Technology Reports

CDC-ROADM WSS MCS

Improving the Reliability of Optical Transmission Networks with CDC Technology

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The recent intensification of natural disasters has resulted in disconnected optical transmission lines leading to large-scale communications service failures and problematic recovery times. One possible solution to achieve continuously connected optical transmission networks is the introduction of CDC ROADM for optical transmission lines, which would improve transmission line redundancy and shorten recovery times by switching to detour routes. In this article, we explain an overview of the CDC ROADM and its CDC elemental technology, which NTT DOCOMO began introducing in 2017.

1. Introduction

Conventional optical transport equipment (Reconfigurable Optical Add/Drop Multiplexer (ROADM)*1) secures 1:1 redundancy by using working/detour transmission lines (two directional paths). However, if a transmission line failure occurs on both the working and detour transmission lines due to a large-scale natural disaster, communications services will be interrupted until one of the lines is restored. Also, recovery from a fault may require cable relaying or splicing work on site, dispatching engineers to the disaster-stricken area could be problematic, and complete service recovery may take a lot of time.

Giving multiple routes to optical transmission lines is a possible solution to this problem. Introduction of optical transport equipment with Colorless, Directionless and Contentionless (CDC) functions, elemental technologies to achieve multiple

*1 ROADM: An optical multiplex system that branches and inserts optical signals.

routing (hereinafter referred to as "CDC ROADMs"), can secure 1: *N* redundancy with multiple detour transmission lines (*N*). This also makes it possible to switch to a transmission line that is not damaged by remote switching by the user or autonomous switching of the equipment, which greatly reduces the time required for service recovery.

In this article, we describe an overview of CDC ROADMs and their CDC elemental technology, which NTT DOCOMO began introducing in 2017.

2. Issues with Conventional Networks

Conventional DOCOMO repeated transmission lines entail large-scale optical infrastructure constructed using e-OADM*2 optical transport equipment [1]. The e-OADM optical transport equipment consists of TransPoNDers (TPND)*3, optical wavelength multiplexing/demultiplexing units, and amplifiers (**Figure 1**). The TPND accommodates client equipment such as routers, and has functions for mutual conversion of the transmission/reception signals of client equipment and e-OADM optical transport equipment (electrical signal <--> optical signal, etc.), and connects to an optical wavelength multiplexing/demultiplexing unit for the desired output directional path. The optical wavelength multiplexing/demultiplexing unit has a multiplexing

