TSUKUBA FORUM 2005

# NTT Tsukuba Forum 2005 Workshop Lectures


The special feature in this issue presents three workshop lectures given at NTT Tsukuba Forum 2005 held at Tsukuba International Congress Center and NTT Access Network Services Systems Laboratories on Nov. 1 and 2. Under the theme of “NTT’s research and development challenge toward 30 million optical fiber subscribers by 2010”, this forum presented the latest research results through lectures, workshop lectures, and exhibitions. They followed the keynote lectures “New Expansion of Broadband Network Services” by Hajime Takashima, Senior Executive Vice President, NTT East, and “NTT West’s Broadband Strategy” by Shin-ichi Ootake, Executive Vice President, NTT West. The workshop lectures reviewed the trend and state of the art of NTT’s technologies, described its research and development efforts, and predicted their future development for optical access network technologies. They were originally given in Japanese.

Workshop lectures were:

- Optical Access Trends in Broadband Ubiquitous Service Development

  by Takashi Nakashima, NTT Access Service Systems Laboratories
- Trends in Optical Access Network Technologies Toward “30 Million Optical Subscribers by 2010”

  by Osamu Yamauchi, NTT Access Network Service Systems Laboratories
- Towards the Development of Broadband Access by Merging Optical and Wireless Systems —Trends in Wireless Access System Technology

  by Shuji Kubota, NTT Access Service Systems Laboratories

# Optical Access Trends in Broadband Ubiquitous Service Development

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**Abstract**

Optical access systems are certain to become more widespread in the future, so the development of new technology for next-generation services is urgent. The development and introduction of GE-PON (gigabit Ethernet passive optical network), WDM (wavelength division multiplexing), and other such optical technology will allow the provision of enjoyable and flexible services. In this situation, efficient operation will be very important.

## 1. Trends in broadband services

### 1.1 Broadband service trends in Japan

The number of broadband lines has increased greatly in recent years. The total number of ADSL (asymmetric digital subscriber line), CATV (cable television), and FTTH (fiber-to-the-home) subscribers already exceeds 20 million. The rate of FTTH expansion is particularly impressive. In June 2005, the number of FTTH subscribers (3,400,000) exceeded the number of CATV subscribers (3,060,000) to take second place after ADSL (14,080,000).

Comparing the quarterly increases in subscriber numbers, we see that while ADSL has shown a gradual but steady decline since 2003, FTTH has been increasing strongly. In the first quarter of 2005, FTTH surpassed ADSL in net increase. We expect this trend to continue in the future.

FTTH initially suffered from high service charges when it was introduced, but it is currently much less expensive. NTT East's B-FLET'S service to individual houses, for example, was initially priced at about 13,000 yen per month (this and the figures cited below do not include ISP (Internet service provider) charges or fees for using in-home wiring), but the current price is less than one-third of that amount, at 4100 yen, while B-FLET'S for condominium buildings is now about 2500 yen. For users, the cost of FTTH has thus come down to about the same level as the cost of ADSL.

We can see how low this service price is by comparing prices in other countries. In September 2004, the charge for broadband service in Japan was equivalent to \$0.06 per 100 kbit/s, compared with \$0.24 in Korea, \$1.77 in the USA, \$1.89 in China, and \$6.18 in the UK. Thus, Japan offered the world's least expensive broadband service. This does not mean that the broadband environment in Japan is perfect, however. One problem that requires urgent attention is the digital divide.

Studies on disparities in the use of the Internet have revealed a distinct generation gap in users at around the age of 50. Internet use has yet to penetrate into the generation of people over 50 years old. This gap is expected to gradually improve, but only over the coming ten years or so.

Examining disparities in broadband service on a city-wide scale reveals prominent regional differences. In most cities with populations above 100,000, the subscription rates are 100% or 80%, but the proportion of service provision decreases with the size of the city. For cities with populations below 5000 in particular, there are still areas in which no service is available [1].

