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TECHNICAL REPORT

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Dynamic modules –
Part 6-10: Design guide – Intermediate controller for multiple dynamic module systems

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DYNAMIC MODULES –

Part 6-10: Design guide – Intermediate controller for multiple dynamic module systems

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IEC TR 62343-6-10, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee TC 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86C/1381/DTR	86C/1422/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62343 series, published under the general title *Dynamic modules*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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INTRODUCTION

Software defined networking (SDN) technology is widely recognized as a promising solution for flexible and efficient provisioning of networks by virtualizing their infrastructures, which results in cost-effective realization of high capacity, low energy consumption and even low latency. SDN technology will remain highly influential over global industries, societies, and the environment for many years to come.

Optical fibre communication technology has offered sufficient transport capacity with a fixed physical topology. However, recent technological progress in optical networking enables physical reconfiguration of optical paths by controlling multiple dynamic modules such as wavelength division multiplexing (WDM) devices and switching devices. Here, the key is to have an intermediate controller that controls and maintains the multiple dynamic modules in an integrated fashion, according to the upper layer controller of the SDN.

In order to realize such a reconfigurable and/or dynamically switchable optical network infrastructures at a hardware level in a cost-effective, reliable, scalable and low-carbon manner, it is important to initiate, in a timely manner and to a wide extent, conceptual and technical discussions, particularly on the intermediate controller for future standardization.

It is very important for industries to identify requirements for network architecture and devices/components in a timely manner, and to improve the technology development and investment efficiencies.

The objective of this part of IEC 62343 is to contribute to the standardization of basic requirements of the dynamic optical path networks using the intermediate controller.

DYNAMIC MODULES –

Part 6-10: Design guide – Intermediate controller for multiple dynamic module systems

1 Scope

This part of IEC 62343, which is a Technical Report, discusses the rationale, conceptual definition, and minimum list of functions for an intermediate controller that delivers a dynamic control signal to multiple dynamic modules. These modules are included in an optical-switch-based network node, according to the upper layer controller of software-defined optical networking.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

AWG	arrayed waveguide grating
C/D/C-ROADM	colourless/directionless/contentionless reconfigurable optical add-drop multiplexing
I/F	interface
IP	internet protocol
mI/F	module side interface
MCOS	multicast optical switch
OCM	optical channel monitor
ODU	optical data unit
OXC	optical cross connect
PLC	planar lightwave circuit
ROADM	reconfigurable optical add-drop multiplexing
Rx	receiver
SDN	software defined networking
TPA	transponder aggregator
Tx	transmitter
Tx/Rx	transceiver

WDM wavelength division multiplexing

WSS wavelength selective switch

WXC wavelength cross connect

4 Background of the software defined networking and its control plane for optical nodes

Optical networks are evolving from static link services to flexible link services to provide future dynamic transport services. Software defined networking (SDN) is one of the network architectures that enable flexible and dynamic network control. The basic idea of SDN is to separate the control plane from the data plane, allowing consolidation of hardware infrastructure to save the overhead associated with per-service deployment of a closed set of resources such as computation, storage, and network. For optically switched networks such as colourless/directionless/contentionless reconfigurable optical add-drop multiplexing (C/D/C-ROADM) based mesh networks to be dynamically controlled through SDN, the control scheme should be designed to be as simple as possible, as they associate with complex configurations of multiple dynamic modules. In particular, common control interface is a key for realizing the control plane for such an optically switched node; thus, these interfaces should be properly defined from not only the software, but also the hardware aspect. Such an interface enables quick network building without hardware restrictions.

5 Research activities on high-performance node systems where intermediate controller plays key role

5.1 Photonic network with OpenFlow®[1] controller

There are several kinds of high-performance node systems for recent high-speed communication systems, such as the internet protocol (IP) router in the field of data communication and the reconfigurable optical add-drop multiplexing (ROADM) system in transport systems. A high-performance node system itself is supported on an agile control basis. OpenFlow® is the first standard communication interface defined between the controlling and forwarding plane of an SDN architecture. The OpenFlow® controller is a well-organized network control method that enables the realization of flexible network control. The OpenFlow® controller, which handles the OpenFlow® protocol, was initiated by the Open Networking Foundation that grew out of work at Stanford University. Several vendors are already supporting OpenFlow® to be featured in multi-vendor interoperability, scalability and support of diverse environments. As a result, network users can make an independent control environment from network configurations. The technical documents are already available for practical use [1][2].

