Appendix I – OTN network topology utilizing Transitional Links

This appendix provides a specific networking example illustrating the use of Transitional Links. The intent is to demonstrate the usage of the Transitional Link construct to represent various network architectures from a routing topology perspective. The modeling shown below is provided to indicate the general direction of Q12's work, and represents a work in progress.

Introduction

In G.800, the Transitional Link allows for the representation of inter-layer relationships that exist in a multi-layer network topology for the purposes of performing path computation. This construct is also extremely useful in networks that support multiple different mappings of a signal (i.e., resulting in multiple instances of a single ODU layer at different bit rates). The multiple mapping cases can be caused by a number of conditions:

- Heterogeneous support of adaptations in the network
- Heterogeneous server layer technologies in the network.

Considering an end-to-end connection spanning multiple domains, a client signal could be mapped into a low-rate ODU at the OTN boundary, and then have that ODU respectively mapped into progressively higher rate ODUs as it progresses across domain boundaries, before it is demultiplexed back down as it approaches its termination point. This appendix explores the usage of Transitional Links in representing such topologies, from a path computation perspective, in ASON networks.

Background

As discussed in Amendment 2 of G.872, the heterogeneous OTN multiplexing hierarchy supports various network architectures, including those optimized to minimize stranded capacity, minimize managed entities, support carrier's carrier scenarios, and/or enable ODU0/ODUflex traffic to transit a region of the network that does not support these capabilities.

This document elaborates on a few cases, and is not intended to provide an exhaustive compilation of all possible cases.

There are heterogeneous network environments for which it is necessary to enable carriage of the newly defined G.709v3 (12/2009) signal types (e.g. ODU0 and ODUflex using 1.25G Tributary Slots) across an existing network based on G.709 (3/2003). Thus, these existing networks do not support ODU0 nor do they support use of 1.25G Tributary Slots in their ODU2 and ODU3 links. One way of accommodating this is by taking the new signals and multiplexing them in a G.709 (3/2003) signal for transmission though the G.709 (3/2003) network. In doing so, there is clearly a possibility for more than one stage of multiplexing between the client ODU0/ODUflex signals and the higher-rate ODUk signals (being carried directly over their respective OTUk signals).

Thus, it is clear that routing solutions must be capable of handling all feasible network architecture and equipment scenarios, including those involving more than one stage of multiplexing.

The architecture of ASON (G.8080) supports the notion of "potential" connectivity. A potential link connection is a member of a link, and enables the link to be selected during path computation. Any actions needed to configure the link connection are delayed until signalling time (when resources are finalized along the computed path). This allows paths to be computed before resources are fully configured and enables different layer networks to share a common server layer before (flexible) adaptation has been configured.

The transitional link similarly presents potential resources to path computation before the configuration of those resources has been finalized. It is not necessary that the adaptation functions that will eventually support the transition have been fully configured before path computation can use the transitional link.

In this document, all discussion focuses on the topology before a new path has been setup. Just as in single layer operations, the topology available to the next request can change as a result of the set up of this request. If, for example, a particular link becomes exhausted as a result of this request, that link may be advertised with zero capacity.

The behavior for transitional links is exactly analogous to that for links, with the additional possibility that setting up a server connection between a pair of transitions can add a new client link into the topology. Because this document is focused on topology before signalling, no further discussion is provided on operations occurring during and after signalling.

Example G.805 model for Single-stage and Multi-stage multiplexing

This section provides Box/Line figures that provide alternate representations of the G.805 examples. These figures depend on the following two box-level detailed descriptions, which are color coded in Figure 1.

