Optical Transmitter | WDM | Variable Wavelength Transponder

Technology Reports

A Compact, Low-power Consumption Optical Transmitter

We have developed a compact, low-power e-OADM optical transmitter intended for constructing regional transmission networks that can flexibly support expansion and conversion to IP. The equipment achieves improved maintainability and operability through use of technologies such as variable wavelength lasers.

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1. Introduction

With recent increases in mobile terminal specifications, increased communications speed, the spread of flat-rate subscriptions, and the increasing requirements of high-capacity packet communications applications such as video distribution, network traffic is continuing to increase. Also, for the introduction of Long Term Evolution (LTE)[*1] technology, a flexible transmission network capable of supporting communications between evolved Node B (eNB) base stations is needed. These conditions have resulted in the need for a new regional-transmission network infrastructure with high capacity and flexibility.

Wavelength Division Multiplexing (WDM) is a technology that allows multiple optical signals to share a single optical fiber, providing dramatic increases in capacity without the need for installing new optical fiber cables. Also, through the use of Optical Add-Drop Multiplexing (OADM)[*2] technology, optical wavelength paths can be freely established between arbitrary transmission devices [1]. Because of these characteristics, WDM and OADM technology is used in optical transmission equipment between regional areas.

However, existing equipment has been developed for traffic transmission between switches in large-scale stations, so it has been difficult to use it for regional transmission networks, because of restrictions in space and power consumption, the variety of maintenance equipment required, and inability to accommodate Gigabit Ethernet (GbE)[*3] interfaces efficiently.

In this article, we describe an overview of new, compact and low-power OADM optical transmission device (hereinafter referred to as "e-OADM optical transmitter") that is able to handle conversion to IP and capacity increases flexibly, and has been developed for constructing regional transmission infrastructures. We also describe introduction of a new, variable wavelength transponder as well as technical issues and solutions encountered in reducing the size and power consumption of the device.

2. Transmission Network Architecture

NTT DOCOMO is constructing a large-scale optical infrastructure as the optical relay path between regions (prefectures) using already-installed WDM optical transmission equipment (**Figure 1**).

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*1 **LTE**: An evolutional standard of the Third-Generation mobile communication system specified at 3GPP; LTE is synonymous with Super3G proposed by NTT DOCOMO.

*2 **OADM**: Insertion or branch of individual wavelengths from multiple wavelengths multiplexed in a WDM.

*3 **GbE**: 1000BASE-SX and 1000BASE-LX Ethernet standards conforming to IEEE 802.3z, and providing 1 Gbit/s communications speeds over optical fiber.