5.2 Dynamic optical path network with a network controller

Dynamic optical path switching systems can provide an end-to-end connection in a network with huge-capacity links. In a network configuration having optical switches mutually connected in a mesh configuration in a transport network, the optical link services are dynamically provisioned in an end-to-end manner. In this case, energy consumption would be much smaller compared to high-end router chains. The National Institute of Advanced Industrial Science and Technology (AIST) proposes to call such networks dynamic optical path networks [2]. Of course, this system requires an additional control plane network; therefore, the necessary communication capacity for the control plane network is prepared. In this network, dynamic modules in systems can be controlled by a single network controller having a joint control interface to the control plane. This single link on the control plane needs to be well-organized.

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1 OpenFlow® is the trademark of a product supplied by Open Networking Foundation. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

2 Numbers in square brackets refer to the Bibliography

5.3 Control interface of the Photonic Layer-2

Future photonic nodes that incorporate technologies such as digital coherent optical transceivers and flexible-grid WDM can create optical paths with arbitrary bandwidths over a large dynamic range of around 30 dB, ranging from 1 Gbit/s to 1 Tbit/s. This can enable the flexible and efficient utilization of fibre capacity in the smart photonic cloud. For efficiently controlling the hypothetical network and synthetic of each photonic node, common interface of the node should be prepared. The Task Force Group of the Photonic Internet Forum is already promoting flexible control schemes for optical network nodes [3]. This forum tries to increase the number of the hypothetical network layer and extend the dynamic range of slice capacity, owing to the flexible spectral arrangement and sub-wavelength path.

6 Intermediate controller for multiple dynamic module systems

6.1 Description of the controller

6.1.1 Controller of multiple dynamic modules for a network node

For configuring a single network node as a high-performance node system, the control part should be a single interface to the network control plane. The control interface is a network controller that unifies multiple dynamic modules with various hardware/software components to make it behave as a single network node. This concept helps in building up the optical network system in a way that simplifies the entire hardware configuration. Figure 1 shows a conceptual block of the control interface for multiple dynamic modules and network devices. From a network configuration point of view, three layers (the application layer, control layer, and infrastructure layer) work as a coordinated network. A large amount of communication equipment, such as optical transport systems, is distributed in the infrastructure layer, and system configuration in the infrastructure layer has an impact on the adjacent layer. The intermediate controller has the role of wrapping up several network devices and dynamic modules in the system. Thus, the intermediate controller provides a simplified communication environment to the system, and it can be a wrap-up control port of the high-performance node system.

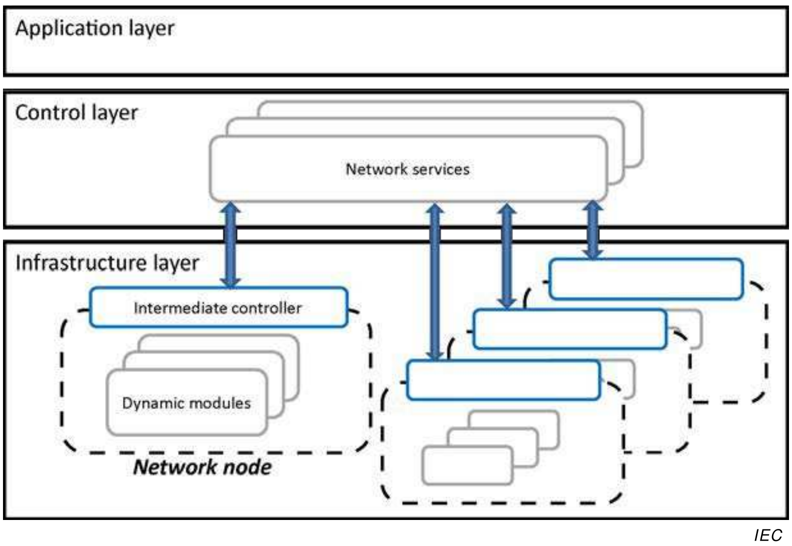

Figure 1 – Conceptual block of the control interface for multiple dynamic modules and network devices