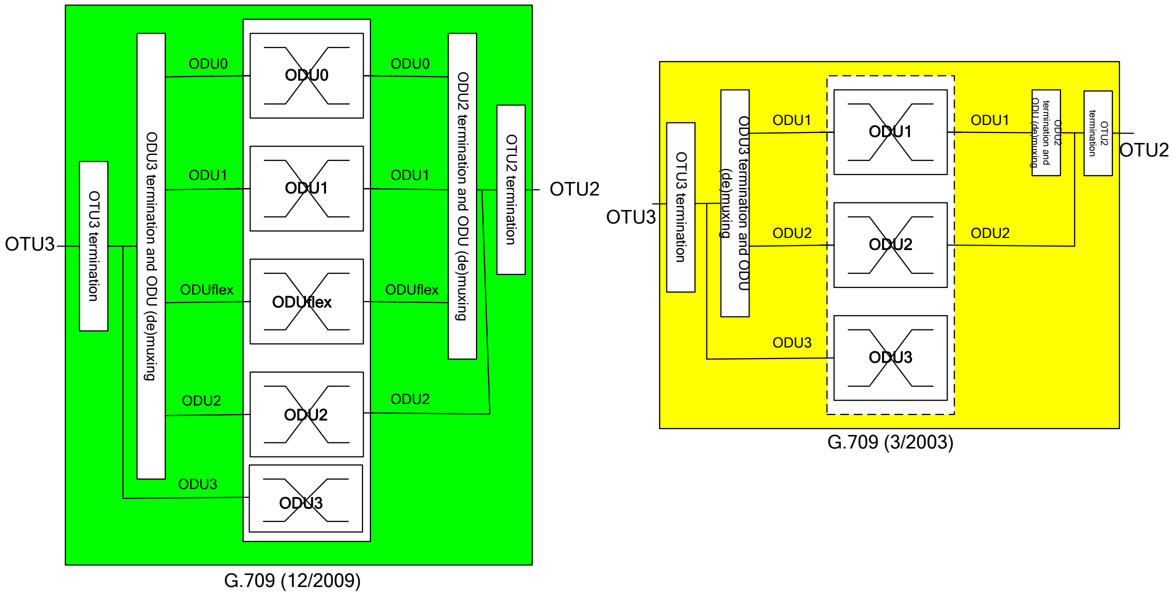


Figure 1. Box Description contents

The rest of this section will discuss the example below. Both box and functional diagrams are shown. Note that these figures are provided to only discuss topology, and they do not make use of the new models provided in G.709 (2010). In addition, the new ODUflex capability is not discussed and is not shown. While G.709 (2010) models a single, rate independent matrix, topology is sensitive to the rate dependent fragments, which are depicted here.

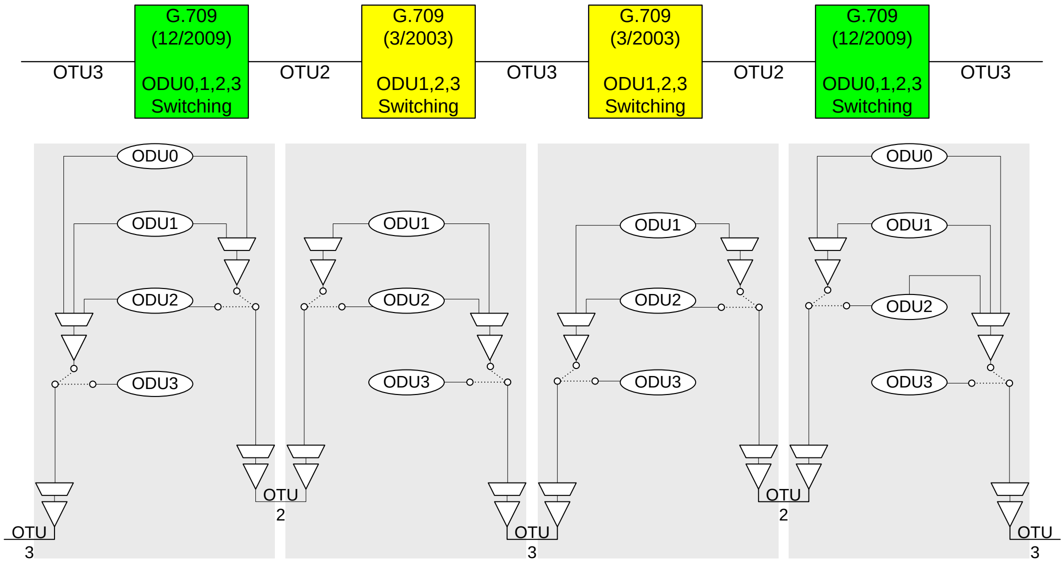


Figure 2. Box and corresponding G.805 diagram

For this network fragment, one possible corresponding routing topology with Transitional link is as follows:

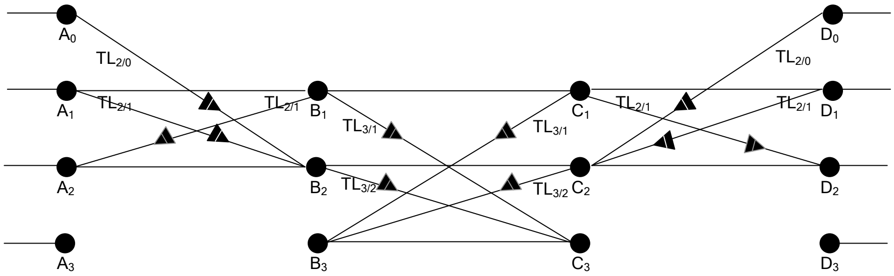


Figure 3. Corresponding Transitional Links

Transitional links are identified with an icon on the link, and in Figure 3 are labelled with the type of adaptation they represent.

While transitional links can make any and all equipment capability available to path computation, in general operator policy is likely to be applied to limit which variability is actually presented. This is no different to operator policy being added to topology in single layer networks. For example, a Shared Risk Group is no more than operator policy added to a link. Thus, the use of none, some, or many, transitional links in a routing topology can be done by applying operator policy. Figure 4 shows an example of the effect of policy on the topology in Figure 3 where there are fewer transitional links present.

