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            Multi layer implications in GMPLS controlled networks
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Abstract

   This document describes requirements for MRN application to multiple
   hierarchies of technologies (e.g. OTN, SDH, ETH). For this purpose,
   after summarizing MRN definitions, rationales and currently supported
   applications, a problem statement is introduced together with its
   implications on GMPLS routing and signaling. New functional
   requirements are derived and MRN extensions required to address them
   are identified.

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
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   This Internet-Draft will expire on August 29, 2013.

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1. Introduction

Generalized MPLS (GMPLS) supports the control of multiple switching technologies: packet switching, Layer-2 switching, TDM (Time-Division Multiplexing) switching, wavelength switching, and fiber switching ([RFC3945]).

The Interface Switching Capability concept has been defined for the advertisement of the Switching Capabilities of the different interfaces of a node [RFC4202], while in the context of Multi Region Networks (MRN) the Interface Adjustment Capabiltiy concept has been introduced [RFC5339] for the advertisement of adjustment capacity within an hybrid node.

With the introduction of G709v3 networks, a new Switching Capability (OTN-TDM) has been defined [OSPF-OTN] and the ISCD updated in order to cope with the OTN specific multi stage multiplexing capabilities. The new Switching Capability Specific Information (SCSI) field provides information about the bandwidth availability at each layer of the OTN hierarchy and about the operations that can be performed on the different layers, in terms of termination and switching capabilities.

These issues have been addressed in the OTN documents within the OTN multi layer scope but need to be extended to MRNs, where the termination of a hierarchical LSP leads to the need of properly managing different switching capabilities and different adaptation functions.

The scope of this document is to describe requirements when MRN is applied to multiple hierarchies of technologies (OTN, SDH, ETH). For this purpose, after summarizing MRN definitions, rationales and currently supported applications, a problem statement is introduced together with its implications on GMPLS routing and signaling. We derive new functional requirements and determine the corresponding MRN extensions that may be required to address them.

1.1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2. MLN and MRN networks: relationship and rationale

As per [RFC5212], the definition of MLNs and MRNs is as follows:

- MLN: "a Traffic Engineering (TE) domain comprising multiple data
plane switching layers either of the same ISC (e.g., TDM) or
different ISC (e.g., TDM and PSC) and controlled by a single GMPLS
control plane instance"

- MRN: "is defined as a TE domain supporting at least two
different switching types (e.g., PSC and TDM), either hosted on
the same device or on different ones, and under the control of a
single GMPLS control plane instance"

A network which is an MLN but not an MRN (i.e. multiple layers but a
single switching capability), like for example an OTN domain, can be
advertised via the utilization of the Interface Switching Capability
Descriptor (ISCD). The ISCD is defined in [RFC4202] and its
technology specific extensions (SCSI) are defined in different memos
depending on the technology, e.g. the OTN ones in [OSPF-OTN] and the
SDH ones in [RFC4203].

On the other side MRNs (i.e. multiple layers with multiple switching
capabilities), like for example an OTN data plane (with one or more
layers) over a WDM data plane (with one or more layers) controlled by
a single GMPLS instance, need the utilization of an ISCD for each
technology and an Interface Adjustment Capability Descriptor (IACD)
[RFC6001] for the advertisement of the internal links providing
adjustment between the switching capabilities. A node able to
terminate data links (over the same interface) with different
switching capabilities is called hybrid node. [RFC5212]. For more
details please see Section 7.

Hybrid nodes have been introduced not only to address the case of
nodes able to switch/terminate LSPs from different switching
capability but also to perform for instance:

  - Traffic-grooming: base GMPLS doesn't enable insertion of traffic
  at an intermediate point along an established LSP, i.e., the
  control plane limits the flexibility of nesting LSP only at the
  head-end of the underlying LSP. MRN extensions enable to
  multiplex and demultiplex e.g. PSC LSP into LSC LSP even if the
  LSC LSP does not originate or end at the nodes where the PSC LSP
  are multiplexed or demultiplexed.

  - Transparent regeneration: enables certain nodes equipped with
  PSC + LSC capability to regenerate the photonic signal without
  interrupting the LSC LSP. This functionality enables to setup
  end-to-end LSC even if certain intermediate nodes are being used
  to regenerate the signal at the PSC level.