Optical communication systems, such as high-performance node systems, employ a variety of modules and components. An intermediate controller is required in the system for controlling the entire set of components. The controller should work as a single control interface to convey control signals to multiple dynamic modules, such as OXC, WSS, and WXC, because a single resource management system sends out the network configuration order to the system. Therefore, the system should have a proper reception block of the control signal of the dynamic modules, which is the role of the intermediate controller. Typically, the controller has several functions in a system. For a high-performance node system in a transport system, the intermediate controllers control the following dynamic modules in the system:

– OXC (optical cross connect);
– WSS (wavelength selective switch);
– WXC (wavelength cross connect);
– MCOS (multicast optical switch);
– OCM (optical channel monitor).

These modules also have some specific interfaces, and their specifications are available in IEC standard documents.

6.1.2 Structure of the intermediate controller

The intermediate controller is located between multiple dynamic modules and specific network services in the control layer for multiple dynamic modules and network devices. Figure 2 shows the structure of the control interface. It consists of a control side interface (I/F) for the network control plane, module side I/Fs (mI/Fs) for various dynamic optical modules, and a programmable block that has reconfigurable logic functions as a hardware abstraction layer. The control side I/F can be a single interface to the network control plane. The logical and physical definitions of I/Fs are consistent with the on-going standardization of the network control plane for SDN and dynamic optical path network. This control interface provides wrap-up functions for multiple dynamic module systems, and several types of dynamic modules of multi-layer and multi-level systems are controlled uniformly from the network control plane.

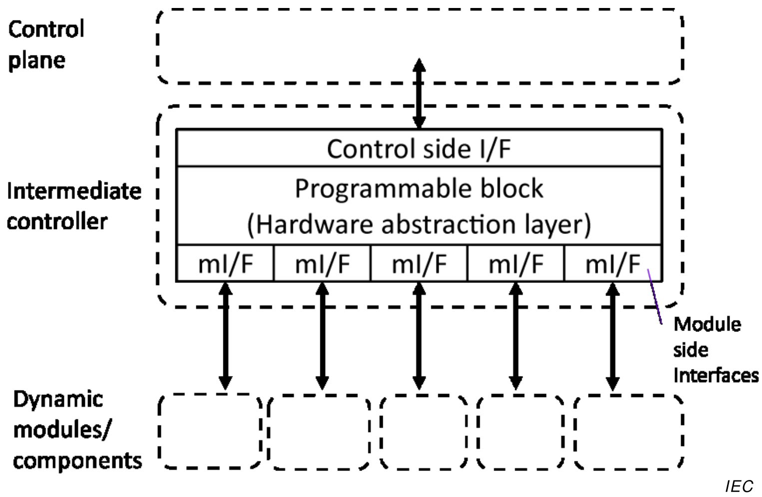

Figure 2 – Basic block of the control interface for multiple dynamic modules

The control side interface is a gateway port to the network control plane, and it works as a command sender/receiver to the control plane. Several physical layers can be set to this port such as Ether port, a network interface card, and a transceiver for the control plane.

The programmable block is located between the control-side I/F and the module side I/F. It is also known as a hardware abstraction layer. It interprets control commands from the network control plane to the dynamic optical modules, and the block refers to the information shared with the network control plane and the dynamic optical modules. It has a memory and look-up table as programmed resources. Monitored information of the modules is also available for sharing through the interface to the control plane. This programmable block provides the function of wrapping multiple optical modules using hardware resource information. This block needs to store the following information:

a) configuration information:
   – constraint information (netlist);
   – command information (interpreter);
   – internal link information (look-up table between control side I/F and module side I/F).
b) connection information;
c) monitoring information.