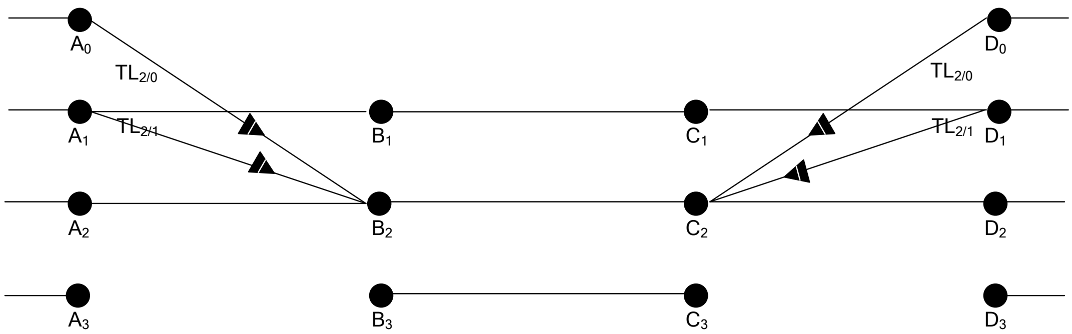


Figure 4. Pruned Transitional Links

Note that the representation of transitional links in multilayer topology as shown in Figure 3 does not proscribe or define how they are encoded in a routing protocol.

Example Single-layer Routing Topology

The resulting advertisement for the network in Figure 2 above is shown in Figure 5 below:

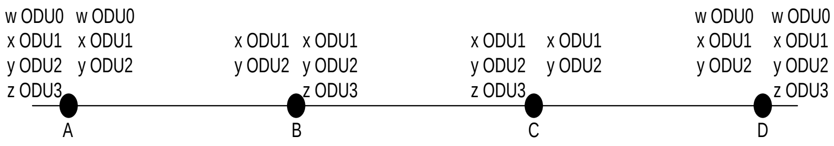


Figure 5. Efficient representation

In past versions of G.8080, there is a requirement for routing to be performed for a specific layer network. In order to facilitate the G.8080 requirement, G.7715.1 requires the information for a specific layer be discerned from the efficient representation. This can be performed through use of a per-layer filtering function. The resulting topology for each of the layers shown in Figure 5 is shown in Figure 6.

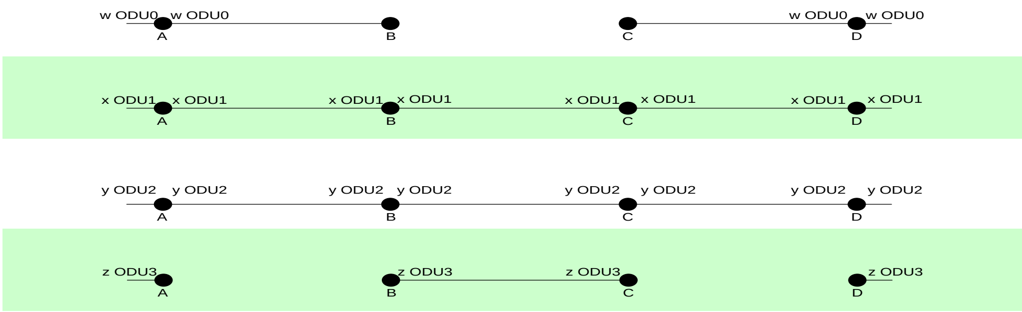


Figure 6. Layer-specific Routing views derived from an efficient encoding (per G.7715/G.7715.1)

Note in Figure 6, the ODU0 link between A and B is shown because the efficient encoding of Figure 5 only shows ODU0 capability on node A. The resulting per-layer filter ends up showing the link, but only places capacity information on the node A link end. This capacity gives rise to the transitional link TL 2/0.

Example Routing Topology for Multistage Multiplexing

In Figure 6, two stage multiplexing capability may be possible. This is illustrated in Figure 7.

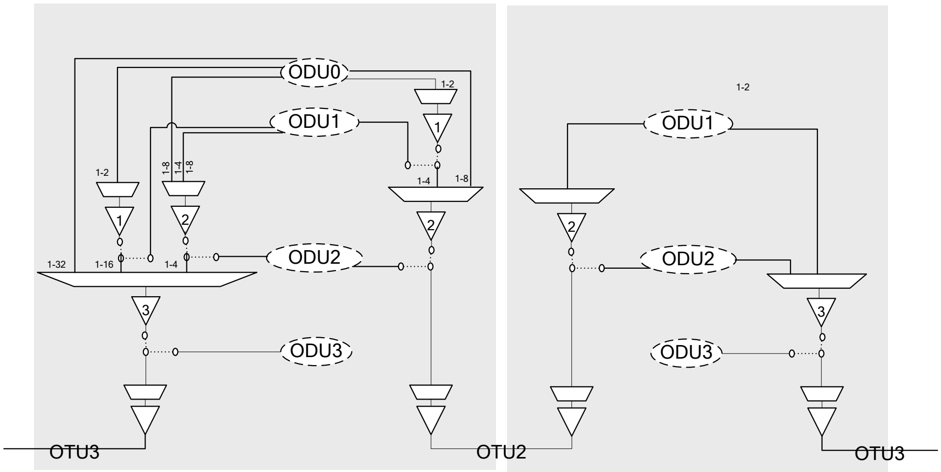


Figure 7. Two-stage ODU muxing in left node in both OTU3 and OTU2 interface ports

Figure 8 shows the complete capability of the equipment in network defined in Figure 6 with two stage mutliplexing shown in Figure 7.