This means that MRN extends the node functionality beyond "terminate

or switch".

The central notion in MRN is "adjustment capability". Adjustment
capability assumes the availability of adjustment capacity or
adjustment pool at given SC (say SC Z, in the following). An
adjustment capability is the mean by mean which LSPs can be adapted/
mapped from one SC X to SC Y via Z, translated from one SC X to SC Y
via Z or inserted (e.g., multiplexed or demultiplexed) from SC X to
SC Y via Z. Note that SC X value MAY be identical to SC Y value and
that SC Z value MAY be identical to SC X or Y value.

For instance, when referring to transparent regeneration SC X = LSC =
SC Y and SC Z = PSC and when referring to traffic grooming SC X = PSC
and SC Y = LSC and SC Z = resource pool enabling the insertion of
packet LSP into a lambda LSP.

Advertisement of adjustment capacity by a given node assumes the
functionality of adjustment is locally supported.

3. Problem Statement

The MRN architectural framework as specified in [RFC6001] models the
internal properties of the nodes by its internal switching
capabilities (referred to as resource pools) and their
interconnection, i.e. single and multiple pool models. However, it
assumed that i) the internals properties of (logical) resource pools
were left uncovered to external nodes, i.e., the technology specific
details composing pools were not part of the IACD advertisement, and
ii) the topology defined by the interconnection of resource pools is
not defining any cycle, i.e., resource pools were not meshed
(following the SC value hierarchy).

The below describes in more details the underlying consequences for
what concerns "routing" and "signaling". Note that beside listing
the SC that have an internal multiplexing / encapsulation tructure we
omit technology specific details to keep the problem description as
generic as possible and thus applicable to Ethernet (C-VID, S-VID,
I-SID, B-VID), SDH, OTN, and future technologies.

3.1. Routing

When referring to routing, two specific elements are to be
considered: representation (information) and exchange. The latter is
not different from any other information exchange detailed in GMPLS
RFCs; hence, not further discussed in the context of this document.
The former raises however the following point: how to represent the
relations between resource pools and their capabilities (beyond un/

used capacity).

The example of Fig.1 is illustrative. A,B,C,D and E represent the
external interfaces of the node, while W,X,Y and Z the internal
switching capacities. If the internal switching capabilities are
associated to the same SC (SC W = SC X = SC Y = SC Z), they could
either be represented as a single (logical) resource pool or be kept
separated into different resource pools at the condition that their
ingress and egress relations does not lead to any loop, i.e., there
is no "X-Y" direct relationship.

```
***A*******B*C*D***
*   |        | | |   *
*   |        | | W   *
*   |        | | |   *
*   |       / \|/    *
*   |      XxxxY     *
*   |      | / |     *
*    ---- Z   |      *
*           \ /      *
*            |       *
***********E*******
```
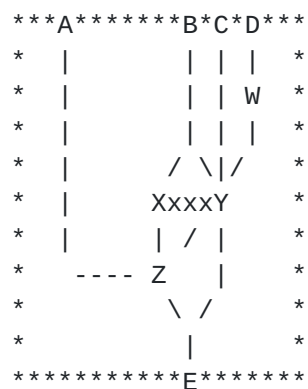
                  Figure 1: Problem statement - Routing

Moreover, assuming that X and Y are part of the same logical resource
pool (SC X = SC Y) but different from the two others, the properties
of the two relationships between the resource pool (associated to SC
Z) and the upper one (SC X = SC Y) may be not identical. In
particular, the encoding associated to each relationship can be
different (while there is only one encoding field per IACD sub-TLV),
for example we could have an L2SC (for SC Z) with two different
encapsulation method GFP-F or GFP-T towards common resource pool TDM
(= SC X = SC Y).