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### 1.2 Broadband service trends in North America

A surge in broadband service opportunities is also being seen in North America. The greatest share of the market is held by the CATV operators, but in 2004 the major telecommunication carriers SBC and Verizon successively entered the optical fiber industry, accelerating the rate of conversion to optical technology. The situation in the USA features a particularly high interest in "triple-play" services (TV, telephone, and Internet access services provided over a single line), and both of these carriers are moving toward the provision of video services.

SBC has targeted provision of an optical service environment for 18 million households in 13 states by the end of 2007 ("Project Lightspeed" [2]) with two wiring models: FTTN (fiber to the node) and FTTP (fiber to the premises). FTTN involves laying optical fiber up to a node that is set up in the vicinity of users and using metal wire for the last kilometer or so to the user's home. FTTP involves laying optical fiber right up to the user's premises and is being applied to newly constructed homes. In addition, because FTTN will involve metal cable, SBC has announced that it will use an IP video service (Microsoft's IPTV service).

Verizon, too, has established its "FiOS" business concept, which aims for FTTP optical coverage of 60% of its subscribers by 2008. One million lines had been provided by the end of 2004 and three million were in place by the end of 2005. Verizon has announced that the number will reach six million by the end of 2006. In the approach to video service, however, Verizon differs from SBC in their use of a wavelength division multiplexing (WDM) technique that is close to the hybrid fiber coaxial cable system used in CATV. That makes it possible to provide video to each home on all channels by applying WDM to the video signal.

RHK, a major U.S. marketing research firm, predicts that the number of FTTH subscribers worldwide will reach 17 million in 2009. That total was estimated before the announcement of NTT's mid-term strategy (September 2004), so unfortunately it does not reflect our "Optical 30 Million Plan". RHK also reported early growth in the Asia-Pacific area in estimates of optical line terminal (OLT) port shipments by region, and it is believed that Japan's share of that will be large. Concerning OLT ports, vigorous activity has also been seen in North America since 2004, and the number of shipments is expected to steadily increase in the future.

## 2. Optical access technology

### 2.1 Trends of PON

The forms of FTTH wiring include the single star (SS), in which there is a single line between the central office and the user, and the double star (DS), in which there is a branch in it. The DS configurations are further divided according to the branching type into the active double star (ADS) type, in which the branching is done by an active device such as a layer 2 (L2) switch, and the passive double star ((PDS) which corresponds to PON) type, in which an optical splitter is placed at the branching point.

Various types of FLET'S service are available, and they use the most suitable wiring configuration for the particular type. For large-volume users of the business and basic services, the SS configuration is used. For services to condominium buildings, on the other hand, SS is used up to the building and then VDSL (very-high-bit-rate digital subscriber line) or Ethernet is used for distribution within the building. The family service, which is suited to individual residences, uses a broadband PON (B-PON). The hyperfamily service (NTT East) and the Hikari premium service (NTT West), which are the newest types of service, use a 1-Gbit/s GE-PON.

NTT's PON system has a long development history, with research beginning as early as the 1980s. The first system introduced was an STM-PON (1997) with proprietary specifications (STM: synchronous transfer mode), followed by a B-PON conforming to ITU-T standards (1999). 2004 saw the introduction of a GE-PON, which uses Ethernet technology. The result of this development has been higher transmission speeds and transmitters that are far more economical and efficient [3], [4].

On the other hand, there has been diversification of services and user needs, so system expansion will be required in the future. To cope with that requirement, we believe that WDM technology will be an effective means of flexible system expansion within the existing framework. Unlike the current PON, in which multiple users and multiple services share a single wavelength, WDM can accommodate additional services or increases in the capacity allocated to each user by changing the wavelengths for each service or each user (**Fig. 1**).