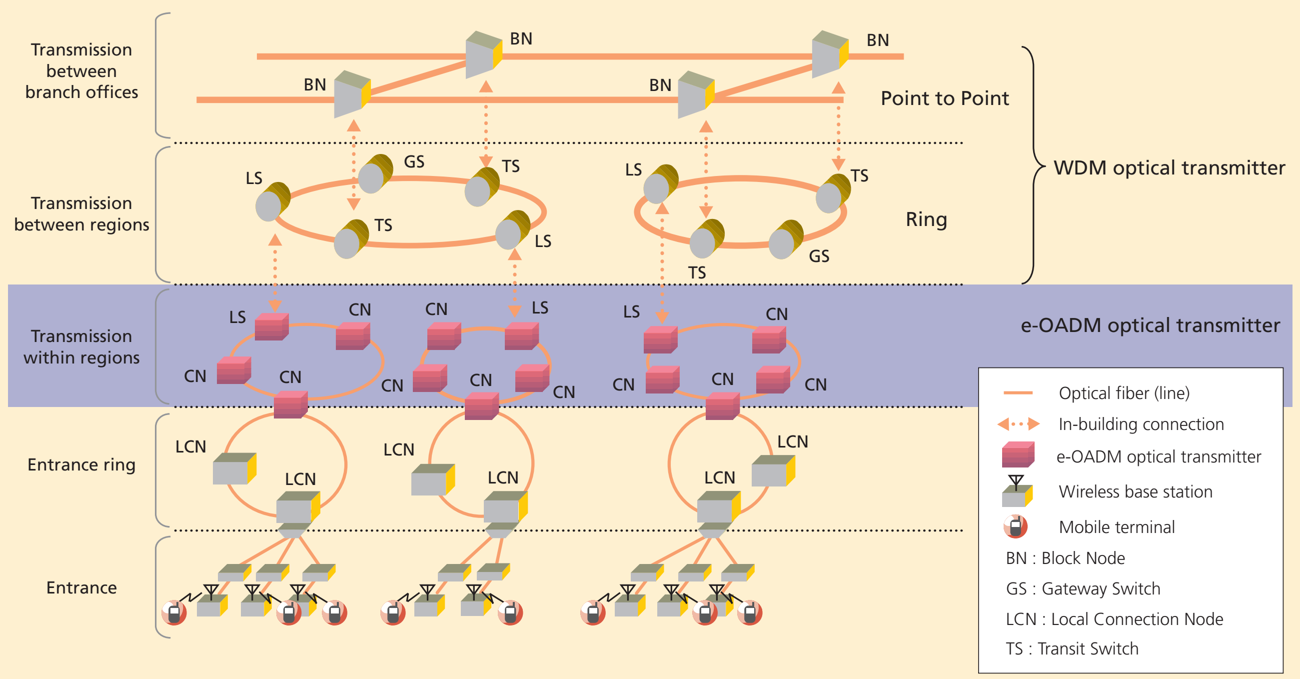

Figure 1 NTT DOCOMO transmission network architecture

Conventionally, optical transmission equipment connecting regions in a point-to-point fashion was used, so an optical-fiber cable (line) between buildings was needed, with transmission equipment at both ends. Most of this optical fiber was obtained by leasing dark fiber[*4], and we plan to reduce running costs by reducing the number of lines leased.

Now, with the introduction of e-OADM optical transmitters using OADM technology, we are able to create a ring structure with the paths between the Local Switch (LS) and Connection Node (CN) buildings, allowing a reduction in the number of optical fiber links and the amount of equipment required.

3. Issues and Solutions Using Optical Transmission Equipment on Regional Networks

3.1 e-OADM Optical Transmitter Development

Current WDM optical transmitters are constructed using specialized racks, so that separate racks are needed for other equipment. Power-consumption and equipment space have been issues in buildings housing regional transmitters, and it has been difficult to use existing equipment under these conditions. Thus, in order to use facilities more efficiently, new equipment has been developed that is not restricted by specialized racks, and can be installed together with other transmission equipment on standard racks. Power consumption has also been reduced by 50% compared with earlier equipment through use of passive components[*5] and athermal circuits[*6] and concentrating package functionality. Further, passive components do not require power, resulting in more flexibility in positioning, and allowing for still further size reduction.

3.2 Variable Wavelength Transponder

Existing WDM optical transmitters require separate transponder parts for each client interface, per-wavelength (approx. 360 types). This has made management and maintenance of the

*4 **Dark fiber**: The portion of optical fiber cable laid by telecommunications operators and other companies that is not in use by those operators and companies.

*5 **Passive components**: Components which operate passively, performing the desired function without relying on external sources of energy.

*6 **Athermal circuits**: Those designed not to require temperature regulation, in order to reduce power consumption and cost.

equipment very difficult. To improve maintainability and operability of the e-OADM optical transmitters, a new variable wavelength transponder was developed to concentrate all per-wavelength transponder parts.

The new transponder makes use of tunable-laser technology[*7], providing wavelengths from λ 1 to λ 40 (oscillator center frequencies from 1,573.71 nm to 1,606.60 nm or from 1,574.54 nm to 1,608.33 nm) in one transponder, reducing the number of parts to 1/40 (**Figure 2**).

Optical wavelengths can also be set or changed remotely using monitoring and control equipment.

3.3 New-functionality Transponder Development

The GbE interface for existing transmitters accomodates two ports per package. In order to accomodate the transmission path more efficiently, it was necessary to multiplex using FTM-D optical transmitters (hereinafter refered to as "FTM-D"), to connect to the WDM optical transmitter at 10 Gbit/s speeds.