3.2. Signaling

Initially GMPLS signaling relies on link property inference for label
allocation. This technique has been progressively complemeted by
technology specific information encoded as part of the label request.
In the present case, multiplexing hierarchies are interconnected but
there is no (TE) link describing these interconnections. Hence, a
mechanism is to be found by which the relationships between them have
to be locally accommodated at provisioning time.

```
   ***A*******B*C*D***
   *   |        | | |   *
   *   |        | | W   *
   *   |        | | |   *
   *   |       / \|/    *
   *   |      X   Y     *
   *   |      | / |     *
   *    ---- Z   |      *
   *          \ /       *
   *           |        *
   ***********E*******
```
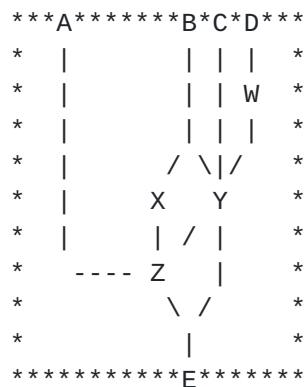
               Figure 2: Problem statement - Signaling

The case depicted in the above Figure 2 provides a simple
illustration. Let's assume that X, Y, and Z are internal switching
capabilities each defining a multiplexing structure. Let's further
consider that X and Z are part of the same logical resource pool (SC
X = SC Z). Hence, an external node receives the routing information
from which it can derive as depicted in Fig.3 the relations between
i) resource pools O, W, Y and ii) resource pools O, W, Y and
"external" interfaces A, B, C, D, E.

```
   ***A*******B*C*D***
   *   |        | | |   *
   *   |        | | W   *
   *   |        | | |   *
   *   |       / \|/    *
   *    -----O - Y      *
   *          \ /       *
   *           |        *
   ***********E*******
```
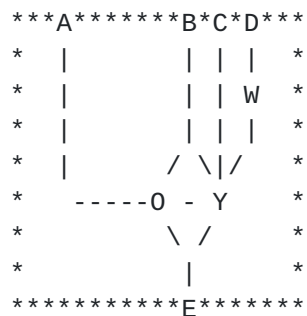
   Figure 3: Problem statement - Relationship between resource pools

There are four ways to reach interface (I/F) B from I/F E:
E->O->Y->B, E->Y->O->B, E->O->B, E->Y->B. Hence, each time there is
possible choice to pass from one SC to another SC (which is not
associated to an "external" interface), there should be a mean by
which the requester can indicate which SC it would like to make use
of or equivalently exclude. In the present case, needs to have the
mean by which it can select if the incoming/outgoing signal will go
through O or Y. MRN signaling (see Section 4.1 of RFC 6001) enables
such choice but only if SC O =/= SC Y.

In other terms, MRN signaling provides the mean to prevent selection/
exclude certain SC (see Section 4.1 of RFC 6001) along signaled path,
but it doesn't allow to select among two resource pools associated to
the same SC.

4. Applicability Scenarios

When moving from OTN MLNs to general MRNs, the multiplexing tree
concept introduced in [OSPF-OTN] needs to be extended so to take into
account both different switching capabilities within the same muxing
tree and adaptations between client hierarchies and server
hierarchies.

In the following figure an example of muxing tree supporting TDM,
PSC, OTN-TDM and LSC hierarchies mixed together is shown.

```
                  VC-4
                   |
          ODU1   STM-16    PSC    L2SC
           |       |        |      |
           |       |        |      |
          ODU2    ODU2     ODU1    |
            \       \        /    /
             \       \      /    /
              \       \    /    /
               \       \  /    /
                \       \/    /
                 \_ _ODU3__/
                    |
                   OCh
```
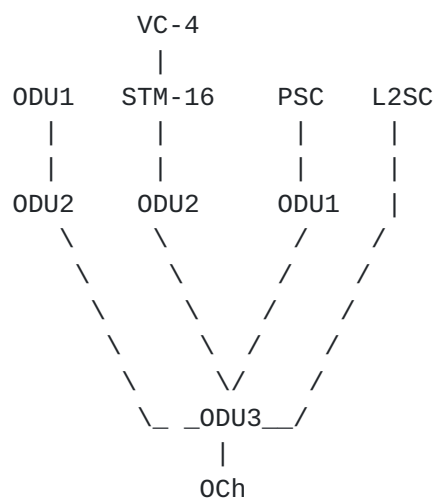
Figure 4: Muxing tree

As it is possible to understand from the figure above, an MRN
equipment can host a variety of client-server relationships. Four
different scenarios can be identified:

   - A signal type X is a client to a Signal type Y (1:1) - e.g.
   Ethernet over WDM

   - A signal type X is a client to a Intra switching technology
   Hierarchy Y (1:N) - e.g. Ethernet over OTN

   - An Intra switching technology Hierarchy X is a client to a
   Signal Type Y (M:1) - e.g. ODU over WDM

- An Intra switching technology Hierarchy X is a client to an
  Intra switching technology Hierarchy Y (M:N) - e.g. SDH over OTN

Being the first three scenarios a particular case of the fourth one,
in the following only the general case of M:N relationship will be
addressed.

