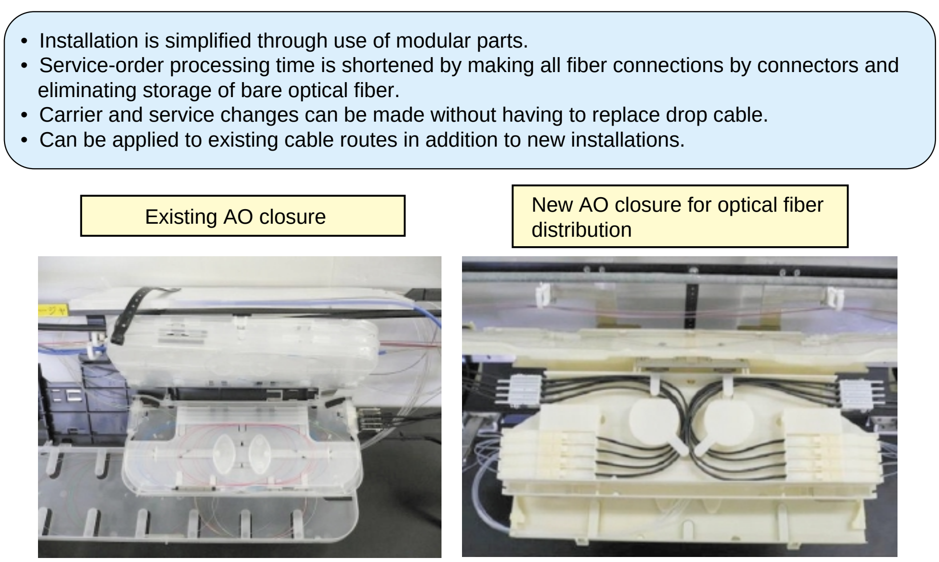

Fig. 6. New aerial optical closure for optical fiber distribution.

knotted, but also being folded, so it enables optical wiring in the home to be laid in a more attractive manner (**Fig. 7**).

4.2 Developments toward reducing lifetime cost

Various problems must be solved to reduce the operating cost after optical facilities have been constructed (**Fig. 8**). To begin with, the application of two-dimensional barcodes or other means of identification can be effective in managing facilities outside the central office [4]. For example, the camera function of a cellular phone can be used by a field worker to send on-site information back to the office for comparison with a database and to receive the results of that query. Such queries could even be performed while a worker is up a telephone pole. It is also conceivable that a cellular phone could be used to activate test equipment within a central office and receive test results.

Progress is also being made in the development of remote testing technology with the aim of reducing field operations. The present method of conducting