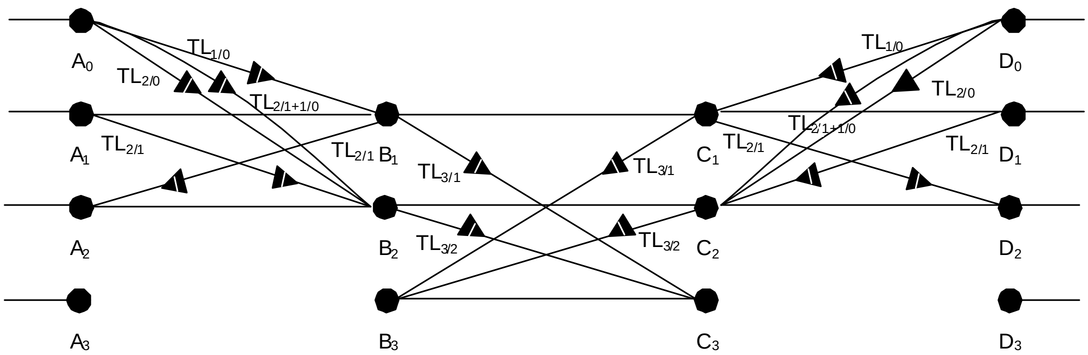


Figure 8. Topology using link-attribute form

While Figure 8 shows the complete equipment capability, many of the Transitional Links shown are not useful and can be pruned from the routing topology based on Network Operator Policy. For the remaining links, Network Operator Policy will also dictate the costs advertised, making some paths through the network desirable over other paths. An example resulting topology is shown in Figure 9. Note that no connections have yet been configured and allocated in the topology. In Figure 9 TL 2/1+1/0 may not be preferred by operator policy over TL 2/0, e.g., by setting cost.

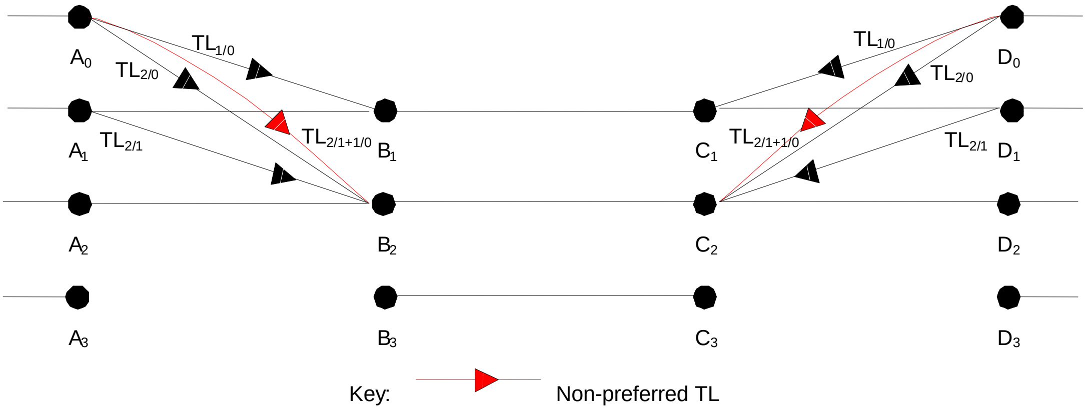


Figure 9. Topology after applying Network Operator Policy

Specific Network Example

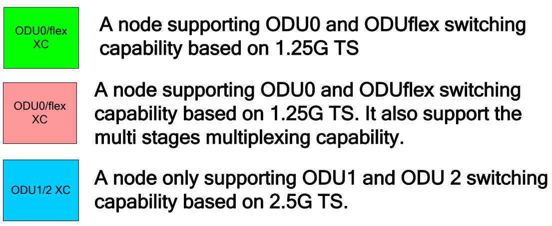
Two network scenarios are illustrated in Figure 10 that results in more than one stage of multiplexing end-to-end across the network:

1) Tunneling of G.709 (12/2009) signals (e.g., ODU0 and ODUflex) through a G.709 (3/2003) network (e.g., an ODU3 network which couldn't support 1.25G TS)

2) Carrier's Carrier, utilizing a higher order ODU connection (e.g., an ODU2) that is carried over a yet higher speed connection (e.g., an ODU3 mapped into an OTU3) to provide a variety of lower order connections (e.g., ODU0, ODU1, ODUflex, and ODU2).

It should be emphasized that these are simply illustrative scenarios. They should not be interpreted as the only scenarios that can result in more than one stage of multiplexing.