With e-OADM optical transmitters, eight or nine GbE interface ports are multiplexed to match the ring transmission speed (10 Gbit/s), improving efficiency without the need for FTM-D multiplexing (**Figure 3**).

Also, by converting client interfaces to optical modules, an arbitrary number of mixed Small Form-factor Pluggable (SFP)[*8] (SX/LX) modules can be accommodated, improving maintainability. We also developed a 10 GbE transponder which will enable support for future increases in demand.

4. Overview of the e-OADM Optical Transmitter

4.1 Equipment Architecture

The e-OADM optical transmitter includes an Optical Add-Drop Multiplexer (OADM), consisting of base unit, optical amplifier and transponder parts, and a relay, consisting of optical relays and optical amplifiers and can be used to reduce equipment size and power consumption.

With this device, a single OADM device is able to communicate with

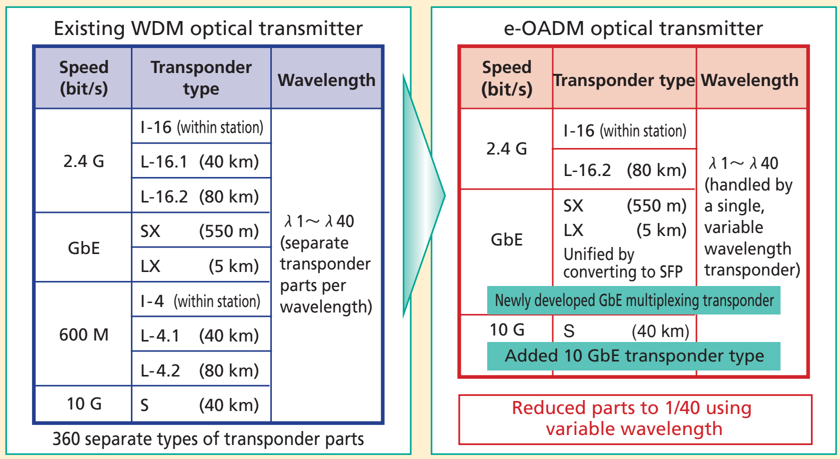

Figure 2 Variable wavelength transponder

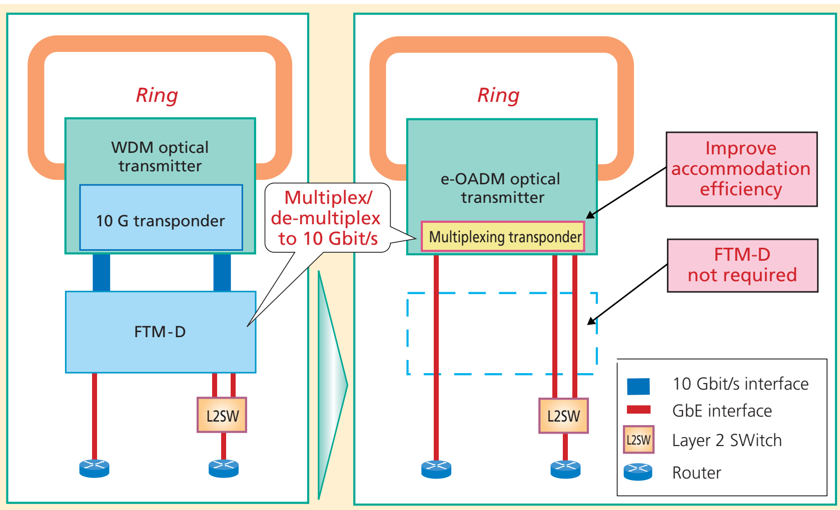

Figure 3 New e-OADM transponder functionality

*7 **Tunable-laser technology**: Technology used to implement the variable wavelength laser module and used in Dense WDM (DWDM) systems.

*8 **SFP**: A physical-layer specification for pluggable modules used in optical fiber telecommunications and measurement devices such as GbE and STM devices.

other devices in a logical star formation. The number of devices in a single ring can range from two (with no relays) to a maximum of 32 (including relays). Under these conditions it is possible to monitor and control all Network Elements (NE)[*9] on a ring from the monitoring/operation equipment (NE-OpS) through two arbitrary Gateway NEs (GNE)[*10](**Figure 4**).