Configuration information and connection information are necessary for the control side I/F. However, these two aspects are completely different control targets from the system viewpoint, and this difference should be well-organized. Figure 3 shows the difference between the connection information and the configuration information based on typical optical fibre connection for ROADM. These aspects are described in further detail in 6.3.

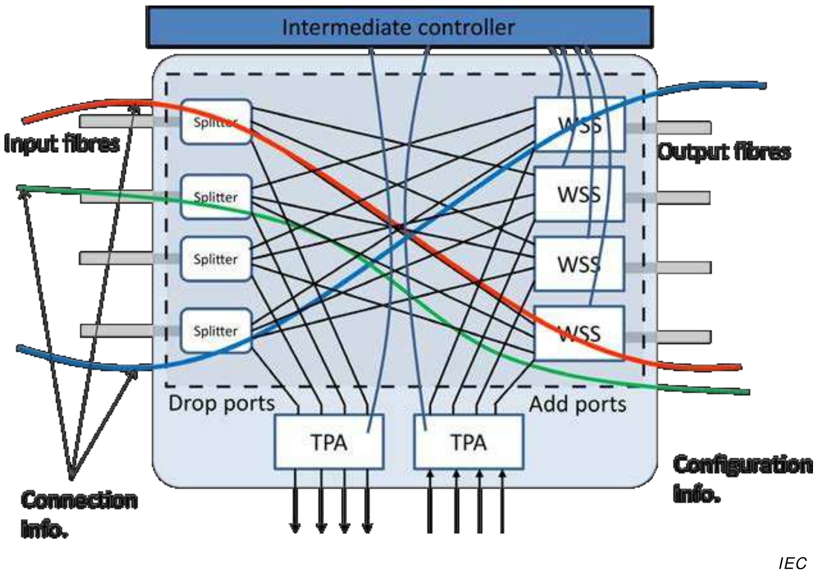

Figure 3 – Difference between connection information and configuration information

The module-side I/Fs are specified as connection interfaces to the devices, especially for dynamic optical modules with proper device drivers. In essence, the dynamic optical modules are optical components providing the optical path-switching function. Example modules are OXC, WSS, WXC, transponder with wavelength-tuneable functions, optical data unit (ODU), and monitor modules such as OCM. Standardized dynamic optical modules in IEC enable the use of logical and physical definitions of module side I/Fs.

6.2 Functions

In terms of function categorization, the intermediate controller for multiple dynamic module systems has three important functions: wrapping, maintenance, and communication. Paragraph 6.2 describes each function in the entire node system in detail.

The control interface provides a wrap-up function for multiple optical modules. Wrapping can be performed in two ways; horizontally and vertically. One of the ways to organize multiple optical modules, such as a large number of WSSs with a large number of ports, is horizontal integration, where the control interface makes a single connection to the control interfaces. The second way is vertical integration, where various kinds of dynamic modules, such as OXC or WXC, are wrapped together. In the case of vertical integration, interpretation of commands for each dynamic module should be realized, where the interpreted commands can be sent out to the dynamic optical modules from the network control plane.

For maintenance of the controller, the control interface can keep the connection and constraint information of dynamic modules and their monitoring status with the network control plane. These information blocks can be used for provisioning and monitoring purposes. Typically, a look-up table is set to this block along with computing and intelligence functions, which can be optional.

The communication function is for transmission and reception of information to and from the control plane. Connection information, constraint information, and monitoring status should be shared through this communication function, and examples of information shared through this function are module conditions, alarms, and reports. Figure 4 shows the function coverage of the intermediate controller. This function has strict relation to the processing speed. Proper timing of the process needs to be set in the controller.