These two scenarios are described by the Red and Blue connections shown in Figure 10. The color legend in Figure 10 is as follows:



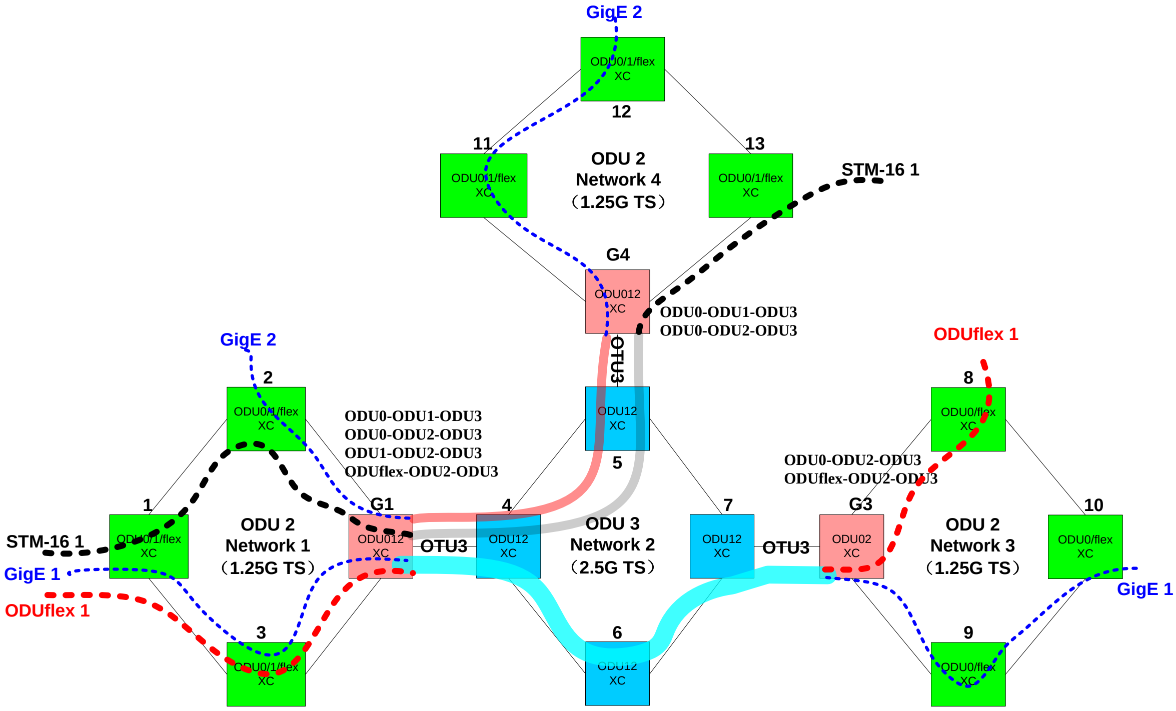


Figure 10. Example Network Deployment Utilizing Multi-stage Multiplexing

To increase understanding of the deployment scenario, some further information is provided regarding implementation options, and illustrative end-to-end service examples. The intent of this discussion is not to restrict the equipment implementation, but rather to provide some examples about how a node providing multi-stage multiplexing capability can be implemented. Modeling methodology (e.g., usage of transitional links) is independent of equipment design.

G1/G3 Implementation Option Examples

Three options for the implementation of G1/G3 nodes in the following figures are presented for illustration, and do not represent all possible implementations:

- Option 1: Integrated Line Card and Equipment

  In this implementation option, illustrated in Figure 11, a unified cross-connect supports ODU0, ODU1, ODUflex, and ODU2 cross connection. Line card 1 solely provides single-stage multiplexing capability. Line card 2 provides the multi-stage multiplexing capability within one single line card in order to interworking with the 2.5G TS network. Both multi-stage and single-stage multiplexing are integrated in a single line card.

  If the line card only supports fixed multiplexing (e.g., only supports ODU0-ODU1-ODU3), the hierarchy of multi-stage multiplexing cannot be configured.

  Note: If the 2.5G TS network just switches ODU2 directly in order to minimize managed entities in the core network, ODU1 can be mapped to ODU2, with ODU2 then mapped into ODU3. So here the line card also provides the ODU1-ODU2-ODU3 multiplexing capability.

  Dependent upon the implementation, it may be the case that not every ODUk is equally available for cross-connection. In Figure 11, for example, the ODU3 must be always terminated on the line boards.

A generic routing solution should be able to clearly differentiate between bandwidth that can only be terminated and bandwidth that can be cross-connected.