This kind of client-server hierarchy can be achieved, depending on
the impelemntation, via single board or a cascade of them. In the
latter case boards are connected via internal links, which can be
either intra or inter switching capaility (e.g. ODU2->ODU3 or
PSC->LSC). Those links should not be modeled as external TE links,
but there is the need to advertise their characteristics and
availability in terms of bandwidth and optical parameters.

```
       +----------------------------------------------------------+
       |        +------------+    Eth   +------------+             |
       |        |            |    |     |            |            |
       |  OTU-1 +----+        |    |     +----+       |            |
       |    +----+   |        |  +--> +  |    |       |            |
       |        | 8  |        |    |    | 4  |        |            |
       |  OTU-1 |ODU1+------+|         |ODU2+------+| OTU-3       |
       |    +----+   |ODU-2 |..........>+   |ODU-3 |+----------|-->
       |        |    +------+|Internal  |    +------+|          |
       |  OTU-1|     |        |Physical |    |       |          |
       |    +----+   |        | Link    +    |       |          |
       |        +----+        | (OTU-2)  +----+       |          |
       |        |             |         |            |          |
       |        +------------+          +------------+          |
       +----------------------------------------------------------+
```
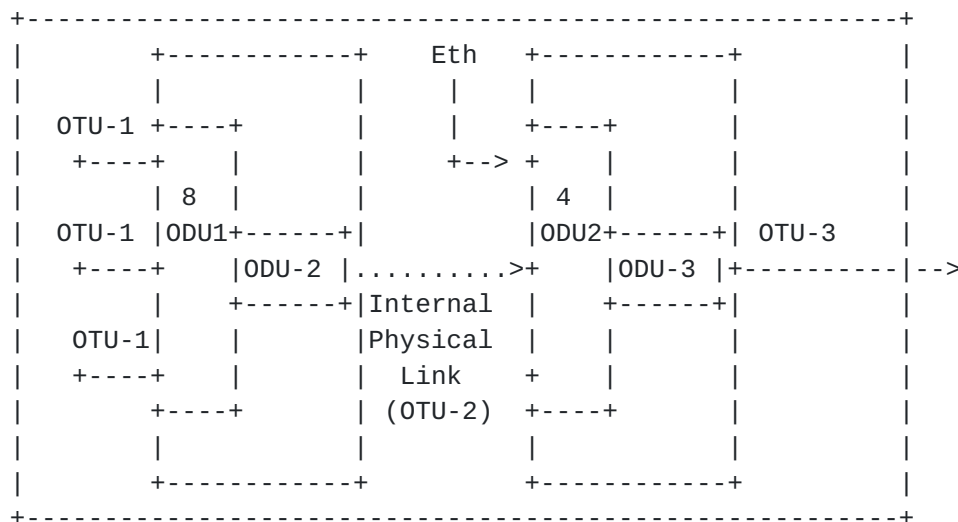
Figure 5: Cascaded muxponder

Moreover, as described in [RFC5212], in a hybrid node there is the
need to take into account also the node's internal adjustment
capabilities between the switching technologies supported. An
example of hybrid node with different switching matrices is shown in
the following figure, where both an SDH and OTN matrix are available
and the two switching elements are internally interconnected so that
it is possible to terminate some resources (e.g. OTN interface Y1)
or provide adjustment for the SDH traffic (e.g. OTN interface Y2
toward the SDH matrix). In addition to the internal links between
matrices it is possible to have internal links between matrices and
cascaded cards for the creation of the muxing hierarchy. In the
example below both the SDH and OTN matrices are client to an