### 2.2 GE-PON system

Flexible service provision requires broadband communication technology, technology for reserving minimum bandwidth, and service priority control

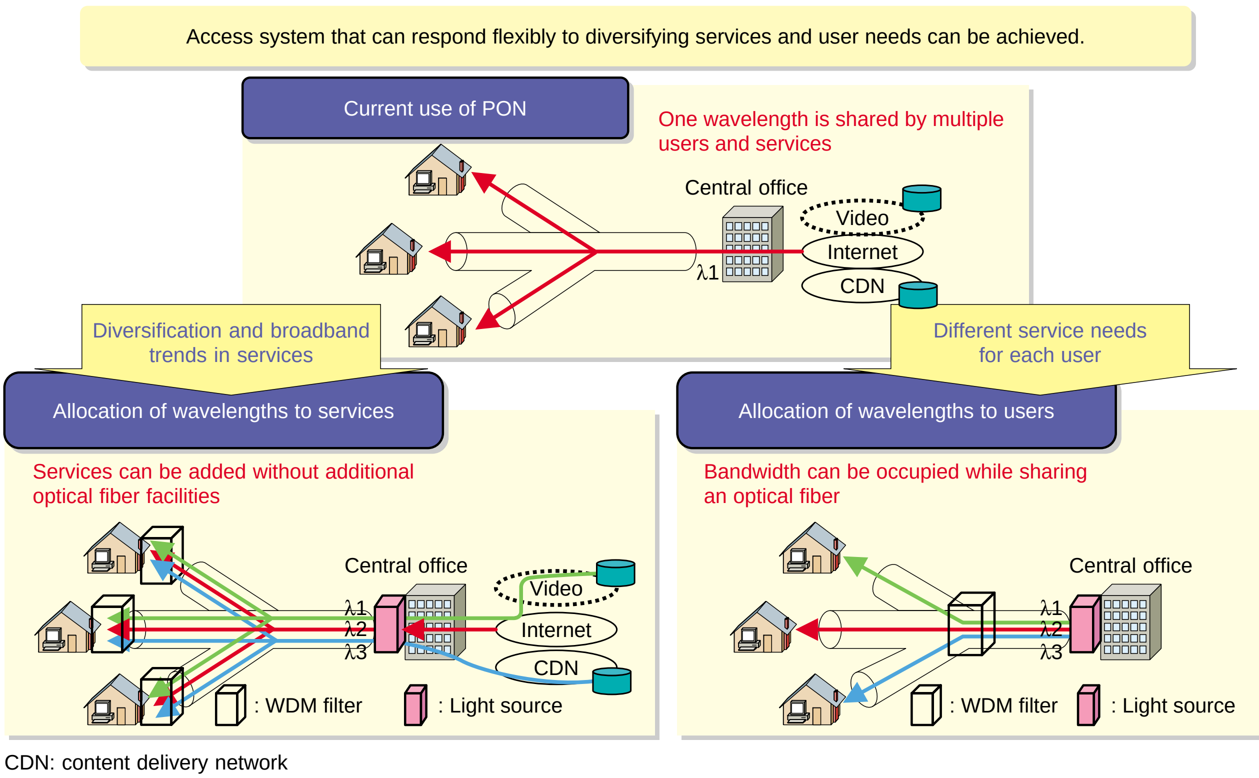


Fig. 1. Wavelength division multiplexing technology for scalable system.

technology. To satisfy these requirements, NTT Access Service Systems Laboratories is developing a GE-PON system based on the IEEE802.3ah standard.

(1) Broadband communication technology

GE-PON is capable of transmission at 1 Gbit/s in both directions, ensuring a broadband access path that can meet future broadband demand. At the same time, a major reduction in cost is expected through the application of Ethernet technology.

(2) Minimum bandwidth reservation technology

A dynamic bandwidth assignment function has been introduced to allow fine bandwidth control. If only a single user is using the network, then that user has an available bandwidth of 1 Gbit/s. In actual practice, however, multiple users use the network at the same time and must therefore share the total bandwidth of 1 Gbit/s. When we decide how the bandwidth will be assigned, we can set the maximum speed and the guaranteed speed (minimum speed) for each user separately. In addition, the surplus bandwidth can be allocated to users either evenly or preferentially by adaptive control.

(3) Service priority control technology

Service content may be delay tolerant or delay sensitive. The GE-PON system also features a flexible function for giving transmission priority to services that are delay sensitive.