4.2 Equipment Functionality

Client interfaces provided include a Synchronous Transport Module (STM) -16/64[*11], GbE (1000BASE-SX/LX) and 10 GbE (10GBASE-LR/ER). Between optical relays, wavelength-multiplexed transmission with up to 40 different wavelengths carrying optical signals of 1 to 10 Gbit/s is possible through optical fiber cable conforming to ITU-T Recommendation G.652[*12] (Single Mode Fiber (SMF)) or G.653[*13] (Dispersion Shifted optical Fiber (DSF)). Each wavelength can be inserted or branched with optional OADM equipment, allowing efficient construction of a ring network as shown in Fig. 4.

The number of devices that can be monitored from the monitoring and control equipment has been approximately doubled (400 or 500 devices) relative to current WDM transmitter equipment. By appropriately placing level-equalization function[*14], level differences between wavelengths can be adjusted within an appropriate range, and adequate signal quality can be maintained through bundled amplification. These measures contribute to achieving longer spans (relay distance : 105 km), and reduction in number of 3R relays (**Figure 5**).

This device uses Uni-directional Path Switched Ring (UPSR) as a redundant architecture, with switching time of less than 50 ms, and the multiplexing transponders are able to switch independently on each client interface.

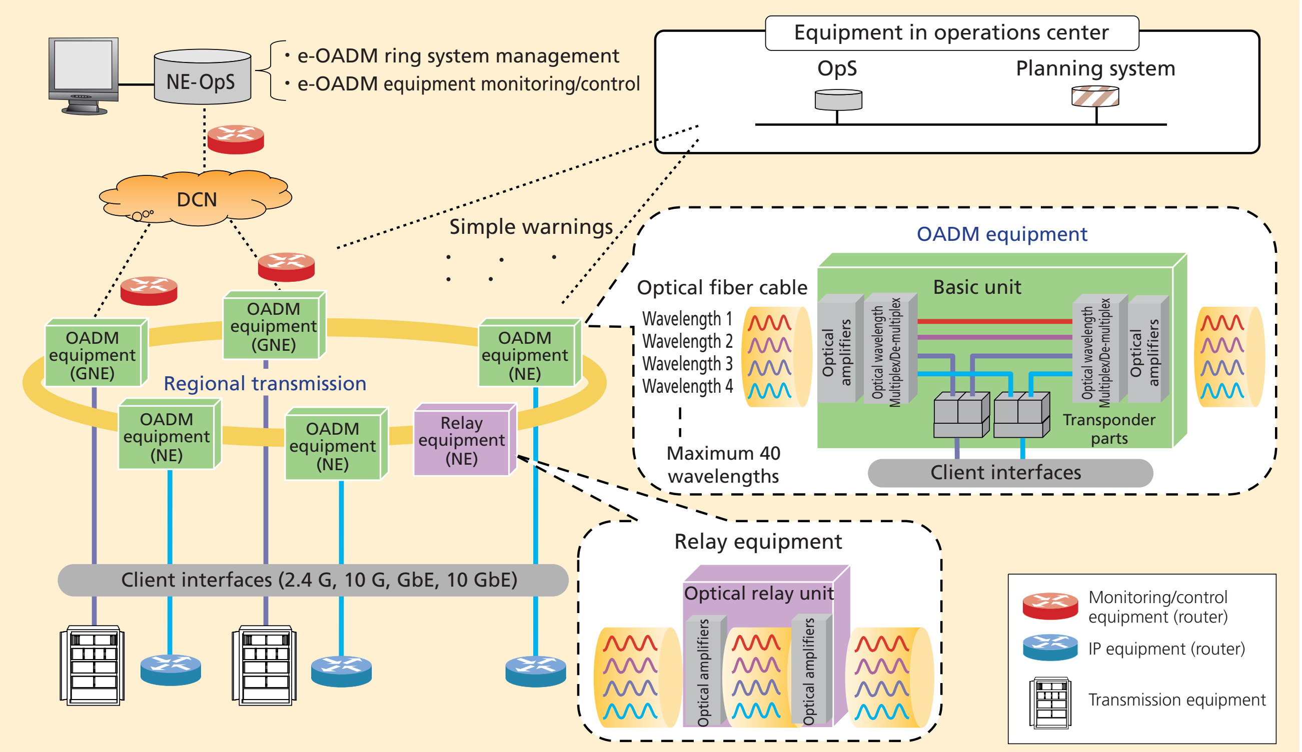

Figure 4 e-OADM system architecture

*9 **NE**: A name for the OADM and relay devices that make up the system.

