Open Networking Foundation

Core Information Model (CoreModel)

TR-512.A.4
Appendix – Analogue and Media Examples (Layer 0)

Version 1.6

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Disclaimer

Open Networking Foundation
1000 El Camino Real, Suite 100, Menlo Park, CA 94025
www.opennetworking.org

Important note

This Technical Recommendations has been approved by the Project TST, but has not been approved by the ONF board. This Technical Recommendation is an update to a previously released TR specification, but it has been approved under the ONF publishing guidelines for 'Informational' publications that allow Project technical steering teams (TSTs) to authorize publication of Informational documents. The designation of '-info' at the end of the document ID also reflects that the project team (not the ONF board) approved this TR.

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Document History

Version	Date	Description of Change
		Appendix material was not published prior to Version 1.3
1.3	September 2017	Version 1.3 [Published via wiki only]
1.3.1	January 2018	Addition of text related to approval status.
1.4	November 2018	Additions of network views using LTP.
1.5	September 2021	Enhancements to model structure

Version	Date	Description of Change
1.6	January 2024	Enhancement of the description of point to point and multi-pointed media channels. Updates to sections 4.4.9 and 4.4.9.1, replacement of section 4.4.9.2, delete of section 4.4.9.3

1 Introduction to the document suite

This document is an appendix of the addendum to the TR-512 ONF Core Information Model and forms part of the description of the ONF-CIM. For general overview material and references to the other parts refer to TR-512.1.

1.1 References

For a full list of references see TR-512.1.

1.2 Definitions

For a full list of definition see TR-512.1.

1.3 Conventions

See TR-512.1 for an explanation of:

- UML conventions
- Lifecycle Stereotypes
- Diagram symbol set

1.4 Viewing UML diagrams

Some of the UML diagrams are very dense. To view them either zoom (sometimes to 400%) or open the associated image file (and zoom appropriately) or open the corresponding UML diagram via Papyrus (for each figure with a UML diagram the UML model diagram name is provided under the figure or within the figure).

1.5 Understanding the figures

Figures showing fragments of the model using standard UML symbols and also figures illustrating application of the model are provided throughout this document. Many of the application-oriented figures also provide UML class diagrams for the corresponding model fragments (see TR-512.1 for diagram symbol sets). All UML diagrams depict a subset of the relationships between the classes, such as inheritance (i.e. specialization), association relationships (such as aggregation and composition), and conditional features or capabilities. Some UML diagrams also show further details of the individual classes, such as their attributes and the data types used by the attributes.

1.6 Appendix Overview

This document is part of the Appendix to TR-512. An overview of the Appendix is provided in TR-512.A.1.

2 Introduction to this Appendix document

This document provides various examples of the use of the CIM to model analogue and media structures.

The examples in this document are built from descriptions in other documents. The media examples are supported by a combination of the FC/LTP (as described in TR-512.2), the physical model (as described in TR-512.6) and the specification model (as described in TR-512.7).

Each case discussed in this document will be supported by FC specs, LTP specs and scheme specs. Most cases do not explicitly show the scheme spec but have been described using the base classes (FC, LTP etc.) from which the scheme spec can be derived.

3 Optical Media

The network model required to support media is discussed in TR-512.2. The symbol set used in this section is explained in the "Key to diagram symbol set" section in TR-512.1.

This document provides examples of usage of the network model to represent various photonic media functions and devices. For each example detailed stylized layouts of functions that are used to drive FD, FC, LTP and scheme spec are provided along with the resulting simple compact representation.

It is intended that sufficient stylized cases are covered here to allow a modeler to represent their specific function/device. It is not intended that all possible cases are covered.

The spec models provide detail to allow interpretation of the properties compacted into the simplified model and hence allow faults to be diagnosed. The figures in this document are essentially pictorial views of specs.

3.1 The basic components of the mode

3.1.1 The basic attenuator and filter

The following figure shows symbols for the basic attenuator and filter. Attenuators and filters are inherently omnidirectional.

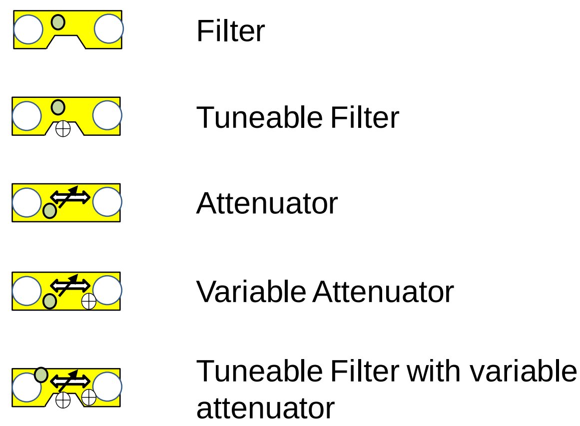

Figure 3-1 Attenuator and Filter (explaining the symbol set)

The filter models the ability to allow only those photons that are within a defined portion of spectrum to be passed. The filter is described as a media channel and is represented by an FC.

The portion of the spectrum is called a frequency slot and is described by centre frequency and width. Frequency slot is an administrative concept and is conceptually square. The actual pass-band of the filter is not square. The frequency slot and pass band relationship is challenging and not covered here.

A single port of a filter can support more than one media channels (see later).

As the filter is represented by an FC the characteristics are expressed in an FcSpec (see TR-512.7).

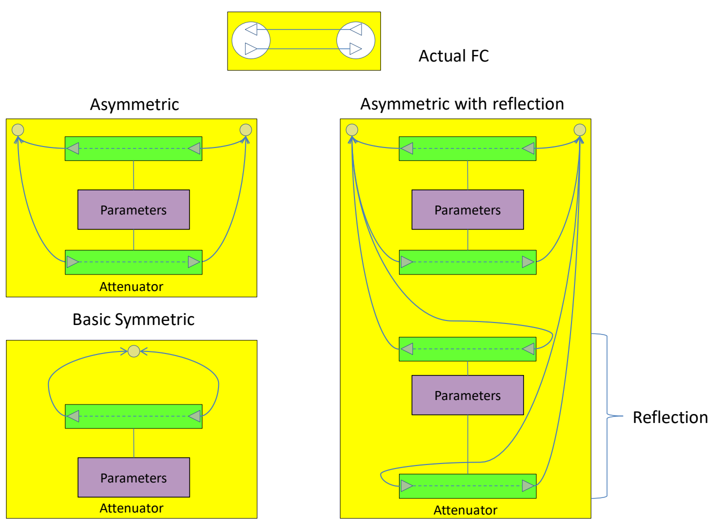

Figure 3-2 Pictorial view of example spec model for attenuator

The figure shows the two port FC along with three spec forms:

- Asymmetric: This allows the parameters for both directions of flow to be different. This is the easiest form to read and is recommended even when the device is symmetric
- Basic Symmetric: Appropriate where the device has exactly the same effect on both flows and there is no independent control of the flows. The current rule for an FcSpec of this form is that there is no flow from a port to itself so this does not readily allow reflection characteristics to be expressed (the FcSpec rule would need to become flexible per flow expression)
- Asymmetric with reflection: Shows a long hand form of the spec. Note that this is relatively verbose for a two port device. For a multi-port device, explicit expression seems particularly verbose and a more compact form of expression would be beneficial.

The parameter blocks in the spec provide invariant and adjustable values. Any aging characteristics could be stated in the parameter blocks.

For a complex filter with different characteristics per "band" the spec could either code the complexity in an expression or show separate "flows" (green) per "band". It is also possible to have a filter instance per "band".

The model (and symbol set) allows for a variable attenuator.

3.1.2 Coupler-Splitter

The following figure shows basic coupler/splitters. Coupler-splitters are inherently omnidirectional.

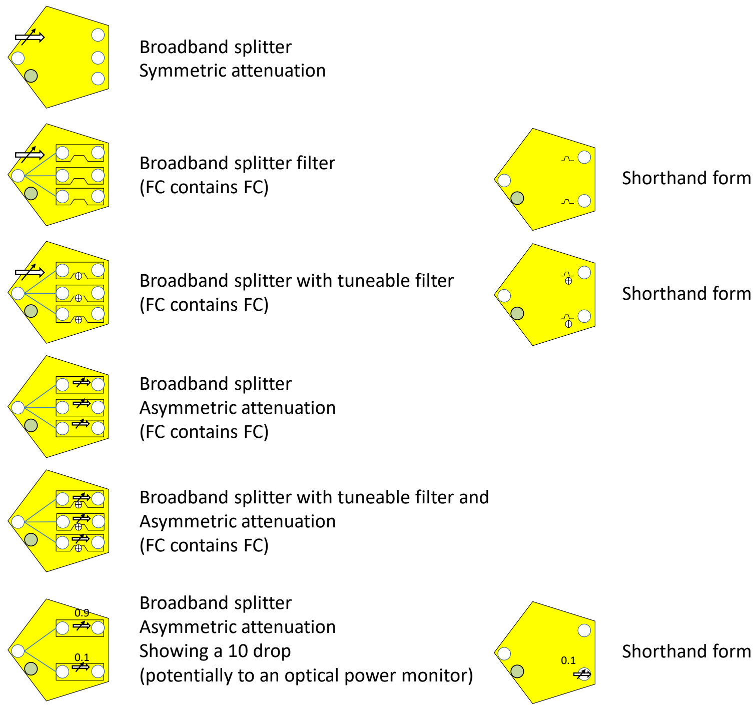

Figure 3-3 Various Coupler/Splitter examples

The Coupler/Splitter provides a set of atomic media channels between one (common) port and two or more other (branch) ports. All of these atomic media channels have the same frequency slot. In the root to leaf direction the "splitter" attenuates the signal, in the leaf to root direction the "coupler" has negligible attenuation.

3.1.3 The circulator

The circulator is a media component that takes advantage of non-linear characteristics to essentially provide a unidirectional flow. A circulator is shown in the figure below.

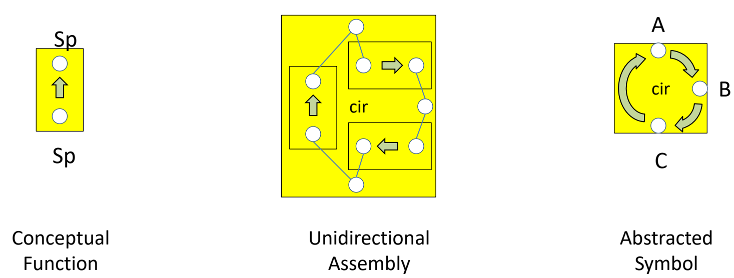

Figure 3-4 The circulator

In the circulator depicted, photons that arrive at FcPort A will emerge from FcPort B, photons that arrive at FcPort B will emerge at FcPort C and photons that arrive at FcPort C will emerge from FcPort A.

3.1.4 The photodiode

The photodiode is a media component that converts a photonic signal (in a frequency slot) to an electrical signal. Both the signal domain and the media change (the domain changes from photonic to electrical and the media from glass to copper (via various intermediate media))[1]. There is a media channel from the Sp to the converter (an adaptation) and a different media channel from the converter to the Se, however it is the domain change that is emphasized by the adapter symbol rather than the media change (as the physical layer is only modeled in abstract). The third symbol shows media transition. The assumption is that the FC is essentially electrical and the element that is not is exposed as an embedded FC with some fiber specification.

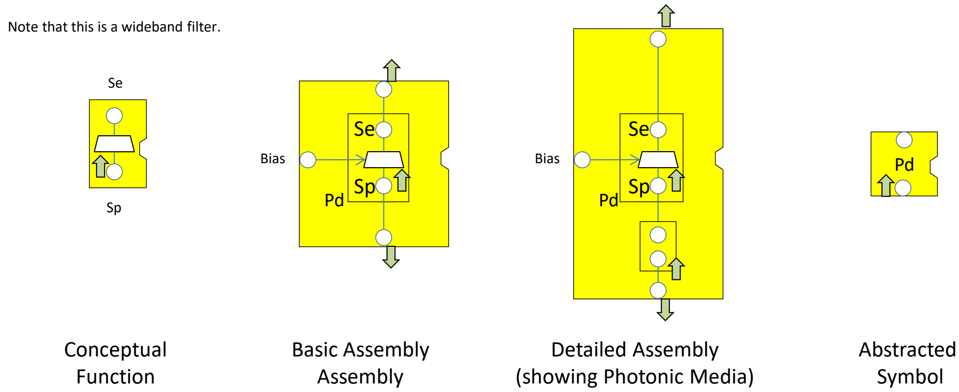

Figure 3-5 Photodiode as an active element (showing media)

The figure below shows the spec model for the Photodiode highlighting:

- The media specification
- The LTP spec representing the transformation from optical to electrical
- A specification of the reflection characteristics.

The bias signal is not supported at this stage.

[1] It was concluded that it was not helpful to indicate media change. The key information relates to domain change. In detail, there are at least four media here and probably more. Fiber to p-type to n-type to copper. This complexity does not add value.

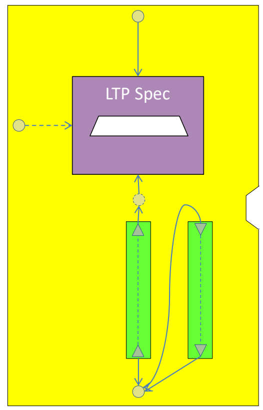

Figure 3-6 Pictorial view of example spec model for Photodiode

The figure below shows a photodiode in the context of an LP. The photodiode may be used for extracting signal or for power measurement. The optical power monitor measures the power of any optical signals that are present in a media channel.

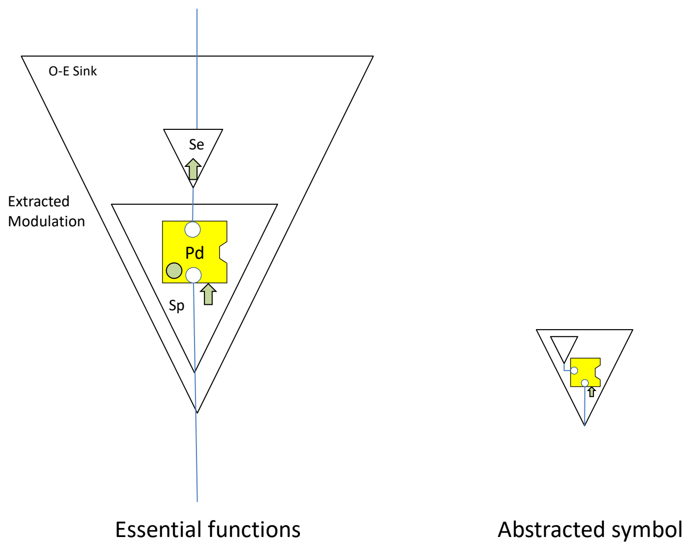

Figure 3-7 Photodiode as an active element showing power monitor

3.2 Complex assemblies

3.2.1 The Laser

The laser is a media component that takes advantage of non-linear characteristics to essentially convert an electrical signal to a photonic signal (with a narrow spectrum).

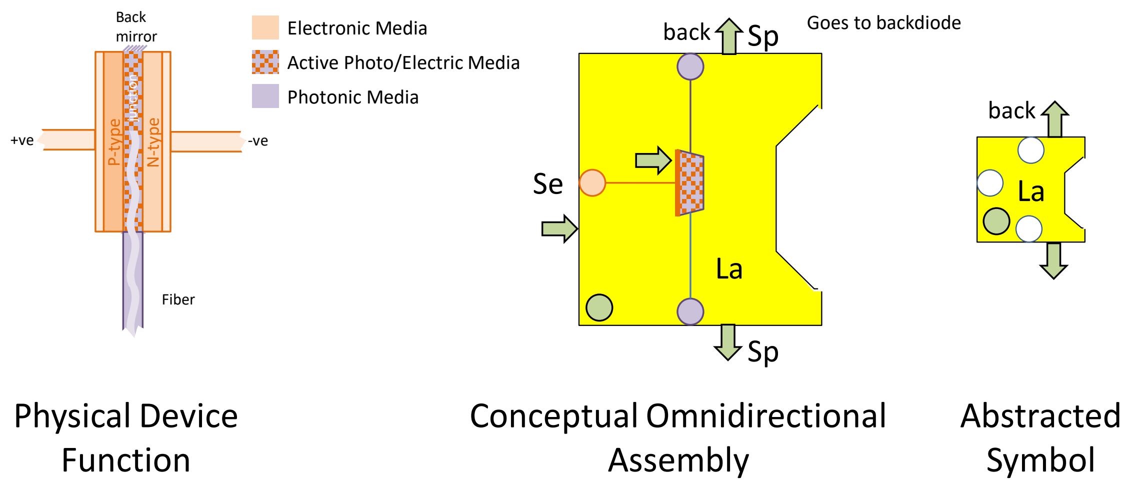

Figure 3-8 Laser as an active elements (showing media)

The lasing medium at the junction between two semiconducting mediums, when stimulated with an electrical signal produces an equivalent photon signal. In the actual implementation the photons emerge at two facets. The "back" facet photon stream is used to measure the output of the laser. The measurement is fed to a control function that adjusts the electrical input to the laser.

The Laser with back diode is shown in the context of the E-O Source LP.

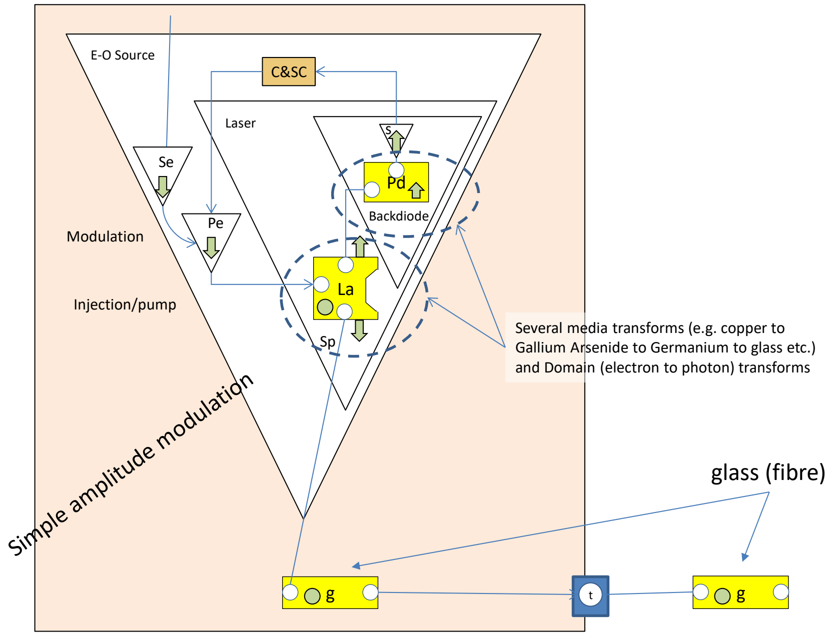

Figure 3-9 Laser as an active element (showing media)

The spec for the E-O Source explains the arrangement of functions and provides a mapping to the E-O LP instance and content. From the figure it can be seen that the LP includes two Terminations an adapter, two FCs and a C&SC. The two FCs can be merged and the spec for the LP then looks as in the figure below.

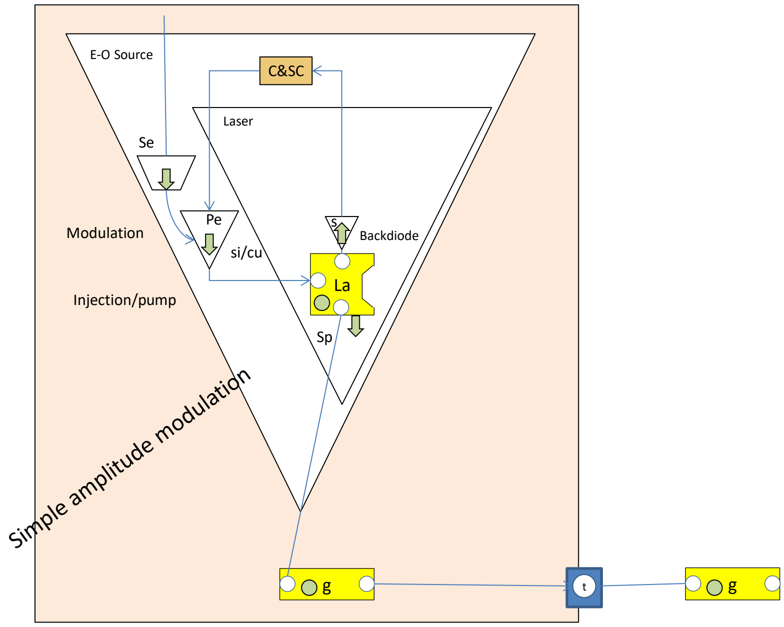

Figure 3-10 Spec for Laser

A compact view of the media E-O LP is shown in the diagram below[2].

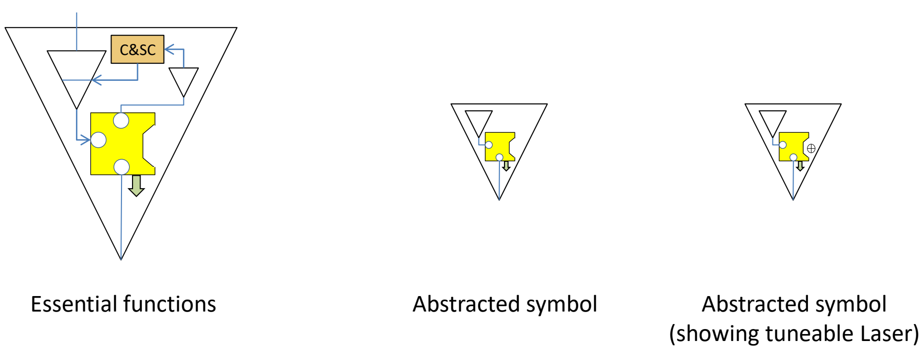

Figure 3-11 Essential functions of a laser and abstracted symbol for a laser

An alternative construction of a photonic transmitter is shown in the figure below. In this case, rather than an output that is amplitude modulated with the signal, the output is phase modulated or amplitude modulated (or both) by an external device. In this case the electrical signal carrying the information is applied to the external modulator and the laser produces a constant power output.

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[2] The structures shown here and throughout this document need to be described in LTP and FC specs (see TR-512.7). The actual spec forms will be developed in the next release.

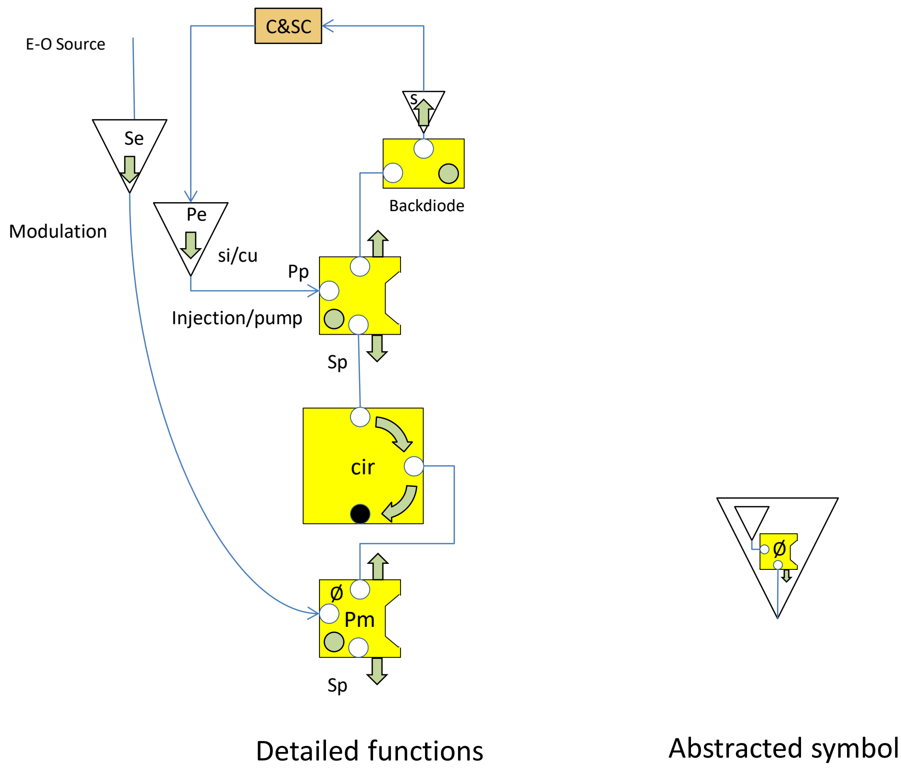

Figure 3-12 Sketch of phase modulated output

3.2.2 The coherent receiver

The figure below shows the simplified view of a coherent receiver with Digital Signal Processing (DSP)[3]. A coherent receiver uses a heterodyne detector to convert the information carried by the photons into a "baseband" electrical signal that is then processed by DSP to correct for impairments introduced by the network domain channel. The abstracted symbol encapsulates the frequency tuning aspects and the DSP in the FC but separates out a termination to deal with the optical to electrical conversion. The symbol is not an accurate depiction of the actual processing but it allows for a more consistent representation from a management-control perspective.

[3] This model will potentially need enhancement when SD FEC (Soft Decision Forward Error Correction) is included.

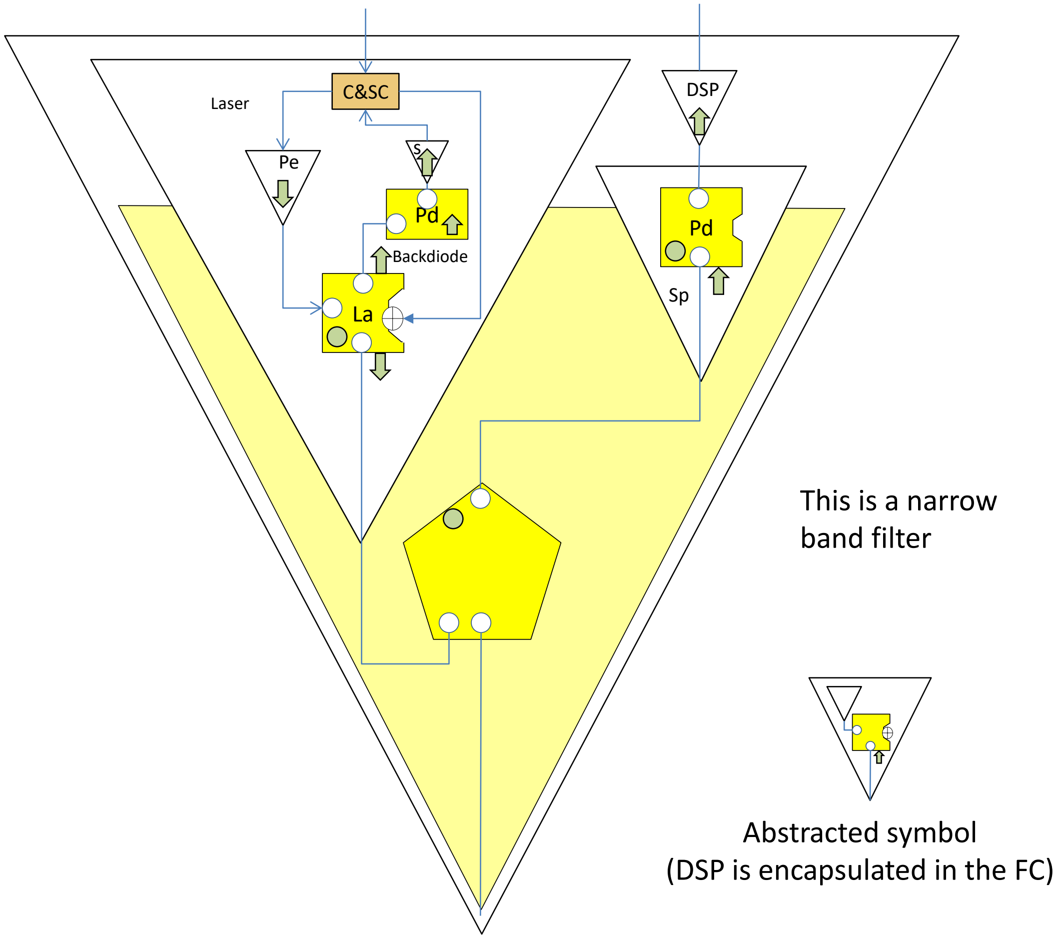

Figure 3-13 Coherent receiver assembly with simplified symbol

3.3 Network considerations

This section provides views of the basic elements described in the previous section combined into network constructs.

3.3.1 The Media Channel and Information Transfer

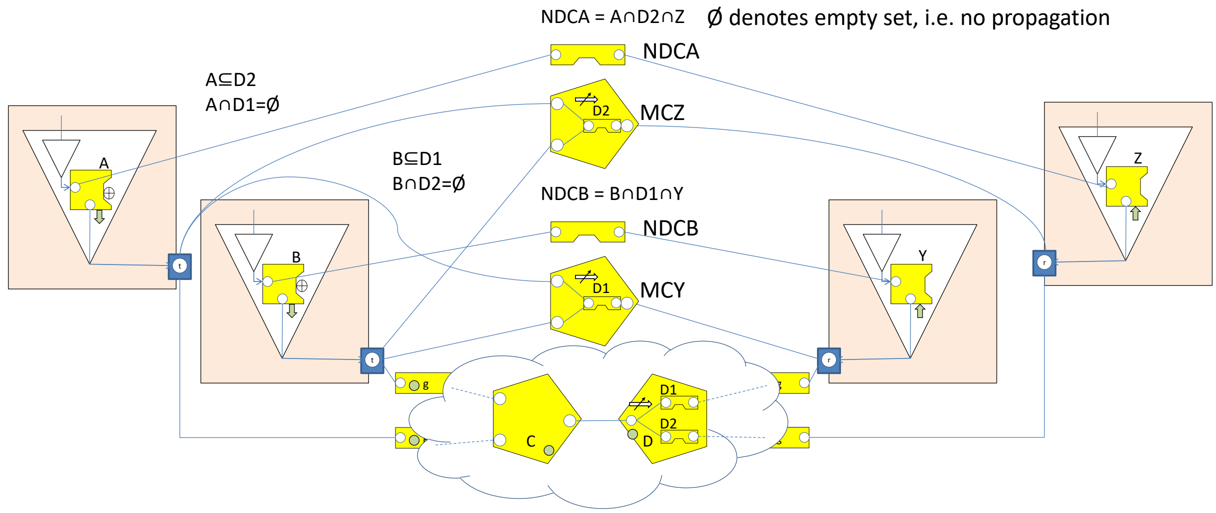

Figure 3-14 Network Domain Channel formed from Media Channels

In this document the Network Domain Channel (the FCs NDCA and NDCB) is considered as being from the point of injection of electrons into the laser medium or external modulator to the point of emergence of electrons from the photodiode[4]. The NDCs shown are formed as a result of the effects of the filters in the coupler C and splitter D which are reflected in the Media Channels MCY and MCZ (both of which are FCs with three FcPorts). It is not until the lasers A and B are applied to the MCY and MCZ that the effective NDCs can be determined. In the figure, Y and Z are wide band receivers. If A and B were tuned such that A⊆D1 (and hence A∩D2=Ø) and B⊆D2(and hence B∩D1=Ø) then NDCA would go from A to Y and NDCB from B to Z.

The figure below shows a basic consideration of information transfer. For the broad band receiver, the information transfer capability is dictated by the NDC. The Information Transfer Channel (ITC), in this case, has the same essential span as the NDC.

[4] Network Domain Channel is used in this document to define the "end to end" span of potentially mixed media that can carry a signal of a particular domain (the domain of electrons or the domain of photons). For example it is defined from the point at which electrons are converted to (modulated) photons to the point where the information carried by the photons is converted to electrons. The term Network Media Channel is not used in this document. An NMC is an MC that spans from the output of a laser to the input of a photo diode. It is potentially mixed media. The MCY and MCZ in the diagram are essentially Network Media Channels. This designation is not helpful in understanding the model or the application.