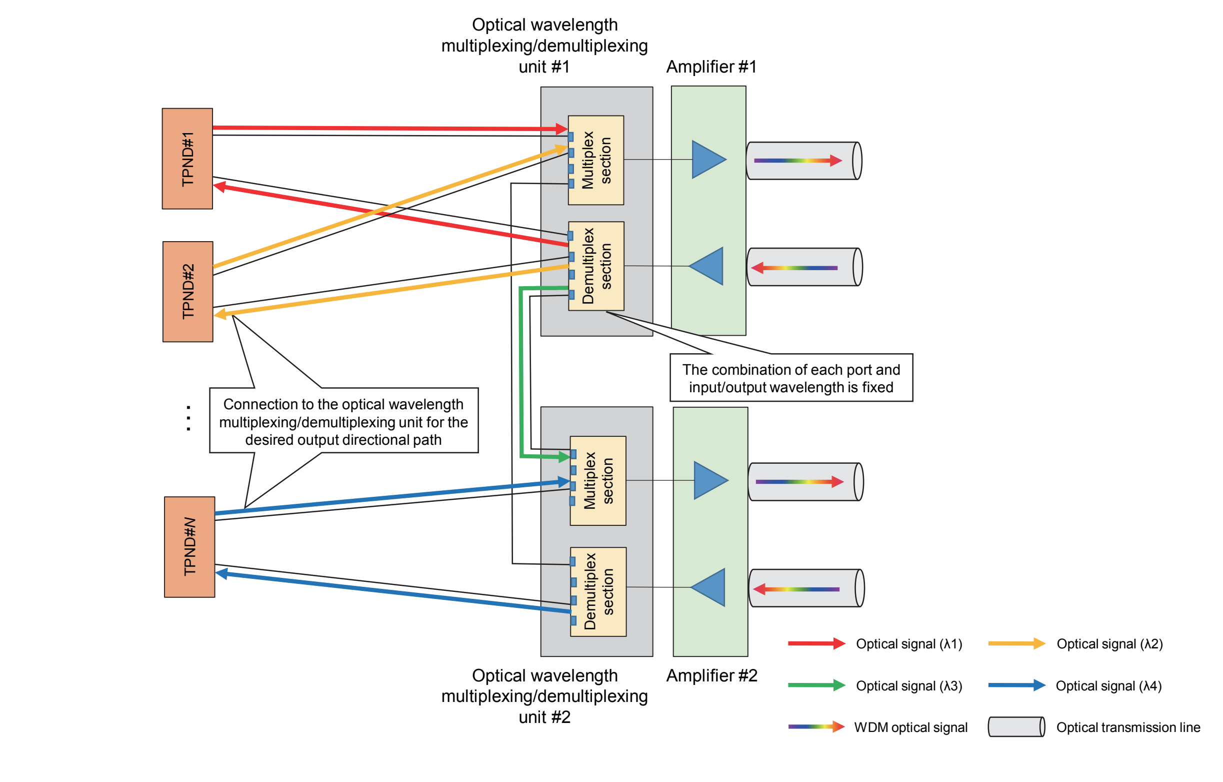

Figure 1　Image of e-OADM optical transport equipment configuration

*2　e-OADM: A compact, low power consumption ROADM.

*3　TPND: A functional section that interconverts signals received and transmitted with client equipment and optical signals transmitted and received with optical transport equipment.

unit for multiplexing multiple optical signals input from the TPND and a demultiplexing unit for demultiplexing Wavelength Division Multiplexing (WDM)*4 signals received from the transmission line. Multiplexing and demultiplexing use Arrayed Waveguide Gratings (AWG)*5. The combination of I/O wavelengths and ports*6 is fixed. Erbium-Doped Fiber Amplifiers (EDFA)*7, etc. are used for the optical amplifiers, which have functions to adjust optical signals to a level that can be received by the TPND or the opposing optical transport equipment.

Since the e-OADM optical transport equipment can output optical signals to a maximum of two directional paths, constructing a ring configuration*8 is an effective way to ensure redundancy of the transmission lines. **Figure 2** (a) shows the signal flow when a ring configuration is constructed using e-OADM optical transport equipment. In this configuration, when a failure occurs on a single directional path, services can be continued by using a transmission line on which no failure has occurred. However, as shown in Fig. 2 (b), if a failure occurs on two directional paths, communication between client equipment becomes impossible and service interruption occurs. On-site work is required to restore the transmission line to eliminate the service interruption. The interruption may be prolonged, depending on the details of the transmission line failure. If transmission line failure recovery is difficult, a new connection to another transmission line that does not pass through the faulty section could be selected, although this could still result in prolonged service interruption because it would require transmission line design or on-site package reseating and wiring.