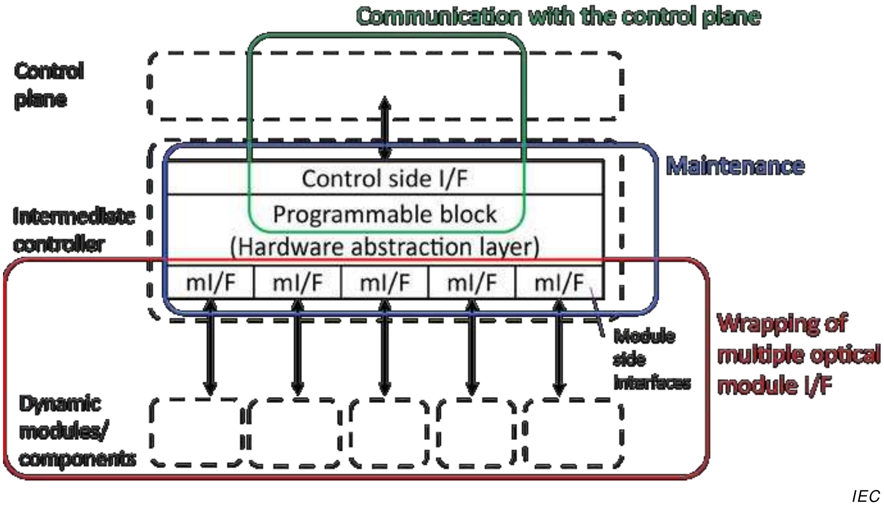

Figure 4 – Function coverage of the intermediate controller

6.3 Shared information between the control interface and the network control plane

Paragraph 6.3 describes necessary information to be stored in the programmable block. The control interface and the network control plane need to use configuration, connection, and monitoring information. Configuration information includes the following:

– constraint information;
– command information;
– internal link information.

Constraint information has limitation conditions for dynamic modules and restricted connection pattern in the controller. For making any special connection that is out of the sequence on the process, this information is used as disorder type. The command information is for translating an inherent command of the module to a specific network command. This information provides a way to control multi-vendor types of modules. The internal link information is for fixed connection of the module for a data plane in the system. Any module characteristic, such as wavelength characteristics and differences, can be stored in the internal link information.

Connection information is primarily for networking of the optical circuits in the node system. In other words, this information corresponds to the optical path having data plane connections.

Monitoring information is given by performance monitoring in the system, and it can be stored in the programmable block.

Shared information with descriptions is described in Table 1.

Table 1 – Shared information in the intermediate controller

Category	Information	Example
Configuration information	Constraint	Limitation or restriction for conditions/connection patterns
	Command	Command translation of the module
	Internal link	Initial connections in the system
Connection information	---	Mainly for networking of the optical paths
Monitoring information	---	Performance monitoring in the system

7 Example of multi-degree ROADM systems

An example of a multiple dynamic module system has the following three blocks: an optical switch block, a wavelength switch block, and an optical transceivers and electrical switches block. Figure 5 shows an example of a single node of the multiple dynamic module system. It consists of an optical switch function part, including an optical mesh network, transceiver for optical fibre transmission, WSS, and TPA. All dynamic modules in the system are controlled through a unified interface, which is an intermediate controller.