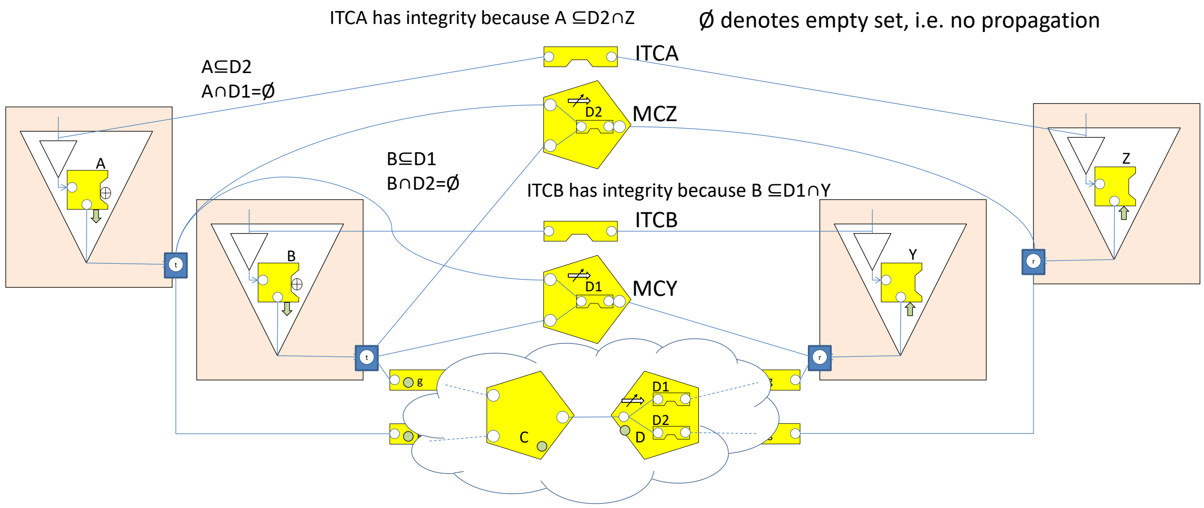

Figure 3-15 Information Transfer Channel formed from Media Channels for broadband receiver

The figure below shows MCZ and MCY are transparent. The ability to transfer information is dictated by setting of the tunable laser, the setting of the hetrodyne detector and the capabilities of the receiver DSP. These settings in combination define the ITC. The figure provides a somewhat simplified representation of the information transfer capability.

The ITC is defined between the point just prior to encoding the information onto the electrical signal that modulates the photon stream and the point just after the extraction of the information from the decoded electrical signal demodulated from the photonic stream.

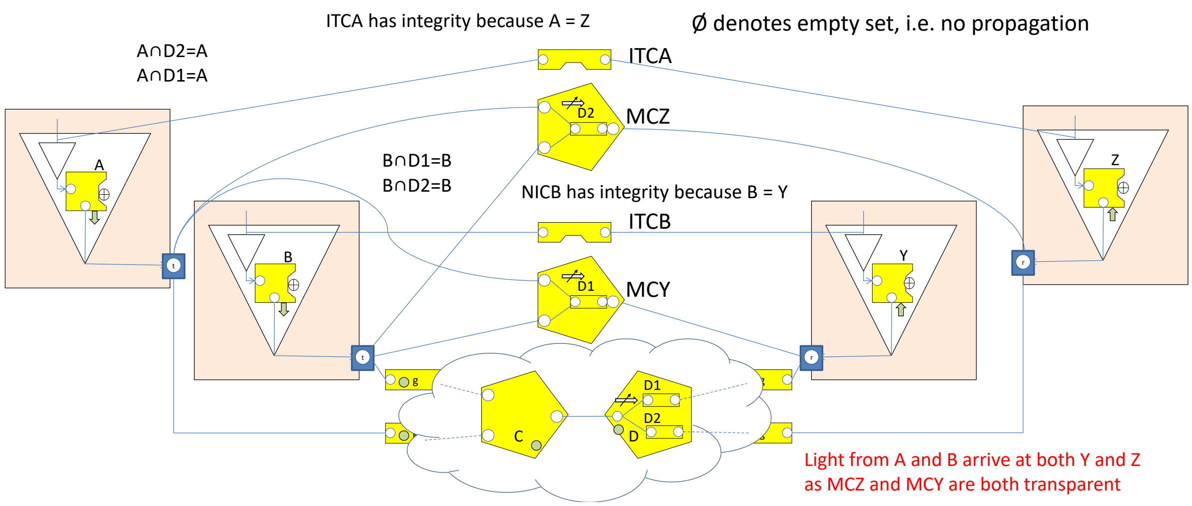

Figure 3-16 Information Transfer Channel formed from Media Channels for coherent receiver

3.3.2 The amplifier

Amplification is achieved using non-linear characteristics of fiber. The optical amplifier acts on a band of frequencies to increase the optical power level.

3.3.2.1 General considerations

The abstract symbol for an amplifier element is shown in the figure below.

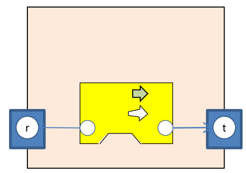

Figure 3-17 Abstract symbol for an amplifier

The abstract symbol can be used to represent an amplifier where a detailed consideration is not relevant. In a simplified view the gain parameters are parameters of the FC and the input and output power measures are parameters of the FcPorts. The spec model set provides the mapping from the parameters in the simplified view and the detailed interpretable view.

Where the amplifier provides different amplification for different bands/slots a number of instances of the symbol can be used as shown below. Where control/monitoring is relevant parameters can be offered on a per amplifier FC or FcPort basis as appropriate.

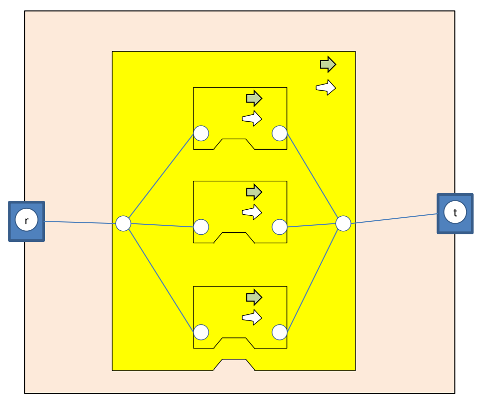

Figure 3-18 Abstract Symbol for a multi-band/slot amplifier

For more complex cases a more detailed model will be required. The following sections detail different application methods.

3.3.2.2 Erbium Doped Fiber Amplifier (EDFA)

This amplifier uses a short length of fiber doped with Erbium as the non-linear element that is fed at one or more points by pump lasers of specific frequency. This combination causes power transfer to a set of signals in some spectrum that arrive at the input side of the amplifier. The EDFA is unidirectional.

The following figure shows a stylized view of an EDFA with one forward (co-directional) pump laser and fragment of control (including measurement of one band of incoming/outgoing signal only). In a full form, many bands may be measured, there may be many pumps in an amplifier and there may be two or more amplifiers in parallel amplifying different bands (e.g. L band and C band[5]).

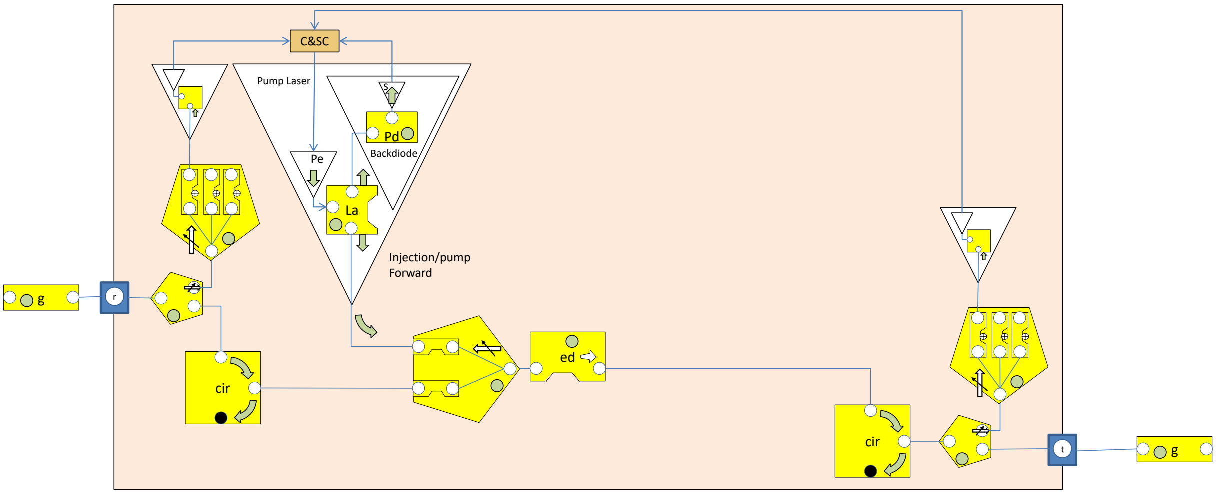

Figure 3-19 A stylized view of a fragment of an EDFA

The essential function of the amplifier is to provide balanced amplification to all relevant incoming signals. To enable interpretation of the measures and adjustment of the controls a suitably detailed spec model should be provided. The spec model should show necessary detail such that the effects of each control and the meaning of each measure can be interpreted. Certain elements of the EDFA (such as the circulators) are not relevant from this perspective. The spec may represent the amplifier as a set of parallel per band amplifiers from this perspective.

Considering fault analysis, it may be necessary to represent the amplifier in more precise detail especially where the amplifier is constructed from a number of separate field replaceable units.

It is likely that several related spec models will be necessary in the most complex case[6].

The following figure shows a fragment of a model of an EDFA with a backward pump.

[5] See https://en.wikipedia.org/wiki/Wavelength-division_multiplexing

[6] Sufficient detail is required in the spec of the amplifier to allow interpretation of the detected conditions. The detail will in part depend upon the FRU structure of the amplifier. The model approach is intended to be suitable for use by the controller that interfaces directly to the optical components, i.e. where there is no lower level controller abstraction and/or analyzing/interpreting the detectors.

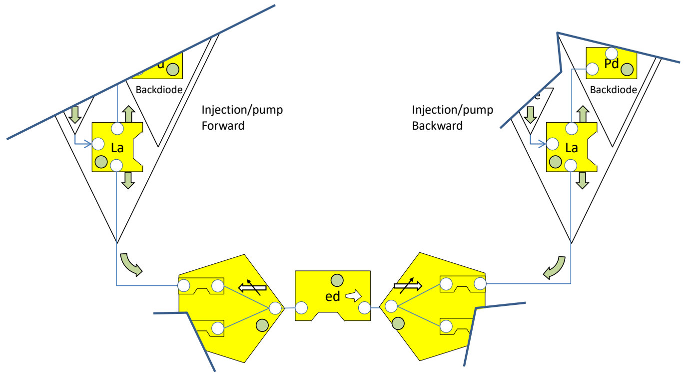

Figure 3-20 A further fragment of an EDFA with a forward and a backward pump

3.3.3 Amplification using the Raman effect

The following figure shows a stylized view of a Raman amplifier. The amplifier uses the main transmission fiber as the amplification element. Various other filters and monitors may be present in full representation.

As for the EDFA there may be a need for several related spec models to provide views for different purposes.

A simplified view may use the amplifier symbol in the figure above or amplification can be shown on the FC for the transmission fiber (as in the figure below).

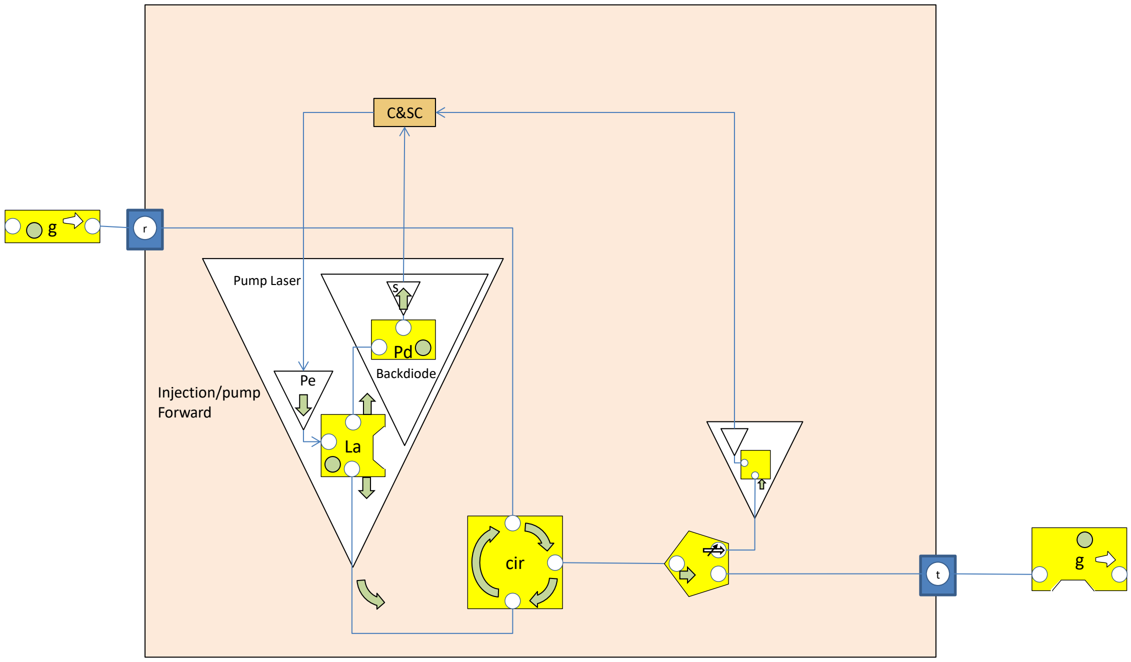

Figure 3-21 Stylized model view of a Raman amplifier

3.3.4 Optical Time Domain Reflectometer (OTDR)

The following figure shows a somewhat simplified representation of an OTDR. The laser fires pulses via the circulator (top) into the fiber (right) and reflections are collected from the fiber (right) via the circulator (bottom) and fed to the detector of single photons (indicated by the "1"). The single photons are counted over time and the results analyzed to provide a view of the lengthwise characteristics of the fiber.

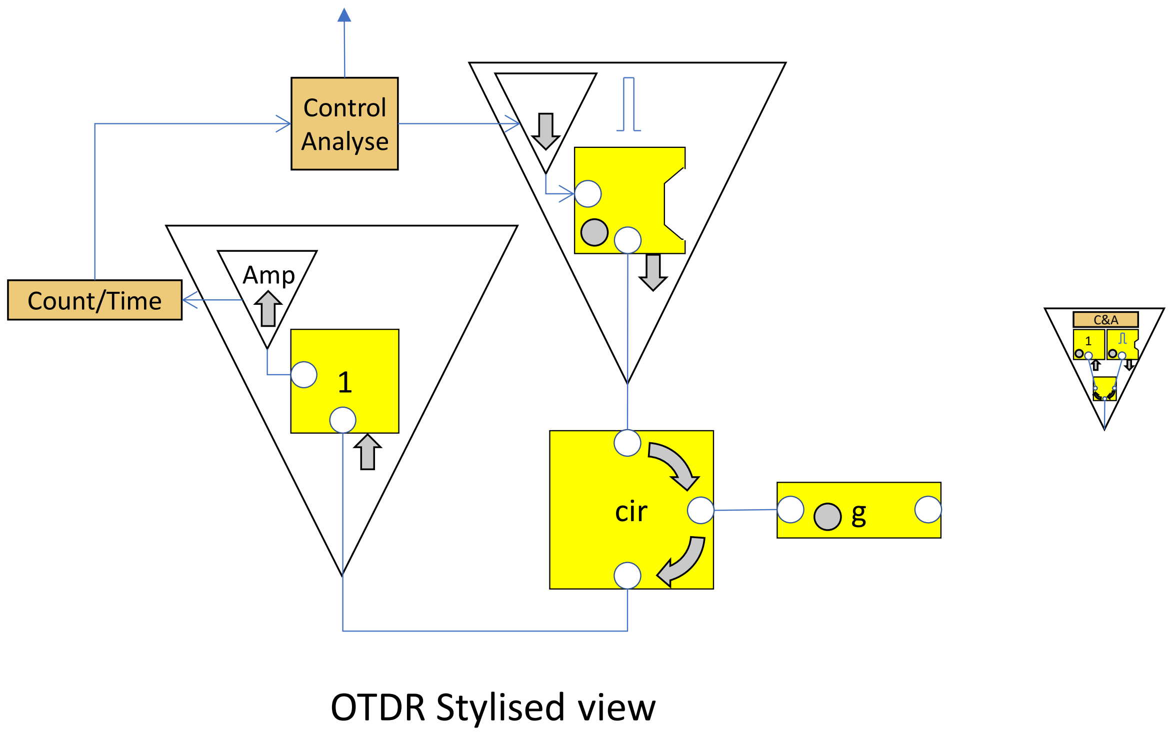

Figure 3-22 Stylized model view of an OTDR

3.3.5 Spectrum Analyzer

The following figure shows a somewhat simplified representation of spectrum analyzer. The coherent receiver is designed to be narrow band and to sweep across the spectrum. The DSP and analysis result in a measure of the spectral characteristics of the light in the channel.

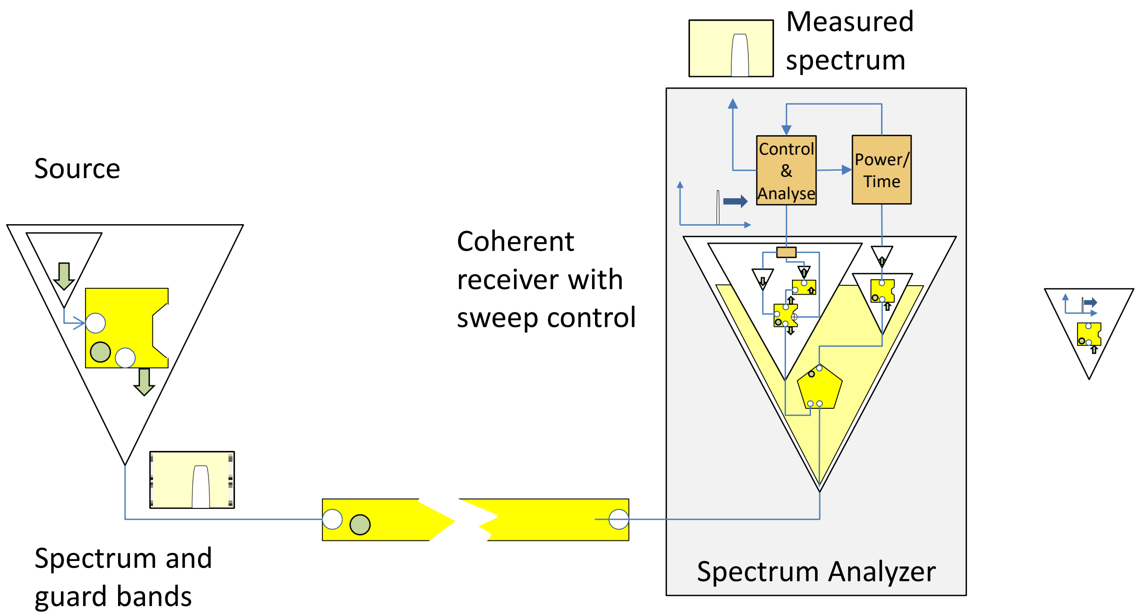

Figure 3-23 Stylized model view of a spectrum analyser

An alternative, potentially more likely, approach is to use a narrow band tunable filter in front of a wide band optical power detector and sweep the spectrum by tuning the filter.

4 Monitoring and Overhead (based on [ITU-T G.872])

4.1 Overview

This section deals with the monitoring of sections of a photonic network. The model is derived from representations in [ITU-T G.872]. The two subsections provide an overview of the basic monitoring capabilities in the context of the ITU-T work and introduce the OMS, OTS and OTSiG-O. Then further subsections explain how the monitoring is factored into the ONF Core model.

4.2 OMS and OTS

The following figure shows a fragment of topology positioning the OMS and OTS with respect the photonic and electronic components. The OMS and OTS spans are defined by the position of the respective OSME spans. The OSC carries signals that have the characteristic information of "overhead" where there is overhead related to the OTS OSME and the OMS OSME.

As the figure shows, the OMS and OTS span define abstract demarcations in the payload carrying photonic signal. The photonic signal shape that crosses the OMS boundary entering the OMS span is not relevantly different, assuming that the amplifier is working well, from that that crosses the OTS boundary entering the OTS span and is not relevantly different from the signal shape that crosses the OTS boundary exiting the OTS span and that crosses the OMS boundary exiting the OMS span.

If there is no amplification, the OMS and the OTS are coincident.

The figure includes three diagrams. The detailed view shows a layout of components (each component view is itself simplified). The measures in the detailed view can be projected to the corresponding points in the simplified view. A set of scheme spec would explain the relationship between the simplified view and the detailed view (and clearly further spec would explain the measures on each component in terms of further detail).

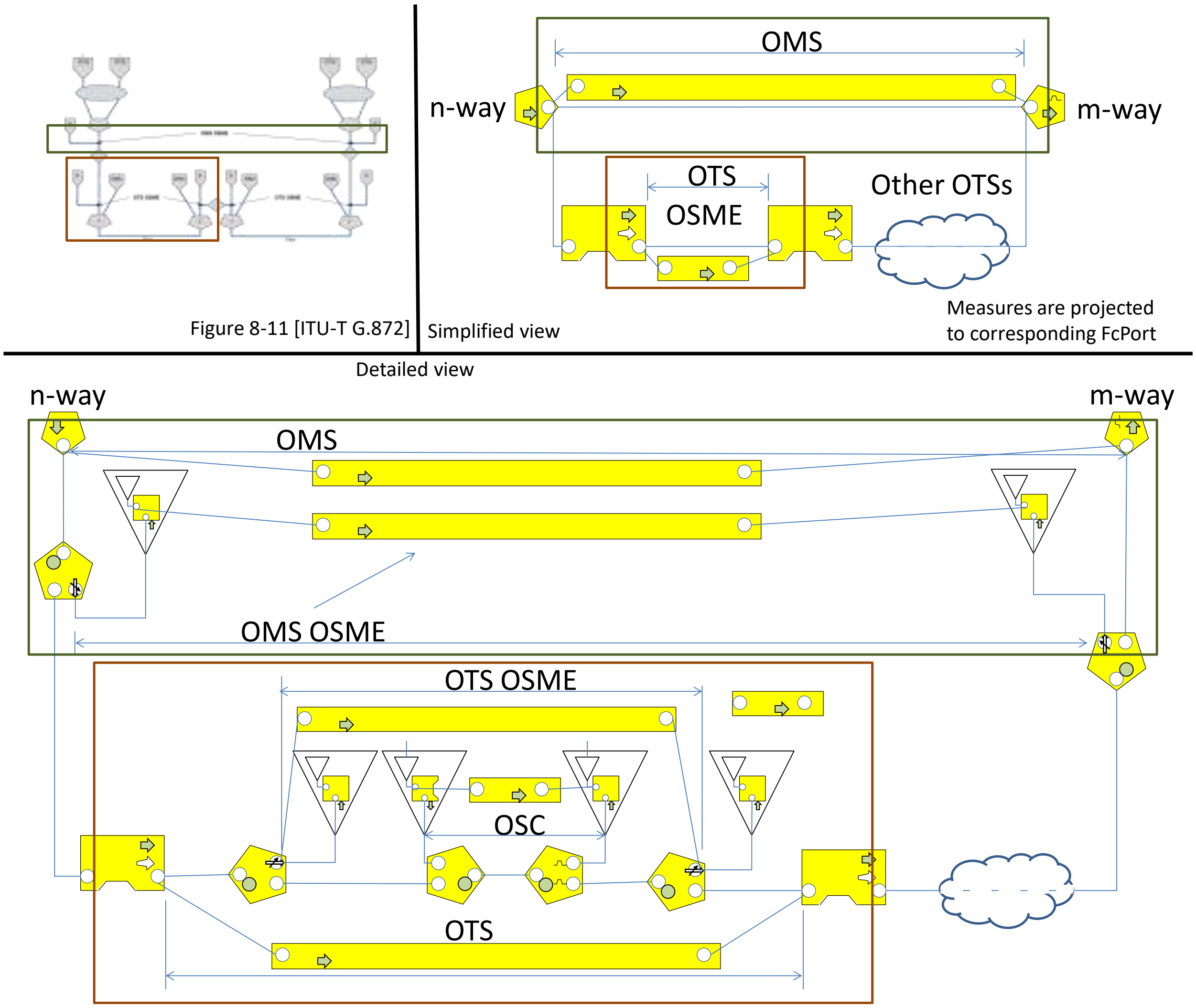

Figure 4-1 Topology fragment showing OTS in detail and OMS in abstract (assuming EDFA)

The OMS information is conveyed via the OSC. The OSC terminates for each OTS span and hence the OMS information needs to be propagated between OSCs at the points of OTS termination. This detail is not shown but would be explicitly modeled in the relevant specs (essentially simple forwarding). Bidirectional considerations of the OMS, OTS and OSC are not covered here.

Note that the OTS monitors shown in the figure above will probably be the monitors of the amplifier itself and hence the OTS OSME will extend between the output port and the input of the amplifiers as show in the simplified view such that the OTS and OTS OSME become coincident.

The OTS, OTS OSME, OMS and OMS OSME are represented by FCs. OTS FC is between the output of one amplifier and the input of the next. The OMS FC is between a point of aggregation and a point of disaggregation.

The Optical Supervisory Channel is essentially an NDC and is represented by an FC.

4.3 OTSi in context of OTU, OMS-O and OTS-O

The following figure provides a detailed view of the representation of the LTPs and FCs that could represent OTU mapping onto media based upon a simple interpretation of the ITU-T figures.

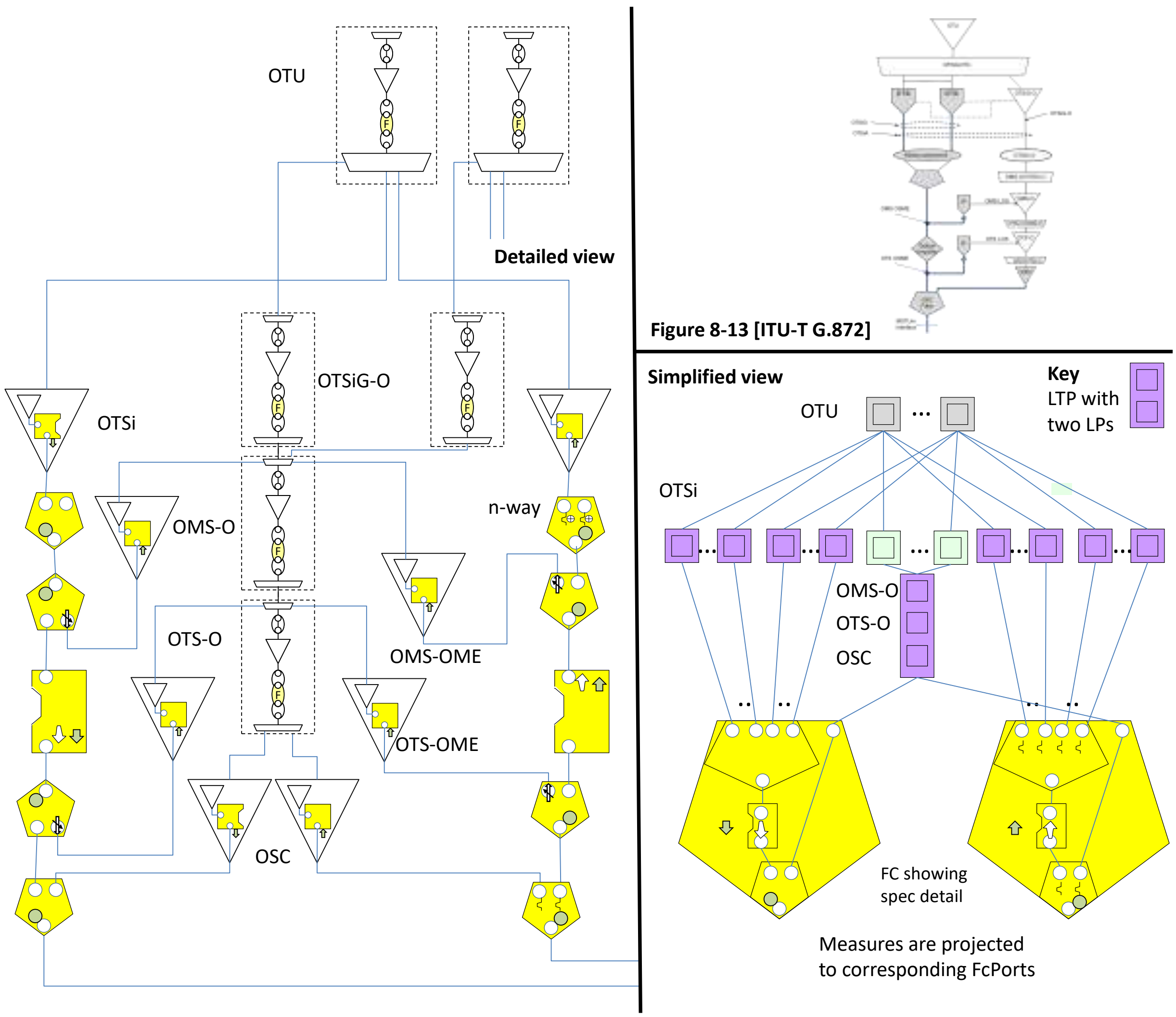

Figure 4-2 OTSi in context of OTU, OMS and OTS

The figure shows both the channels and the related overhead and depicts an OTU carried by a set of OTSis where that set is considered as an OTSiG with related overhead, OTSiG-O. The differential delay between members of the OTSiG must be controlled. If the OTSiG-O is used, then all members of the OTSiG and the OSC that carries the OTSiG-O are carried over the same fiber.

However, the approach taken in the figure disassociates the monitoring, overhead and the channel/signal. The model developed in the remainder of the document ensures the appropriate association of channel/signal with its monitors and associated overhead.

4.4 Function blocks and network considerations

The basic photonic structures discussed in the earlier sections are blended with the model of the overhead termination to provide a representation of a ROADM (Reconfigurable Optical Add-Drop Multiplexor) node. The model allows for monitoring of the OTSi at intermediate points. Not all the monitoring opportunities will be present in all devices. The model also supports the opportunity for Tandem monitoring of OTSi which is not currently present in the relevant standards.

The model is first shown with basic photonic parts grouped into LayerProtocol units and then into LTPs. It should be noted that the overhead aspect of the LTPs is layered but the photonic aspect is not layered. The grouping into LTPs is intended to minimize complex coupling between components. It is also designed to simplify the migration from more traditional layered models. It is important to recognize that the photonic aspects of the model are all in one layer, the "photonic media" layer

The discussion starts from the line side of the ROADM.

4.4.1 OTS and amplification

The figure below shows a fragment of a ROADM where the brown background partial rectangle represents the ROADM node boundary. The figure does not show the FRU arrangement.

To the right of the diagram are the two fiber strands (white rectangle in a blue rectangle where the blue rectangle represents the sheath and hence a cable[7]). The strands are terminated by connectors (blue squares) each of which has one pin (the white circle in the blue square)[8].

The connector on a cable plugs into a compatible connector on the equipment (this is shown at the boundary of the ROADM node). This connector has one pin, highlighted, related to the strand and the relevant signal flow. The connector is depicted as having more pins that are not shown.

As the OTS overhead (OTS-O) termination is bidirectional, there are two pins highlighted on the equipment, one for receive (lower) and one for transmit (upper)[9]. The two pins are grouped into a bidirectional AccessPort and this is related to a bidirectional port on a MultipleStrandSpan (see TR-512.6). The MultipleStrandSpan is a physical model abstraction that represents the flow

[7] Each cable is assumed here to have only one fibre.
[8] In some cases, particularly with Raman amplifiers the amplifier pig tail may be spliced directly to the fiber. The model will assume a connector even in the case of direct splicing.
[9] This assumes dual fibre working. In a single fibre working case there would be a single pin.

between AccessPorts. In the figure it represents a bidirectional flow between the AccessPorts on the two ROADM nodes. The MultipleStrandSpan aggregates two serial concatenations of strands between the two adjacent ROADMs (one carrying the signal from left to right and the other from right to left in the diagram).