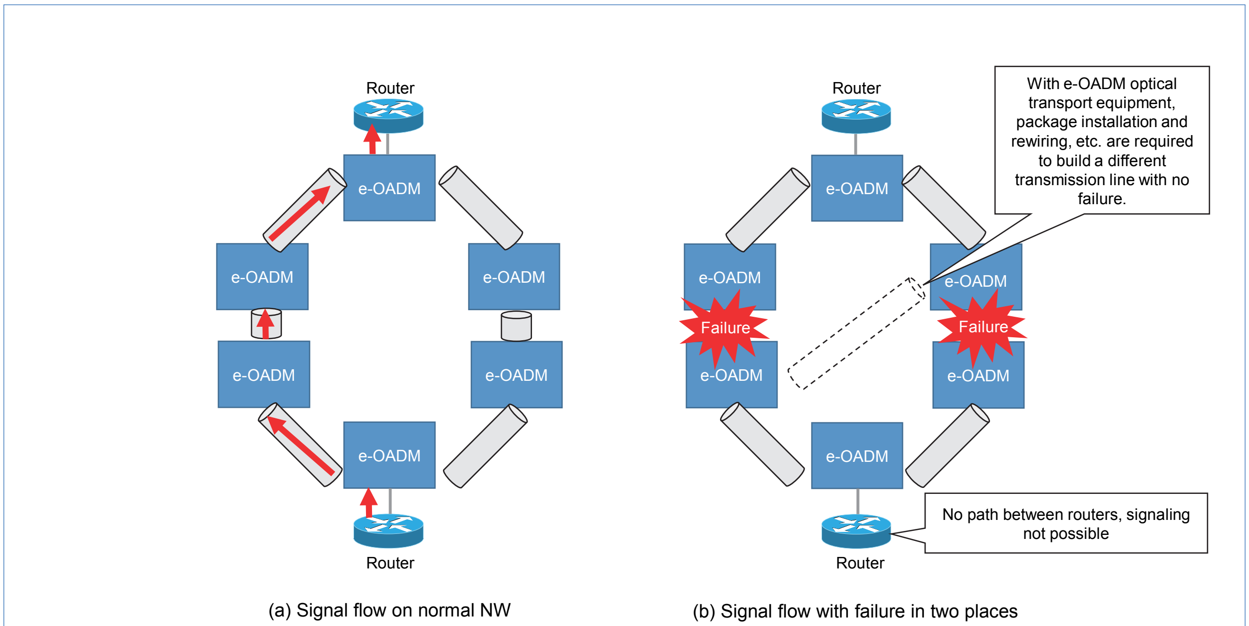

Figure 2　Example signal transport routes in the ring configuration

*4　**WDM**: Technology to transmit multiple optical signals with different wavelength on one optical fiber.

*5　**AWG**: An optical component that enables multiplexing and demultiplexing of multiple different wavelengths.

*6　**Port**: A physical interface for exchanging data with other equipment.

*7　**EDFA**: A type of optical amplifier for raising the level of optical signals.

*8　**Ring configuration**: A type of network topology that entails optical transport equipment connected in a ring.

3. Networks Achievable with CDC ROADM

CDC ROADM makes it possible to construct a mesh configuration[*9] by connecting to three or more directional paths with the CDC functions and output optical signals on any transmission line without the need to install packages or change wiring. **Figure 3** (a) and (b) show the flow of signals in the mesh configuration. When a failure occurs on multiple transmission lines, services can be continued by using transmission lines on which no failure has occurred.

3.1 CDC ROADM Configuration

Figure 4 shows an image of the functional parts of CDC ROADM and the CDC functions. CDC ROADM is configured by combining TPNDs, a MultiCast Switch (MCS), Wavelength Selective Switches (WSS) [2] and amplifiers. The TPND and the amplifier have the same function as the e-OADM optical transport equipment. The MCS has an $N \times M$ switching function that outputs optical signals input from the TPND side and the WSS side to an arbitrary port. WSS consists of a demultiplexing unit that demultiplexes the WDM signals input from the transmission line side, a switching unit that outputs the demultiplexed optical signals to an arbitrary port, and a multiplexing unit that multiplexes the optical signal input from the TPND side. Combining the elements of MCS and WSS makes it possible to realize the CDC function and establish a maximum of M directional paths to ensure redundancy.

3.2 CDC Function Overview

CDC is an abbreviation that stands for the colorless, directionless and contentionless functions.

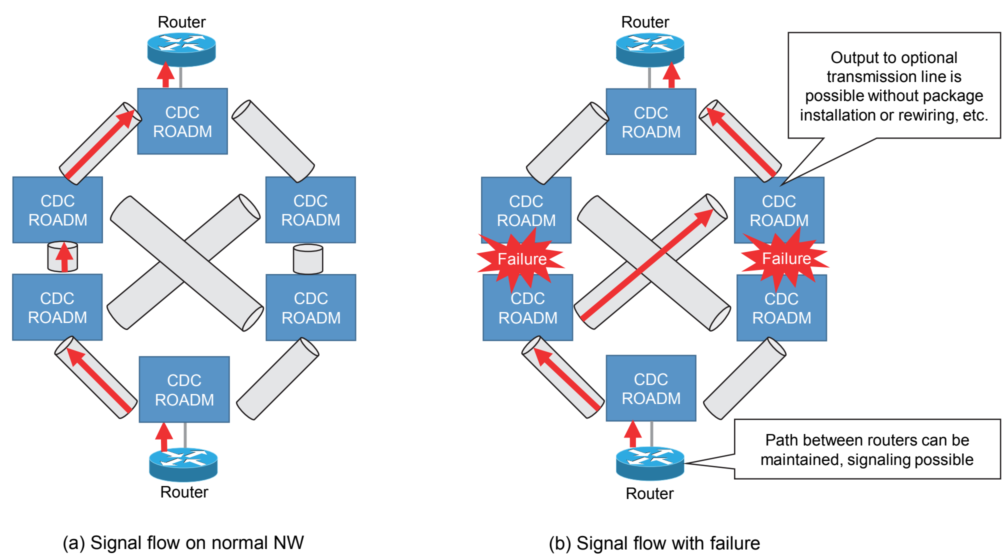

Figure 3 Example signal transport routes in the mesh configuration

*9 Mesh configuration: A type of network topology in which multiple pieces of optical transport equipment are connected to each other in a mesh.