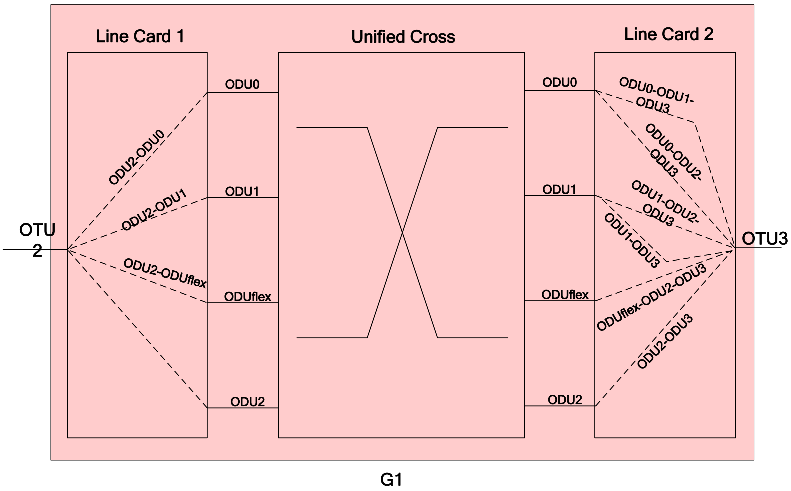


Figure 11

- Option 2: Cascade Card

In this implementation option, illustrated in Figure 12, the line card does not provide multi-stage multiplexing within a single card or only uses single stage multiplexing. In this case the signal must be back-hauled to another line card that can support the re-muxing. (This involves back-to-back multiplexing within the NE).

There is a selector for the different hierarchies of multi-stage multiplexing (e.g., the selection for ODU0-ODU1-ODU3 or ODU0-ODU2-ODU3). If the line card just supports a fixed interface (e.g., only support ODU0-ODU1-ODU3), the hierarchy of multi stage multiplexing can't be configured. There is no selector within the node.

In the same manner as in Option 1, dependent upon the Option 2 implementation it may be the case that not every ODUk is equally available for cross-connection.

A generic routing solution should be able to clearly differentiate between bandwidth that can only be terminated and bandwidth that can be cross-connected.

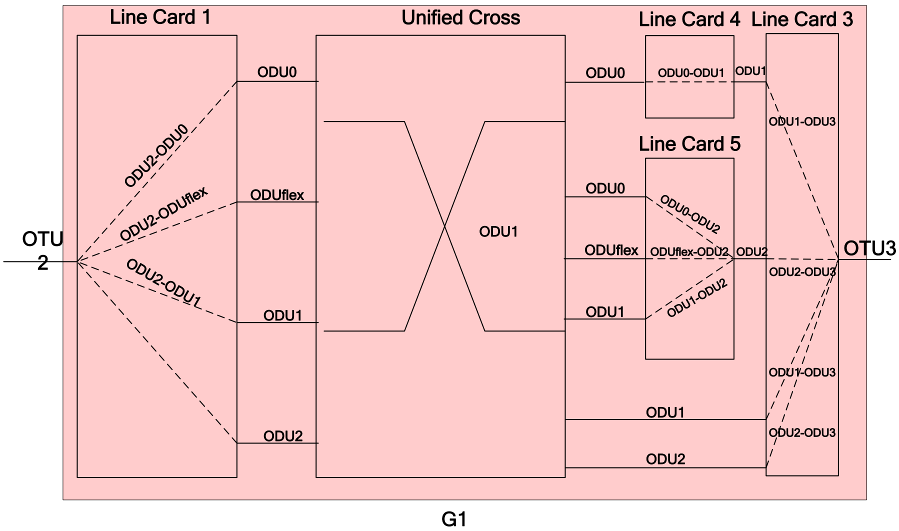


Figure 12.

- Option 3: Cascaded NEs

  In this option, illustrated in Figure 13, multi-stage multiplexing is obtained by cascading network elements (back-to-back multiplexer). The signal has to be back-hauled to equipment that can support the re-muxing.

  Note: The cross-connect in back-haul equipment may not be necessary for ODU1/ODU2 being mapped into ODU3.

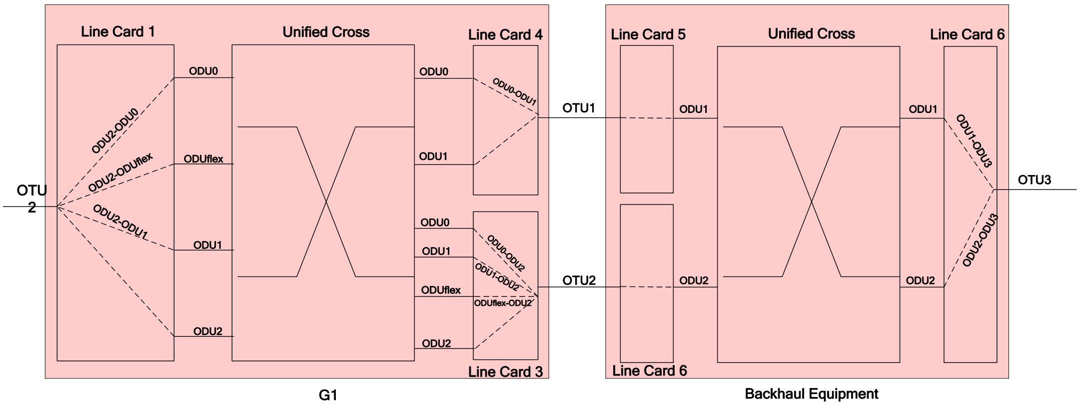


Figure 13.