The pins designated transmit and receive both connect to ports on FCs. The upper FC represents a coupler and the lower a splitter. The coupler takes the light from the OTS-O laser (OSC) along with the main signal (discussed more in following sections) and the splitter separates out the OTSi[10] carrying the OSC (OTS-O) signal from OTSi signals carrying client information.

The OSC transponder is shown as a photonic transmitter and receiver. The transponder portion of the OSC termination then feeds to the OTS-O protocol termination (bidirectional) which has two clients. One of the clients (with the red line emerging) will be discussed in the next section. The other client relates to the monitoring detail.

Returning to the lower part of the diagram, the coupler and splitter discussed above each have to their left a splitter. In each case the splitter takes a small sample of the signal and feeds it to a receiver. The upper splitter samples the outgoing signal (a contra-directional[11] measure equivalent in positioning to the up-MEP) and the lower splitter samples the incoming signal (a co-directional termination equivalent in positioning to a down-MEP). Both samples are terminated and the power, and potentially other optical parameters are measured. The two measures feed to the OTS termination to send to the far end. The monitoring is applied to the OTS-O as a "client" information stream. The expectation is that all OTS related local and remote information will also be available at this point.

In the case where there are monitors but no overhead, the local measures will be folded back into the optical parameter measurements units.

The OTS is essentially a measurement demarcation/span. The main signal is non-intrusively monitored. The transiting signal is not terminated in any way.

[10] Any photonic signal is considered as an OTSi regardless of what it is carrying. So the photonic signal that carries the OSC is considered as an OTSi.
[11] A term used by [TMF MTNM]. Usually signals are assessed as they are demultiplexed etc. entering a device, fabric etc. These measures are considered as co-directional. The assessment of a signal just prior to it being multiplexed etc. to exit a device, fabric is considered as contra-directional.

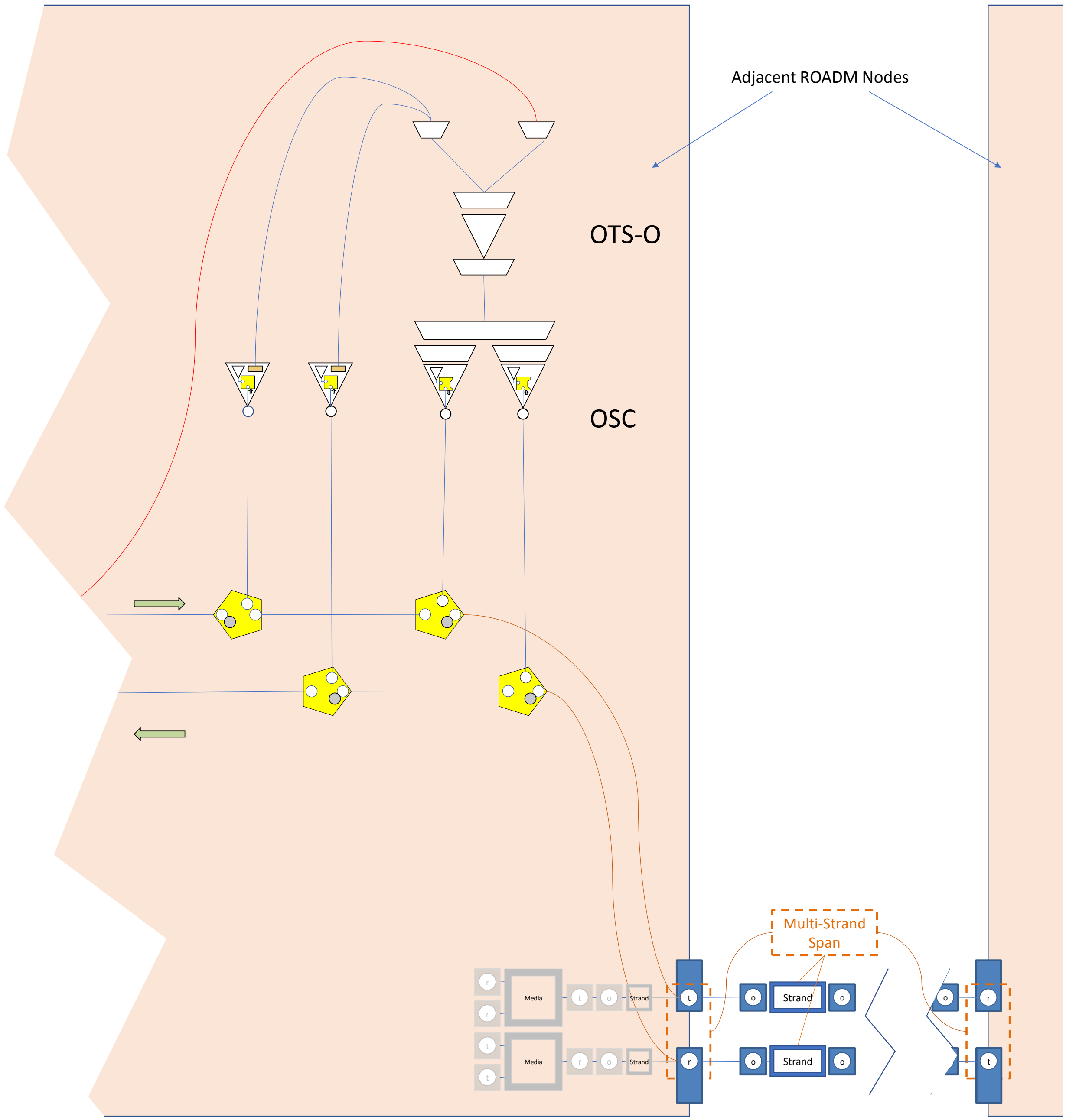

Figure 4-3 OTS showing physical connectors[12]

Considering the physical layer further, inside the node boundary there are potentially many connectors, strands and other media components. A pair of media components are shown in grey attached to the receive and transmit pins of the connectors. This is a very small fragment of the overall structure. The physical structure is considered more in a following section (see section 5 The relationship between functional and physical on page 94).

[12] The Overhead splitters will filter out the overhead light from the main flow. The symbol used in the figure is the simple generalized splitter/couple. This will be updated in a later release.

The figure below groups the various termination and forwarding elements in functional units. As will be seen, these will become LayerProtocols of LTPs. The photonic elements of the OTS termination are grouped in a single bidirectional LayerProtocol. The elements of the two measurement functions, which measure total OTS power, are also grouped into a bidirectional LayerProtocols. The photonic elements of the LayerProtocols are shown as unidirectional connections and terminations. The measurement client is MEASURE_AND_CONTROL layerProtocol and the other client of the OTS_O is OMS_O layerProtocol.

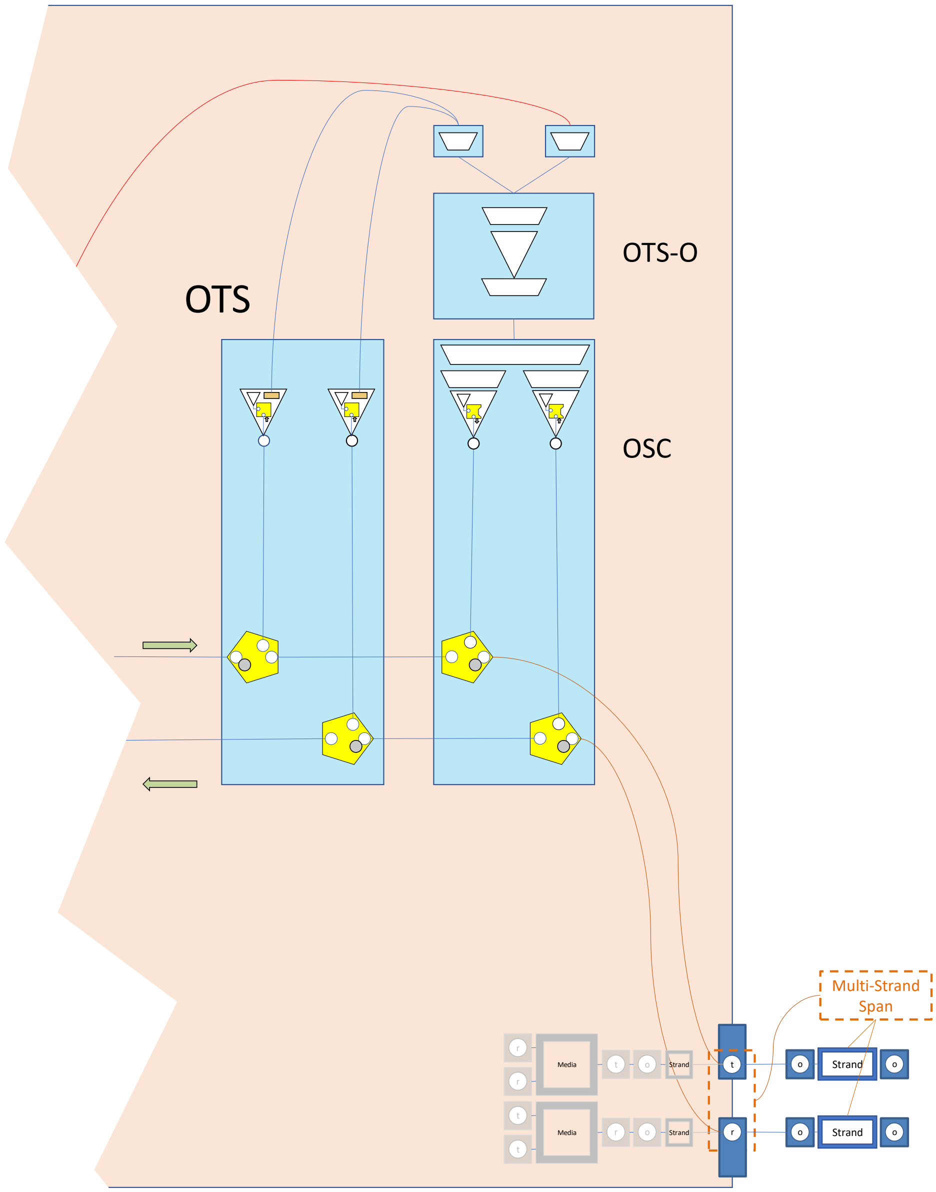

Figure 4-4 OTS[13] showing LayerProtocol groupings[14]

[13] OTS definition in [ITU-T G.872] excludes the OSC signal. To simplify the model, it has been chosen to include the OSC as part of the OTS conglomerate in the ONF model.
[14] LP should strictly be shown with ports. This will be developed further in following releases.

The general justification for grouping is explained in section 4.4.16 Rationale for groupings on page 87. Traditional LayerProtocols have encapsulated equivalent, or even greater, functional complexity, but this has been obscured as that complexity has solely been documented in protocol specifications.

The figure below extends to add the amplifiers. The amplifier is in itself a complex functional component as described in abstract earlier in this document (see 3.3.2 The amplifier on page 23). Depending upon the measures and controls exposed the amplifier may break down into further functional units which can be modelled using LayerProtocol recursion and/the subordinate parts of the LayerProtocol (as set out in the LpSpec). It is assumed in this case that amplification is both in the receive and transmit direction for both L and C band. It is the position of these amplifiers that defines the boundary of the OTS.

The total OTS power measure, highlighted in the figure above, could also be present. This has not been shown in the figure below to reduce clutter.

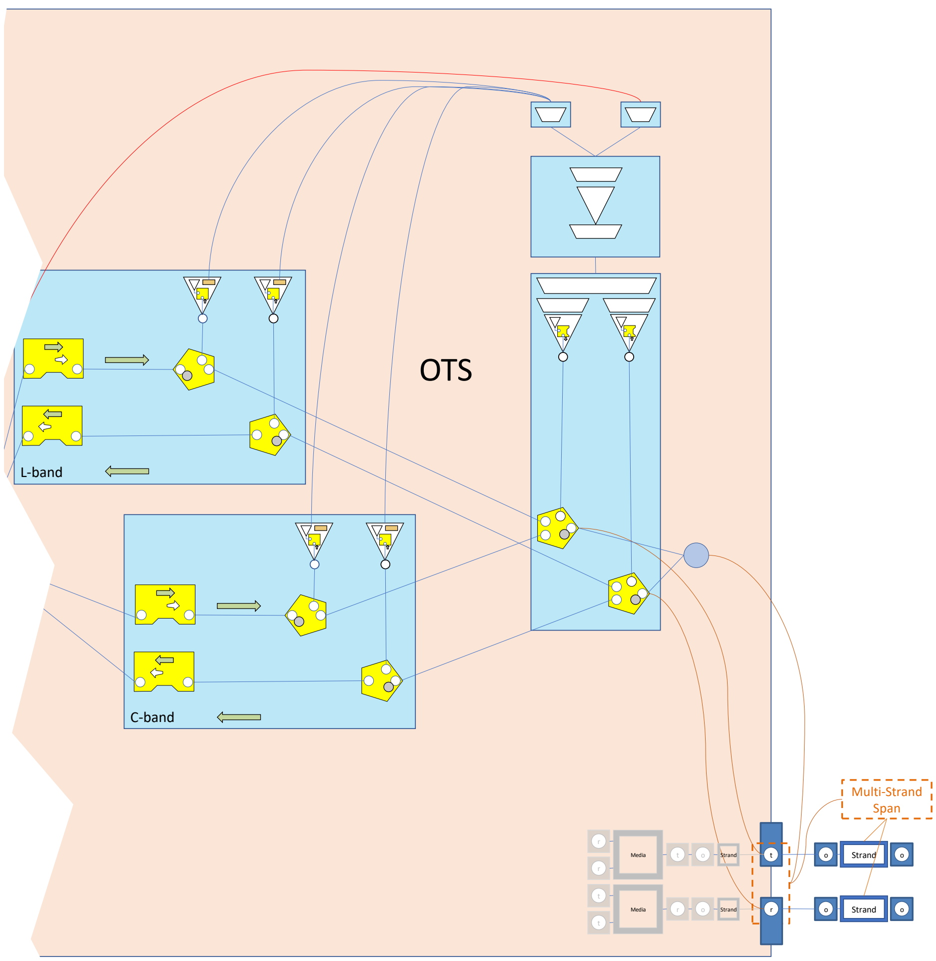

Figure 4-5 OTS with two amplifiers

All of the LayerProtodols are PHOTONIC_MEDIA LayerProtocol entities other than the:

- OTS overhead termination which is an OTS_O LayerProtocol entity

- Right-hand client of the OTS overhead termination which is an OMS_O LayerProtocol entity (which represents the flow of overhead signal)
- Left-hand client of the OTS overhead termination which is a MAINTENANCE LayerProtocol entity (which represents the flow of measurement content (near end measures)).

The figure below shows the assembly, discussed above, encapsulated in an LTP. In the figure above the OSC LayerProtocol entity is shown connected via a single conceptual port, this becomes the port of the LTP in the figure below. The LTP is considered as including the main signal, which is not terminated, along with the measurement points and overhead termination.

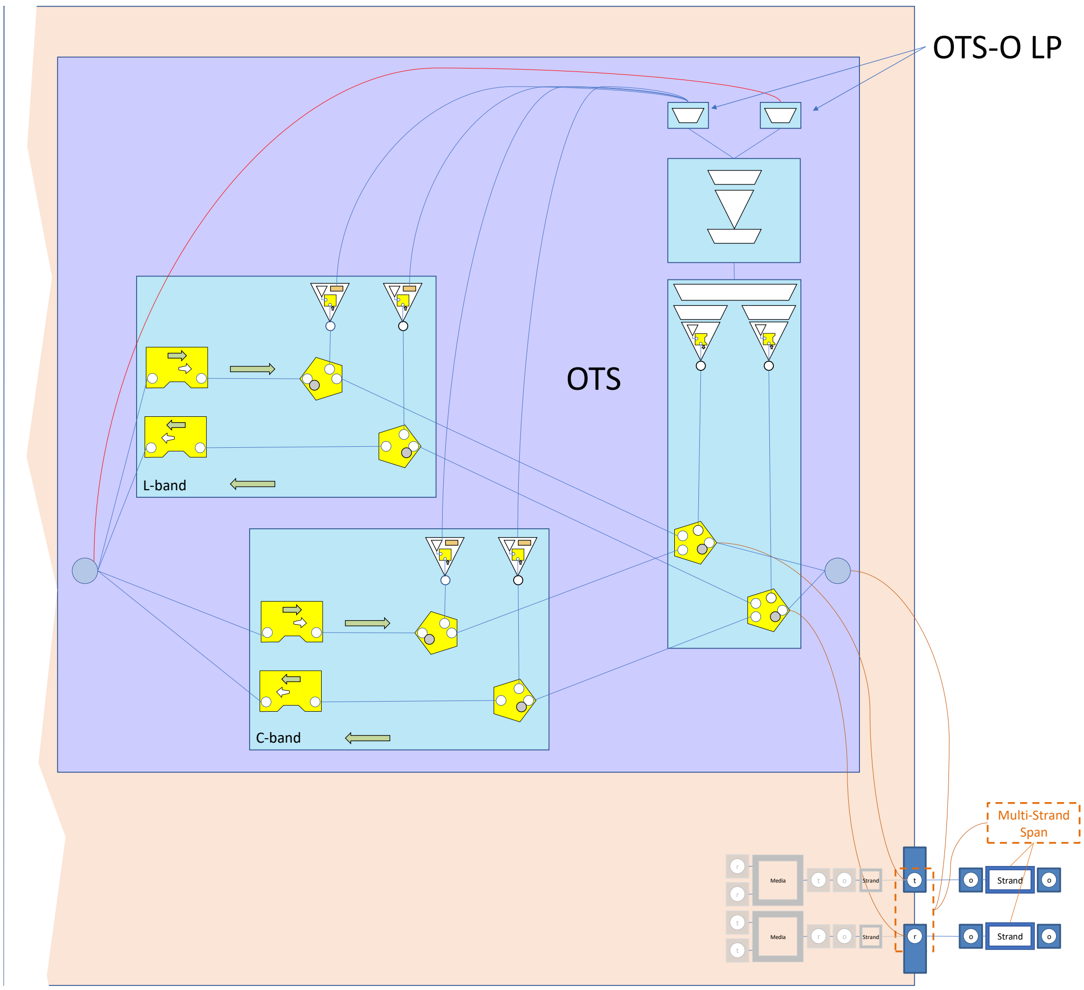

Figure 4-6 OTS encapsulated in an LTP

The LTP shows encapsulated ports (blue/grey-filled circles to the left and right of the LTP, equivalent to the FcPort (see also TR-512.A.2).

- The right port is supported by the LtpSignalUsesPhysicalPort association (via the _accessPort attribute of the LTP).
- The left port carries both photonic and electronic signals. In the next subsection the specific association will be identified.

- The merge of the signals of the three LP ports merge on one LTP is not dissimilar to the models for electronic technologies where overhead and signal are carried through the same single port

From a management-control perspective, the left port is essentially no different from a port carrying a protocol that has a signal structure with a mix of encodings (e.g. PathTrace protocol in a frame structure), but it is novel to have a discrete multi-layer propagation from an LTP (especially where part is photonic and part electronic). From a management-control perspective this novel distiction is irrelevant.

An instance of the LTP could have any subset of the functionality:

- C-band only, no L-band
- No OTS total power monitor (i.e., the case shown above)
- Only receive side amplifiers
- No amplifiers
- Etc

The enabled capability of an LTP could change "on-the-fly" as defined by the LTP spec. The Spec of an instance of LTP could change "on-the-fly" as defined by the Equipment spec.

4.4.2 OTS network considerations

The following figure shows an FC between two OTS LTPs where the FC is supported by MultipleStrandSpan (MSS). The MSS is essentially the upper-most abstraction of the physical model that bridges to the logical model. The MSS plays the role of a Link although it is unlike a link in that it is an abstraction of physical things rather than functional things. The relationship between the FC and the MSS is covered in (see TR-512.6).

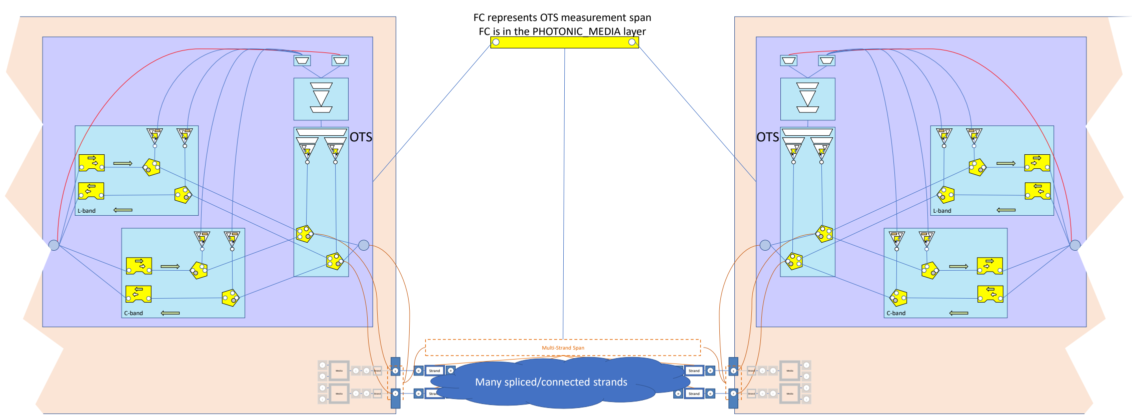

Figure 4-7 OTS ForwardingConstruct

The FC represents the relationship between the LPs in the OTS LTPs and encapsulates FCs representing:

- OSC Transponder span

- OTS-O Frame span
- L-Band OTS Monitored Span
- C-Band OTS Monitored Span

It also represents the OTS-O Monitoring span.

More precise FCs could be constructed as encapsulated detail in the OTS FC as shown below. The FCs in the diagram do not show the dependencies.

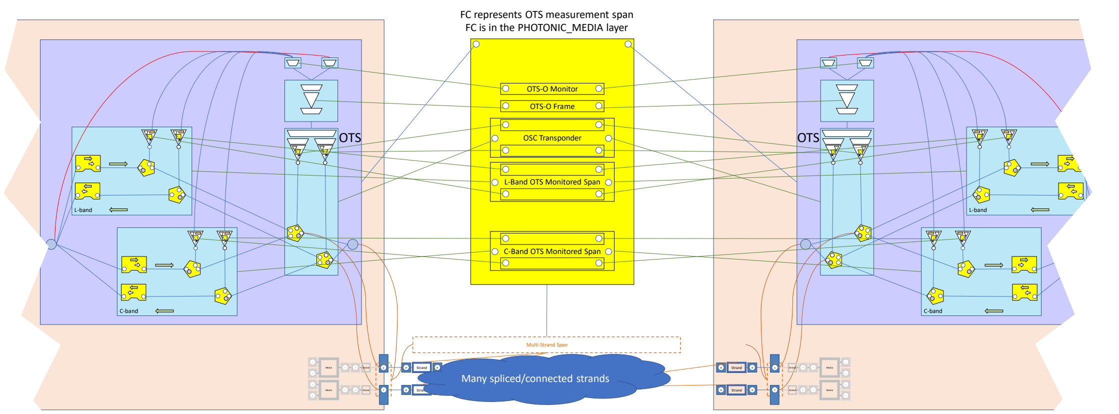

Figure 4-8 OTS ForwardingConstruct

Clearly these details can be derived from the LTP, the LtpSpec and the single FC shown in the previous figure. On that basis these detailed FCs are not intended to be expressed in an instantiation of the model.

4.4.3 OMS

The next figure shows the relationship between the OTS and the OMS. The OMS is modelled as if it is a client of the OTS as it is related to the OTS by the LtpHasClientLtps association represented by the _clientLtp attribute in the OTS LTP.

The OTS LTP shows six LayerProtocol (LP) units (built up in the description in the subsections above):

- One LP unit for OSC overhead termination
- Two LP units, each containing coupler/splitters, monitoring (termination) and amplification (forwarding) functions, one for L-band monitoring and one for C-band.
- One LP unit for OTS-O termination/adaptation
    - This may vary in detail depending upon the specific approach to overhead encoding
- Two LP units, each with a simple monitor adapter to take the power measurement etc. and apply it to the OTS-O, one for L-band monitoring and one for C-band.

The OMS LTP similarly shows six LP units:

- Two LP units, each containing coupler/splitters, monitoring (termination) and amplification (forwarding) functions, one for L-band monitoring and one for C-band.
    - These are abstractions of the actual coupler/splitter in the equipment as the wide channel of the OMS is divided into narrower channels for interconnection between ports and to the drop side of the device.
- One LP unit including a coupler/splitter (for C-band and L-band combined) presenting the client OTSis
    - These are abstractions of the actual coupler/splitter in the equipment as the wide channel of the OMS is divided into narrower channels for interconnection between ports and to the drop side of the device.
- One LP unit for OMS-O termination/adaptation
    - This may vary in detail depending upon the specific approach to overhead encoding
    - There are many potential realizations of overhead. This model represents where the OMS-O is conceptually
- Two LP units, each with a simple monitor adapter to take the power measurement etc. and apply it to the OMS-O, one for L-band monitoring and one for C-band.

The measures are PHOTONIC_MEDIA LayerProtocol entities and hence the OMS LTP is essentially PHOTONIC_MEDIA.

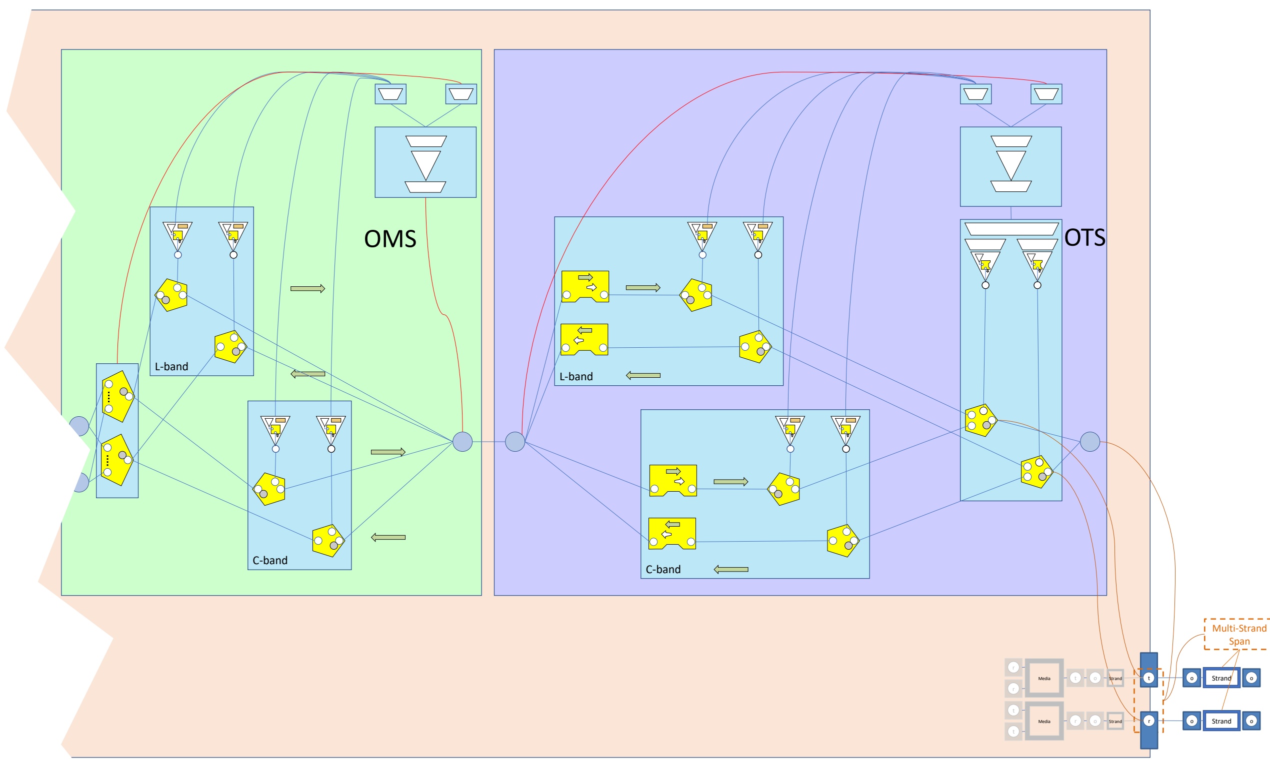

Figure 4-9 Adding OMS encapsulated in an LTP

The OMS LTP shows multiple encapsulated LtpPorts to the left. This is equivalent to the multiple encapsulated LtpPorts that result from adaption supporting multiple client CTP instances and types.

The intention is that only used capacity is exposed as explicit instances and potential capacity/capability is "confined" to the Spec.

4.4.4 OMS in an amplifier node

In an amplifier node there is only a need for one set of amplifiers for L/C band. If two OTS LTPs as depicted in the figure above were put back to back, then there would be two sets of amplifiers.

The OTS LTPs could be populated with only outgoing amplifiers (towards the Multi-Strand Span) and the OMS LTP degenerated to a simple point as shown in the figure below.

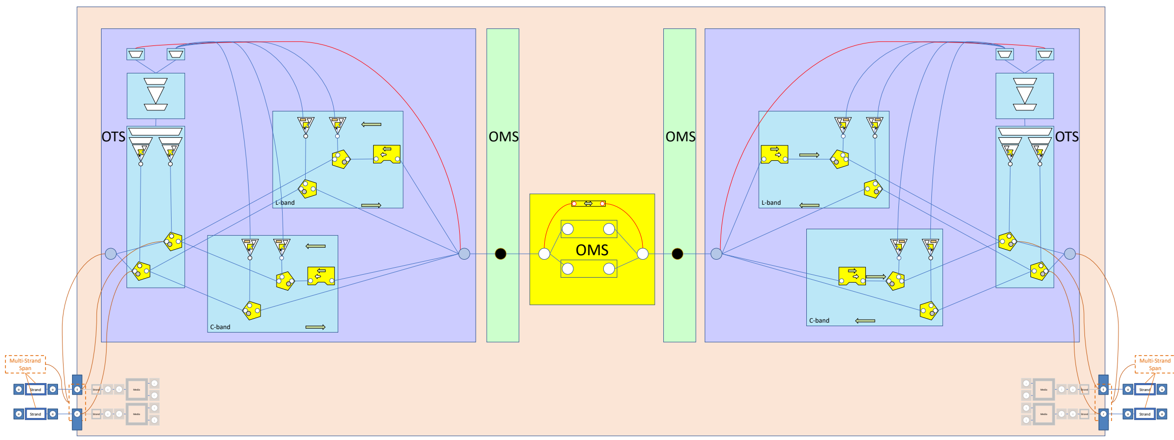

Figure 4-10 OMS as a empty FC with "null" OMS LTPs

The structure could be simplified by folding OMS "null" function into the OTS LTP.

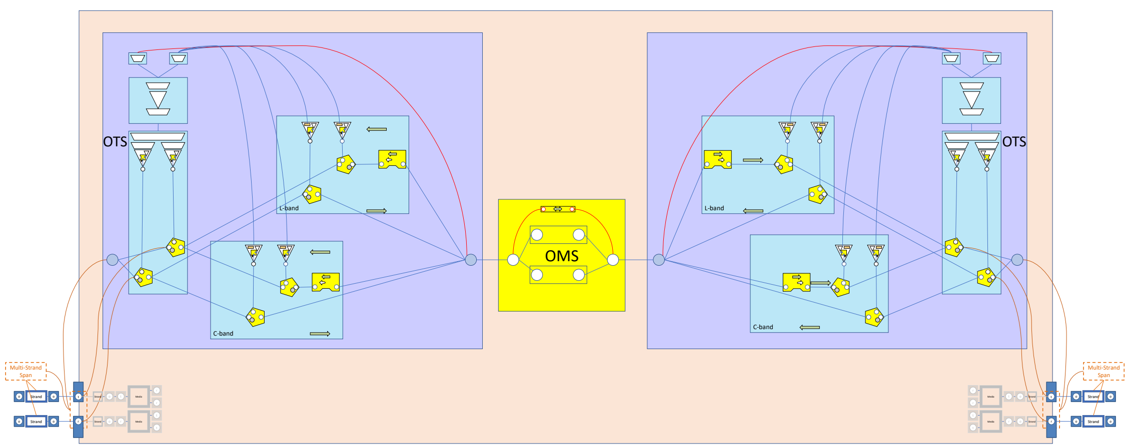

Figure 4-11 OMS as a empty FC with no OMS LTPs

The structure could be further simplified by removing the "null" FC and replacing it with the peer relationship LtpConnectsToPeerLtp.