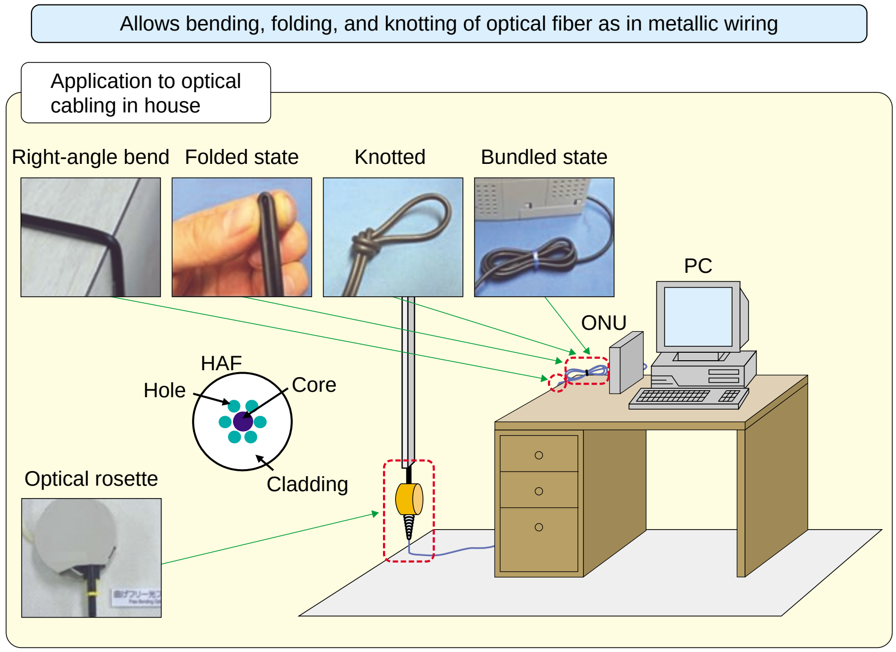

Fig. 7. Free-bending optical fiber cord.

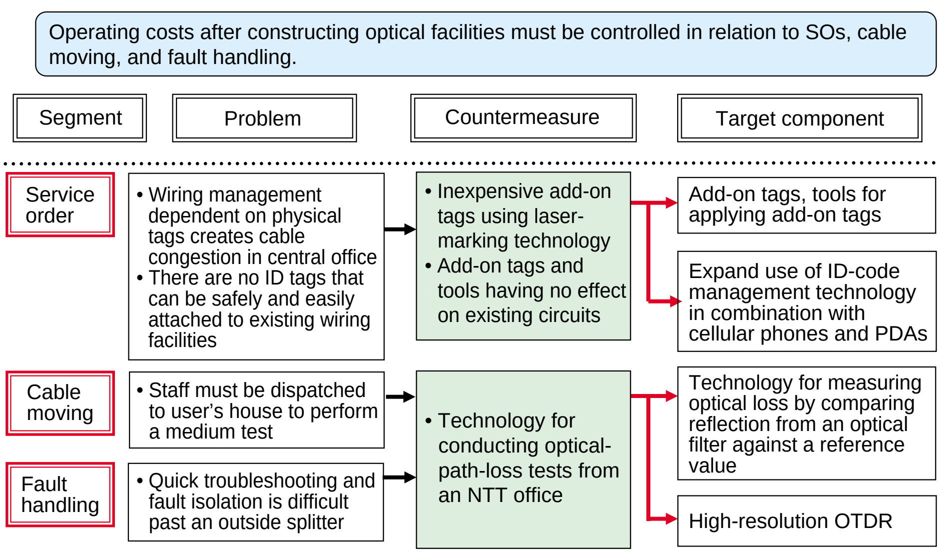

Fig. 8. Reducing lifetime cost: problems and solutions.

optical-path-loss tests after optical-fiber cables have been moved is to dispatch workers to the user's house. The key to enabling remote operations from a central office is to reflect a signal from an optical filter placed just before the user's optical network unit (ONU). Furthermore, if the same type of optical filter is installed inside the office, the difference in reflection levels in both directions can be read, enabling a true optical-path-loss test to be performed without requiring a visit to the user's house.

Furthermore, it is difficult to identify a faulty branched optical fiber using conventional OTDR (optical time domain reflectometer), because reflections from optical filters are included in the OTDR trace. We developed high-resolution OTDR that can identify a faulty fiber because the reflections are separated. So we can isolate the faulty fiber without dispatching any workers.

5. Conclusion

As FTTH continues its rapid spread and becomes a more familiar means of connecting to the network, “ease of use” will become a matter of prime importance. And as the need to respond quickly to rising demand for FTTH also grows, ways to reduce the total cost must be found. Recognizing the urgency of this situation, we are focusing our R&D efforts on implementing DIY schemes as a key technique while reducing lifetime cost.

References

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Profile

■ Career highlights

Project Manager, Promotion Project 2, NTT Access Network Service Systems Laboratories.

He received the B.E. and M.E. degrees in telecommunication engineering from Tohoku University, Miyagi in 1978 and 1980, respectively. He joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980. Recently, he has been engaged in the development of optical fiber cable systems.