### 2.3 Line concentration switch

Flexible service provision cannot be achieved with only a GE-PON between central office and user, so we bundled multiple GE-PONs together and installed a large-scale L2 switch to feed them. This large-scale switching technology groups multiple GE-PONs together and allows flexible distribution at the desired node according to the type of service. In the same way as for GE-PON, this configuration provides a minimum bandwidth guarantee to each line, service priority control, and efficient use of surplus bandwidth.

### 2.4 Video multiplexing technology

Aiming at true triple-play services, research and development on video transmission is also under way. Specifically, simultaneous delivery of multiple video signals for Internet access by using WDM is being studied (**Fig. 2**).

An amplitude modulation (AM) direct transmission method has conventionally been used for video transmission for CATV. That technique transmits frequen-

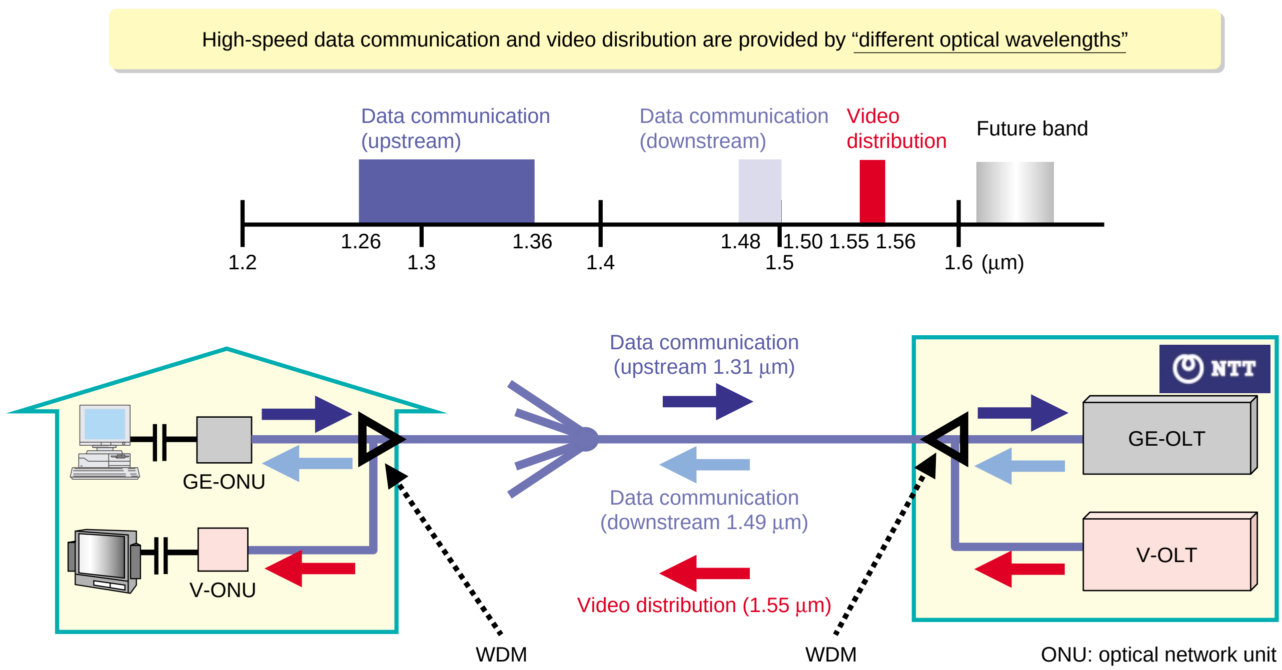


Fig. 2. Wavelength allocation for data and video signal.

cy-multiplexed signals without modification, which causes no problem as CATV is delivered over coaxial cable in the final link. In the case of FTTH, however, the optical signal is distributed, so a method that is robust against loss, degradation, and reflection is required. The AM direct transmission method has the merit of a relatively simple optical transceiver configuration, but it is easily affected by noise and fiber degradation in the transmission path. Therefore, when FTTH is applied, multiple splitting of the optical signal is not possible and high-performance optical amplifiers are required, so that method is not suitable.