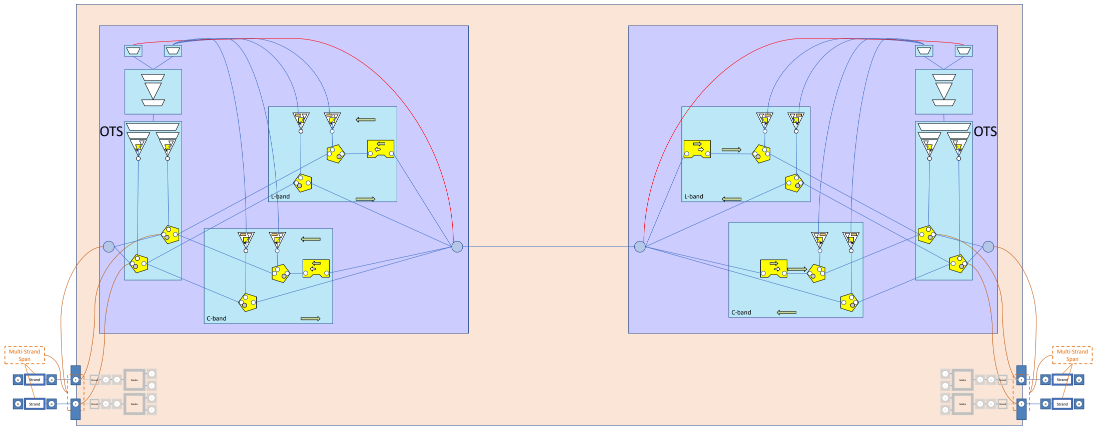

Figure 4-12 OMS as a simple peer association

Alternatively, the amplifiers can be encapsulated in an FC as shown in the figure below.

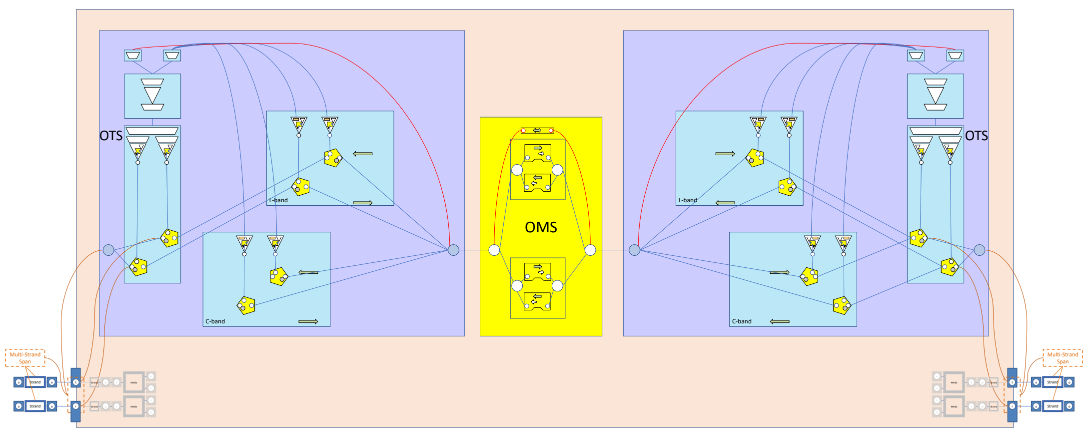

Figure 4-13 OMS passing through an amplifier

The following figure provides a potential physical realization in terms of FRUs.

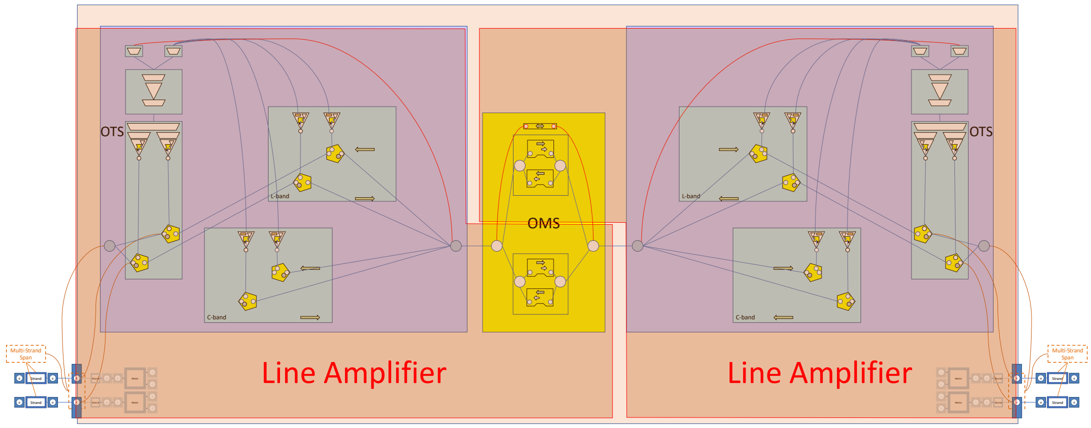

Figure 4-14 Amplifier site showing FRUs

4.4.5 The layered model, similarities and differences

Traditionally the OMS-OTS hierarchy has been over emphasize in the modeling of photonics. It is clear that the photonic solution is NOT layered and that there is no hierarchy of layering in the photonic environment. It is also clear, though, that the overhead is essentially layered and that there are a number of nested measurement spans. The hybridized LTP model discussed in this section combines the essential layering of the overhead with the non-layered (flat) photonic-media model to provide an LTP arrangement that looks remarkably similar to that of a layered model.

The key distinctions are that the LTPs are in the same base layerProtocol of PHOTONIC_MEDIA.

Migration from a layered model to this flat model should be relatively straight forward in terms of structure. However, the interpretation of the LTPs is radically different and more complex. This approach, i.e. use of an LTP for the OTS demarcation and encapsulation of the the amplifier in the OTS termination, was specifically chosen to simplify the migration from the existing (incorrect) fully layered representations.

The multi-layer aspect of the LTPs follows the approach for non-intrusive monitoring but assumes both co-directional/down measures and contra-directional/up measures. The figure below shows a simplified representation where the monitors represent both up and down measures. The yellow trapesoid represents the combiner/splitter/amplifier complex in the LTP. Some aspects of this may be reflections of the actual implementation of the functionality and others may be conceptual.

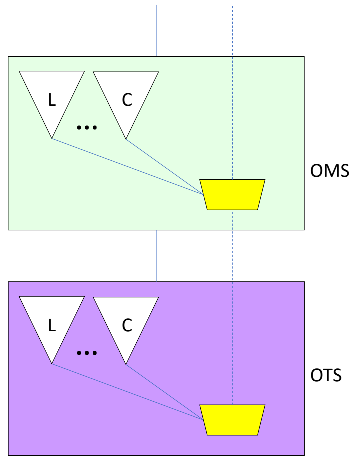

Figure 4-15 Simplified representation of the model of OMS and OTS LTP

The OMS and OTS provide demarcation points in the network. These points can be maintained even if overhead is not present and measurements are not being taken. The OTS demarcation is defined by the end of the inter-device fiber[15].

In a ROADM, the OTS span demarcation (the boundary between the OTS and OMS) is defined by the amplified span. The OTS "upper" demarcation (i.e. the OMS "lower" demarcation), from a device egress perspective, is the point prior to the amplification of the signal applied to the inter-device fiber and, from a device ingress perspective, as the point after the amplification of the signal from the inter-device fiber.

In a device that does not do channel switching the OTS ends, but the OMS continues, as shown in the amplifier model earlier and in the simplified model below (which follows the model set out in Figure 4-10 OMS as a empty FC with "null" OMS LTPs on page 41).

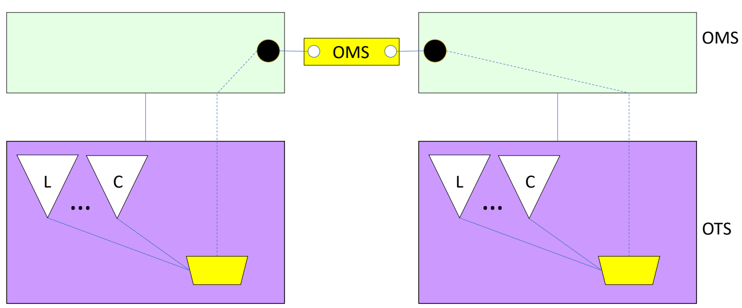

Figure 4-16 Simplified representation of OTS LTP in an amplifier

The figure below shows an amplifier site where there is monitoring. The figure highlights another valid form of the FC/LTP model of an amplifier and also includes physical aspects.

15 Where there is a long fibre span across some significant geography

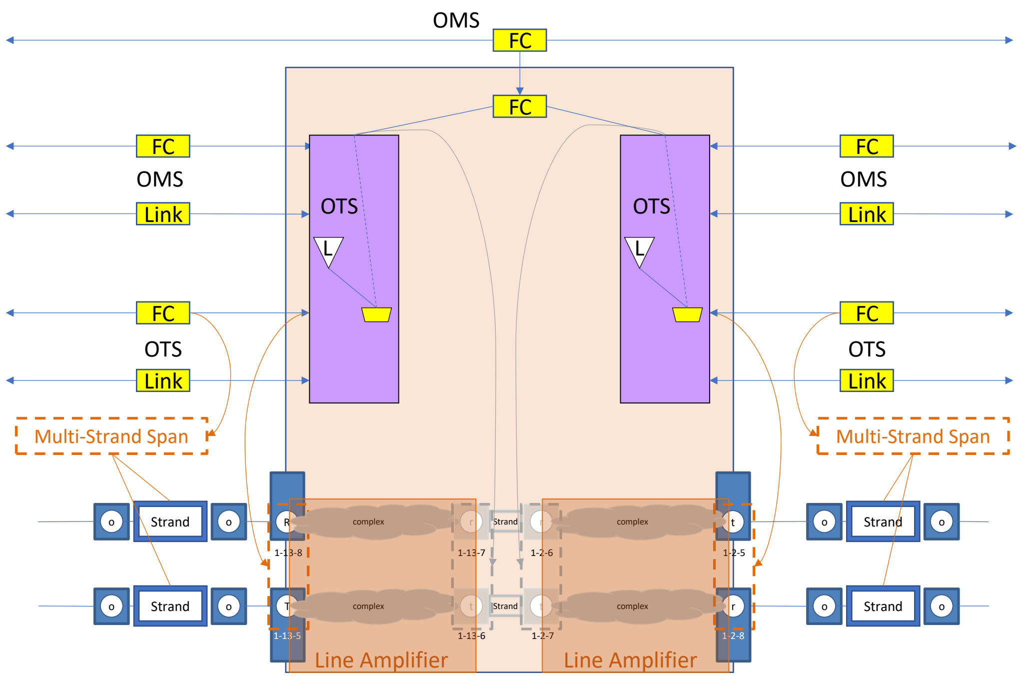

Figure 4-17 Simplified representation of OTS LTP in an L-band amplifier showing physical aspects

The presence of the LTP is justified by the presence of termination of some form. In the most basic of systems where there is no overhead, no amplification and no monitoring of spans, the representation of the photonic aspects collapses back to the traditional model (i.e. the Optical Section LP).

4.4.6 OMS network considerations

The figure below shows both the OMS and OTS FC. Both are in the Photonic layerProtocol. The interpretation of the OMS FC is similar to that of the OTS FC.

The OMS FC is supported by the OTS FC via FcHasLowerLevelFc represented through the _lowerLevelFc attribute of the FC. The OMS FC is at the PHOTONIC_MEDIA layerProtocol.

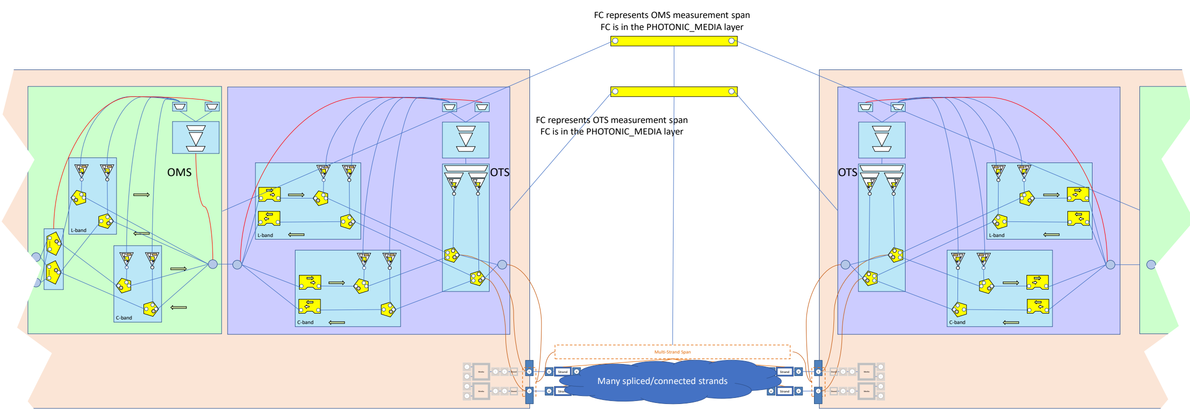

Figure 4-18 Adding OMS ForwardingConstruct

4.4.7 Signal, channel, overhead, grouping and assembly considerations

In the photonic representations from [ITU-T G.709], [ITU-T G.798] and [ITU-T G.8.72] there are a number of useful concepts (although they have not been consistently applied in the ITU-T material). These concepts are identified and clarified below. The definitions below extend and refine those in the ITU-T material.

4.4.7.1 Signal (Si)

Signal (Si): The thing that conveys information over space in time

- In the case of a photonic realization this is a sequence/flow of photons where the sequence/flow is modulated in some way governed by an information sequence such that on examination of the sequence/flow of photons the information sequence can be extracted. The sequence/flow of photons is thus a carrier of the signal
- The OTSi, used later in this document, is a case of a signal
    - Note that the definition in the ITU-T material appears somewhat ambiguous in that the OTSi is both a photonic and an electronic signal. The use of the term Optical (the "O" in OTSi) is often applied in the industry to a thing that is actually electrical. Where relevant in this document usage will be clarified with a "p" for photonic and "e" for electronic. The following ITU-T terms have been augmented in this way for use in this document:
        - OTSi → OTSi(e) and OTSi(p)
        - OTSiG → OTSiG(e) and OTSiG(p)
        - OTSiA → OTSiA(e) and OTSiA(p)

4.4.7.2 Media Channel (MC)

Media Channel (MC): A contiguous spectrum, i.e. a continuous band of frequency bounded by an upper and lower frequency, its width, where that spectrum is defined over some distance, its length. The photonic MC is such that a photon entering the channel at one point may exit, at some other point on the channel, unchanged (clearly there is a potential for loss). In the photonic application:

- The MC may be omni-directional, such that photons can travel in any direction, or unidirectional, due to directionally non-linear channel element

- The MC may have a complex topology partially meshing many points, via points of channel merge and channel split.
    - In this case a photon entering the channel at one point has a probability of exiting the channel at one of many of the other points on the channel based upon the specific topology
- The MC is available to carry one or more signals where the characteristics of each signal match the characteristics of the MC such that each signal passes through the channel unimpaired[16]
    - Consider the photonic signal originating at the modulation of a coherent light source. The coherent source has an inherent quiescent light frequency (such that all photons produced are in an extremely narrow band). When it is modulated other frequencies appear around the quiescent frequency. This gives rise to the definition of the signal carrier in terms of center frequency (the quiescent frequency) and width (assuming symmetry of spectrum produced by the modulation).
    - Clearly for the signal to be conveyed it cannot require greater width than that of the channel, and clearly the upper and lower frequencies of the signal (center +/- 0.5 width) must be within the channel upper and lower frequencies.
        - The MC provides usable spectrum defined by its upper and lower frequencies
    - Within the channel multiple signals can be carried to the degree that a receiver can be designed/implemented to extract each one uniquely (i.e. they can be a partition of the channel spectrum or can overlap in any way that still enables their extraction by an appropriate receiver)
- An MC may be divided into smaller MCs. This may be either a "hard" division through the application of Guard Bands and filter or a conceptual division considering intended use.
- There may be several MC views of the same spectrum (see 4.4.8 Subdividing the Media Channel on page 50)
    - For example, the spectrum of a MC may be divided into 5 MCs in one view and 3 MCs in another where the views are orthogonal, and the MC boundaries do not align (other than on the upper and lower boundary of the MC that is being divided)
        - Clearly these will be conceptual divisions as the application of a real Guard Band to an MC in one view would disrupt the MC in the other view
    - In some constrained cases several views of the same spectrum may be valid simultaneously
- The MC may have other complex characteristics related to the physical environment supporting it, where some of the characteristics may be non-linear in nature
- In the ONF Core model the FC is used to represent[17]:
    - The raw MC: represented by a multi-pointed omnidirectional/unidirectional FC

[16] Impairment to a degree is acceptable so long as the Information in the Signal is recoverable.
[17] The ForwardingSpec will be used to specify the capability. The ForwardingSpec of an FC instance can change through the life of the instance.

        - The directionality detail of the FC depends upon the characteristics of the specific channel and the FC spec depends upon the coupler/splitter arrangement.
    - A contra-directional pair of MCs that are between the same points and that are used bidirectionally: represented by a bidirectional FC (see 4.4.16 Rationale for groupings on page 87).
    - A contra-directional pair of MCs that are emergent from consideration of the application of a bidirectional signal to a pair of multi-pointed omnidirectional/unidirectional MCs: represented by a bidirectional FC
        - This FC is essentially representing the NMC (Network Media Channel)[18] where the NMC represents the thread, through the MC mesh, that supports a single OTSi(p) FC that is itself supporting information transfer (i.e. as noted earlier, is supporting the Information Transfer Channel) bidirectionally between the two points (assuming a bidirectional client of the OTSiA(e)[19]). The NMC is an MC that is expected to be carrying purposeful signal between two transmitter/receiver pairs.

4.4.7.3 Guard Band

Guard Band: A small band of frequencies contiguous with, and below, the lower frequency of an MC or contiguous with, and above, the higher frequency of an MC where that small band of frequencies is considered to be not available for the conveying of signal.

4.4.7.4 Photonic (p) and electronic (e)

Some signals have equivalent photonic and electronic forms. The suffix (p) is used to distinguish the photonic form and the suffix (e) is used to distinguish the electronic form.

4.4.7.5 Group (G)

- In the context of the photonic solution discussed here, covers signals and channels as follows
    - A group of Media Channels that pass over the same series of fibers where the members of the group are not (necessarily) adjacent/contiguous in frequency and do not form a continuous band[20]
    - A group of signals that is supported by the same series of fibers, although they may each use a different channel, where the members of the group are not (necessarily) adjacent/contiguous in frequency and do not form a continuous band
- In the ONF Core model:
    - The MC Group (MCG) is represented by an FC
    - The signal Group (SiG) is represented by an FC
- The aspect of the OMS (and from a perspective, the OTS) where the L-band and C-band are considered together as one unit, as discussed above, is essentially an MCG as the L-band and C-band are channels. The combining of them forms the Group
- Clearly the MCG abides by the Guard Band

[18] The NMC has a somewhat ambiguous definition in the industry hence the clarification in this bullet.
[19] The complexity here is related to coherent detection and DSP as multiple receivers may receive the light but only one will produce information.
[20] If this restriction were to be loosened to allow MCs that pass over different fibres to be included in a Group, then the LTP model would need to allow for floating LTPs to represent the Group. The current model descriptions a purposely simplified in this respect.

- OTSiG(p) is a group of photonic signals
    - The OTSiG(e) is the electrical signal that results from the inverse multiplexing of a number of OTSis
- The fiber is a Media Channel Group (as there are a number of Channels available that are discontinuous due to fiber characteristics)
- The emergent group of bidirectional MCs (NMCs) that support, end-end the OTSis of OTSiG(p) is an MCG
    - This could be called NMCG

4.4.7.6 Monitoring

Monitoring: Observing some properties of an entity.

- In the case of the photonic solution, the primary monitored entities are:
    - The signal source and signal receiver to validate the characteristics of the signal
    - The MC (the MC may only be relevantly monitored in detail when one or more photonic signals are present)
        - At its boundary to validate the insertion of the signals and other related considerations
        - At some intermediate point to validate that the channel is correctly conveying the signal(s)
    - The various active functions such as amplifiers
- The source/MC etc may be monitored for various properties (see 4.5.1 Relevant properties on page 88).

4.4.7.7 Overhead (O)

Overhead (O): Information about a monitored entity and information related to control of an entity where that information is conveyed from one place to another[21].

- The term also includes aspects of the signal used to carry the information.
- The carrier for overhead is assumed to be a separate photonic signal propagated on the same fibers as the signal related to the monitored entity.
- The information may be about the entity local to the point of generation of the overhead or may be about an entity remote from the point of generation of the overhead.
- OMS-O is an example of overhead

4.4.7.8 Assembly (A)

Assembly (A): A Group with its Overhead where the Group may have only one member

- In the discussion above the OTS termination (MCG) is an assembly of the OTS MC (Traffic Carrying), the OSC signal transponder, the OSC (Overhead) MC, the OTS MC measures and the overhead.
- Later in the document the OTSiA(p) represents the OTSiG(p) and the OTSiG-O considered together
    - As it is the channel that is monitored, there is also a corresponding MCA (the NMCA) through the network supporting the OTSiA(p) (see 4.4.11 NMCA FC and dealing with the "OTSiA coordination" on page 72)

[21] The term “Overhead” originally relates to an aspect of the technique for carrying the information. In this case the term is being used specifically for the information alone with no consideration of the encoding technique.

- The notion of an Assembly being allowed with monitoring, but no Overhead, is also useful.
- Where there is a single OTSi(p) with no monitoring and no overhead that is to be considered across the network this can also be considered as a degenerate Assembly to help with model uniformity

4.4.7.9 Application of G, O and A terminology

On this basis the G, O and A terminology could be applied more uniformly:

- OTS, as used in this document, is an Assembly as it includes several channels, one for the Overhead transmission (OSC) and one or more for service (L-band, C-band etc), where the Overhead and signals are monitored (essentially OTS (A))
  - The OTS, in this document, is bidirectional
  - As emphasized, the channel cannot be monitored it is only the signal in the channel that can be monitored
- OMS, as used in this document, is an Assembly as it includes L-band, C-band etc, signal monitoring and conceptual overhead (essentially OMS (A))
  - The OMS, in this document, is bidirectional

4.4.8 Subdividing the Media Channel

4.4.8.1 Simple subdivision of the Media Channel

The figure below shows the subdividing of the overall MC provided by the OMS into narrower MCAs. This subdividing could be at a transponder or it could be at some intermediate point in the network (i.e. at a point where the OTSiA is NOT being terminated).

The MCA:

- May be bidirectional or unidirectional and may be point to point or multi-pointed.
  - In this example the MCA is assumed to be bidirectional.
- May be at the granularity of a single OTSi(p)[22], i.e. is an NMC, or may be capable of carrying several OTSi(p)
- Is shown with monitoring of the total MC for both directions where the monitoring may be:
  - Total power
  - Power over the spectrum of the MC
  - Eye (where the MC is an NMC corresponding to a single OTSi)
  - etc
- Is shown in the figure (via the entities related to the FC with red ports) with the opportunity to insert information related to the monitoring into the Overhead in both directions

In the figure below, it is also assumed that only L-band is being used and hence the OMS and OTS also only have one monitor.

[22] I.e., a degenerate assembly with only one member.

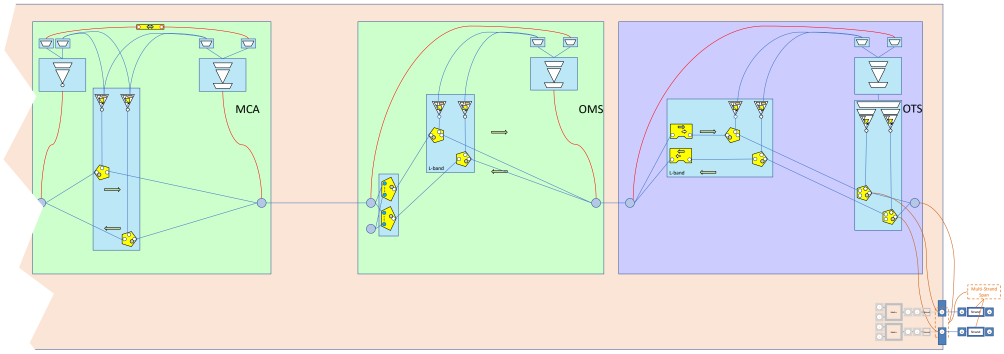

Figure 4-19 The monitored MCA LTP

The figure above can be presented in the simplified form as below[23]. Where the MCA is a single MC (hence there is only one monitor) supporting a single OTSi that supports all the information transfer required for a single service. Hence, the MCA monitor is the OTSi Monitor[24]. In this case the MCA is the NMCA as discussed in 4.4.7 Signal, channel, overhead, grouping and assembly considerations on page 46.

In the figure below, it is also assumed that only L-band is being used and hence the OMS and OTS also only have one monitor. In all cases the monitoring could be both co-directional/down and contra-directional/up.

In a ROADM, the OMS span demarcation (the boundary between the OMS and MCAs) is defined as the point at which the opportunity is provided for multiple MCs to be combined into one stream, at the ingress, and split, at the egress. Several groups of non-contiguous MCs each with associated overhead (i.e., several MCAs) may be combined into (and split out from) a single OMS. This is the point at the boundary of the channel switching capability. The OMS is considered as ending at this point.

[23] This simplified form is used for many examples later in this document. In all cases the multiplicity on an association end is "1" unless otherwise stated.
[24] In the general case the MCA monitor is a set of MC monitors where the MC monitor monitors the whole MC and hence several OTSis.

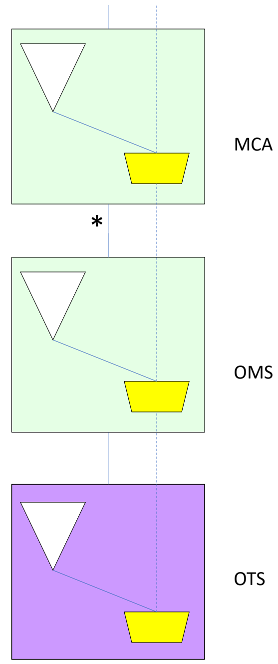

Figure 4-20 Simplified representation of the model of MCA, OMS and OTS LTP

If there is no monitoring present the MCA LTP degenerates to a set of pass-throughs as shown below.

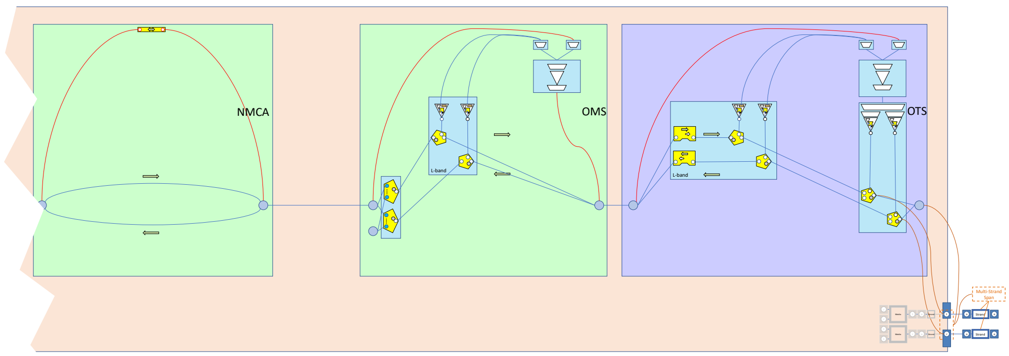

Figure 4-21 The degenerate MCA LTP

These are essentially null functions. The following figure shows a usual representation of a low functionality LTP.

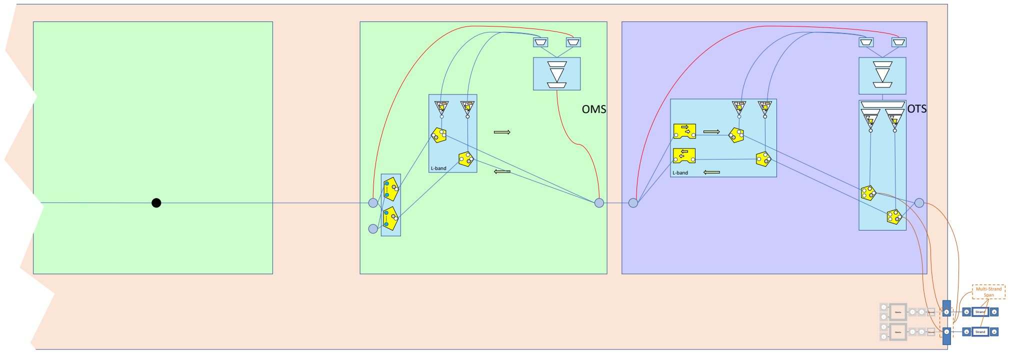

Figure 4-22 The compact degenerate MCA LTP

The LTP spec will consist of an LP for each of the monitors etc where each LP has only one connection function that states it key properties.

This can be represented in the simplified form as below.

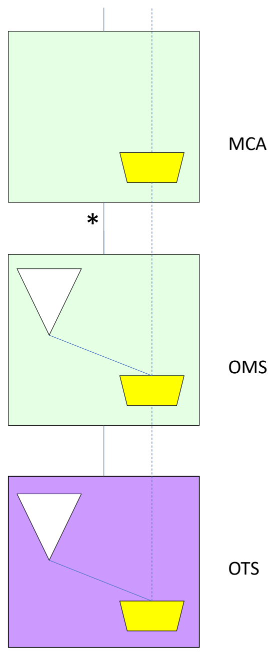

Figure 4-23 Simplified representation of the model of MCA (with no monitors), OMS and OTS LTP

4.4.8.2 The MCA LTP and the NMCA

Assuming a point to point bidirectional signal is to be carried, the OTSiA(e) FC (which defines the point to point bidirectional signal span) is supported by the OTSiG FC (which is a parallel assembly of OTSi(e) FCs[25]) with the corresponding monitors and overhead (OTSiG-O).

[25] The point to point nature of this FC is defined by the coherent transmitter/receiver and the DSP.

The OTSiA is supported by a bidirectional NMCA where the NMCA is a parallel grouping of NMCs[26] (each NMC supports a single OTSi of the OTSiG) and where each NMC has the same route (see 4.4.7 Signal, channel, overhead, grouping and assembly considerations on page 46).

Each NMC of the NMCA has associated monitoring as does the overall NMCG and the NMCG has associated overhead. As it is possible to monitor an MC at any point in the network, it is also possible to monitor the NMC at any point.

Where the MC is known to be further subdivided into multiple MCs or is known to carry several OTSis it is possible that multiple monitors could be present. The MCA LTP depicted in the figure below shows multiple monitoring opportunities. One monitor may assess the total channel and other may assess parts of the channel.

In this case both L-band and C-band are also being used.