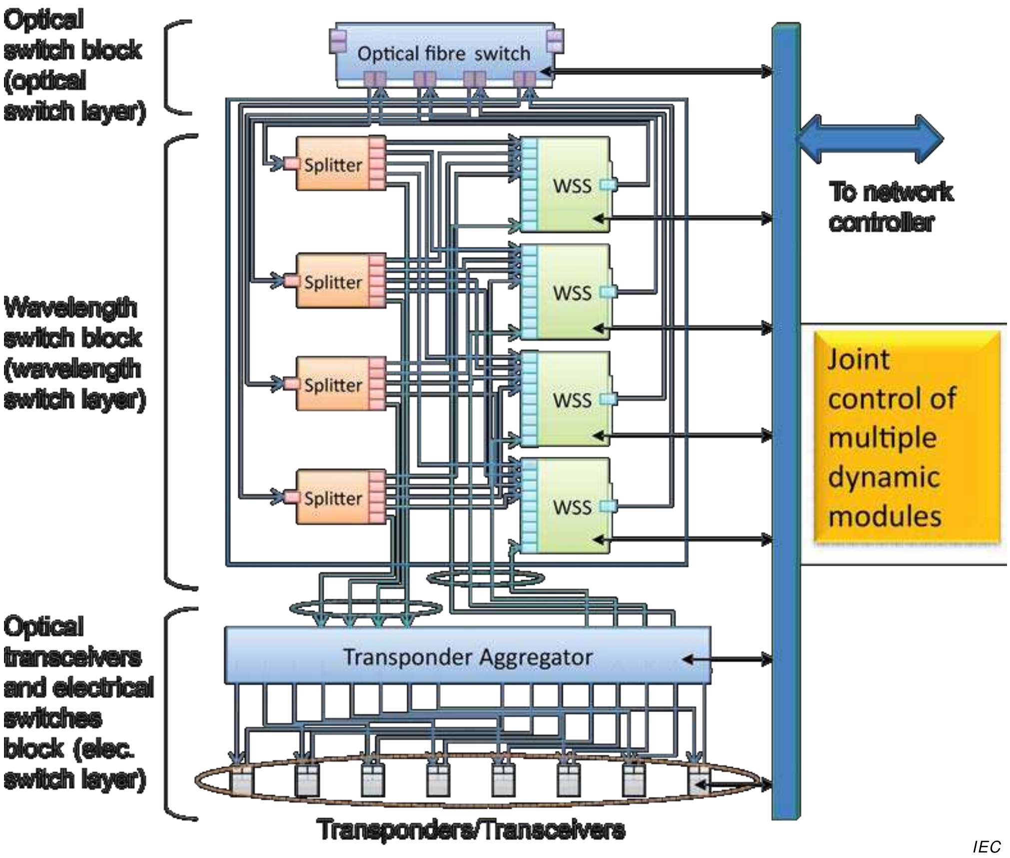

Figure 5 – Example of a multiple dynamic module system

There are several types of multi-degree ROADM systems. Figure 6 shows a configuration example of 4-degree ROADM node architecture. It consists of arrayed-waveguide gratings, power splitters, wavelength selective switches (WSSs), and transceivers (Tx/Rx). The single intermediate controller for these components can set in the node systems. A single multi-degree ROADM system can be controlled by using the controller.

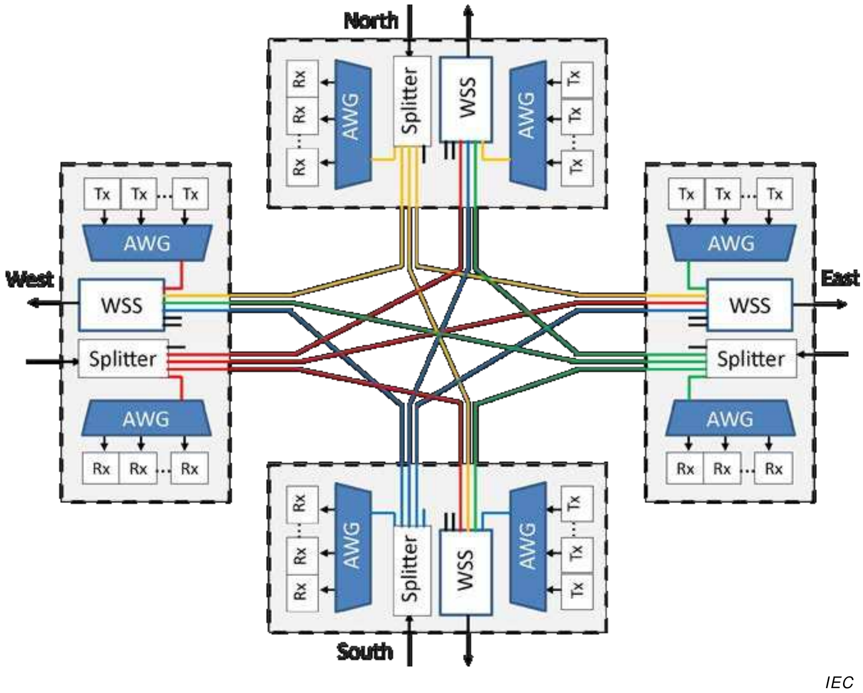

Figure 6 – Example of 4-degree ROADM node architecture

Figure 7 shows architecture for ROADMs with colourless and non-directional capability [4]. This type of architecture provides full interconnection among fibre routes, as well as full interconnection to add/drop ports. Figure 8 shows an example of a compact planar lightwave circuit (PLC)-based transponder aggregator (TPA) to realize any colour and any direction configuration [5]. The TPA can assign any wavelength and any input/output fibre without signal contention. Implemented dynamic modules such as WSS, transceivers, and client-side fibre cross connects are targets of the control.