With that motivation, we developed a transmission system in which the frequency-multiplexed signals are transmitted together as a frequency-modulated (FM) signal. Although it is very difficult to electrically convert signals in the wide range from 90 to 770 MHz to an FM signal, optical signals can be converted all at once. The method for FM conversion complicates the optical transmitter somewhat, but it increases robustness to noise and fiber degradation and facilitates multiple splitting of the optical signal for distribution to multiple locations. It may also lead to less-expensive optical amplifiers.

This system is capable of providing both digital video and analog video. Up to about 500 channels of all-digital video standard TV or up to about 100 channels of HiVision TV (Japan's high-definition television scheme) can be transmitted. Even when used together with existing broadcasting or CATV, about 150 standard TV channels or about 30 HiVision TV channels are possible (**Fig. 3**).

## 3. Trends in WDM access technology research

### 3.1 Improving ease of use with WDM

The transmission speed of media converters is increasing very rapidly, making possible the successive transition of the PON system from STM-PON to 150-Mbit/s B-PON and 600-Mbit/s B-PON, and then to GE-PON. We believe that it is necessary to proceed with research and development for a new next-generation access method.

Working towards the "30 million optical users" era, research that has proceeded with priority on "performance" and "economy" must now consider a third need: "flexibility and ease of use". WDM technology is the driving force behind improvements in ease of use (**Fig. 4**).

In a network that uses WDM, the access node point (customer accommodation station) side will have a metro node point (central office for access node points) and a system for creating a ring with other access node points and sending signals using multiple wavelengths. Between the access node point and each

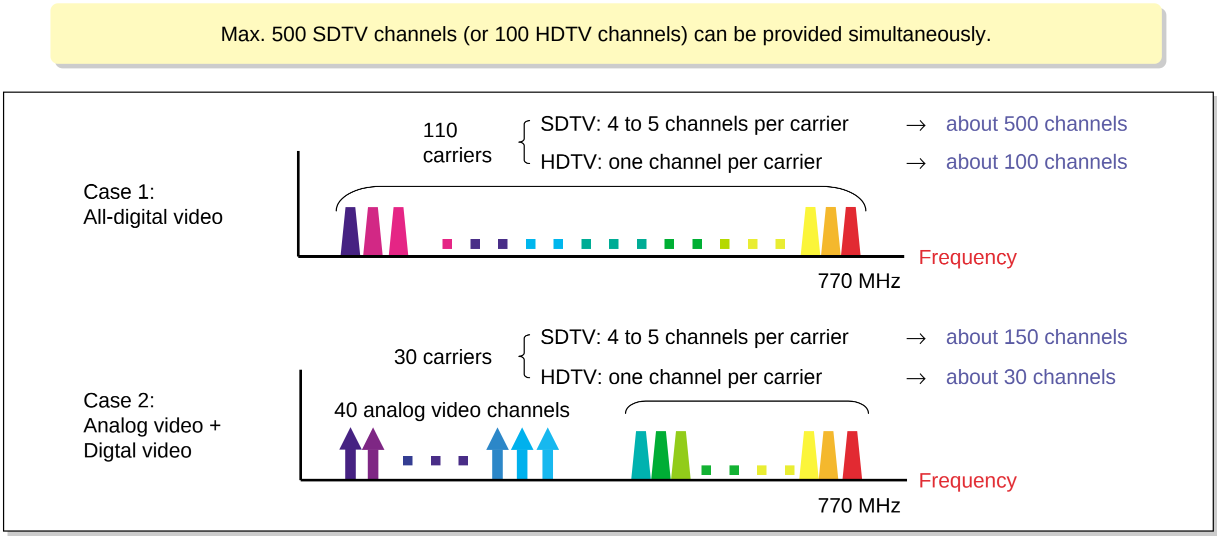


Fig. 3. Number of video channels that can be transmitted.