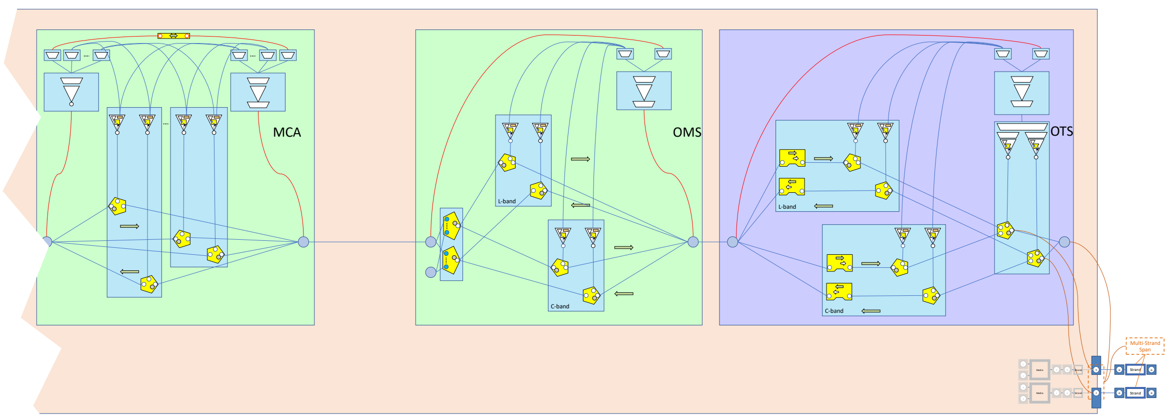

Figure 4-24 The MCA LTP with multiple monitors

Each monitor of part of the MC could be for an individual NMC and the MCA LTP could represent an NMCA. Alternatively, the LTP could represent a single MC wide enough to carry multiple NMCs where that MC is monitored for NMCs passing but the NMCA is formed from NMCs in different MC LTPs.

The model pattern is capable of representing any of these perspectives. The combination of multiple cases of the pattern can be used to represent several perspectives at once (in one view). This will be shown later in this document.

Whilst not currently standard, this has been shown to:

- Emphasize the multiple OTSis passing through
- The OTSiA passing through
- Show a hybrid LTP with both OTSiA photonic signals and OTSiA overhead content passing through.
- Demonstrate the flexibility of the model pattern

[26] As noted earlier, this is emergent from the MC mesh.

It is assumed that as monitoring capability advances and as disaggregation becomes more viable monitoring at various intermediate points to assist in fault location across a mixed vendor and mixed operator environment will become vital and a simultaneous interrelated representation of several perspectives simultaneously will be necessary.

Each monitor has an adapter (at the MEASURE_AND_CONTROL layerProtocol)[27] for each side of the LTP.

In this case as there are multiple monitors associated the with MC this can be represented by the following simplified figure.

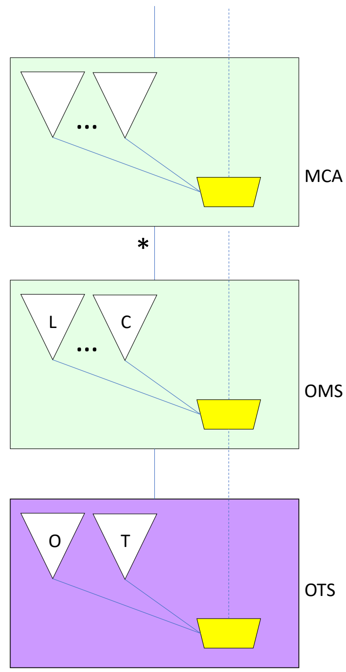

Figure 4-25 Simplified representation of the model of MCA, OMS and OTS LTP

In an instantiation of the model, it could be expected that MCA LTPs would be formed only when there is active monitoring and that that would normally occur when an FC was present associated with the MCA LTP (see 4.4.11 NMCA FC and dealing with the "OTSiA coordination" on page 72). In the degenerate case (see Figure 4-21 The degenerate MCA LTP on page 52) the MCA LTP would appear as the MCA FC was created even with no monitoring.

4.4.8.3 Multiple levels of subdivision

In some cases, it will be necessary to consider multiple levels of subdivision either as levels of subdivision or as views of subdivision.

The following figure, using the simplified representation, considers a multi-level view from the perspective of the measures.

[27] The MEASURE_AND_CONTROL layer is electronic/digital (e.g., optical power measurement).

In the figure, the MCA (1) could be a group of coarse granularity MCs and MCA (2) could be a grouping of finer granularity MCs. The model assumes that the MCs of a single instance MCA (2) must be supported by the MCs of a single instance of MCA (1), and hence there is a simple group hierarchy.

It is likely that MCA (2) is the NMCA. The application of this structure is discussed in section 4.4.10.1 Planning approaches on page 68.

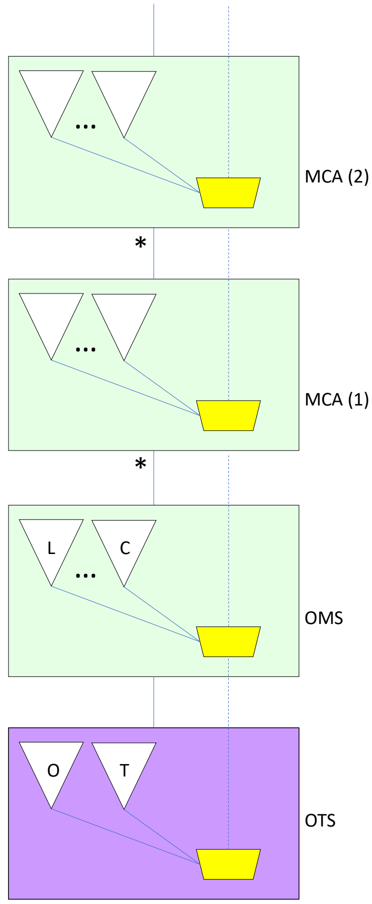

Figure 4-26 Simplified representation of the model of two MCAs, OMS and OTS LTP

The rules for MCA nesting will be further developed in a network context (see 4.4.9 Point to point and multi-pointed Media Channels on page 56 and 4.4.10 Planning channels on page 68). It is expected that only two levels of nesting above OMS will be required.

4.4.9 Point to point and multi-pointed Media Channels

In general, is possible to set up MCs independent of there being specific demand[28] where MC is represented in the model by the FC as described.

Whilst it is possible that filtering is set up in the network such that the MC travels point to point between only the desired transponders it is also possible to construct MCs in a multi-pointed

[28] The MC can only be measured when a signal is present.

form. The bidirectional point to point nature of the information transfer channel associated with the OTSi may be realized by tuning the source (transponder) and using a frequency selective receive (transponder). The bidirectional aspect can be satisfied by either using two fibers, one for each direction of transmission (in which case the same frequencies may be used for both directions of transmission) or different frequencies can be used in the two directions, this allows operation over a single fiber. In general, the spectrum used for transmitters at a node is segregated from the spectrum used for receivers.

In effect a point to point bidirectional channel for information flow is set up from part way through the transmitter to some way into the DSP of the receiver (as discussed in Figure 3-16 Information Transfer Channel formed from Media Channels for coherent receiver on page 23).

The following subsections discuss different degrees of directedness of the channels.

4.4.9.1 Point to point Media Channels

The first figure shows a tightly directed (i.e, filtered) channel where each pair of places is connected by a dedicated bidirectional channel through a number of intermediate (grey) ROADM nodes. In the figure, two MCs are shown, one between Transponders (brown) A and L and the other between Transponders B and M.

In the case shown below the same frequencies are used for both bidirectional services (as they are isolated).

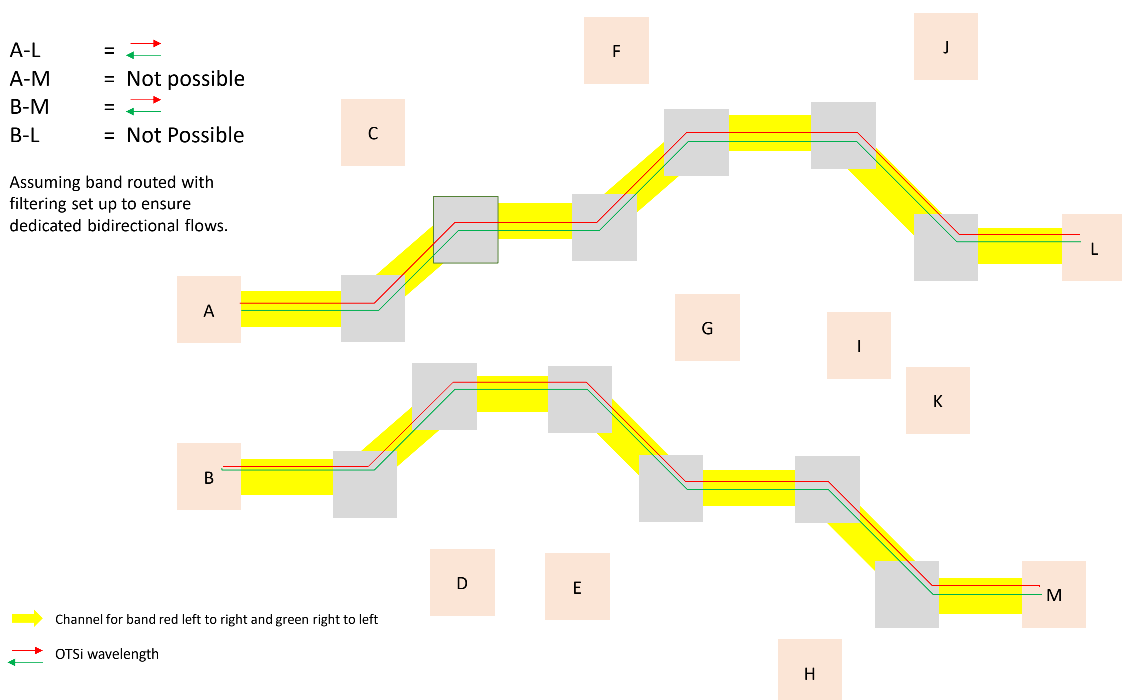

Figure 4-27 Point to point directed Media Channel

4.4.9.2 Multi-pointed Media Channels

A multi-pointed media channel is constructed by inserting a coupler in a media channel. A coupler has one common port and two or more branch ports. In the splitting direction any signal present on the common port is transferred to all of the branch ports, the signal power is divided across the branch ports. In the combining (or merge) direction any signal on a branch port is transferred to the common port.

4.4.9.2.1 Tree topology

Couplers may be used in networks when the fiber is deployed in a tree topology (e.g., in access, feeder, and aggregation networks). An example of a (simple) tree using couplers is shown in the figure below.

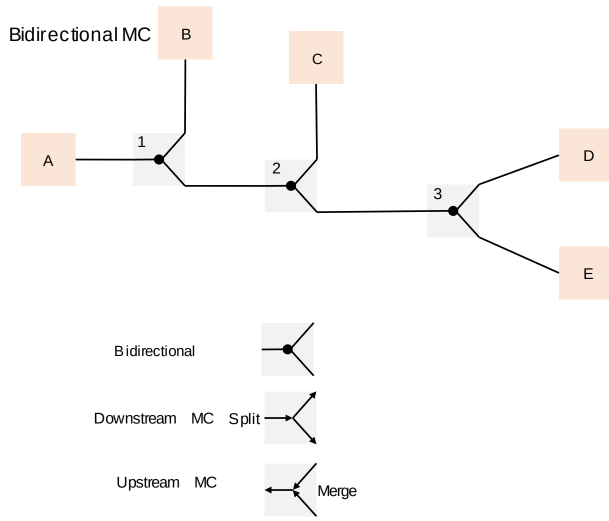

Figure 4-28 Tree topology constructed with couplers

The bidirectional topologoy can be redrawn to show the two unidirectional MCs (one for each direction of transmission). It is convenient to refer to the root to leaf direction as "downstream" and the leaf to root direction as "upstream". With this topology the downstream and upstream MCs can be supported on separate fibers or by using two different segments of the optical spectrum.

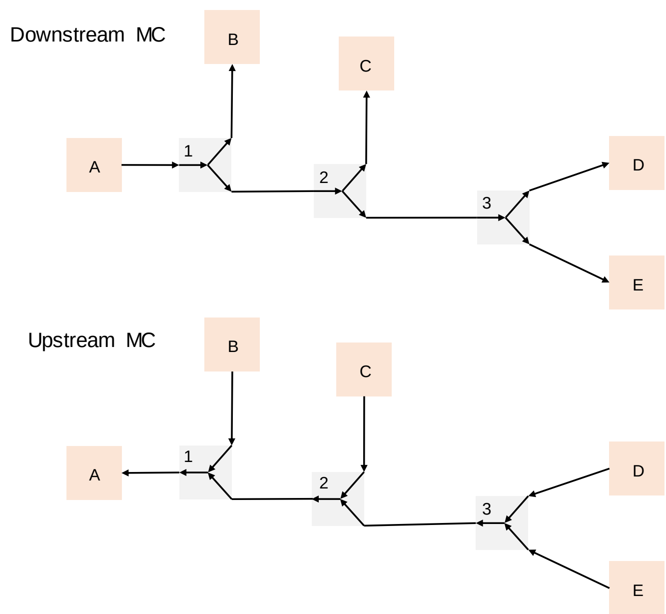

Figure 4-29 Unidirectional media channels in a bidirectional tree

As shown in in the figures below the topology can be pruned to show the tree for each source which results in a set of overlayed (tree) topologies.

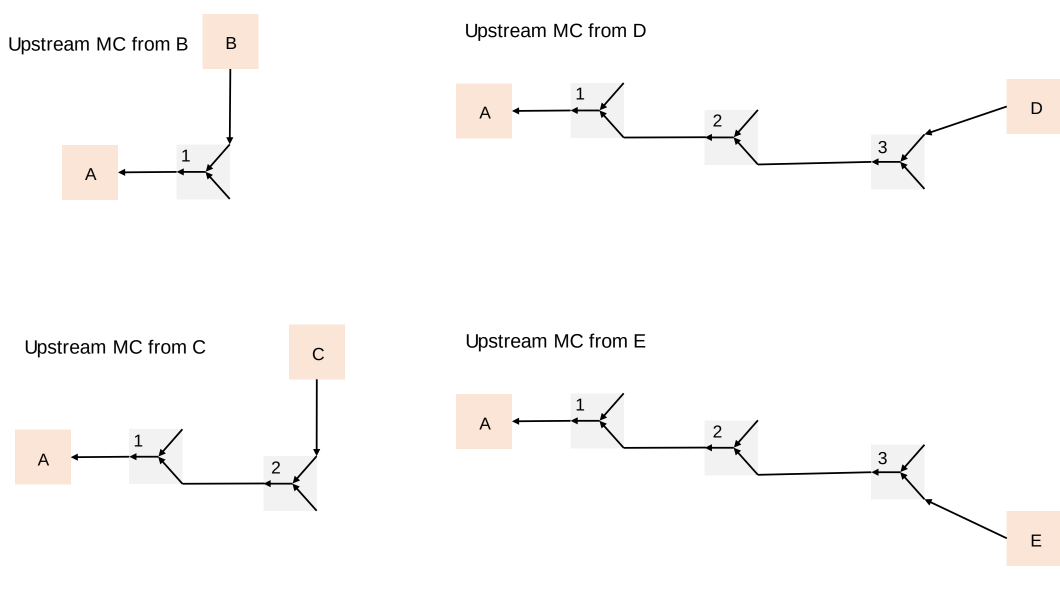

Figure 4-30 Per source upstream tree topology

The connectivity provided is summarized in the tables below:

Downstream connectivity:

Source node	Destination node				
	A	B	C	D	E
A		√	√	√	√

Upstream connectivity:

Source node	Destination node
	A
B	√
C	√
D	√
E	√

A check mark in the row indicates that a signal from the source reaches a destination

A column with multiple check marks indicates that signals from multiple sources reach the destination.

In a WDM network point-to-point bidirection information transfer is provided by a dedicated wavelength to interconnect A-B, A-C, A-D and A-E for each direction of transmission. Note that if two fibers are used (one for each direction of transmission) the same wavelenght can be used for downstream and upstream. Use of filters (instead of couplers) in this topology would not change the utilization of the optical spectrum (since all of the signal appear on the interface at A).

In a TDM PON network a single fiber is used, the downstream direction of transmission uses one wavelenght (i.e. one point to multipoint forwarding construct) and the upstream direction uses a different wavelength (i.e. a multipoint to point forwarding construct). In the downstream direcion node A (the OLT) broadcasts the same signal to each downstream node (the ONUs). Each ONU only decodes that part of the information that is targetted to that destination. In the upstream direction the OLT receives the signals from all ONUs. To allow the information content to be recovered by the OLT each ONU only transmits an optical signal in the time window assigned by the OLT. The OLT receives a time interleaved burst of information from each ONU.

If the connectivity between the nodes is increased (beyond the simple tree topology described above) the number of "collisions" between wavelenghts will increase restulting in a less efficent use of the optical spectrum than a network that uses filters. A simple example of increased connectivity is shown in the figure below. In this example the connectivity of the simple tree described above has been increased by spliting nodes B (into B_1 and B_2) and C (into C_1 and C_2) and spliting couplers 1 (into 1_1 and 1_2) and 2 (into 2_1 and 2_2). Nodes B_1 and C_1 continue to be leaf nodes on the tree with a root at A. B_2 is a new root node for a tree with C_1, D and E as leaf nodes. C_2 is a new root node for a tree with D and E as leaf nodes. Since this topology is a set of overlayed trees the downstream and upstream MCs can be supported on separate fibers or by using two different segments of the optical spectrum.

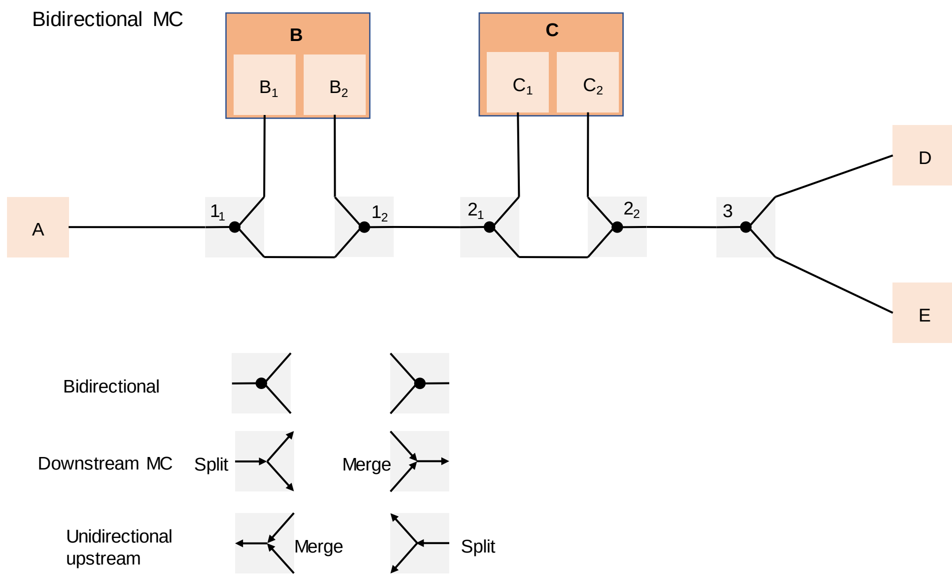

Figure 4-31 Bidirectional topology constructed with couplers

The bidirectional topologoy can be redrawn to show the two unidirectional MCs (one for each direction of transmission).

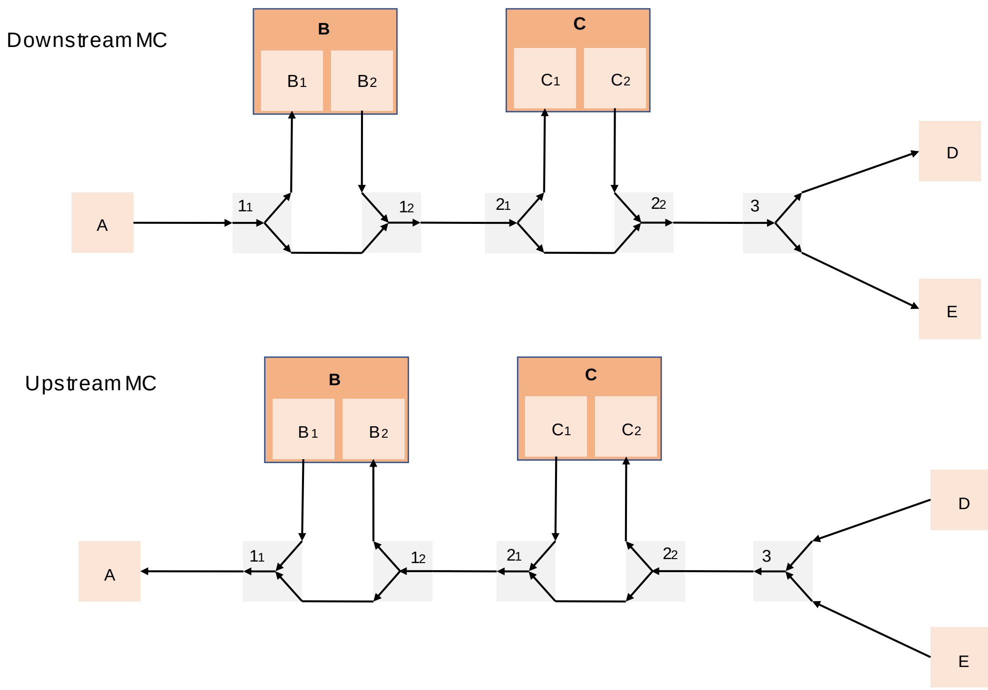

Figure 4-32 Unidirectional representation

The topology can be pruned to show the tree for each source which results in a set of overlayed (tree) topologies as shown in the figures below.

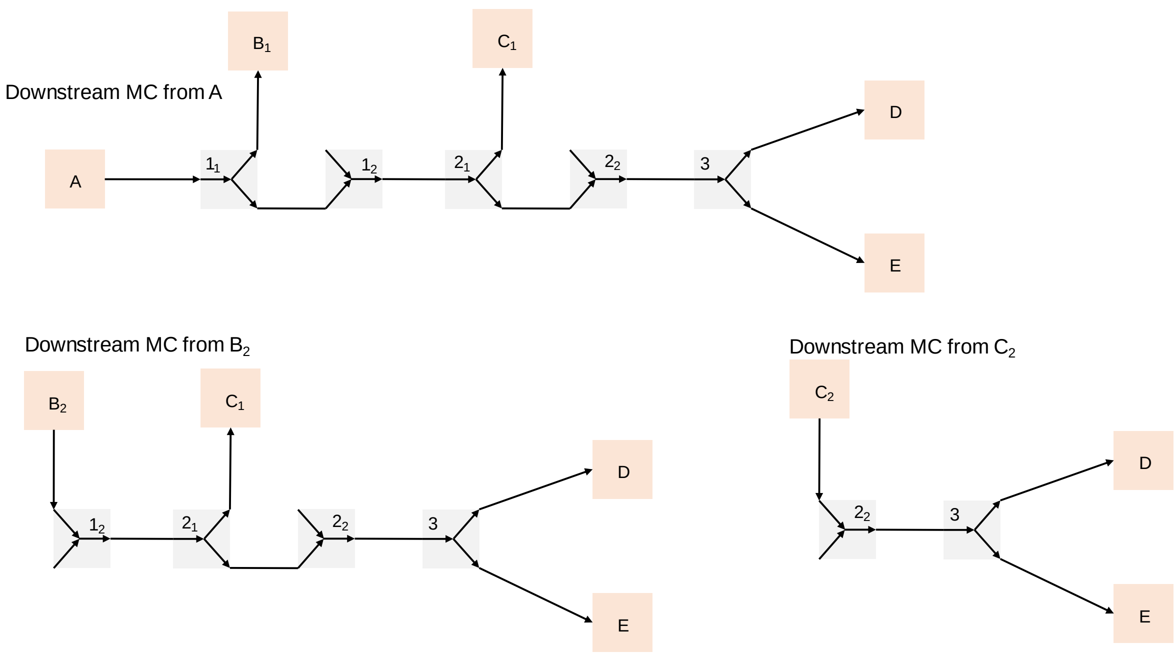

Figure 4-33 Per source downstream tree topology

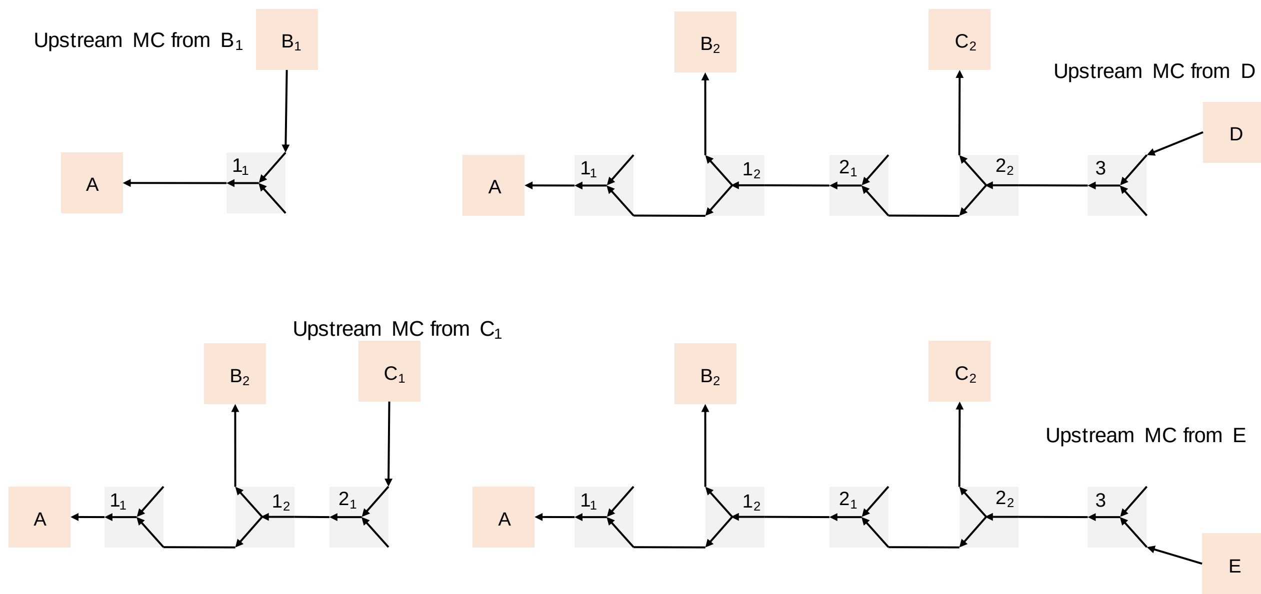

Figure 4-34 Per source upstream tree topology

The connectivity provided by this topology is summarized in the tables below.

Downstream connectivity

Source Node	Destination node			
	B_1	C_1	D	E
A	√	√	√	√
B_2		√	√	√
C_2			√	√

Upstream connectivity

Source Node	Destination node		
	A	B_2	C_2
B_1	√		
C_1	√	√	
D	√	√	√
E	√	√	√

A check mark in the row indicates that a signal from the source reaches a destination.

A column with multiple check marks indicates that signals from multiple sources reach the destination.

The wavelength utilization (and collisions) can be shown by extending the tables to include per λ forwarding constructs (FCs).

T = Topology of the point to multipoint media channel
P = signal present at destination node
S = signal providing service
× = cannot be used by the source node

Downstream example FCs: A-D (λ_1), A-C_1 (λ_2), B_2-C_1 (λ_3)

Source Node	**Destination node**															
	B_1				C_1				D				E			
	T	FC (λ_n)			T	FC (λ_n)			T	FC (λ_n)			T	FC (λ_n)		
		1	2	3		1	2	3		1	2	3		1	2	3
A	√	P	P		√	P	S	×	√	S	P	×	√	P	P	×
B_2					√	×	×	S	√	×	×	P	√	×	×	P
C_2									√	×	×	×	√	×	×	×

Upstream example FCs: D-A (λ_4), C_1-A (λ_5), C_1-B_2 (λ_6),

Source Node	**Destination node**											
	A				B_2				C_2			
	T	FC (λ_n)			T	FC (λ_n)			T	FC (λ_n)		
		4	5	6		4	5	6		4	5	6
B_1	√	×	×	×				×				
C_1	√	×	S	P	√	×	P	S				
D	√	S	×	×	√	P	×	×	√	P		
E	√	×	×	×	√	×	×	×	√	×		

Note: If two fibers are used the wavelenghts used in the downstream direction can be reused in the upstream direction.

When a wavelength is activated to provide a point-to-point connection i.e. a forwarding construct (FC) to a particular destination the signal is present (P) at all destination nodes on that tree and cannot be reused to communicate to any other destination on the tree. Also the presence of the signal on a destination node blocks another source (on the same tree) from using the same wavelength to communicate with that a node on that tree (indicated by × in the λ/destination cell). For example, in the downstream direction if A uses λ_1 to communicate with D source nodes B_2 and C_2 cannot reuse λ_1 to communicate with node E (indicated by a × in the cell for each λ/destination). Similarly, in the upstream if node D uses λ_4 to communicate with node A, node E cannot use λ_4 to communicate with node C_2. This results in an inefficient use of the optical spectrum.

4.4.9.2.2 Mesh topology implemented with couplers

It is possible to construct a fully interconnected mesh network with couplers as shown in the figure below.

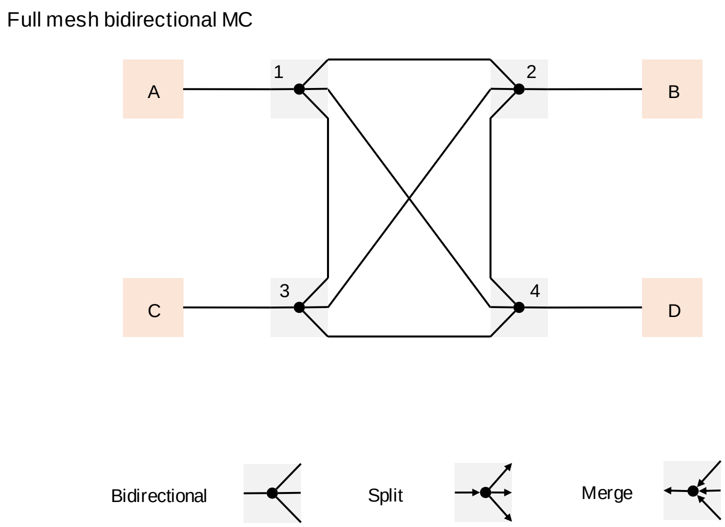

Figure 4-35 Fully connected mesh topology

The topology of the MC from each source node is shown in the four figures below.