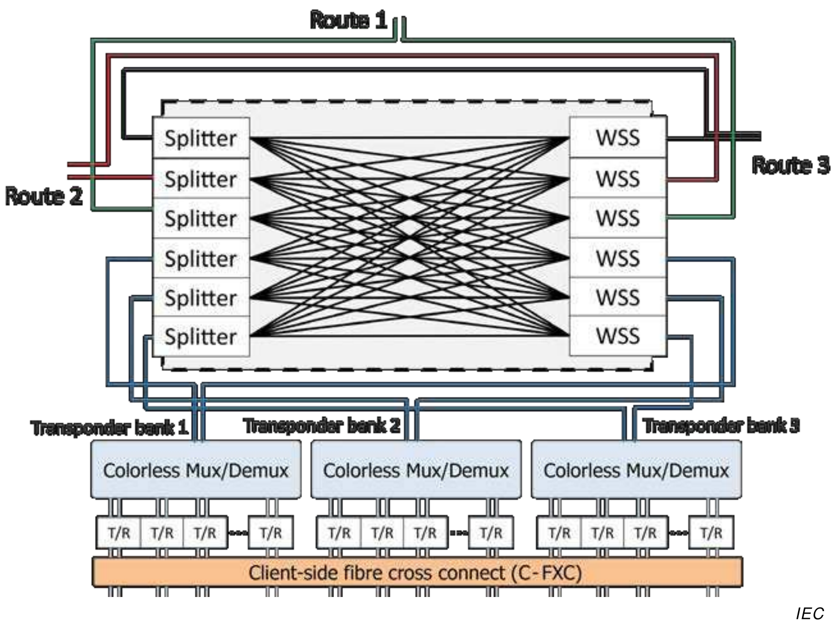

Figure 7 – 3-degree ROADM node with colourless, non-directional add/drop ports

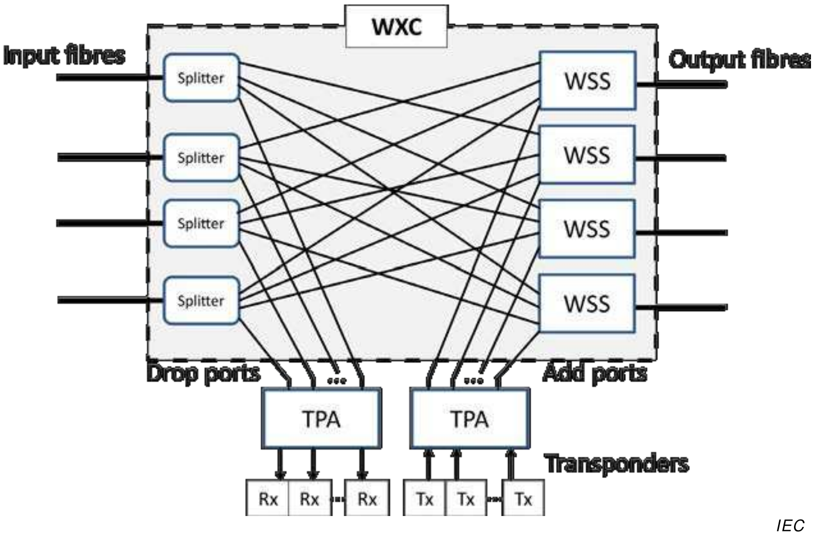

Figure 8 – Compact PLC-based transponder aggregator for colourless and directionless ROADM

8 Conclusion

Individual control of each of these dynamic modules and network devices by using a network control plane is necessary to realize high-performance node systems with a unified signal or disaggregated signal implementations. This document explained the conceptual definition of an intermediate controller that controls multiple dynamic modules and network devices along with technical trends.

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