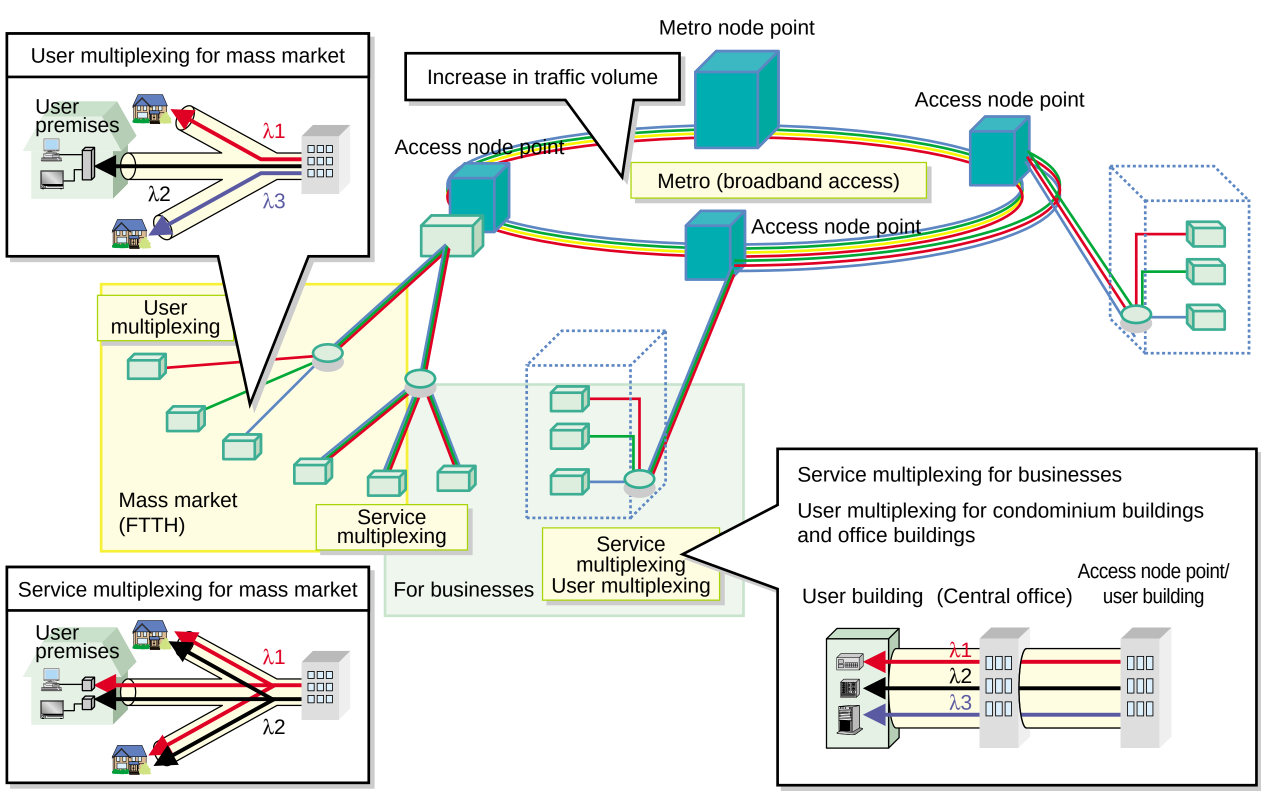


Fig. 4. Examples of wavelength use to improve ease-to-use.

user there will be a system that can apply either of two wavelength usage methods according to user needs: either user multiplexing, in which a wavelength is assigned to each user, or service multiplexing, in which a different wavelength is assigned to each different service. User and service multiplexing are used for mass markets: service multiplexing is used for businesses, and user multiplexing is used for condominium buildings or office buildings. As wavelength use expands, however, the following two problems arise.

(1) Hardware diversification for increasing wavelength ranges

As the number of available wavelengths increases, the demand for equipment and devices for each wavelength decreases, which results in greater hardware diversification.

(2) Special optical module specifications

Because the systems for various services also differ, the types of optical modules also become different.

Both of these problems decrease economy, flexibility, and ease of use, so new ways to address them are required.

### 3.2 Pluggable modularization

First, to move towards greater economy, we take the approach of separating out the optical part of the system and creating common specifications for it. This means a full separation into a wavelength module (optical part) and a signal processing module (electrical part). The optical part is given a plug-in design, which yields the following benefits.