ODU2->ODU3 muxponder (through interfaces Y4 and Y5), which in turn is
client to an OCh WSS.


```
                                           | 10GbE
          +------------------------+------------+
          |                        |            |
          |                        |            |
     +-+  |          +---------+    |            |
     |X|  |     X1   |         |    |            |
   __+-+__|_____ |    \  / |    |            |
          |        `     \/    | X3 |            |
          |     X2   |    /\    '''| |   ODU2     |
          |     |'''''   /  \   |  | | Y6+---+    |            +---------+
          |     |    |  +---+   |  | +---+    |   |            |         |
          |     |    |  |SDH|   +  | Y5 |     | ODU3|          |         |
          |     |    |  |__+---+__|   +-----+   +----+|          |         |
          |     |                    |    |     ||  OTU3/OCH|  +---+   |
          |     |                    |    |     ++----------+  |WSS|   +---
          |     |              Y4 |  |    ||  Y7        |  +---+   |Y8
          |     |  +----------+  ......   +----+|          |         |
     +-+  |     |  |  \  /    |  |  |__|    |+--+ |          |         |
     |Y|  |     |Y2 |   \/    |  | | |  +---+|OT| |          |         |
     +-+  |     .....|   /\    |Y3| |     +--+ |          +---------+
   -------+----------+  /  \   | | | |        |
          |     Y1   |         .... |        |
          |          | +---+   |    |    +    |
          |          | |OTN|   |    | ODU2    |
          |          |__+---+___|        |
          +--------------------------------------+
```
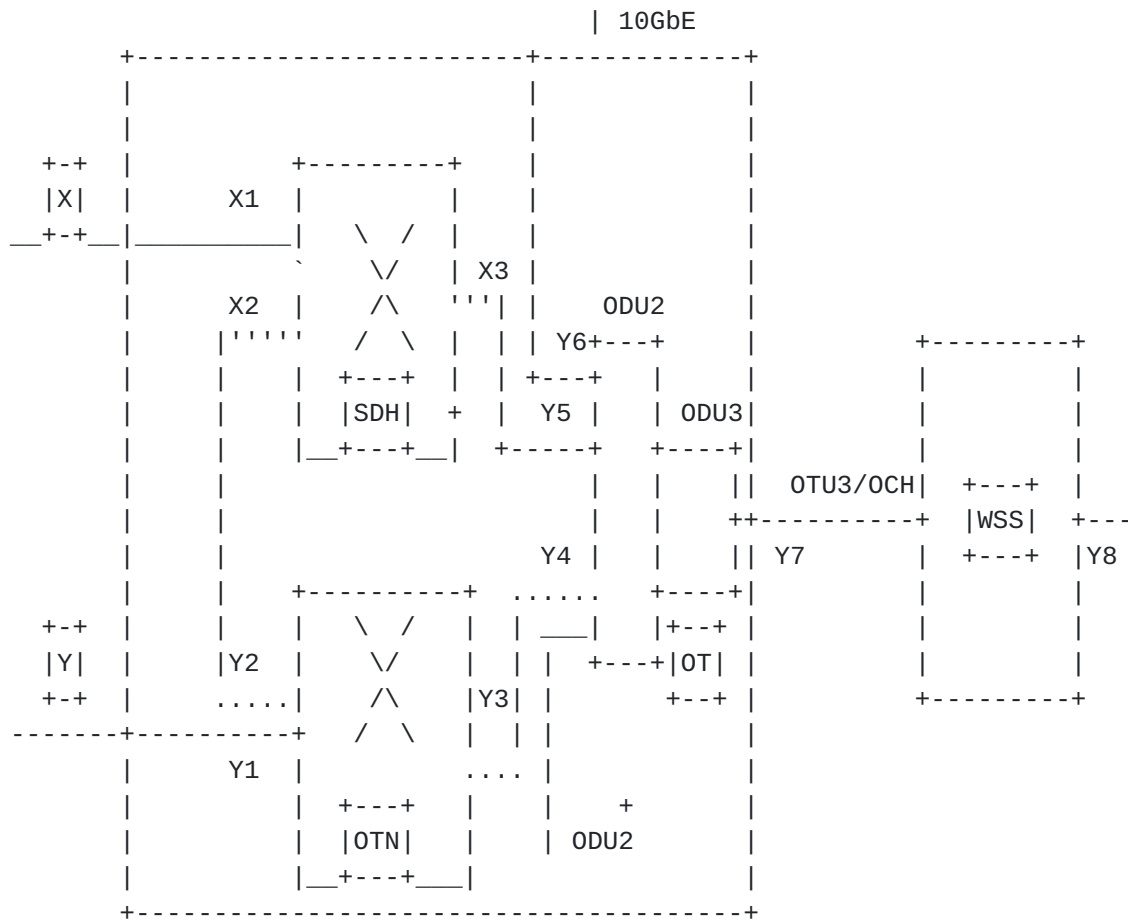
         Figure 6: Hybrid node with optical muxponder and different switching
                                 matrices