The unified cross connection matrix in back-haul equipment (very often a DWDM system) may just consist of a few internal physical links.

A generic routing solution must be capable of representing constrained connectivity of electrical matrixes.

End-to-End Service Use-Case Examples

An example about the end-to-end service, which is configured by connected equipment, is shown in Figure 14. This example does not present all possible implementation arrangements. Refer again to Figure 10, and using the same color conventions.

Multi stage multiplexing capability can be integrated in a single line card or the composition of line card (e.g., G-3). Also using back-haul equipment and/or line cards can provide the multi-stage multiplexing capability (e.g., G-1 and NE-4 of Figure 14.

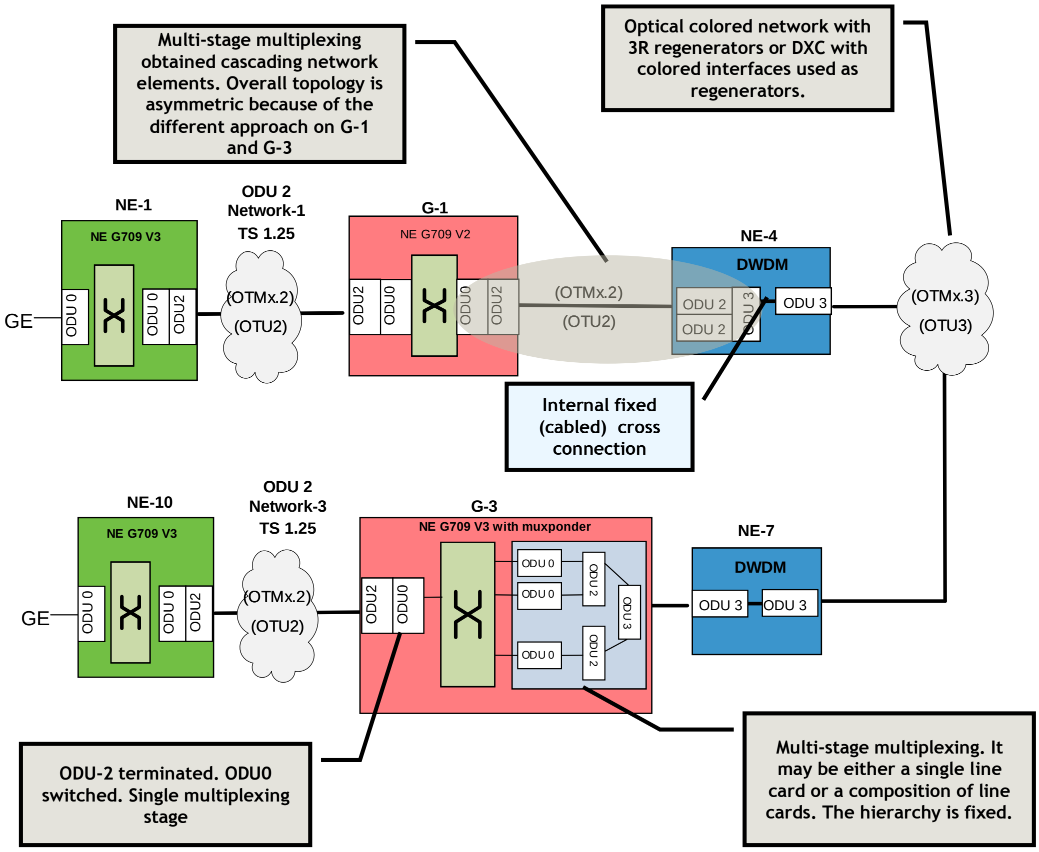


Figure 14 Network Example.

The functional model representation is provided in Figure 15 below:

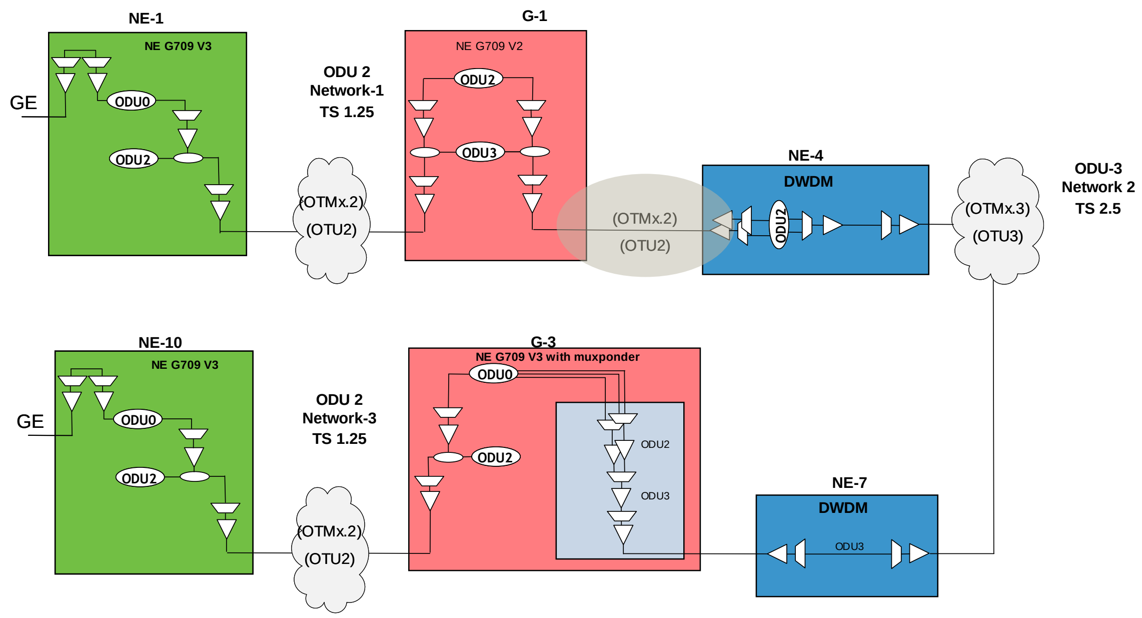


Figure 15 Functional Representation.

Application of Transitional Link Construct

Focusing upon the portion of the example network deployment, considering G1 and NE4 from Figure 10, the routing topology representation using Links and Transitional Links is illustrated in Figure 16. Note that, independent of the equipment implementation, the model of transitional link construct is the same for three implementation options illustrated in Figure 11, Figure 12 and Figure 13.

Note: the modeling methodology must be capable of supporting any equipment design. Figure 16 gives an example of how to model the G1 and NE-4 of Figure 10 into the topology view.

NE-4 cannot support the ODU0 and ODUflex switching capability.

G1 supports the following multi stage multiplexing capability when signal is mapped into ODU3. Path computation must know multi stage multiplexing capability constraint information.

- ODU0-ODU1-ODU3
- ODU0-ODU2-ODU3
- ODU1-ODU2-ODU3
- ODUflex-ODU2-ODU3

Because the ODU0-ODU1-ODU2-ODU3 multi stage multiplexing hierarchy is not supported within the G1 NE of Figure 10, the constraint of prohibiting ODU0 in ODU1 in ODU2 must be expressed in the topology view. However, there are some limitations from G.805 conventions. So there should be some constraint information attached with Transitional Link between ODU0 and ODU1 subnetwork (i.e., TL1/0 of Figure 16) to prohibit ODU0 being mapped into ODU1-ODU2-ODU3. It depends on the routing encoding to express this constraint information. The path computation entity has to consider this constraint information. Costs can be associated with TLs for directing path computation.

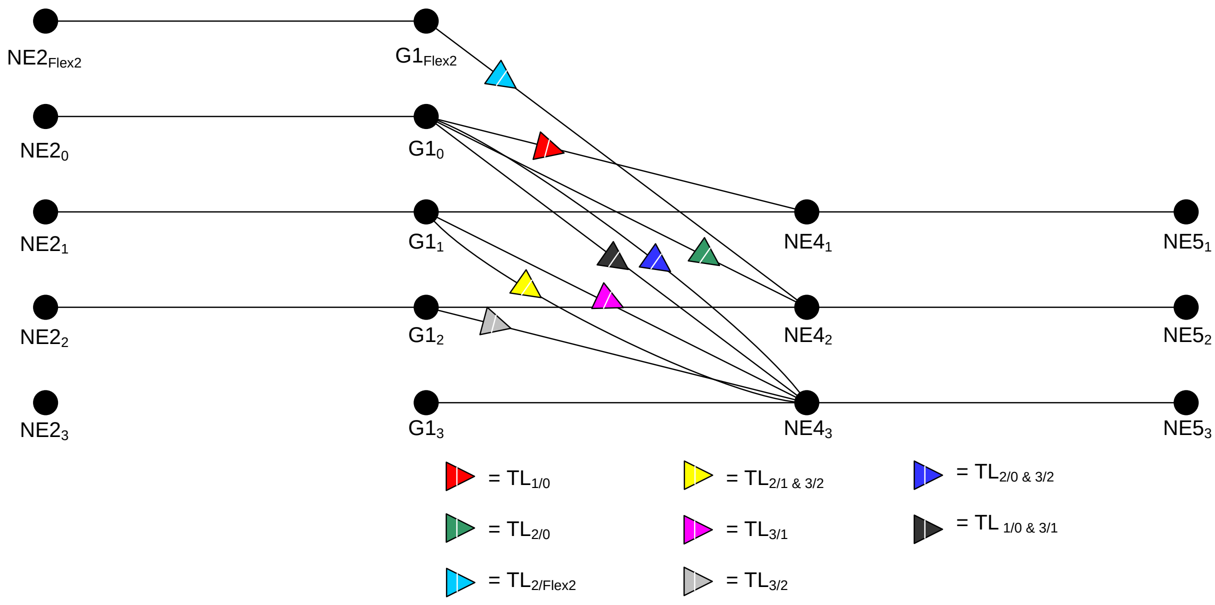


Figure 16 Transitional Link representation