- The use of common specifications increases market fluidity, which relates to system economy (greater economy results from market fluidity due to common specifications)
- Because the signal processing module is made independent, common equipment that is independent of wavelength can be used (economy results from the use of common signal processing module hardware that is not dependent on wavelength characteristics)
- The optical plug-in module can use various nonelectrical systems, which reduces the danger of them being out of stock (economy results from simpler inventory management)

The internal configuration of the WDM transmitter has a signal processing module (electrical part) in the center and an optical transceiver module on each end. Pluggable transceiver modules can be used to generate various wavelengths.

Plug-in modules provide several advantages: the wavelength, transmission distance, and transmission speed can be easily changed simply by changing module combinations. For example, modules can be replaced without regard for the transmission method (two-core or one-core), the transmission distance (short or long), or the wavelength. Furthermore, flexibility in network topology makes it possible to construct a virtual network by using wavelengths.

Existing user equipment that is not compatible with WDM can also be used for the WDM transmission if it can be connected to the developed pluggable filter module as an external device.

### 3.3 Colorless ONUs

An effective way to avoid loss of flexibility or ease of use is to control the system itself to handle various wavelengths rather than matching the optical module to the system. Such a system uses colorless ONUs, i.e., no ONU is wavelength specific. Control on the system side is also related to achieving care-free or topology-free operation. That involves the application of two kinds of technology. One uses of a super luminescent diode (SLD) as an optical source. This features a very wide spectral range but the output can be limited to a narrow desired wavelength by selecting an output location from one of the sliced parts. When you want to change to another wavelength, you merely select another location. In this way, a single ONU can generate multiple wavelengths. The other technology is the tunable device. Flexibility can be achieved by connecting a variable wavelength filter and variable wavelength transmitter on the user side and a variable wavelength transceiver on the access point side.

## 4. Access network operation system

Although the demand for optical service is rising rapidly, construction work is not keeping up with that demand. Now that optical transmission has become commonplace, expediting optical service provision can be considered an urgent matter.

The main procedure for providing a service is to 1) receive and check the equipment, 2) allocate plant and equipment, 3) adjust the work schedule, 4) order the work, and 5) perform the inside office and on-premises work. This procedure currently takes several days. While measures to reduce the time required are already being taken, automation of plant allocation and other time-consuming processes may reduce the start of service time to about the same as for ordinary telephone services.

The optical access plant allocation system (PAS) that is now being introduced consists of modules for optical plant allocation, inside optical fiber management and allocation, and outside optical fiber allocation. These modules can be used together for automatic allocation of the appropriate equipment. When the operator receives the user’s request for service, he