5. Use Cases

5.1. Multiple internal matrices with different inter-link types

```
          PT21
      +-----------+     `-.._              OTU2         +------------+
    '''' TDM      |     |          `-+.._+ NRZ,RS-FEC   |            |
     | Switch#1   +----+   +---+ |  _:----------------|            |
    ''''          |    |   |   |.+-'                    |            |
     +-----------+      |.-'                            |            |
                                                        |            |
             PT20 `-.._             OTU3,coherent, |    |            |
                  |   |   `-+.._+ HD-FEC            |    |            |
                  .'    ---+ |  _----------------|  LSC     |
     +-----------+ .' |   |  |.+-'                 |  Switch    |
    '''| TDM       .'  |.-'                         |            |
     | Switch#2  `.   `-.._           OTU3  ,coherent_|        |OTS line
    '''|           | `. |   |   `-+.._+ SD-FEC        |        +--------
     +-----------+    `.   +---+ |  _:----------------|        |
                      |   |   |.+-'                    |        |
    OTU,Eth,       PT21|.-'                            |        |
FC, SDH, Sonet                                         |        |
   lines as input        `-.._             OTU4, coherent,|     |
                PT21|   |   `-+.._+ HD-FEC            |        |
                    .'   +---+ |  _:----------------|        |
     +-----------+ .' |   |   |.+-'                  |        |
    '''| TDM       |'   |.-'                          |        |
     | Switch#3  |                     UTU2 , NRZ     |        |
    '''|           | `. |   |   |-+.._+ RS-FEC        |        |
     +-----------+    `.   +---+ |  _:----------------|        |
                PT21|   |   |.+-'                     |        |
                    |.-'                              +------------+
```
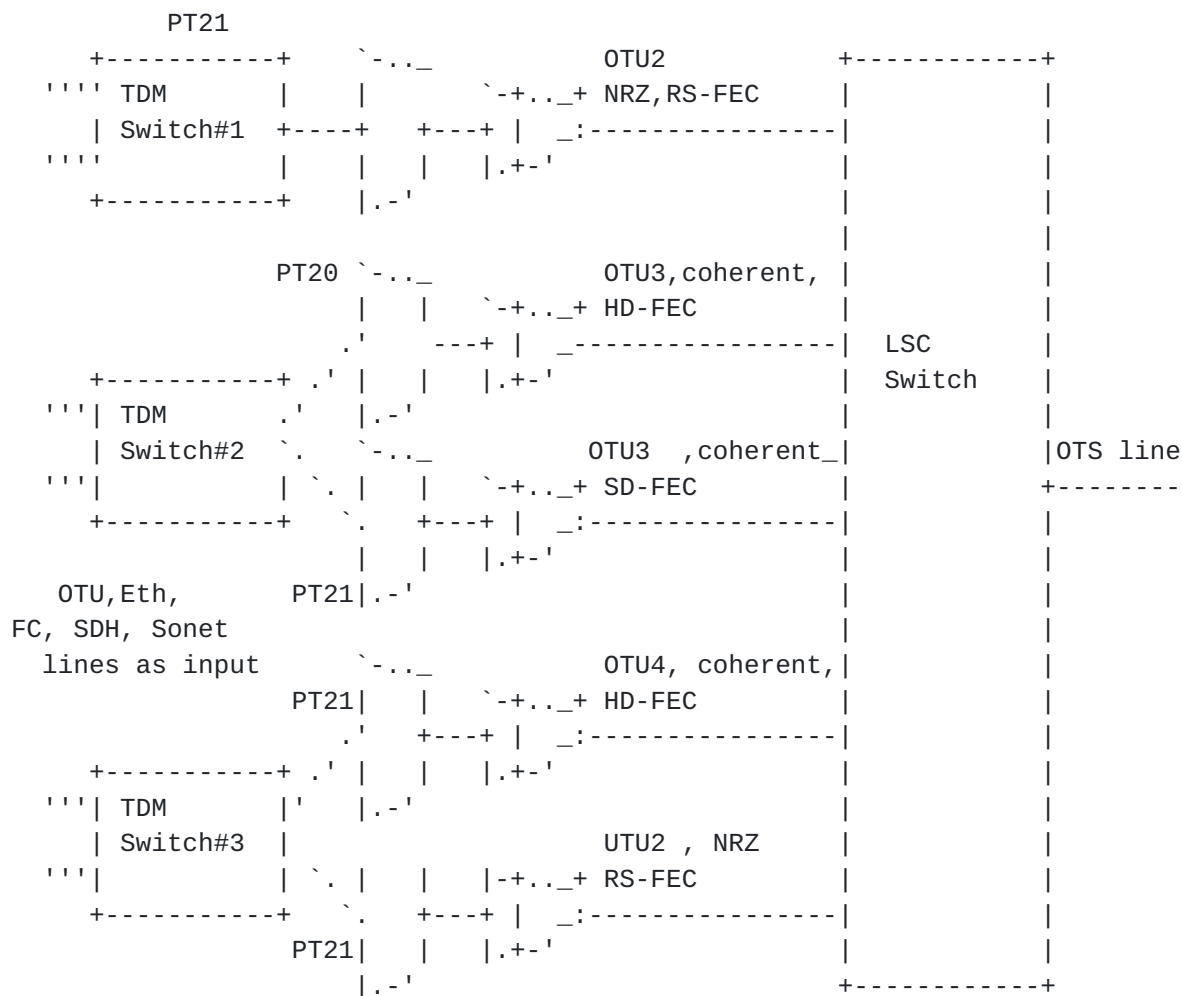
   Figure 7: Multiple internal matrices with different inter-link types