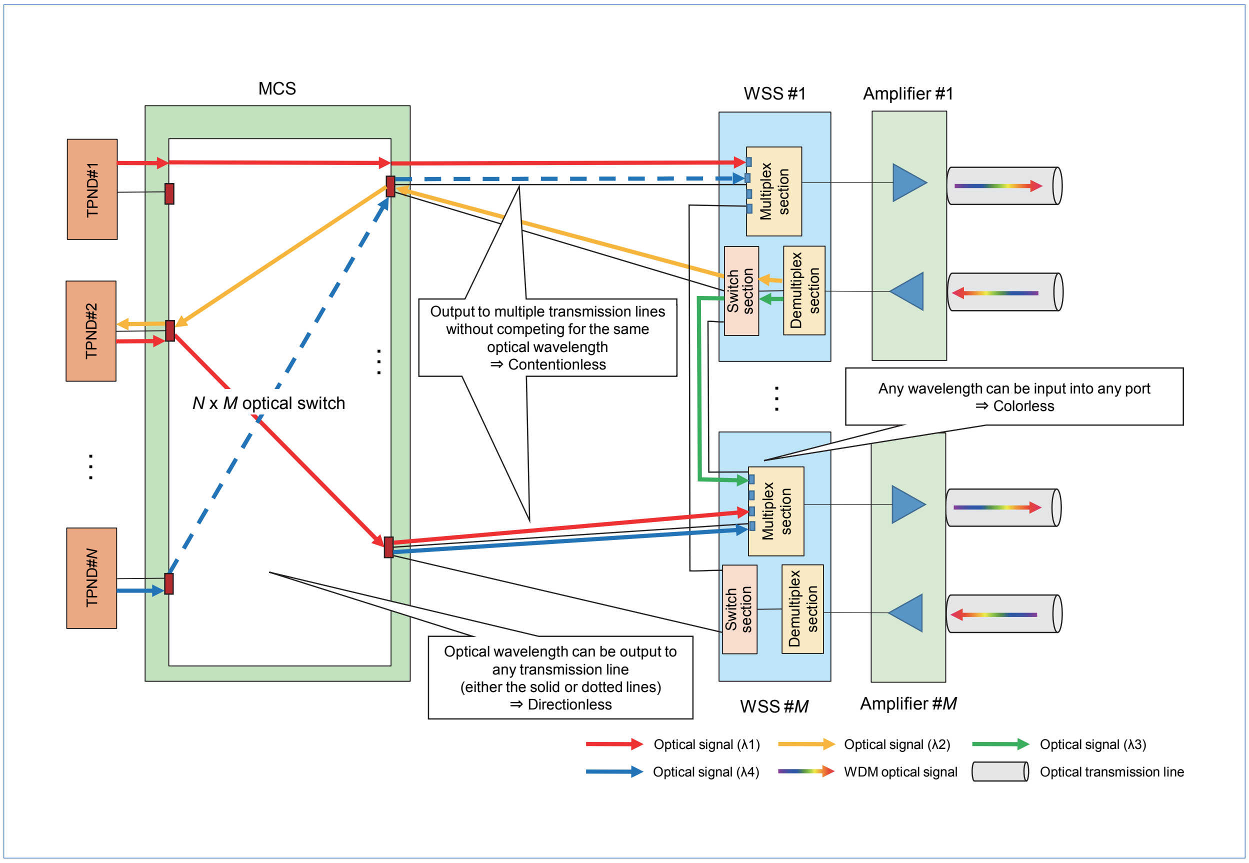

Figure 4 Image of the functional parts of CDC ROADM and the CDC functions

Combining these functions makes it possible to output optical signals with arbitrary wavelengths to arbitrary transmission lines to provide an efficient network operation.