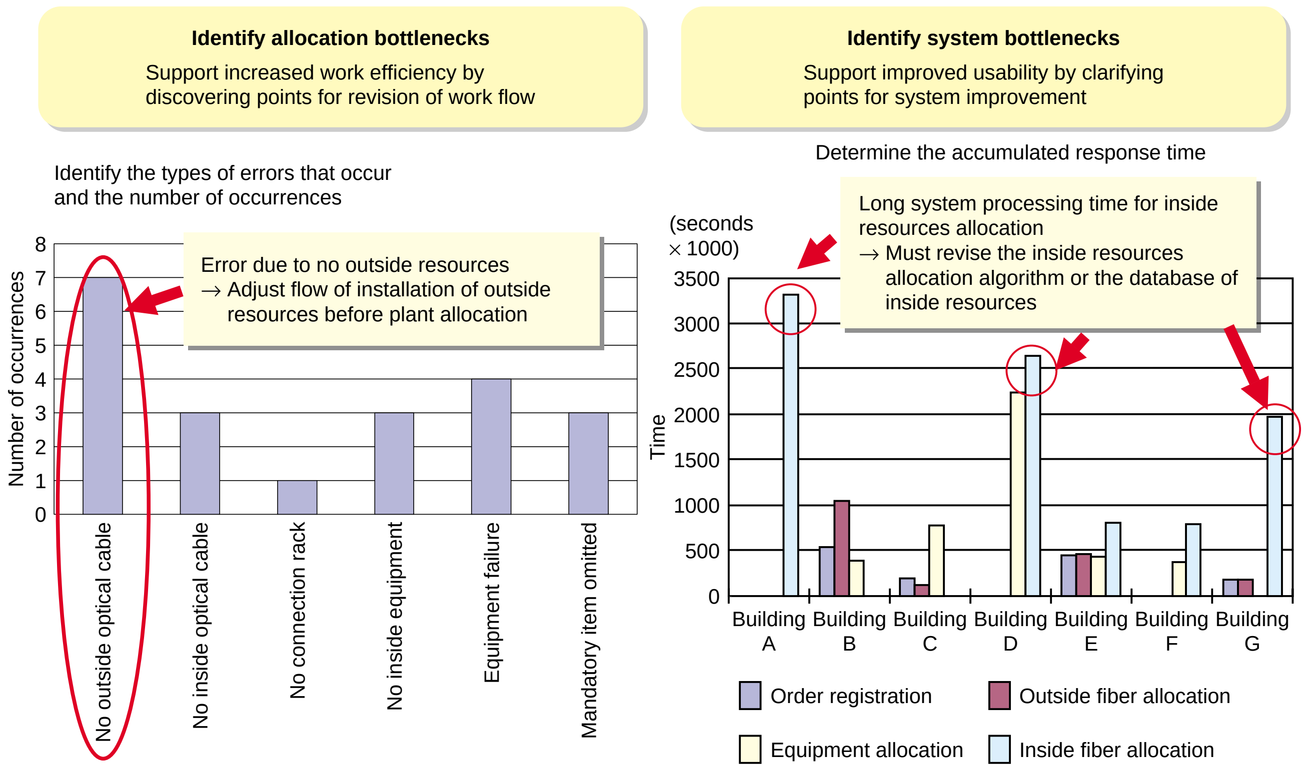


Fig. 5. Example of applying operation log analysis tool to PAS.

can use the user's location and address to quickly and efficiently allocate the equipment and the access point internal line. In addition, there is a operation log analysis tool for expediting the work flow. It has the three main functions.

- Collecting and analyzing the information from various operation logs to understand the current state of the work process
- Automatically extracting potential points for improving access facilities installation work
- Running simulations to verify the effects of improvements

In this way, a continuous cycle of work improvement can be established by feeding the analysis results back into the work process.

Finally, we present the results of applying the operation log analysis tool to PAS. If the operation log analysis tool is applied to PAS itself, rather than to the work process, it is possible to check for proper operation of PAS as described below (**Fig. 5**).

(1) Identifying an allocation bottlenecks

Determining where in the system errors occur and the extent to which they occur, as well as the types and numbers of such errors. For example, if an error occurs because there are no outside resources, then work efficiency can be improved by discovering this and adjusting the flow of installation of outside resources before plant allocation to eliminate the error.

(2) Identifying system bottlenecks

Investigating the work efficiency of each task, including order registration, outside fiber allocation, equipment allocation, and inside fiber allocation. For example, if the analysis result is that "the system processing time for inside resources allocation is extremely long", then points for system improvement can be clarified by investigating changes to the inside resources allocation algorithm or the database of inside resources to improve usability.

## 5. Conclusion

Research and development concerning optical access, which is making the transition from the phase of initial introduction to the phase of popularization, faces various demands, including ones for improvements in economy, usability, and ease of management, an expanded service menu, and more efficient installation work. We will continue to aggressively respond to those research demands in the future.

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**Profile**

■ Career highlights

Executive manager, Access Service and Network Architecture Project, NTT Access Service Systems Laboratories.

He received the B.S. and M.S. degrees in communication engineering from Osaka University, Osaka in 1981 and 1983, respectively. In 1983, he joined the Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) and engaged in research on the transmission characteristics of optical fiber. Since 1987, he has worked on developmental research of ATM transmission systems, PON systems and operation support systems for the optical access network. His current job is R&D management in the access network area.