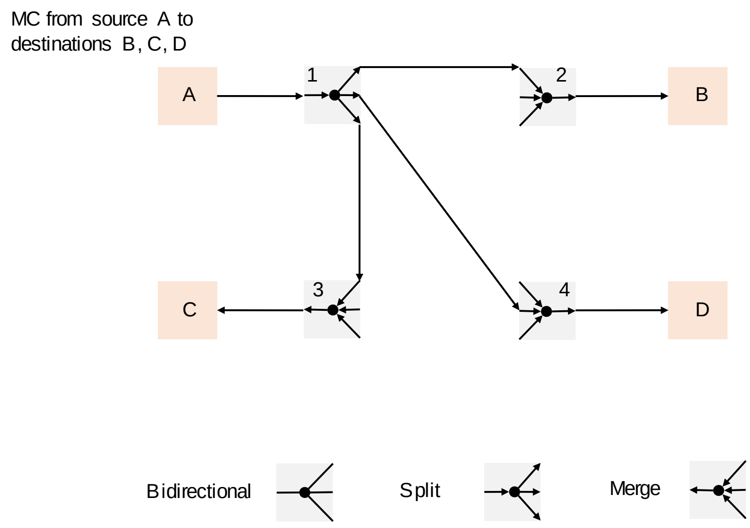

Figure 4-36 MC originating from node A

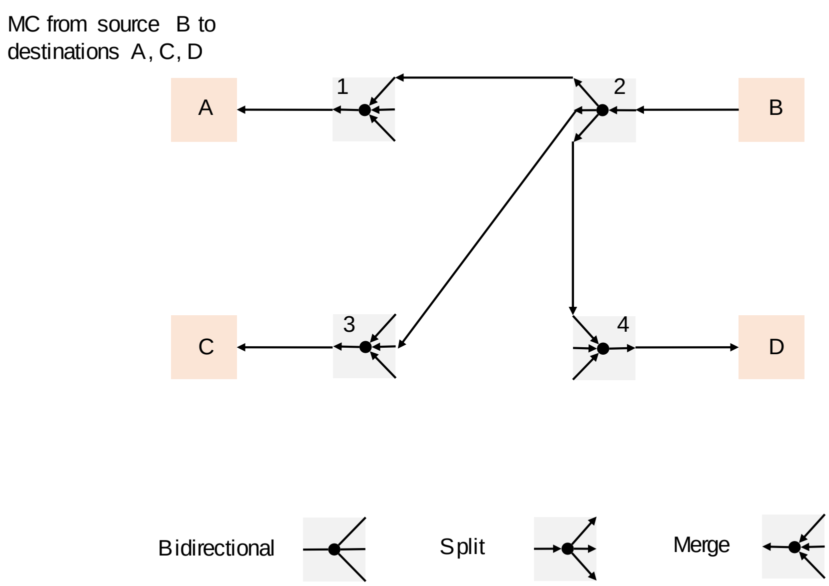

Figure 4-37 MC originating from node B

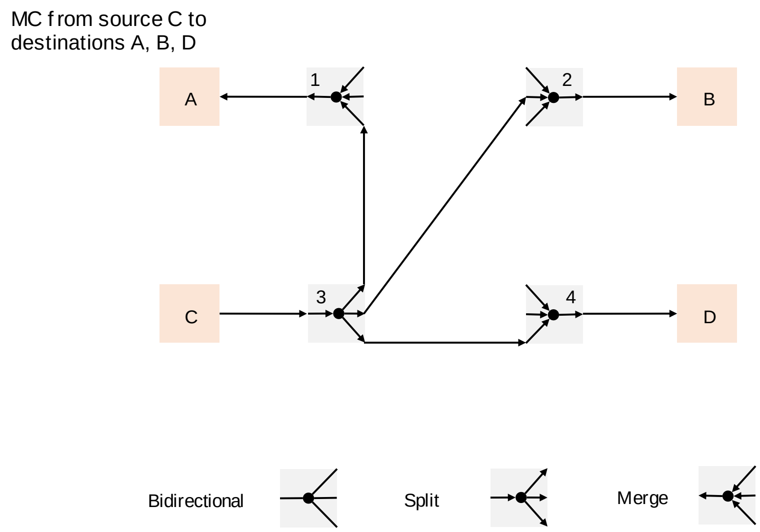

Figure 4-38 MC originating from node C

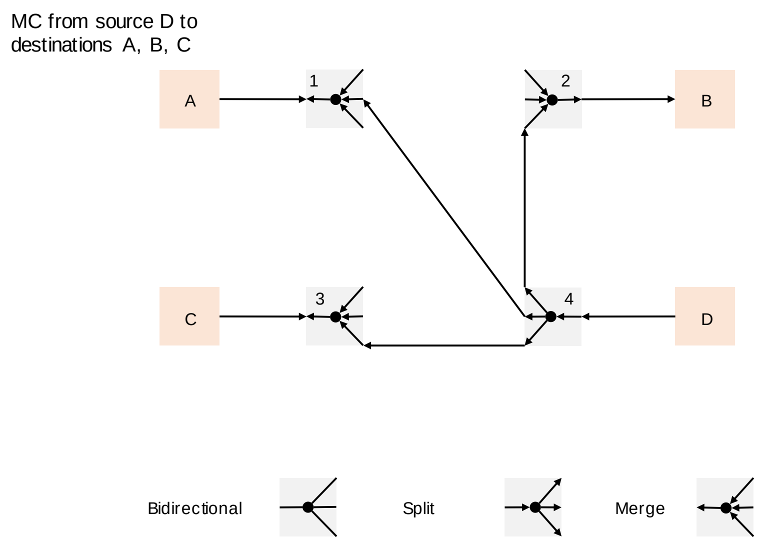

Figure 4-39 MC originating from node D

The connectivity provided by this topology is summarized in the tables below.

Source Node	Destination node			
	A	B	C	D
A		√	√	√
B	√		√	√
C	√	√		√
D	√	√	√	

Each source uses one wavelength to establish a point-to-point FC to each of the three destinations (i.e., a total of three wavelengths). Since source nodes are connected to all of the destination nodes, none of the wavelengths can be reused, this consumes 12 wavelengths. A WDM implementation would only require 6 wavelengths.

Single fiber operation is difficult to support since the spectrum used for the transmitters at a node cannot be segregated from the spectrum used for receivers.

4.4.10 Planning channels

Clearly, MCs will need to be constructed that will support the necessary flows (Information Transfer Channels (ITCs)) across the network.

4.4.10.1 Planning approaches

There are several distinct approaches to operation which can be used in any mix:

1. **"Just in time" set up of MCs** as services are requested to simply support each requested service between its endpoints where the MC support only the capacity of the service. In some cases:
    - A single MC may be sufficient to support the total capacity of a service (this is a sub-case of 4.4.9.1 Point to point Media Channels on page 57)
    - The service may be several MCs and those MCs will usually have stringent constraints, such as same OTS for all MCs supporting the service

    Note that as a part of the MC set up the compatibility of the MC with the OTSi must be verified.
2. **Preplan point to point MCs** for subsequent use when service requests are made, where MCs are allocated between points that are not necessarily the endpoints of the service and where the capacity of the preplanned MCs is significantly greater than the normal service request. With this approach the compatibility of the MC with the intended OTSi can be confirmed in advance.
    - There may be a group of co-routed (same OTS) non-contiguous MCs which go between the same points where each MC may be monitored as may the group of MCs be
    - The resultant MCA structure is discussed in 4.4.8.3 Multiple levels of subdivision on page 55.

- In Figure 4-26 Simplified representation of the model of two MCAs, OMS and OTS LTP, MCA (1) represents an end of the monitored group of MCs that have been preplanned.
- When some of the MCA (1) capacity is used to convey an OTSiA, then the NMCA is represented (MCA (2) on the figure) and can be monitored.
- Monitoring at any granularity can occur at any point in the network where there is a capable device

3. **Preplan multi-pointed MCs** (as discussed in 4.4.9.2 Multi-pointed Media Channels on page 57) between boundary points on the network prior to any service request so that services can be directed simply by selecting the frequency available in an MC. The capacity of the preplanned MCs is significantly greater than the normal service request.
4. **Pre-planned edge to edge MC** with edge fan-out where the MCs do go point to point between the same two nodes but then go to all Tribs on the node. The capacity of the preplanned MC is significantly greater than the normal service request.

4.4.10.2 A mixed planning example

The figure below shows a ROADM network (R1-R5) with transponder disaggregation where there are seven transponders (T1-T7) which are each assumed to be in separate equipments (for simplification of the discussion). Two pre-planned MCs have been set up. In R1 there is no filtering and all channels go to all transponder as there is edge fan-out. T1 has been tuned to red transmit and green receive and T2 to blue transmit and brown receive.

At the other end T5 has been tuned to red/green such that T1 and T5 are connected. Retuning T2 and T1 would change the connectivity to T5 with no need for change in the ROADM network as both receive green and brown and both have the opportunity to transmit on red and blue. T2 is currently connected to T6 via blue/brown.

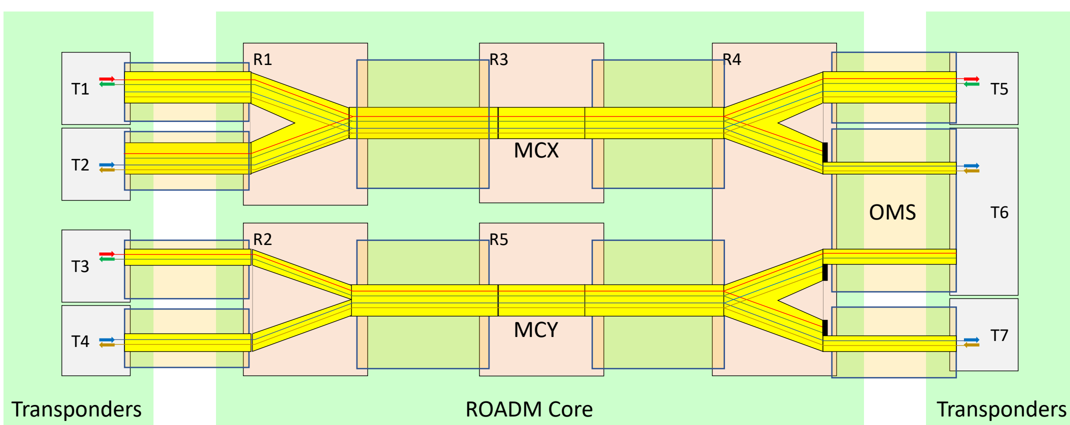

Figure 4-40 Media Channel with partial split and merge showing filters

The link to T6 is filtered at the R4 at the port facing T6 such that T6 only receives blue (and does not receive red) from MCX. T6 can only send on brown to R4 as R4 filters everything else out including green. On the same OMS (fiber pair), T6 receives red and green from the MCY via filters at the edge of R4.

At the other end of MCY, T3 and T4 have per service MCs constructed in R2. These could have been constructed as the service demand was received. At the other end of MCY, which was preprovisioned in R5, T7 is connected to T4 as a result of a filter at the edge of R4. This could be a preplanned fixed configuration.

T3 is not connected to a Transponder as whilst the configuration in R4 is such that T6 receives red from T3 and has an opportunity to send green to T3, T6 is currently tuned to connect to T2.

4.4.10.3 Abstracting the MCs

The figure above is a hybrid view of the effects in the network observing some details of implementation technology.

The figure below generalizes the representation to focus on the effect at the edge and considers that in the context of each node and each node adjacency[29]. The figure emphasizes where flexibility is offered to the transponders.

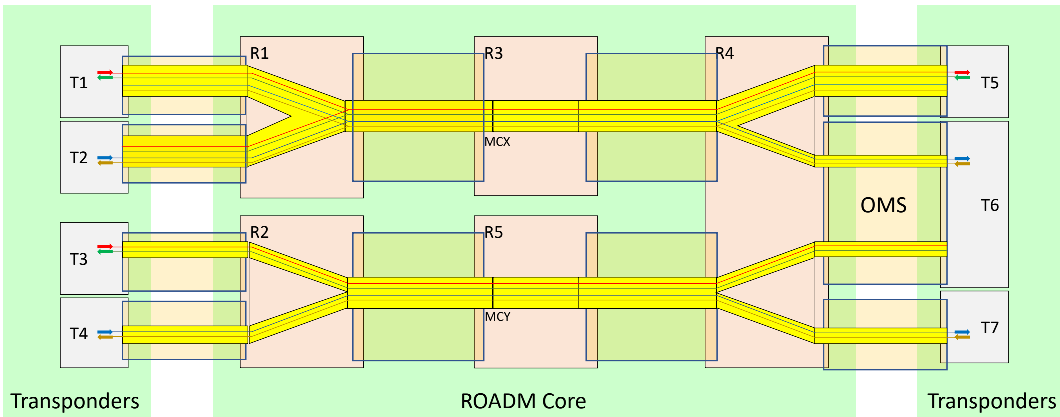

Figure 4-41 Media Channel with partial split and merge showing abstraction of filters

The transponders T1, T2, T5 and T6 can be tuned to change the connectivity in the network. Currently T3, whilst on, is not connected.

Taking the abstraction one step further it is reasonable to consider the effect of the MCs as perceived by the overall controller in terms of FCs.

The figure below shows the end to end OTSi FCs (X1, X2, Y1 and Y2) and the corresponding FCs in the ROADMs (FCX1.1 etc). Clearly, FCY1 is not a complete FC as T6 is selecting blue/brown which is from T2.

These FCs (FCX1 etc.) are abstractions. In a mesh deployment the FCs shown highlight the relevant flow through the network that supports the Information Transfer Channel (other than FCY1 that clearly does not due to the setting at T6).

[29] Removing clutter of redundant light never relevant for forwarding.

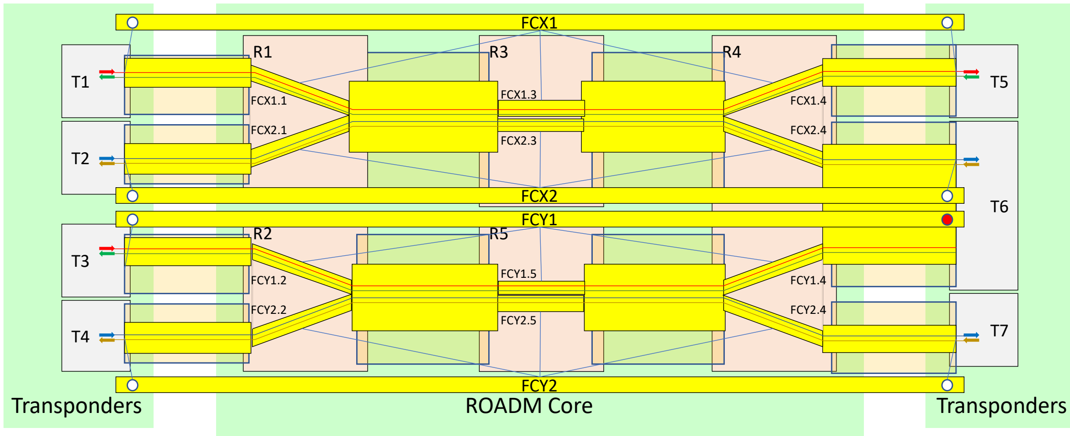

Figure 4-42 Media Channel represented as FCs showing enabled forwarding

The figure above emphasizes the enabled forwarding (but does not indicate enabled potential or total potential). At each intermediate point, in R1, R2 etc., there may be monitors per NMC (as discussed in 4.4.8.2 The MCA LTP and the NMC on page 53). In the more general case the NMCA will be monitored (as discussed in 4.4.8.2 The MCA LTP and the NMCA on page 53).

To ensure appropriate operation the ROADM Core will need to be aware of the spectral power at all points for each channel:

- To determine appropriate amplifier settings
- To determine what spectrum to monitor for:
  - Absence of light, especially where presence of light would cause disruption to other signals
  - Presence of light
    - On the path supporting the Information Transfer Channel
    - Where there is waste light

4.4.10.4 The monitoring aspect is dealt with in section 4.5.2.5 Capability (requested/intended, current, threshold and alarms)

For all parameters there will be definition. The degree of support for each may vary in terms of range supported etc.

- Default
- Range
- Preference
- Interaction

Considering Tandem Connection Monitoring and mapping to OAM (MEP/MIP etc) pattern on page 92.

4.4.10.5 Dealing with the route through the MC mesh

Returning to the essence of Figure 4-40 Media Channel with partial split and merge showing filters on page 69, the figure below focusses on the effect of the brown/blue spectrum in MCX from Figure 4-40. The lasers and receivers in T2 and T6 are set to enable forwarding whereas those in T1 and T5 are set to not handle blue/brown.

The following FCs are shown:

- FC CC1 – the effect of the ROADM network configuration showing the enabled potential for forwarding in the ROADM network and understood by the Core Controller
- FC OC1 – the effect of the ROADM network configuration extended to the Transponders as understood by the Overall Controller
- FC OC2 – the intended Information Transfer Channel effective at the transponders as understood by the Overall Controller
- FC CC2 – the intended Information Transfer Channel across the ROADM Core as understood by the Core Controller
- FC T21 – the effect of the ROADM network focusing on only T2 on the left side.

All FCs highlighted above represent channels as they can be configured in the network in preparation for a signal. It is clear from the figure that CC2 is a route through CC1 and that OC2 is a route through OC1.

As the blue light from T1 and T2 is merged in R1, T1 must not send blue light as it will clash with the intended blue light from T2. As a consequence, it would be expected that the Access Port on R1 towards T1 would be monitored for absence of blue light.

On this basis, in general, the FCs that correspond to CC2 highlight what from FC CC1 should be monitored for presence and what should be monitored for absence.

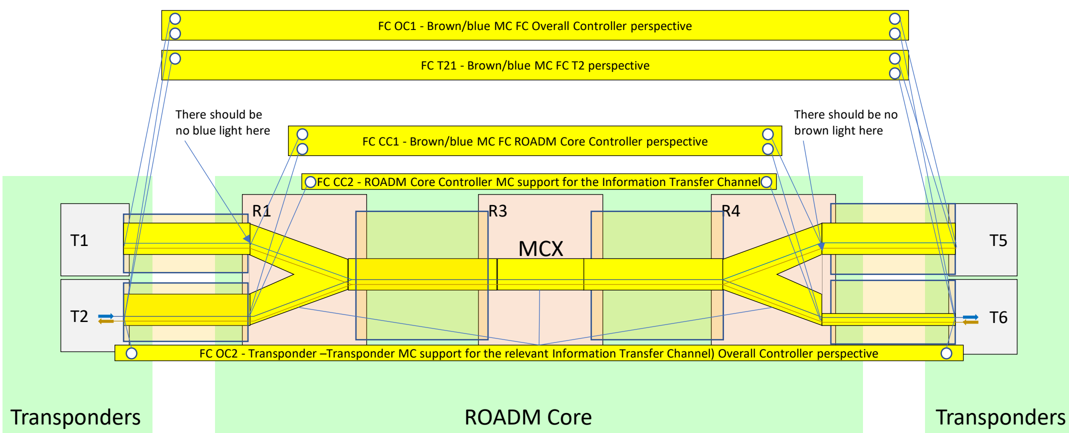

Figure 4-43 Media Channel focussing on brown/blue spectrum in MCX

4.4.11 NMCA FC and dealing with the "OTSiA coordination"

The following figure is extracted from [ITU-T G.872] highlights the need for coordination of the OTSiG-O connection with the connections of the corresponding OTSis in the OTSiA and coordination of the adaptater/modulator and the tunable filter characteristics. The latter has been dealt with by encapsulating the coupler/splitter function (abstract) and the OMS-O/OTSiG-O overhead within a combination of the OMS and NMCA LTPs (see 4.4.8 Subdividing the Media Channel on page 50).

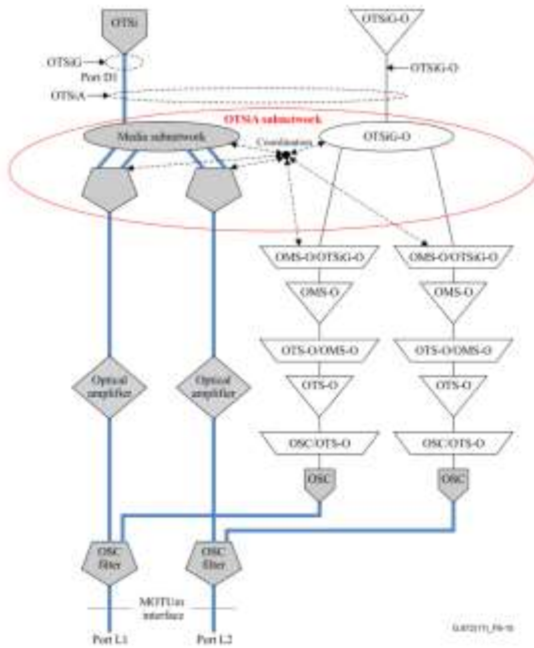

Figure 8-15 – OTSiA subnetwork and the supporting media and OTSiG-O sub-networks

Figure 4-44 [ITU-T G.872] Figure 8-15 showing OTSi and OTSiG-O connection coordination

The main aspect of this coordination, i.e. that of the actual connection, is dealt with by simply encapsulating the connections of the NMCs and of the OTSiG-O in a single NMCA FC. Whilst the FC is mixed layerProtocol, the main layerProtocol is PHOTONIC_MEDIA and hence that is the layerProtocol of the FC[30]. The underlying spec detail will explain the mix. It is assumed that the "NE" carries out the coordination identified e.g. for managing an OTU connection.

The following figure covers the basic case discussed above, in the context of the "just in time" planning approach detailed in 4.4.10.1 Planning approaches on page 68, assuming just one level of MC at the granularity of the OTSi and hence the NMCA.

In the figure below, the MCA LTP shown in earlier figures (see Figure 4-24 The MCA LTP with multiple monitors on page 54) is shown as an NMCA LTP. The NMCA LTP is shown with the associated FC which is expanded to expose the internal detail of each NMC and the overhead. The formation of the NMCA FC provides the instructions for coordination as the FC has a spec that expands the internal structure as shown.

[30] The layerProtocol can be qualified with further detail, but that is essentially for human consumption as the spec provides all necessary details.

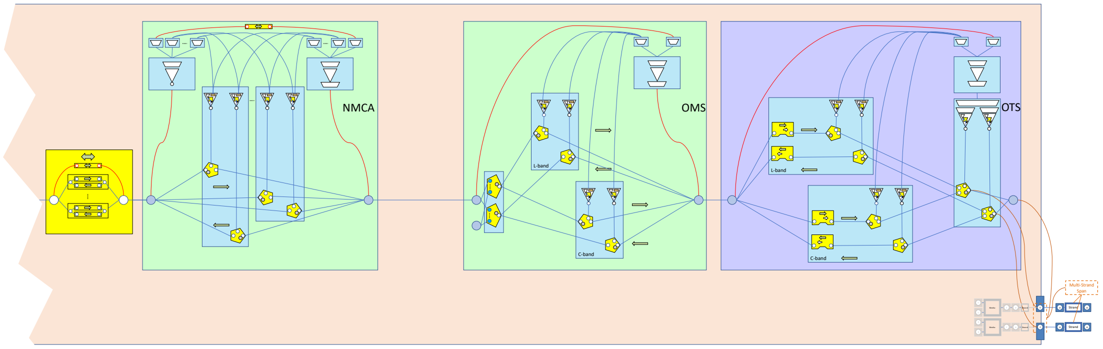

Figure 4-45 Adding NMCA FC

Clearly the FC shown will connect to at least on other LTP. For through going traffic this may be an LTP in a chain identical to that shown above on the right side of the NMCA FC. The Termination of the NMCA/OTSiA is discussed in the next section.

The usual FC capabilities are available so if there is some form of resilience this can be represented with multi-pointed FC and/or multiple overlaid FCs as appropriate (see TR-512.5).

4.4.12 Adding the OTSiA termination

In a simple solution where there is no disaggregation the termination transponder is part of the ROADM. In the case it is assumed that there is an OTU/ODU client that is bidirectional. The figure below shows the OTSiA terminations at one end of the bidirectional FC supporting the OTU/ODU client.

The LTP representing the termination encapsulates:

- A set of bidirectional LayerProtocols, one for each OTSi transmitter/receiver pair (at the boundary between the OTSi(p) and the OTSi(e)
- A bidirectional LTP for the OTSiG-O overhead termination
- A set of bidirectional LayerProtocol units one per OTSi measurement and parameters related to the OTSiG-O
- A bidirectional LayerProtocol that deals with the inverse multiplexing of the OTU/ODU to signals to be carried by the OTSis.

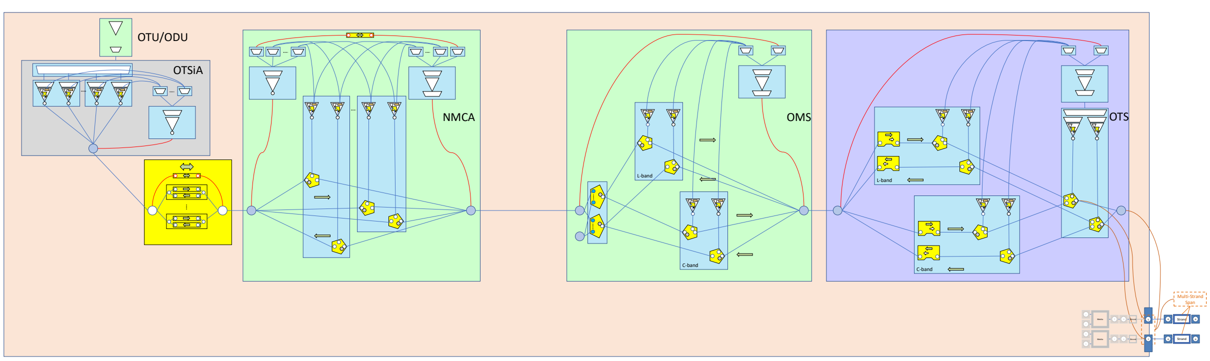

Figure 4-46 Adding OTSiA transponder

The lower part of the OTSiA LTP is the OTSiA(p) which corresponds directly to the NMCA termination. In this simple case the end-end bidirectional NMCA FC defines the OTSiA FC (see 4.4.9.1 Point to point Media Channels on page 57 as depicting the NMCA FC) between two transponders.

The structure in the figure above can be represented using the simplified form

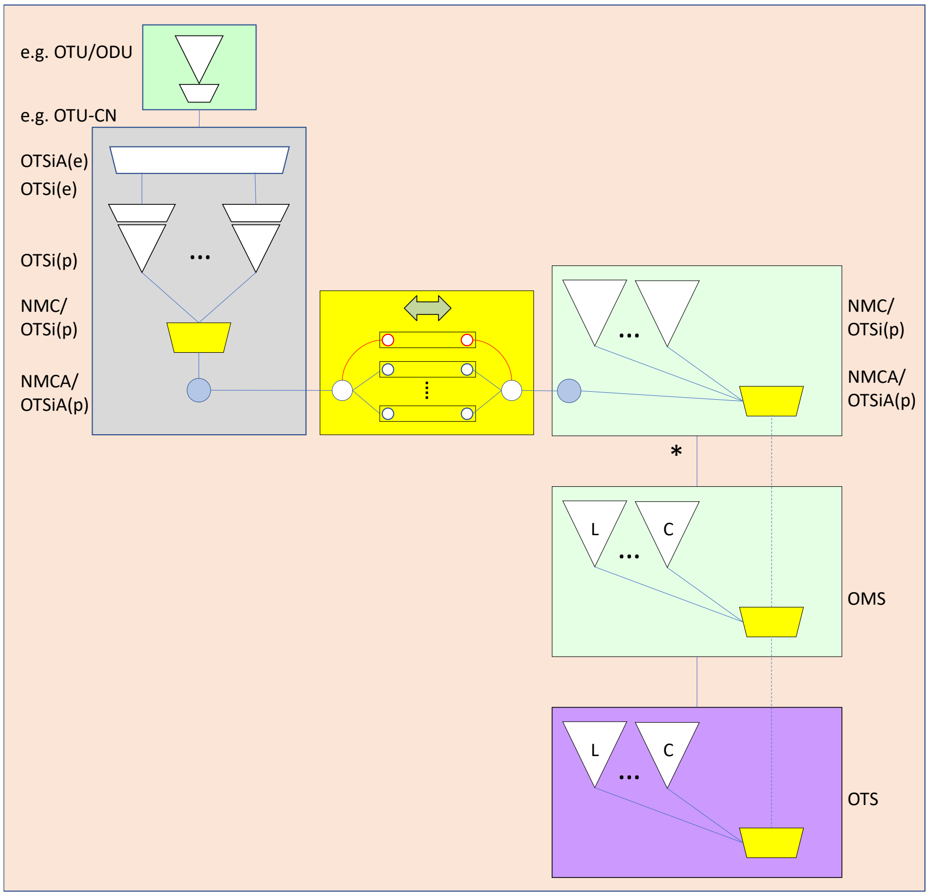

Figure 4-47 Simplified representation showing OMS/OTS, NMCA, and OTSi termniation

In more sophisticated cases where the MC structure supporting the OTSiA is multi-pointed. the OTSiA bidirectional point to point FC is defined by tuning transponders and receivers. This then defines the relevant NMCA span and hence defines where the relevant places are to measure in the multi-pointed MC (see also 4.4.10.5 Dealing with the route through the MC mesh on page 71).

4.4.13 Multiple levels of MCA in a ROADM

As discussed earlier in this document, an MC has a spectral width and may be such that several OTSi(p)s can pass through it. In the scenario considered here the ROADM is configured with several wide MCs each suitable to pass several OTSi(p)s[31].

The wide MCs are considered as being in a Group and that Group has associated monitoring and overhead and as such are considered as an MCA[32, 33].

The figure below shows two ports of a multi-port ROADM "X". The ROADM is shown as an opaque node. The internal details are represented as capabilities for creation of FCs etc. using ONF specs. In the figure the MCA FC shown is bidirectional point to point between the MCA LTPs of AccessPort 1 and AccessPort 2 of the ROADM. The FC has more than two MCs present (along with the overhead). The MCs of the MCA have been configured via some form of filtering and each is guarded.

It is possible that the MCA was set up during a preplanning activity prior to the connection of transponders (see 4.4.10.1 Planning approaches on page 68) and it is possible that none of the MCs is passing any light. Under these circumstances the MCA cannot be monitored[34].

[31] Typically, an express channel is a “hardwired” by pass of the filters and media subnetwork. i.e., typically, the FC representing the express media channel has no flexibility. The capability described here is assumed to be flexible.
[32] In current solutions monitoring and overhead is not standardized for arbitrary MCAs.
[33] The MCA is the normal granularity of the FC/LTP. A Group of one MC where there is no associated overhead etc is still considered as an MCA so as to simplify the model and its usage.
[34] It is possible to apply a test signal in the absence of an appropriate payload carrying OTSi.

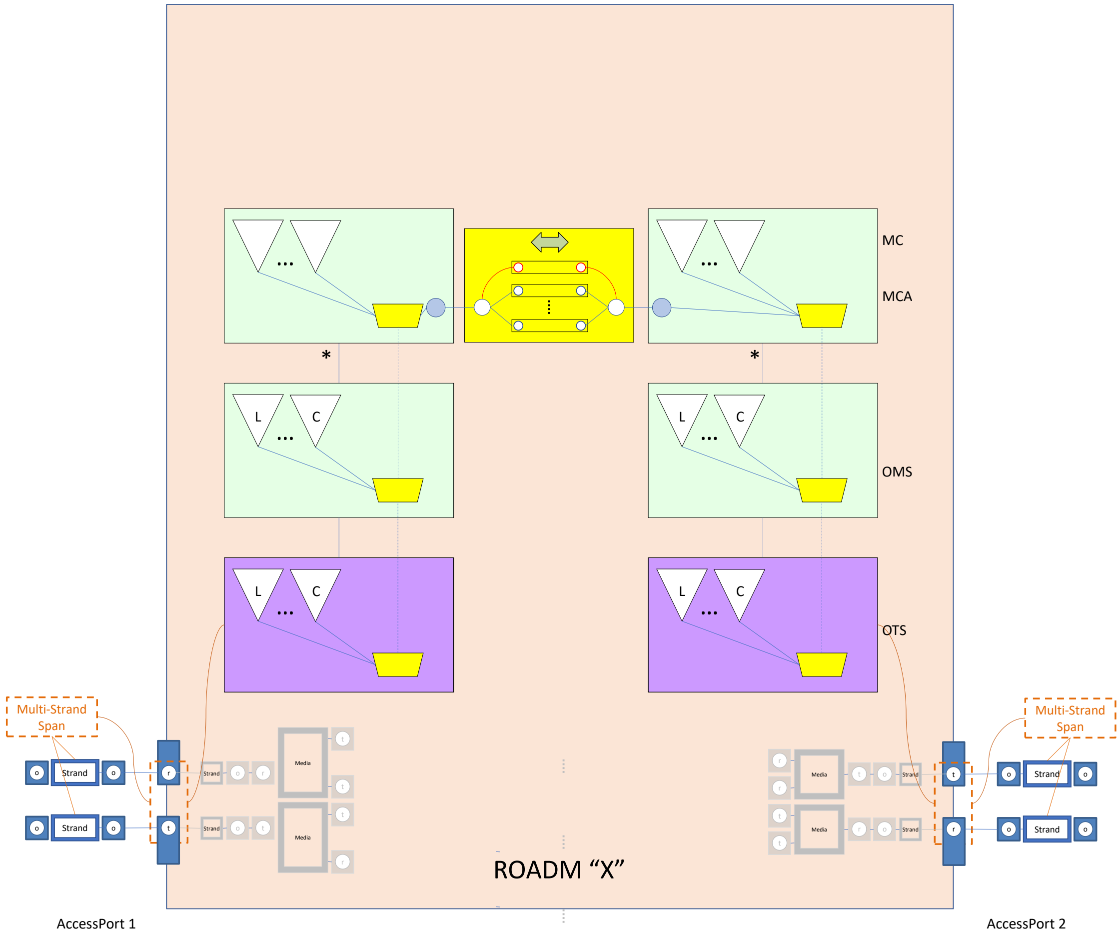

Figure 4-48 Simplified representation showing transit MCA in ROADM "X"

When there is demand for an Information Transfer Channel an OTSiA(p) will be routed across the network. This will result in definition of an NMCA with one or more NMCs (based on the number of OTSis in the OTSiA(p)). Depending upon the structure of the network (topology and ROADM capability) this may be a point to point route through a multi-pointed MC.