1) Colorless Function

The colorless function assigns an arbitrary wavelength to each port of the multiplexing and demultiplexing units. If equipment does not have a colorless function, the wavelengths that can be input for each port of the multiplexing and demultiplexing functions are fixed. For this reason, if it was necessary to change the wavelength, on-site work to change port connections was required. In contrast, the colorless function enables input with an arbitrary wavelength at each port of the multiplexing and demultiplexing units, which eliminates the need to change port connections on site to change wavelengths, and can be done just by changing equipment settings.

2) Directionless Function

The directionless function enables output of an optical signal with a specific wavelength to an arbitrary transmission line. If equipment does not have the directionless function, the output destination for an optical signal of a specific wavelength is fixed to one transmission line. For this reason, if it is necessary to change the destination transmission line, on-site work to change port connections, etc. will be required. In contrast, equipment with the directionless function enables optical signal output to an arbitrary transmission line by utilizing the MCS or WSS optical switch functions. Therefore, destination transmission lines for output can be switched just by changing equipment settings.

3) Contentionless Function

The contentionless function outputs the same optical wavelength to multiple transmission lines so that there is no conflict in equipment that has the colorless and directionless functions. This enables efficient transmission line switching when failures occur.

3.3 Signal Flow on Normal Transmission Lines

Figure 5 shows the route of the optical signal when a mesh configuration optical transmission network is constructed by combining CDC ROADMs. An optical signal from TPND#A2 of CDC ROADM #A (hereinafter referred to as #A) to TPND#C1 of CDC ROADM #C (hereinafter "#C") is transmitted to WSS#A2 by MCS#A, and output to the optical transmission line to which WSS#A2 is connected. Then, WSS#C2 receives the optical signal and sends it to TPND#C1 via MCS#C.

Similar to the optical signal of TPND#A2, the optical signals transmitted from TPND#A1 and

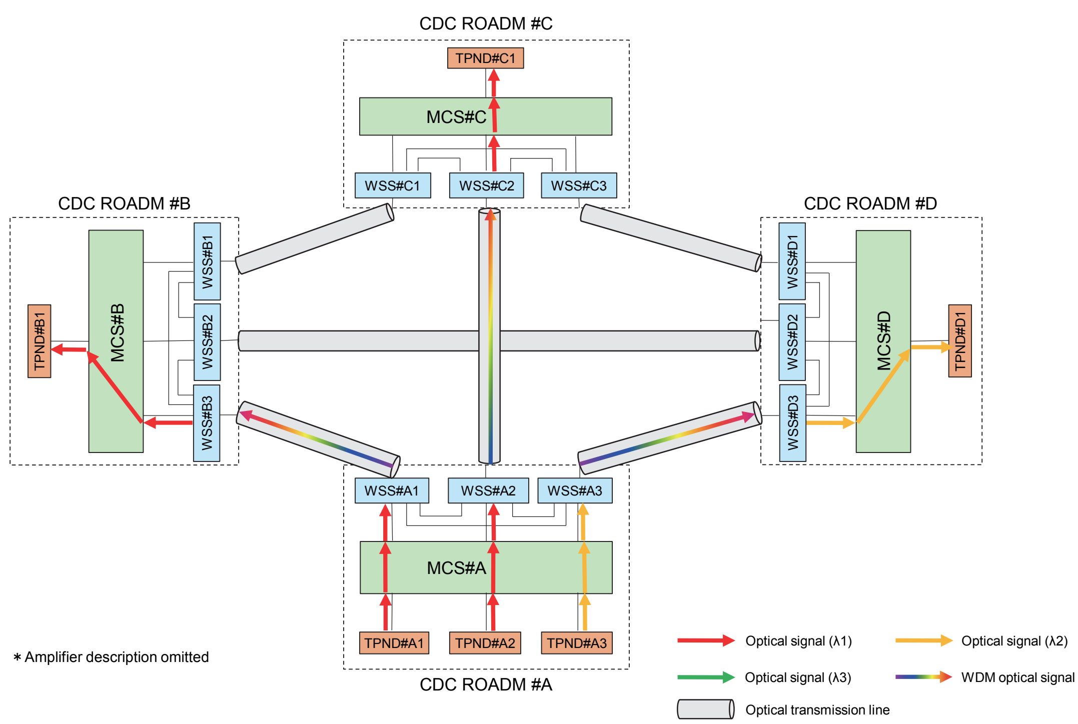

Figure 5 Example of signal routes in a mesh configuration with 4 CDC ROADMs

TPND#A3 are output to arbitrary directional paths by MCS#A. Here, optical λ1 signals are sent to multiple transmission lines without confliction by the contentionless function.