*10 **GNE**: An NE that acts as a gateway for communication with the NE-OpS server over the Data Communication Network (DCN)

*11 **STM-16/64**: Indicates the SDH (Synchronous Digital Hierarchy) structure. Transmission speed is 2,488.320 Mbit/s for STM-16, and 9,953.280 Mbit/s for STM-64.

*12 **ITU-T Recommendation G.652**: ITU-T Recommendation for standardizing optical fiber structure related to general, single-mode fiber. Its main feature is having zero-dispersion wavelengths in the 1,310 nm band.

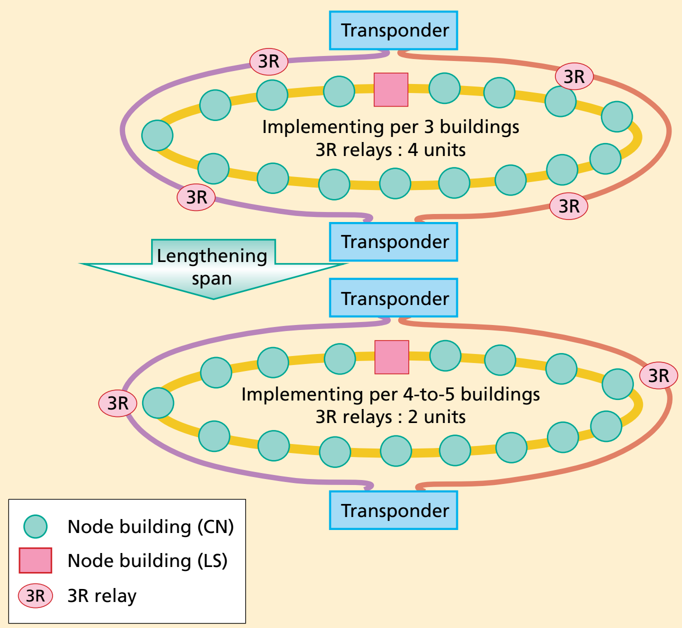

Figure 5 Elimination of 3R relays by lengthening span

5. Conclusion

We have been able to reduce running costs for regional transmission networks by developing and introducing an e-OADM optical transmitter which overcomes equipment space and power consumption restrictions.

Gradual introduction of the device began in July, 2008, and is achieving more efficient use of the central optical fiber*15 and reduction of dark fiber usage fees along with the related cost improvements.

We have also provided a 10 GbE interface in anticipation of increasing entrance transmission capacity requirements with the future introduction of technologies such as LTE and 4G.

With this device it is possible to build arbitrary logical paths between nodes and/or buildings, but LTE base stations communicate with each other, so they must be connected in a mesh path. We intend to implement this using Ethernet transmission equipment that is currently under development.

REFERENCES

[1] Y. Matsumoto et. al: “WDM Equipment for Optical Backbone Networks,” NTT DoCoMo Technical Journal, Vol.11, No.3, pp.48-54, Oct. 2003 (In Japanese).

*13 **ITU-T Recommendation G.653**: ITU-T Recommendation of standardizing optical fiber structure related to dispersion-shifted single-mode fiber. Its main features are low losses in the 1,310 nm band and zero-dispersion wavelengths in the 1,550 nm band, allowing transmission over longer distances.

*14 **Level-equalization function**: Function to equalize individual optical signals to a standard level before amplification, because if the input levels to the wavelength multiplexer from the transponders are varied and the multiplexed signal as a whole is amplified, original signals with low levels will not be amplified adequately.

*15 **Central optical fiber**: A line in an optical fiber cable.