To simplify the discussion at this stage, it is assumed that the network structure is such that point to point MCs are defined and that the NMCA uses pre-configured wide MCs for at least part of the transit and specifically uses the wide MCA in ROADM "X".

It is possible that there is no further configuration in ROADM "X" and that it is not required to be monitored at any finer granularity that the existing MCs. In this case, when an OTSi is actually enabled some light will appear in part of the spectrum of the MC and that can be monitored simply as power in the channel.

It is also possible that a further level of configuration is applied to enable NMCA power balancing and NMCA monitoring. The figure below shows the addition of the more detailed view of the NMCs in the NMCA and the provision of monitoring. The upper FC representing the NMCA is fully dependent for its boundary definition on the pre-configured wide MCA (the FC below the NMCA FC in the figure). It is essentially emergent from the definition of the OTSi(p) overlaid on the MCA FC.

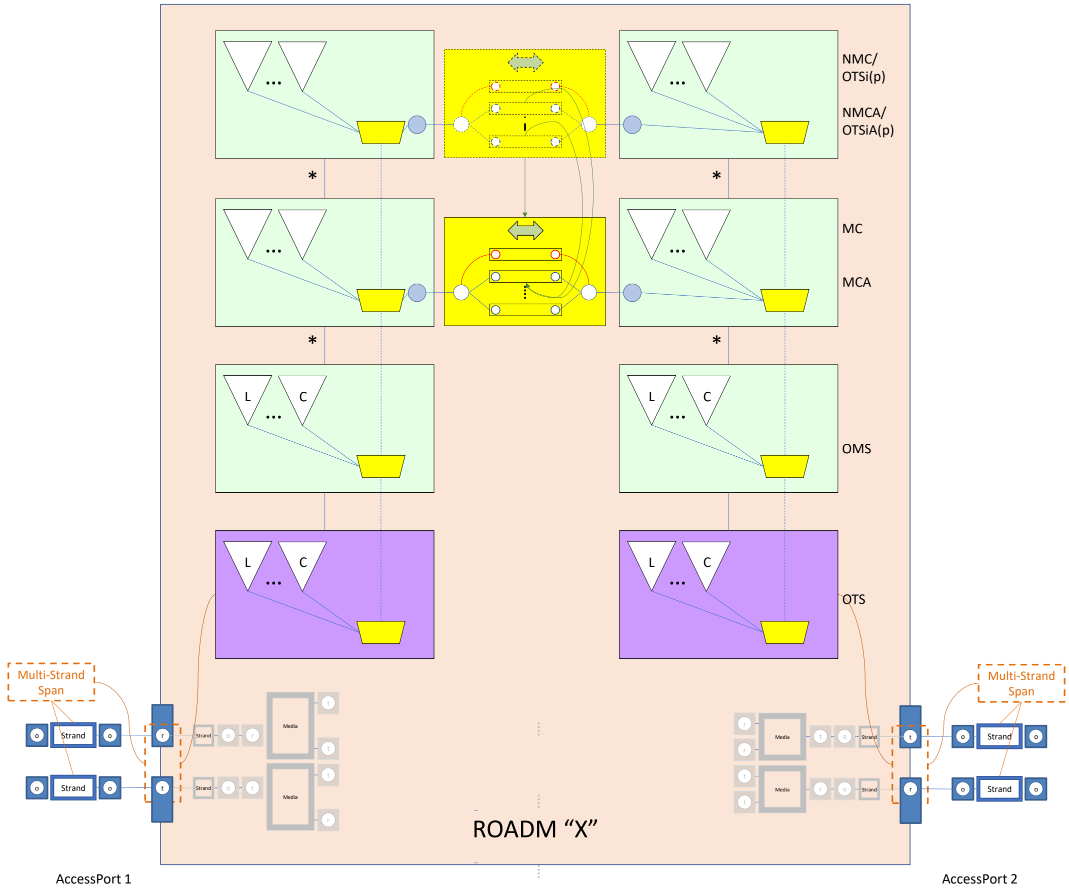

Figure 4-49 Simplified representation showing transit MCA with NMCA configuration

The relationship between the NMC FCs of the NMCA FC and the MC FCs of the MCA FC is understood through the spectrum definition of each NMC in the context of the spectrum definition of the MCs of the MCA.

In this configuration it is possible to assess characteristics (such as power) for the MCA, MC, NMCA and NMC.

Considering a multi-pointed MC as discussed in 4.4.9.2 Multi-pointed Media Channels on page 57 and especially Figure 4-29 on page 59, it is clear that there are points in the network where monitoring is relevant and points where it is not.

Take the C<>G OTSi in Figure 4-29 , measuring red and green in C, 2, 3 and G provides information about the integrity of the C<>G OTSi. Green is also sent through ROADM 1 but there is no reason to measure the power at this point.

Recognizing that there is a red merge in node 2 (see Figure 4-28), it would be sensible to monitor the red power on the 1→2 link to ensure that it is zero.

The termination in a ROADM with several levels of MC configuration could be represented as in the figure below.

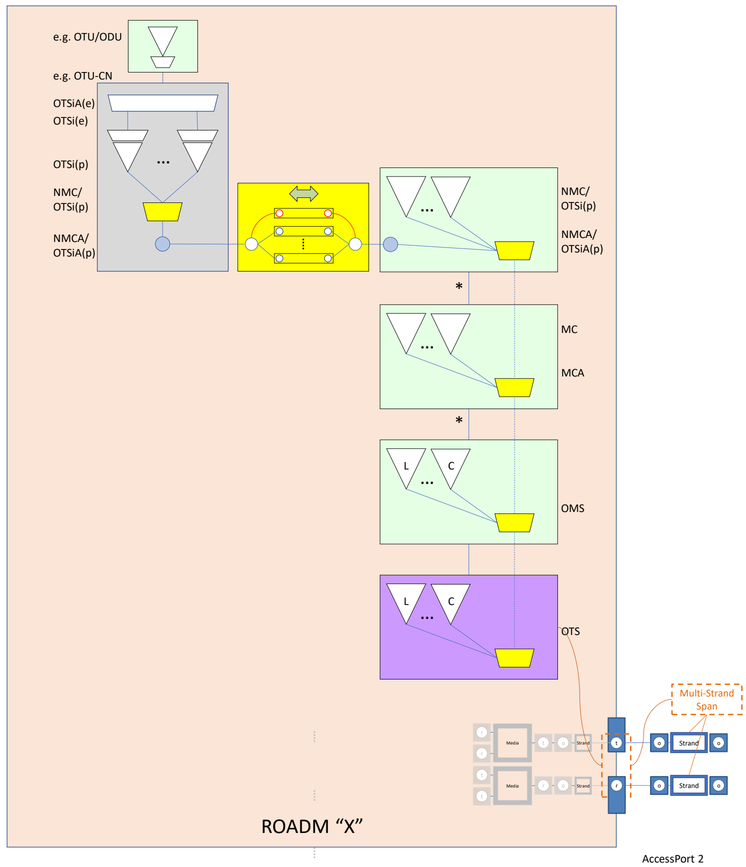

Figure 4-50 Simplified representation showing OMS/OTS, MCA, NMCA, and OTSi termniation

4.4.14 MCA network considerations

Using a further simplification of the symbol set depicting the constructs discussed in the previous section, a simple linear network view can be constructed that shows various MC configurations in a network context.

In the figure below, the planning strategy is assumed to be "Preplanned point to point MCs" (see 4.4.10.1 Planning approaches on page 68).

In the figure below:

- There are three preplanned MCs A-B-C, D-E-F and F-G-H
- Node A shows two levels of MC (MCA and NMCA) with a termination
- Node B, E and G have all been switched at the broad MC/MCA level such that the NMC/NMCA route is constrained.
- Node C, D and F have been switched at the NMC/NMCA granularity

- The NMC, although shown between two points, may be multi-pointed. The ITC (Information Transfer Channel), resulting from the application of tuned transmitters and receivers is bidirectional point to point

It is assumed that the ROADM nodes have many AccessPorts and hence the figure is highly simplified. It is assumed that the MC set-up at each AccessPort each port may be different.

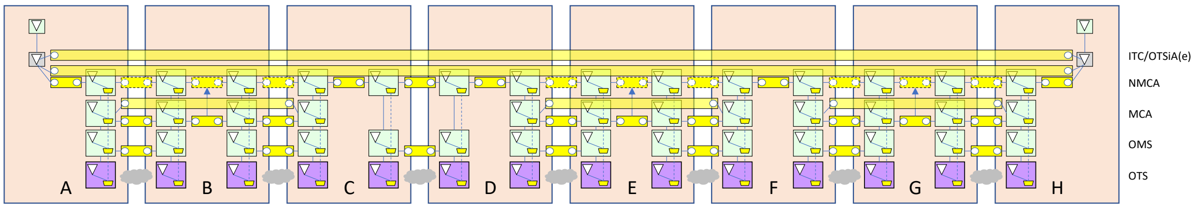

Figure 4-51 Simplified representation of the model of MCA, OMS and OTS LTP

In the figure above, the NMC/NMCA granularity switching in Node F allows a transition from one wide MC arrangement between Node D-E-F to another wide MC arrangement between Node F-G-H. It is only possible to change MC structure within a Node. The MC arrangement either side of an OMS must be understood in the same way (due to guard bands etc.).

Clearly, if there is a change in MC arrangement within a node, there are still many limitations as the spectrum of a signal remains the same as it crosses the node and hence the guard band situation in the MC arrangement on either side of the node must be compatible with the signal.

The model does not restrict the MC arrangement in any way. On that basis it is possible to put in place extremely inefficient MC arrangements in a network where guard band positioning in on MC arrangement blocks signals in another arrangement.

4.4.15 A disaggregated node

In the previous sections various components were gradually built up into a full ROADM. Although this is a valid configuration, many deployments disaggregate between the transponder and ROADM switching node, such that all transponders are separated from a photonic switching ROADM network.

This section deals with this degree of disaggregation and focused on the interconnect between the transponder and the ROADM switching node.

4.4.15.1 Single OTSi per ROADM tributary with single OTSi per OTSiA

This is the simplest of cases to consider. The ROADM will have many tributary ports, and each is "filtered" to ensure only one OTSi is provided. Normally, this OTSi spectrum will be fixed per tributary.

The figure below shows this form of access. The figure does not fully cover the propagation of overhead from the Transponder to the ROADM. This is covered in section 4.4.15.6 Dealing with propagation of overhead in a disaggregated solution 86.

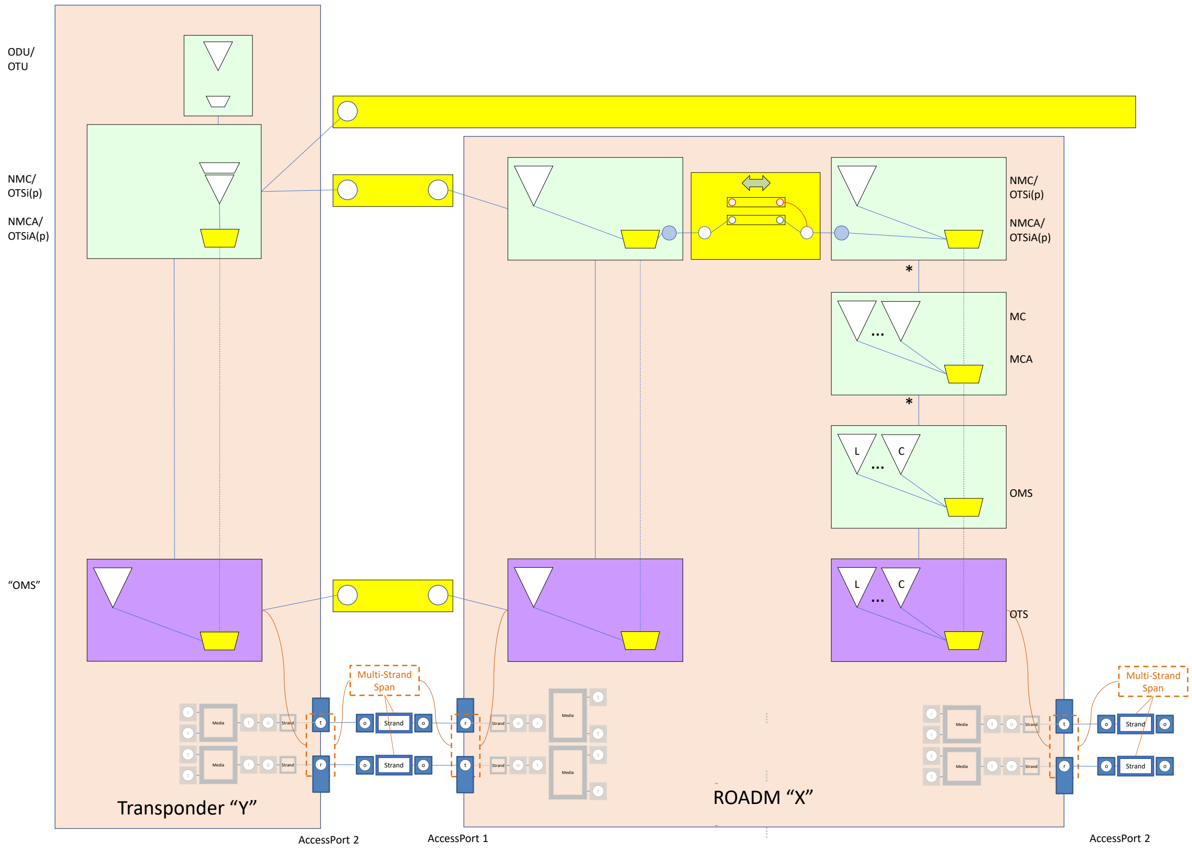

Figure 4-52 Single OTSi per trib Access Port

The connectivity is still considered to be an NMCA/OTSiA for consistency even though the OTSiA has only one OTSi. It is assumed that there is associated overhead and that this overhead is co-routed with the OTSi.

4.4.15.2 Single OTSi per ROADM tributary with multiple OTSis per OTSiA

An OTSiA may have multiple OTSis. If the device only allows one OTSi per tributary there is a need to have shared knowledge of the grouping between the Transponder and the ROADM. The figure below shows this case.

The figure does not fully cover the propagation of overhead from the Transponder to the ROADM. This is covered in section 4.4.15.6 Dealing with propagation of overhead in a disaggregated solution 86.

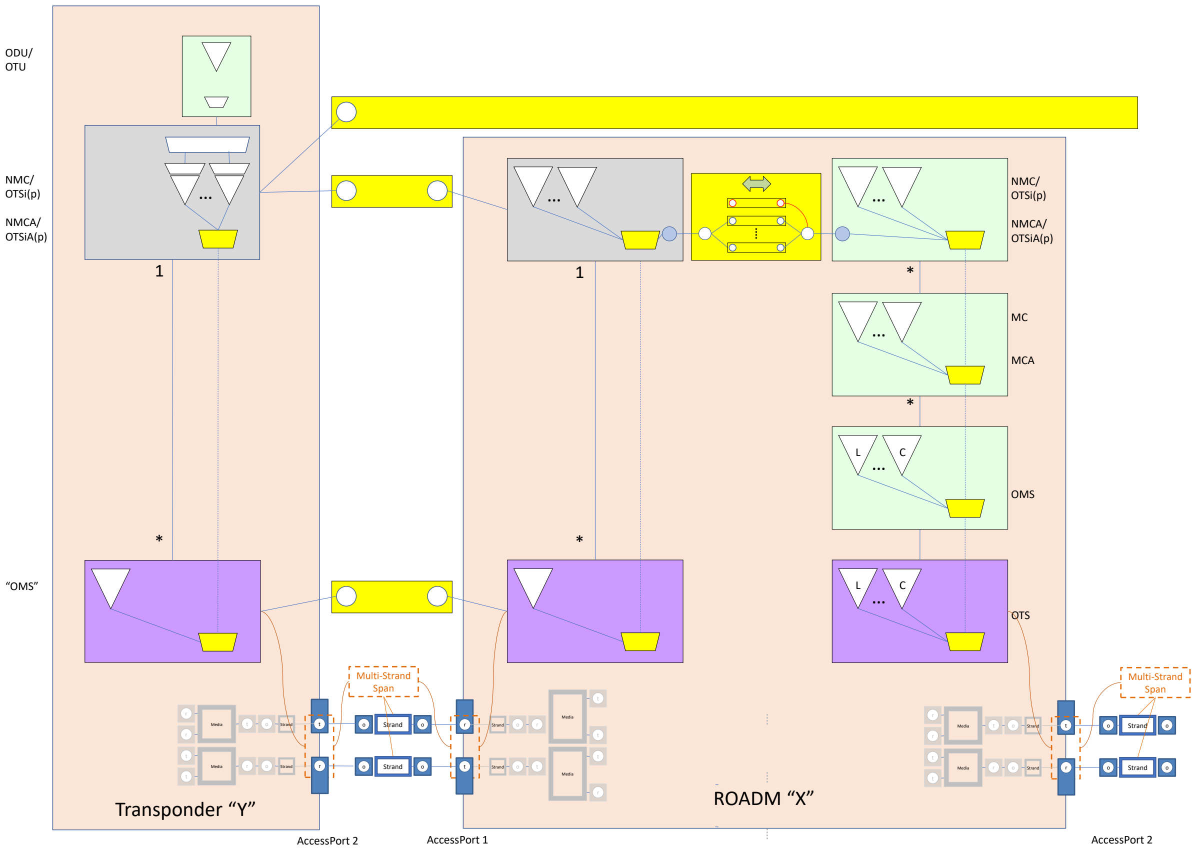

Figure 4-53 Single OTSi per trib Access Port with multiple OTSis per OTSiA

4.4.15.3 Multiple OTSi per ROADM tributary with multiple OTSis per OTSiA

An OTSiA may have multiple OTSis. The device may have one single port that carries all OTSis between the Transponder and the ROADM. It is possible that the device may support several OTSiAs each with several OTSis over the same AccessPort.

The figures do not fully cover the propagation of overhead from the Transponder to the ROADM. This is covered in section 4.4.15.6 Dealing with propagation of overhead in a disaggregated solution 86.

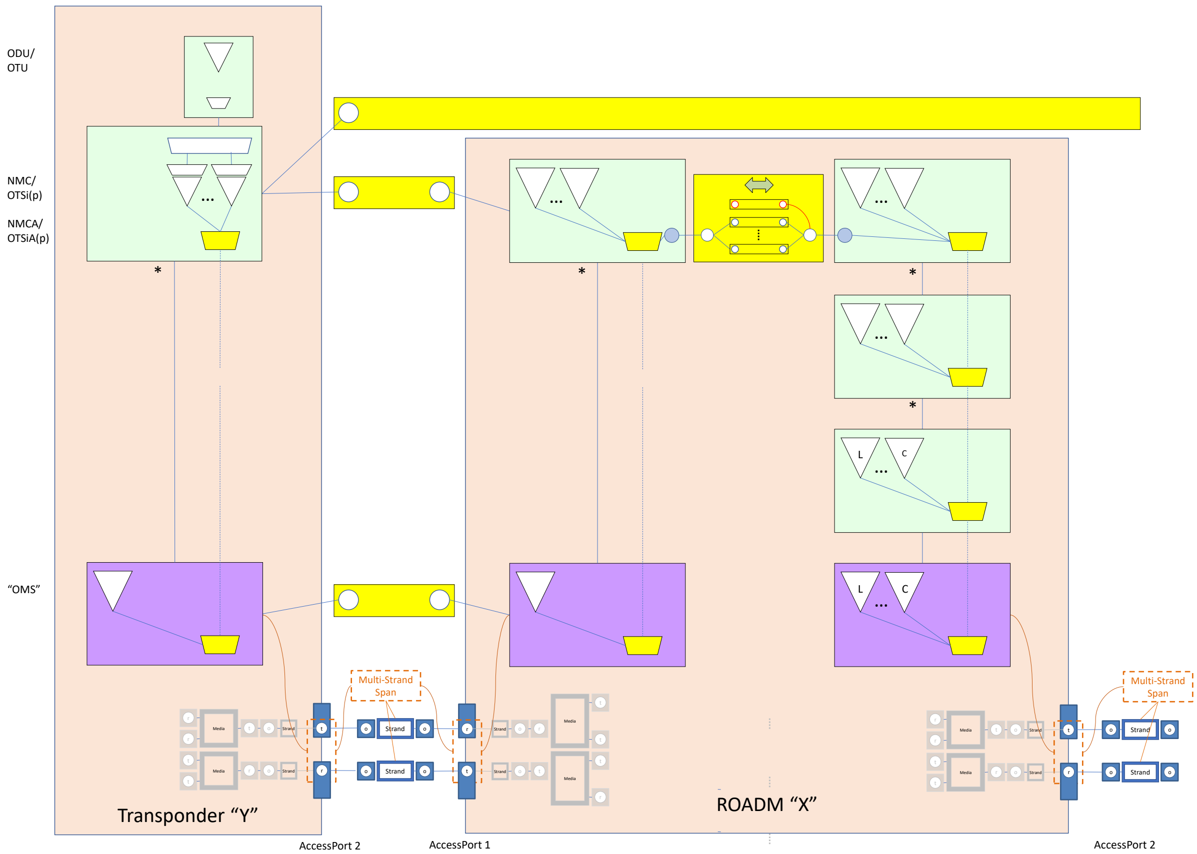

Figure 4-54 Transponder with a single AccessPort with several OTSiAs each with several OTSis

The port may have some broad channelization (MCA). The figure below shows this option.

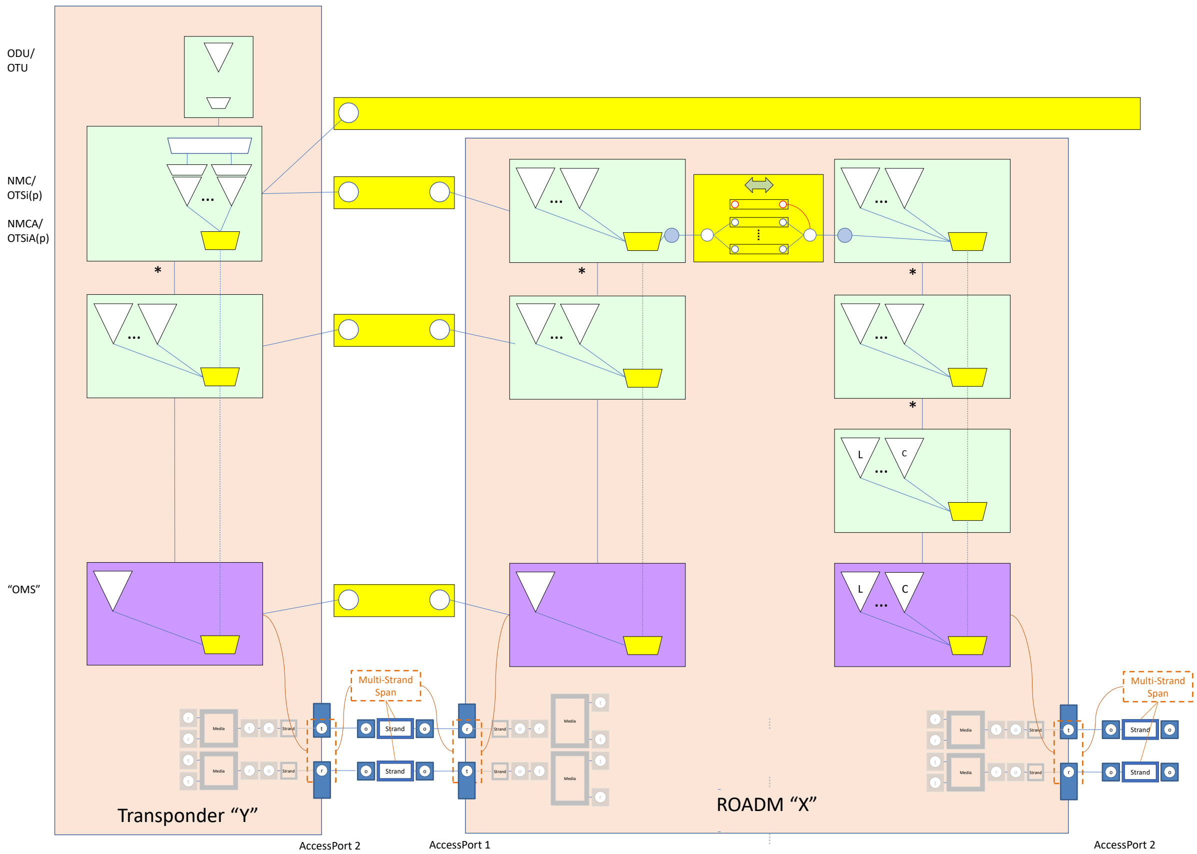

Figure 4-55 Transponder with a single AccessPort with several MCs in an MCA

4.4.15.4 Transponder with each OTSiA spread across several multi-channel Access Ports

The transponder supports an OTSiA with multiple OTSis. The device may have several ports that each can carry several OTSis between the Transponder and the ROADM. It is possible that the device may support several OTSiAs each with several OTSis scattered over several Access Ports. The port may have some broad channelization (MCA). The figure below shows this option.

The figure does not fully cover the propagation of overhead from the Transponder to the ROADM. This is covered in section 4.4.15.6 Dealing with propagation of overhead in a disaggregated solution 86.

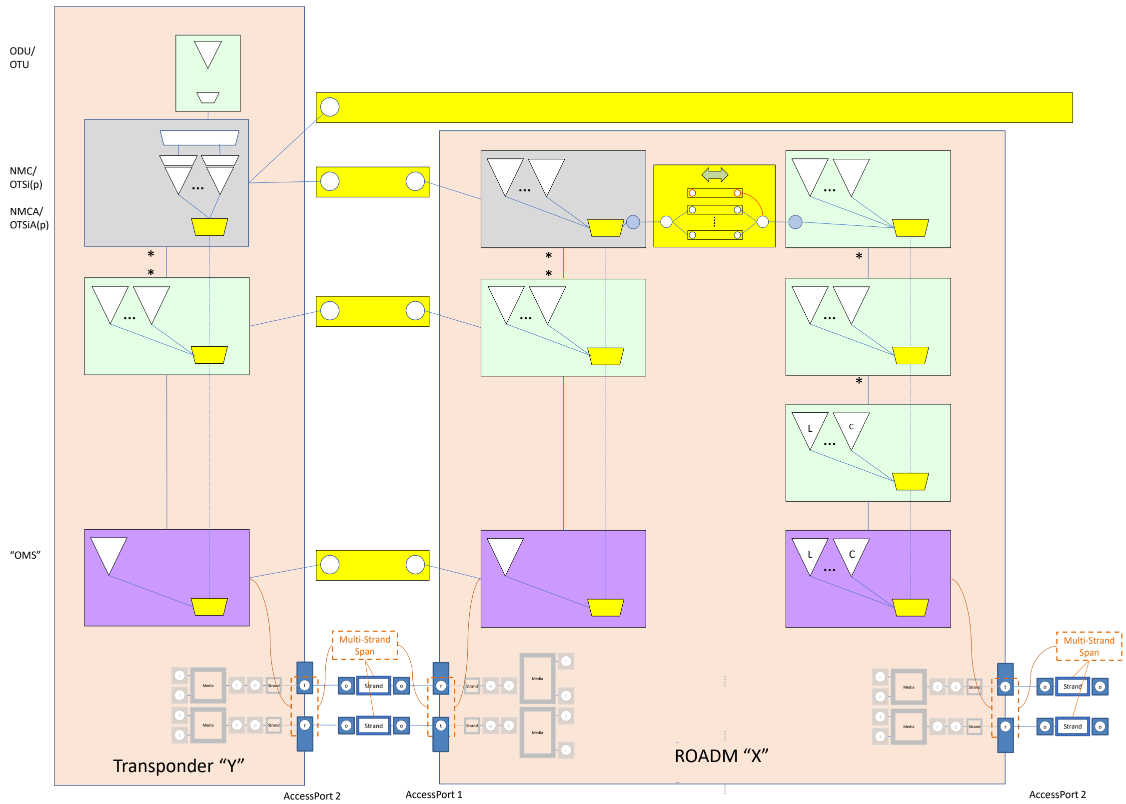

Figure 4-56 Transponder where an OTSiA may spread across several multi-channel AccesPorts

4.4.15.5 Transponder with the network MCAs extended to the Transponder

The network is assumed to have been planned using the "Pre-planned edge to edge" approach (see 4.4.10.1 Planning approaches on page 68). The transponder supports an OTSiA with multiple OTSis. The transponder device has one Access Port can carry all OTSis between the Transponder and the ROADM. The port is arranged in a number of MCAs that are defined by the ROADM network planning where different MCAs may go to different places in the network. All NMCs of an NMCA must use the same MCA. The destination is selected by choosing the MCA at the transponder.

The figure does not fully cover the propagation of overhead from the Transponder to the ROADM. This is covered in section 4.4.15.6 Dealing with propagation of overhead in a disaggregated solution 86.

The figure below shows this option.

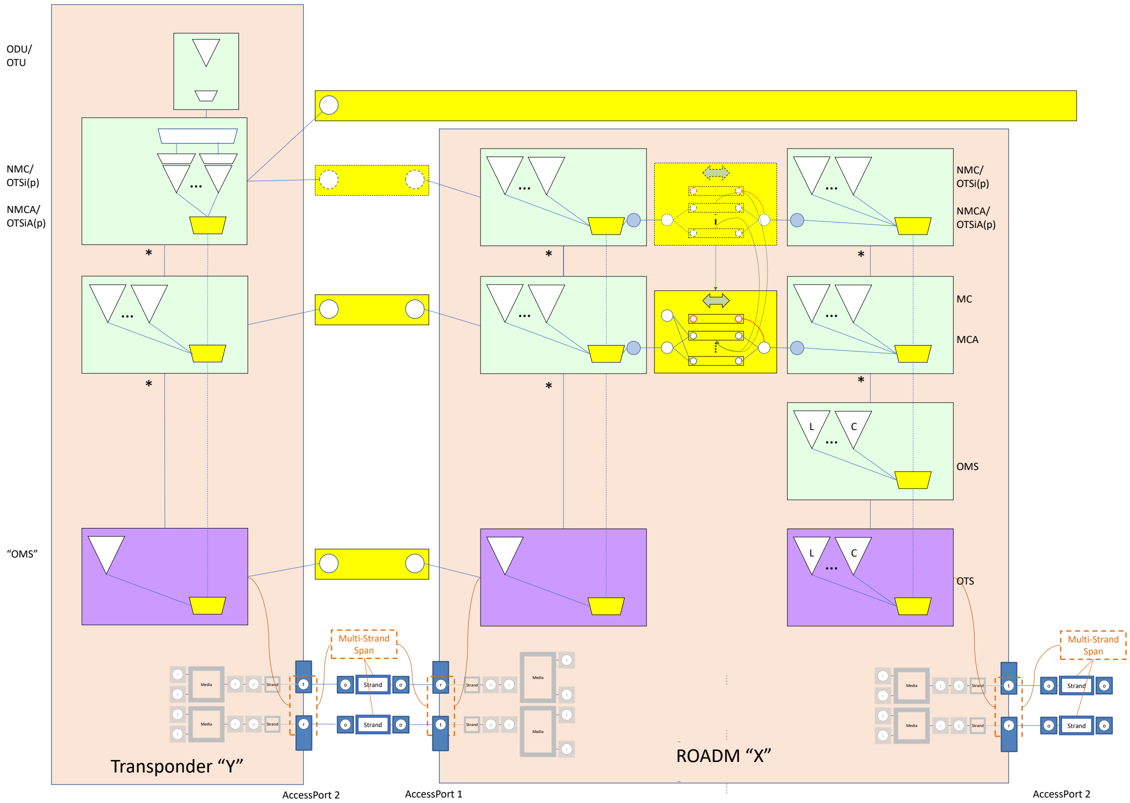

Figure 4-57 Transponder ending network wide MCAs

The transponder could also have multiple ports, but it seems unlikely that an NMCA would spread across several ports but within the same MCA (which would requre a floating LTP) on each port. On that basis the multi-port transponder would appear to have the same model as the single port version where each NMCA is constrained to one port.