3.4 Signal Flow When Failures Occur on Transmission Lines

1) With an Optical Transmission Line Failure between #A and #C

Figure 6 shows the signal route when an optical transmission line failure occurs between #A and #C in the mesh configuration with four CDC ROADMs shown in Fig. 5.

The optical signal (λ1) of TPND#A2 sent via #A and #C is switched from WSS#A2 to WSS#A3 by MCS#A, and is multiplexed with the optical signal (λ2) of TPND#A3 and output to the transmission line for CDC ROADM #D (hereinafter "#D"). After arriving at #D, the optical signal of TPND#A2 is demultiplexed at WSS#D3, switched to the WSS#D1 direction and output to the transmission line for #C. After arriving at #C, the signal is switched to the direction of MCS#C by WSS#C3 to arrive at TPND#C1. Thus, if an optical transmission line failure occurs between #A and #C, it is possible to bypass the failure and reach the target TPND. Here, the optical signal of TPND#A2 is switched to #C via #D by the directionless

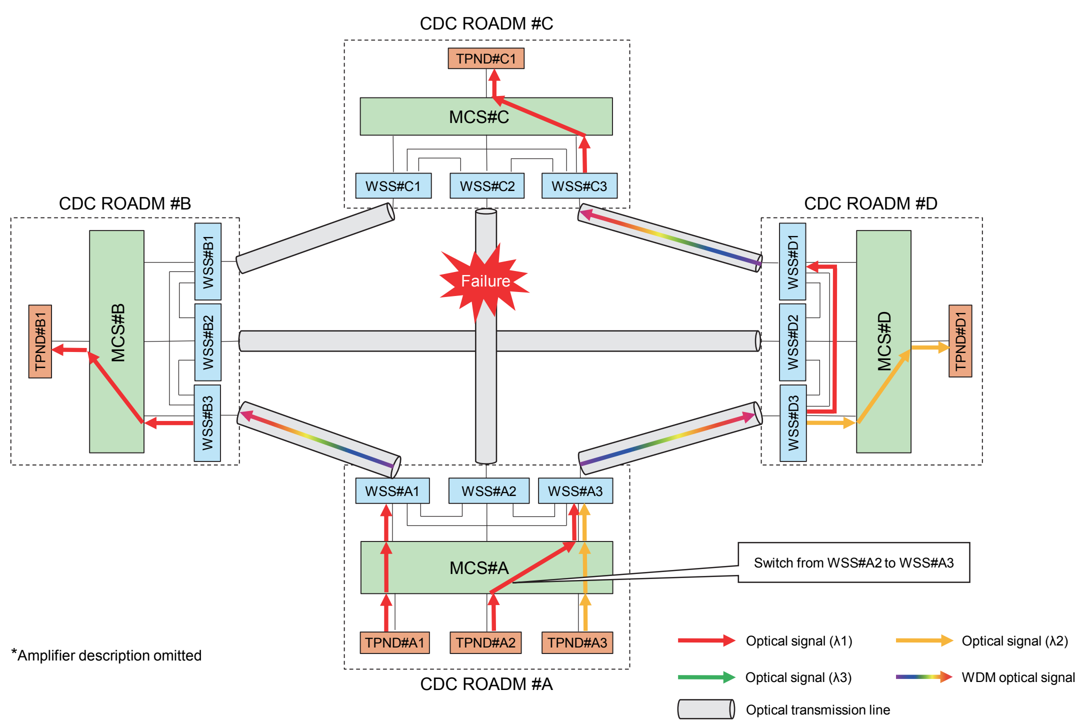

Figure 6 Example of signal route with transmission line failure between #A and #C

function without the need for work such as on-site port connection changes.