   A single IACD sub-TLV is associated to describe all the 1:1
   relationships TDM_i (i = 1,2,3) - LSC.

   When TDM-LSC has multiple relations, the following alternatives are
   possible:

      - the IACD sub-TLV aggregates information (assuming multiple LSP
      encodings could be listed in a single IACD sub-TLV)

      - a dedicated IACD sub-TLV describes each 1:1 relation TDM_ij -
      LSC (i=1,2,3; j=1,2)

   Note: one ISCD sub-TLV is associated to each TDM_i interface (left
   part of the figure) or a single ISCD sub-TLV (bundle) can describe
   all TDM interfaces

5.2. Multiple internal matrices with different inter-link types and shared server layer capacity

```
                       PT21
     +-----------+    `-.._             OTU2              +------------+
  '''' OTN        |    |        `-+.._+ NRZ,RS-FEC    |            |
     | Switch#1  \----+   +---+ |  _:---------------|            |
  ''''            |\    |    |   |.+-'               |            |
    +-----------\ \  |.-'                            |            |
                | \   PT20                           |            |
                \  \`-.._             OTU3,coherent, |            |
                 \  +   |    `-+.._+ HD-FEC           |            |
                 |.'     ---+ |  _----------------|  LSC          |
    +-----------+ .\ |   |   |.+-'                   |  Switch      |