4.4.15.6 Dealing with propagation of overhead in a disaggregated solution

There is clearly a need to coordinate the propagation of overhead between the Transponder and the ROADM. There are several techniques for propagation and there is no formal standardization at this point.

The following mechanisms have been identified:

- Using an OSC on one or more of the fibers between the Transponder and ROADM
    - This allows the same techniques that are applied to the ROADM model to be applied between the Transponder and the ROADM
- Using a separate DCN to communicate between the Transponder and ROADM
    - This is the OCC in [ITU-T G.7712]
- Embedding the overhead in the client signal of the OTSi

The overhead may be frame structure or packet based.

4.4.16 Rationale for groupings

The groupings shown above are driven by the following considerations:

- In general, the services supported by a photonic network are bidirectional.
- The critical integrity is that of the client signal, hence the most appropriate grouping is of all transponders relevant to the client signal in both directions of flow
    - The bidirectional OTSiG provides the relevant grouping for where the OTSiG is an assembly of one or more OTSis
- Bidirectional services benefit from co-routing of the two directions as:
    - This reduces probability of failure. When a duct is disrupted it is usually the cases that all fibers are disrupted
    - This minimizes the differential delay between directions, beneficial for some services

  On that basis the two directions of an OTSi should be corouted.
    - As a consequence, any examination of an OTSi at some intermediate point can be made on a bidirectional signal
- The emergent MC supporting an OTSi is the NMC
- The OTSiG has stringent differential delay constraints such that it is appropriate to coroute all OTSis of an OTSiG
    - On that basis it is reasonable to route an entire OTSiG as one unit
        - considering the routing of support for a service that requires only one OTSi as an OTSiG is also reasonable
    - As a consequence, it is meaningful to consider examination of an OTSiG as one unit at any intermediate point where the OTSiG is some combination of the measures of all of its component OTSis
- When present, the OTS-O is bidirectional
    - The OTS-O provides communications to convey information about a bidirectional OTS, hence the OTS as a whole is considered as bidirectional
    - As discussed earlier the OTS is essentially an Assembly (see 4.4.7 Signal, channel, overhead, grouping and assembly considerations on page 46).
- The whole OMS MC spectrum is available for clients, the L/C split is not relevant to the clients, there is no relevance to the client signal whether the lasers are tuned to L-band frequencies or tuned to C-band frequencies
    - For large capacity clients, several photonic carriers may be required to carry the signal, i.e. an OTSiG may be required. The OTSis of an OTSiG may be a mix of L/C band (provided that the differential delay is acceptable)
    - The OMS is essentially an Assembly (see 4.4.7)
    - As the OMS is used to carry bidirectionally co-routed client signals and it uses an OTS which is bidirectional it makes most sense to treat the OMS as bidirectional
    - Hence the OMS is a bidirectional Assembly
- The LTP grouping has been chosen:
    - Following the usual principles of breaking LTPs at:
        - Points of client flexibility
        - Points of multiplexing/assembly inversion
        - Points of change of multiplicity

- Following the additional principle that a change of Assembly such as the change to L-band/C-band split/combine between OTS and OMS should cause a break in the LTP even though the LTPs are both 1:1, same assembly orientation and inflexible.

4.4.17 Spec model enhancements supporting the composite LTPs and FCs

The development of the photonic model has led to the need to enhance the spec model. The spec model is covered in TR-512.7.

The enhancements essentially move the LP spec and the FC spec closer to the Scheme/System spec include:

- Opportunity to represent multiple terminations in a single LP
- Opportunity to represent complex arrangements inside an LP
- Opportunity to represent complex forwarding inside an LP
- Opportunity to represent complex termination in a FC
- Introduction of the port on the LP to allow complex arrangements of LPs in an LTP (not just an ordered stack of LPs

The capability of the LTP, LP and FC spec to describe complex system arrangements is enhanced.

4.5 Measurement and Configuration considerations

Appropriate normative sources of media properties will be chosen (e.g. ITU-T, Open ROADM, OpenConfig, Open Device etc.), the models from these sources will be Pruned and Refactored as appropriate and the properties will be extracted and assembled in example spec models. The properties will be mainly represented in LtpSpecs[35]. As usual, all properties will be available and a selection can be made by the vendor etc. The specs will provide interrelationship rules between the properties.

This section provides an overview of some of the key properties that can be set/measured and in what context those measurements would be made.

4.5.1 Relevant properties

This section provides a list of properties with some key considerations. The intention is that this becomes one or more formal specs within the next phase and hence this list is only intended to provide initial draft information. The list is not yet complete.

4.5.1.1 Summary properties

Properties that provide summaries of combinations of other properties.

- applicationIdentifier
- receiverApplicationType
- modulatorApplicationType

[35] Note that for management purposes some "parasitic" parameters e.g reverse loss in an isolator may not need to be represented.

- operationalState

4.5.1.2 Spectrum properties

Properties that relate to and define the spectrum. These can be use in the context of the channel (filters etc.), the receiver and the transmitter. Units of frequency and wavelength etc

4.5.1.2.1 Channel

Properties defining the channel spectrum.

- upperFrequency
- lowerFrequency
- guardUpper
- guardLower

4.5.1.2.2 Laser

Properties related to the laser and its modulation.

- centralFrequency
- channelWidth

4.5.1.2.3 Grid

Properties defining constraints on the arrangement of channels. [ITU-T G.694.1] uses an m,n 12.5 step, 25 width scheme.

- gridType
- adjustmentGranularity
- channelSpacing
- widthNumber
- channelNumber

4.5.1.3 Wave shape properties

Properties that relate to the quality of the signal modulation.

- eyeMask
- extinctionRatio
- OSNR

4.5.1.4 Channel properties

Properties that relate to the characteristics of the channel through its length and at its boundaries. The properties listed cover simple loss of power as well as chromatic and polarization effects.

4.5.1.4.1 Channel summary

Properties that summarize the effects of several other properties.

- channelPenalty

4.5.1.4.2 Channel entry effects

Properties that cover the effects at the entry of the channel.

- channelInsertionLoss
- channelReturnLoss

- channelReflectance
- discreteReflectance

4.5.1.4.3 Channel loss

Properties that cover the simple loss over the extent of the channel.

- channelAttenuation

4.5.1.4.4 Channel dispersion

Properties that cover signal property dependent propagation effects over the length of the channel.

- channelDifferentialGroupDelay
- chromaticDispersionCharacteristic
- polarizationModeDispersion

4.5.1.4.5 Channel signal crosstalk properties

Properties that cover signal interference in the channel.

- interChannelCrosstalk
- interferometricCrosstalk

4.5.1.5 Laser properties

Properties that relate to the laser.

- laserApplicationType
- laserBiasCurrent
- laserTemperature
- laserShutdown

4.5.1.6 Modulated light properties

Properties related to the modulation of the source..

- spectralWidth
- modulationApproach

4.5.1.7 Receiver properties

Properties that relate to the receiver.

- receiverEquivalentSensitivity
- receiverSensitivity
- receiverReflectance

4.5.1.8 Power properties

Properties that relate to power at any point in a channel (including at the transmitter and receiver)

- totalPower
- powerSpectralDensity

4.5.1.9 FEC properties

Properties related to FEC and hence the signal quality

- preFecBer
- postFecBer
- uncorrectableBits
- uncorrectableBytes
- correctedBytes
- correctedBits
- qualityValue

4.5.1.10 Channel Trace

Properties related to the conveying of the identity of a transmitter in the channel.

- traceTransferMethod
- traceTransmitted
- traceReceived
- traceExpected
- traceMismatchDetected
- traceMismatchDetectionMode
- traceMismatchDetectionAction
- traceGenerationApproach

4.5.1.11 Signal Source Label

Properties related to the conveying of some characteristic of the transmitted signal.

- signalLabelTransferMethod
- signalLabelTransmitted
- signalLabelReceived
- signalLabelExpected
- signalLabelMismatchDectected
- signalLabelMismatchDetectionMode
- signalLabelMismatchDetectionAction
- signalLabelGenerationApproach

4.5.1.12 Signal characteristics

Properties related to the signal.

- OpenConnectionIndication
- bitRateLineCoding

4.5.1.13 Far end indications

Unusually named here as various names used elsewhere still do not convey semantics adequately.

- farEndProblemTransmitToHere
- farEndProblemReceiveFromHere
- farEndProblemTransmitAwayFromHere
- farEndProblemReceiveTowardsHere

4.5.2 Attributes related to each property

This section attempts to rationalize which attributes will be required for each property listed above. It covers spec, configuration, measurement and reporting considerations. It also implies which will benefit from notification and hence be in some streaming telemetry.

4.5.2.1 Requested/Intended

For all adjustable parameters it is reasonable to state constraints in an outcome oriented constraint based interaction.

- Target (average/mean)
- ToleranceLower (deviation)
- ToleranceUpper (deviation)

4.5.2.2 Current/actual – measure

A key consideration is the degree of change of the property. If it changes rarely then notification is reasonable, if it changes frequently or in bursts, then notification may not be sensible other than for spotlighting.

- instantaneousState
- instantaneousValue
- averageMean
- currentEventCounts

4.5.2.3 Threshold – measure

Any measure may require a combination of thresholds. In some cases the best value is zero and hence only upper threshold are meaningful.

- lowerWatermark
- upperWatermark
- LowerWarn
- LowerSevere
- LowerFail
- NoValueWarn
- NoValueSevere
- NoValueFail
- UpperWarn
- UpperSevere
- UpperFail
- TimePeriod

4.5.2.4 Alarms

- BooleanAlarm

4.5.2.5 Capability (requested/intended, current, threshold and alarms)

For all parameters there will be definition. The degree of support for each may vary in terms of range supported etc.

- Default
- Range

- Preference
- Interaction

4.5.3 Considering Tandem Connection Monitoring and mapping to OAM (MEP/MIP etc) pattern

Recognizing that ITU-T have not yet specified Tandem Connection Monitoring (TCM) for photonic networks, with the ongoing progress towards disaggregated networks it is anticipated that TCM will emerge. In the ONF, a consistent approach for TCM and MEP/MIP has been adopted and is being progressed through the OAM activity in [TAPI].

Although the OAM work in the Core model is on-hold at this time (V1.4) it is still reasonable to relate to the general principles of OAM and the representation in [TAPI]. Earlier in the document (see 4.4.1 OTS and amplification and page 32, 4.4.5 The layered model, similarities and differences on page 43 and 4.4.8 Subdividing the Media Channel on page 50), co-directional/down measures and contra-directional/up measures were recognized. These points are where TCM/MEPs/MIPs would be meaningful

In addition, in 4.4.10.5 Dealing with the route through the MC mesh on page 71, it was recognized that not all points in the NMC mesh are meaningful to measure for photonic characteristics and that a specific bidirectional point to point thread through the mesh reflects the OTSi(e) and it is this that needs to be measured. This measurement span appears to equate to the Maintenance Entity in traditional Ethernet OAM [ITU-T G.8013].

It is possible that the OAM model[36] will remove the need to specifically model an OTSi(e) reflection in the MC layering, i.e., no longer require an NMC that follows the route taken through the NMC mesh by the light carrying the OTSi(e), and will allow the NMC mesh to be all that is required to be represented in the connectivity space as the parallel OAM model dictates the relevant measurement span supporting the OTSi(e) and the OTSiA(e).

On that basis the ROADM core requires the provisioning of the NMCA and of the Maintenance Entity, but not of the OTSiA(e) (which is essentially "alien" as the ROADM core deals with MCs and the maintenance of MCs).

Clearly the same approach can be used from any MCA structuring. In the case of the OMS and OTS there is a 1:1 between the bidirectional FC and the Maintenance Entity. For intermediate levels of MCA between the OMS and NMCA, the maintenance may be complex as it depends on encompassed lite channels as well as utilization and waste (see 4.4.9.2 Multi-pointed Media Channels on page 57).

In some deployments, structures at all MCA levels (from OTS to NMCA) will be point-to-point bidirectional. In these cases, the Maintenance Entities will have exactly the same topology as the FCs (i.e. both will be the point-to-point bidirectional between the same two points over the same route).

In such cases, where there is only one maintenance level (generally the case for current photonic networks) then the Maintenance Entity can be folded into the FC and the MEP/MIPs into the LTPs to yield a traditional model of monitored LTPs.

[36] Using the "Maintenance Entity" of the OAM model.

Even in the mesh MCA cases, the Maintenance Entity can be considered as a route of the FC and, as a consequence, where there is only one maintenance level, the FC and LTP model can be used to represent the monitoring. Each Maintenance Entity is represented by an FC that is a route of the mesh FC representing the MCA.

Where there are many maintenance levels, the LTP/LP can have multiple pacs of the same measures where each is identified by the level and each maintenance span is represented by an FC that is considered as a route of the mesh FC representing the MCA.

On this basis the current FC/LTP model can be used to represent multi-level maintenance of a complex MCA mesh topology.

5 The relationship between functional and physical

5.1 Overview

As discussed in earlier sections of this document, and as is the case for all devices, there is no strict relationship between the physical arrangement and the functional capability. Some functions will be supported by the combination of several FRUs and FRUs will each support several functions.

This section provides a number of examples of layouts (see also Figure 4-14 Amplifier site showing FRUs on page 43 and Figure 4-17 Simplified representation of OTS LTP in an L-band amplifier showing physical aspects on page 45). The arrangements are intentionally somewhat arbitrary and do not necessarily reflect actual device implementations.

The functional representation is especially relevant when provisioning current capability in a device. Explaining the model that supports provisioning capabilities has been the main focus of the document so far. The physical arrangement, especially of Field Replaceable Units (FRUs) becomes critical during planning activities, when determining how the capability of a device can be extended/changed (as it is the FRU that is the unit of capability adjustment), and during fault analysis and repair activities, when identifying what to repair (as the FRU that is the unit of replaceability in the device).

5.2 The Field Replaceable Unit (FRU)

The following figures depict assemblies of one or more FRUs[37].

[37] ITU-T have defined the term “Media Element” (see Figure 7-1 Figure 8-16 from [ITU-T G.872] (on left) with ONF Core model overlay (on right)). The “Media Element” in some cases encompasses both the halves of a protection scheme (as shown in the figure) and does not encompass the control functionality. A “Media Element” larger than an FRU is not ideal as the FRU is the key granularity for field replacement. If a Media Element is deemed to have failed all FRUs that it is built from will need to be replaced. This is not a useful management/control construct.

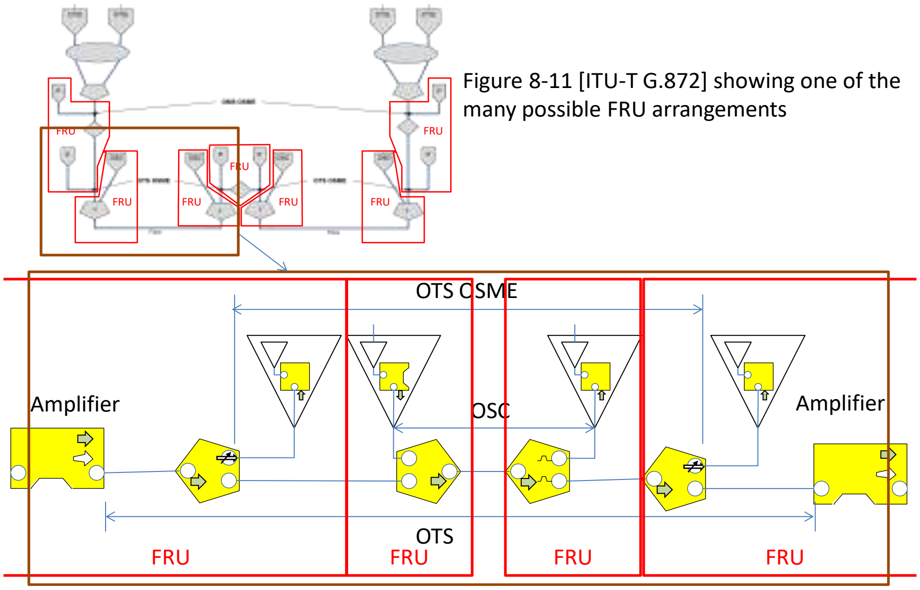

Figure 5-1 One of the many possible FRU arrangements

The figure below shows other possible arrangements of FRUs (recognizing that the upper diagram is probably unlikely as the monitor is likely to be part of the amplifier).

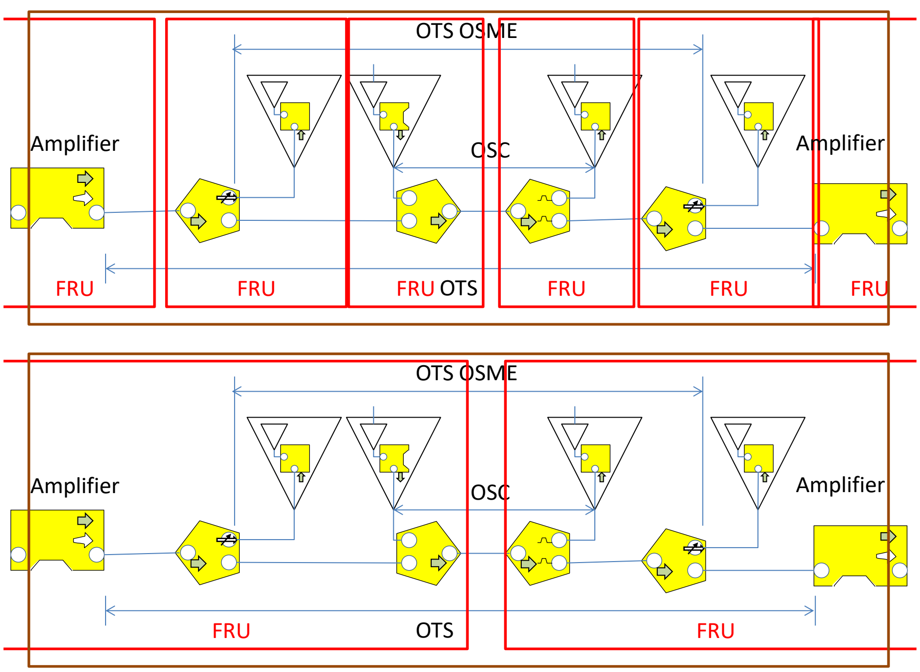

Figure 5-2 Two other possible FRU arrangements

5.3 Relationship to the internal physical structure

[Editor's note: This section is an early draft and will be completed in a later release of the document]

Notes:

- Exposure if physical detail is driven by the need to carryout repairs/replacement in the field and to determine the impact of any potential field replacement
- To enable this, FRUs need to be defined and modelled as equipments
- The connectors between and from FRUs and any exposed flexible cabling that could easily be misconnected or disconnected needs to be exposed.
- Cabling and connectors inside the FRU boundaries need not be exposed (assuming that any fault in this cabling can be easily isolated to the FRU).
- The FRU boundaries need to relate to the functional model even if the boundary is essentially in the middle of a functional unit (an LTP, LP, photonic/media element etc)
- The spec model that relates equipment to functionality should be suitably detailed to express the relationship especially where the FRU is shared be several functions

6 Other Photonic cases

6.1 Passive Optical Networks

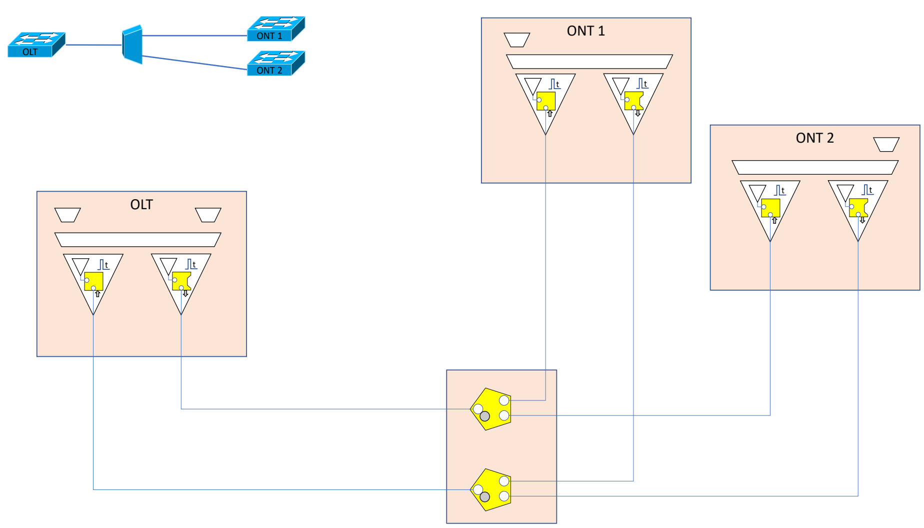

Figure 6-1 PON showing two ONTs

The figure above shows a photonic view of PON.

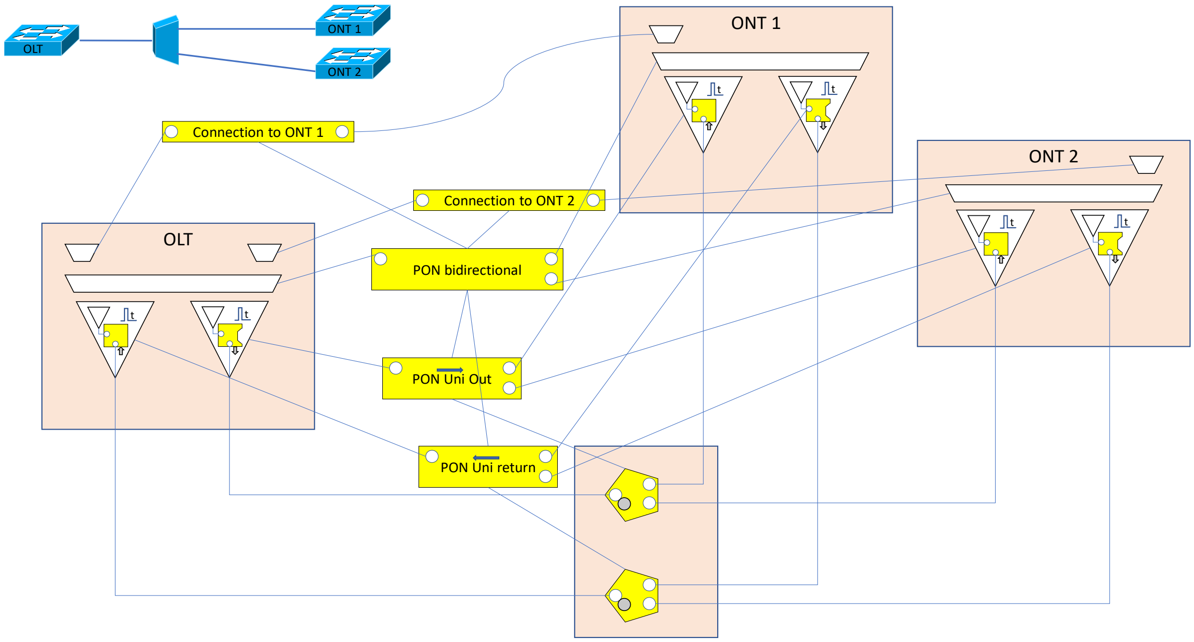

Figure 6-2 PON showing two ONTs with unidirectional photonic forwarding

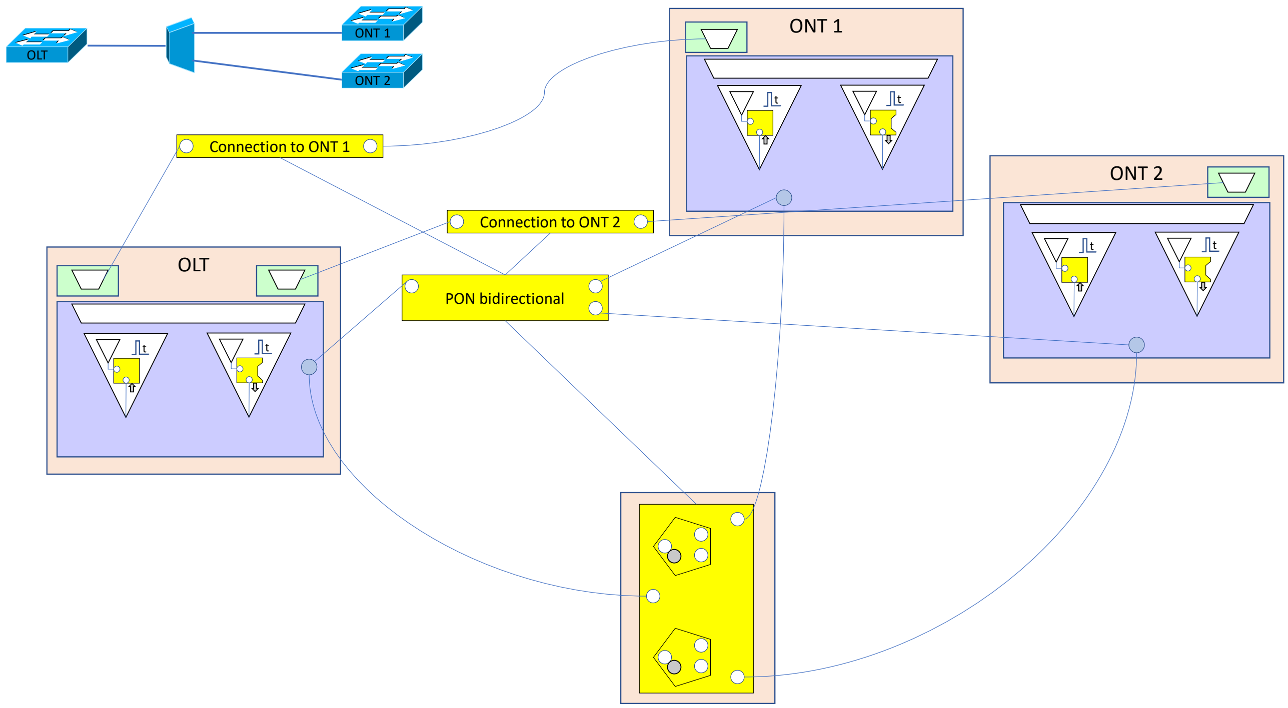

Figure 6-3 PassiveOptical Network showing two and bidirectional connectivity

7 For further study

7.1 Media Element

The Media Element of [ITU-T G.872] does not seem a useful construct from a Management-Control perspective. The figure below highlights the positioning of the Media Element and the corresponding positioning of LTPs and FCs.

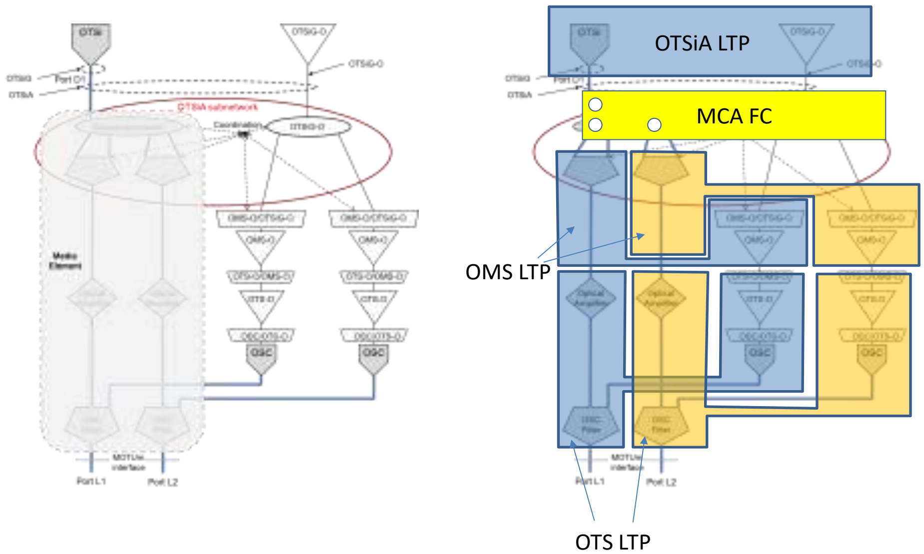

Figure 7-1 Figure 8-16 from [ITU-T G.872] (on left) with ONF Core model overlay (on right)

7.2 Raman

The model for Raman needs to be considered from a networking perspective. The following figure from ITU-T needs to be redrawn using the ONF Core symbol set introduced in this document. The boundaries do not look coherent (with Raman, there is no hard end to the amplifier). In some cases it is LTP in others it is some multi-LTP construct

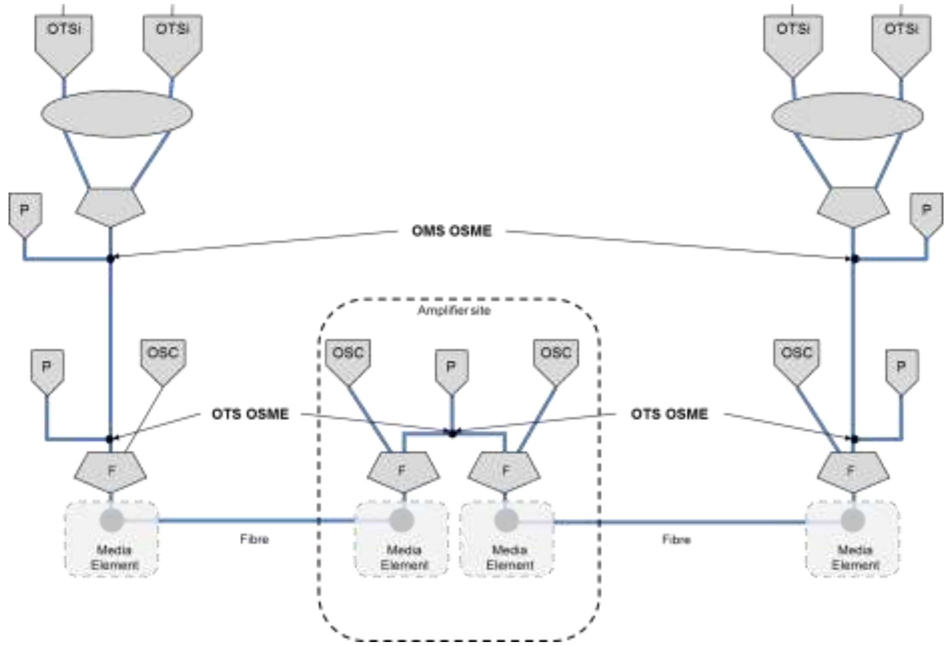

Figure 7-2 Copy of Figure 8-12 from [ITU-T G.872]

7.3 Considering [ITU-T G.872]

- Media port – covered by AccessPort
  - Media construct/element boundary
  - Media Port: *a logical abstraction that represents the ends of a media channel, the boundary of a media construct or the boundary of a media element*
- Media channel – represented by the FC. Definition refined.
- Network Media Channel – represented by the FC. Definition refined.
- Media Link – represented by the FC. The Link can be used, but it appears superfluous.
- Media Subnetwork – represented by the FD

End of Document