2) With Optical Transmission Line Failures between #A and #C, and #A and #D

Figure 7 shows the signal route when an optical transmission line failure also occurs between #A and #D, in addition to the state described in Fig. 6. TPND#A2 changes the wavelength (λ3) that is not overlapping with TPND#A1 to output an optical signal from the transmission line for #B where no failure has occurred, and MCS#A switches the transmission line from WSS#A3 to WSS#A1. Then, the optical signal is multiplexed with another wavelength and output to the transmission line for #B. After arriving at #B, the optical signal of TPND#A2 is demultiplexed at WSS#B3, switched to the WSS#B1 direction and output to the transmission line for #C. After arriving at #C, the signal is switched to the MCS#C direction by WSS#C1 to arrive at TPND#C1. Similarly, the optical signal of TPND#A3 can arrive at #D by MCS#A switching the transmission line through #B. This makes it possible to switch to a normal transmission line even if a failure occurs on two transmission lines. Also, if the same wavelength exists on the switch destination route, the wavelength can be changed to a non-overlapping wavelength by the colorless function of CDC ROADM.

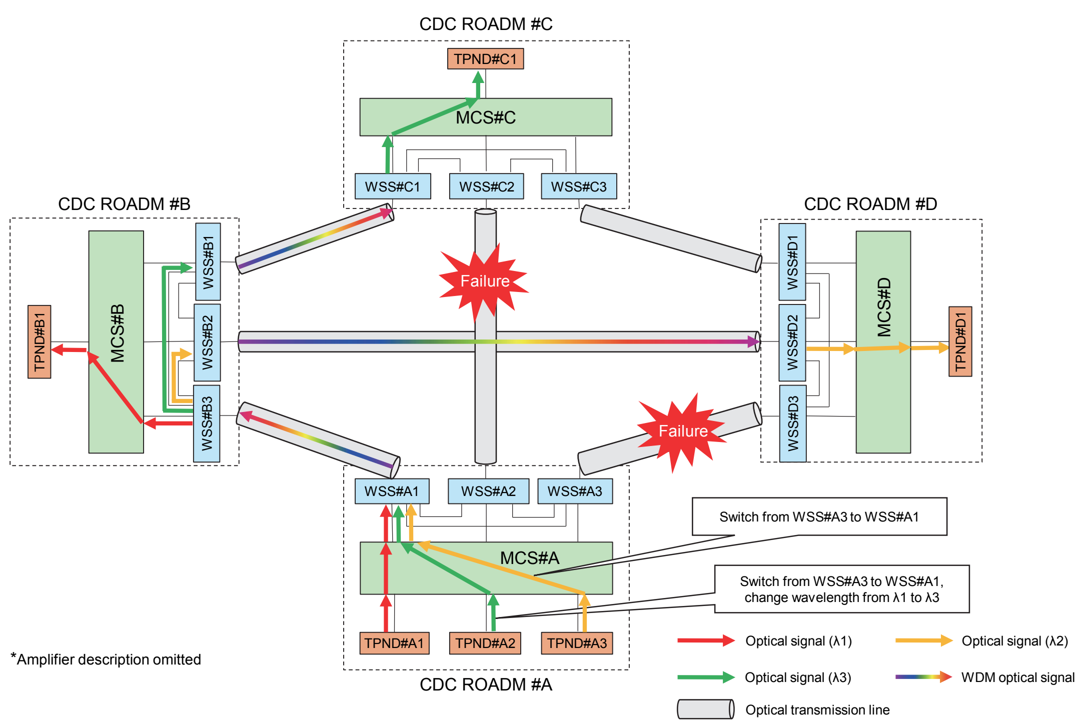

Figure 7 Example of signal route with transmission line failures between #A and #C, and #A and #D

4. Conclusion

This article has described an overview of CDC ROADM and its CDC elemental technology.

As described above, CDC ROADM using CDC technology enables detour by selecting one of multiple routes, which greatly shortens the duration of service interruptions, even in the event of a disaster, and enables construction of optical transmission networks that are continuously connected.

For future support of 5G, realization of more than 100G per wavelength (Beyond100G) will be required to increase the capacity of the inter-branch transmission lines that bundle the traffic of the backbone network. We would also like to study ultra-low power consumption to enable node configuration regardless of the installation location to achieve low latency in consideration of various applications such as eHealth and autonomous driving, and connections to controllers to achieve wavelength visualization in response to the increasing numbers of wavelengths accompanying the larger capacities.

REFERENCES

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[2] Y. Sakamaki, T. Kawai and M. Fukutoku: "Next-generation Optical Switch Technologies for Realizing ROADM with More Flexible Functions," NTT Technical Review, Vol.12, No.1, Jan. 2014.