  '''| SDH       .'  \|.-'                           |            |
     | Switch#2  `.   |-..PT21       OTU3  ,coherent_|           |OTS line
  '''|           | `. +   |    `-+.._+ SD-FEC        |           +--------
    +-----------+  +--   +---+ |  _:---------------|            |
                | |  .'   |.+-'                      |            |
   OTU,Eth,       | .-'                              |            |
 FC, SDH, Sonet   +-++                               |            |
   lines as inp  /    \                           +|            |
            +---+--+GFP-F                            |            |
                 |                                   |            |
    +-----------+  |                          +      |            |
  '''| Ethernet '''|                                 |            |
     | Switch#3  |    `.              OTU4,coherent  |            |
  '''|           |    | `-.    `-+.._+  HD-FEC        |            |
    +----------- `.. .    +---+ |  _:---------------|            |
                | +-+   |   |.+-'                    |            |
         GFP-T | | |.-'                              +------------+
                |-'    PT21
```
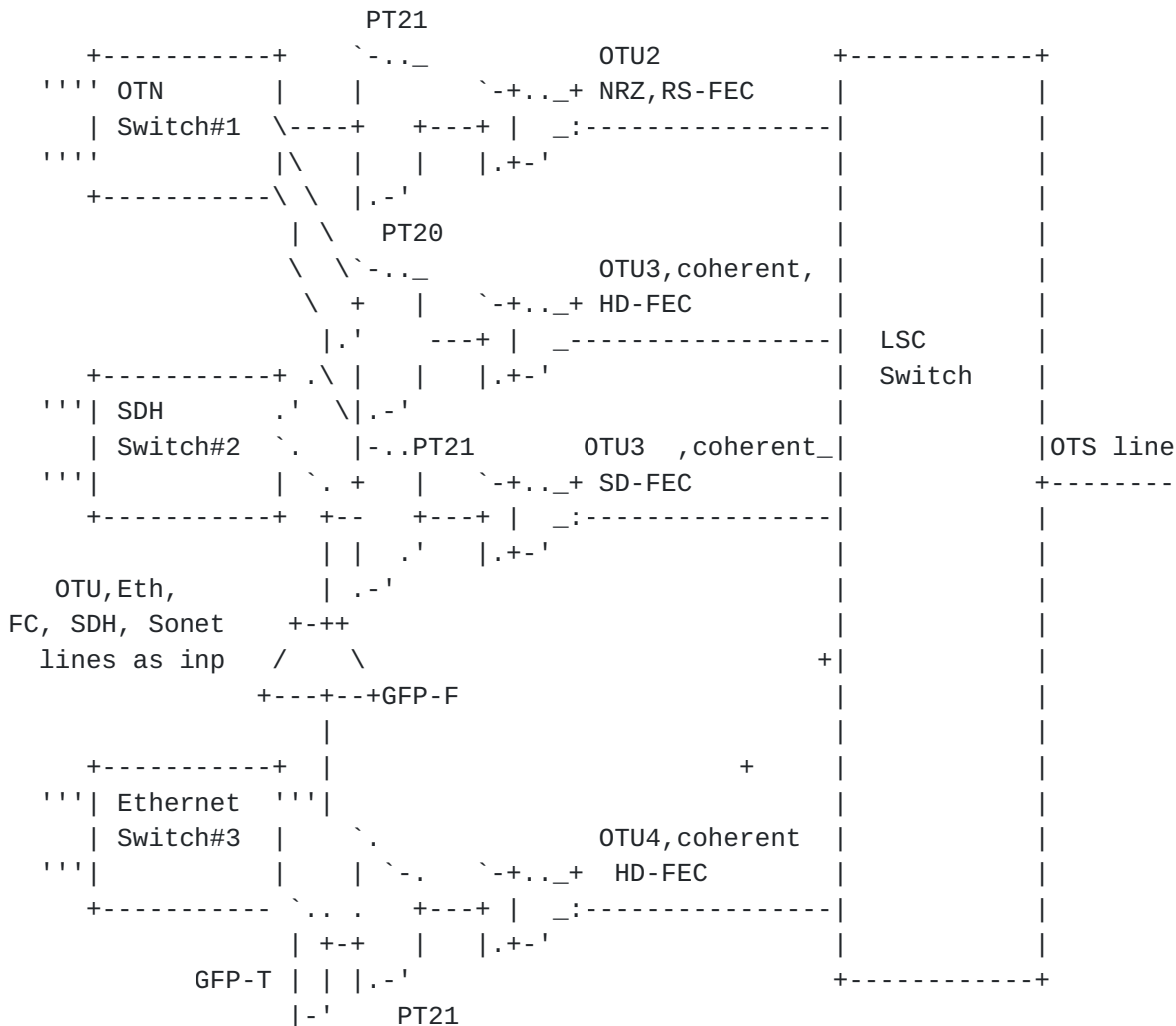
Figure 8: Multiple internal matrices with different inter-link types
and shared server layer capacity

+ Like in the previous example, a single IACD sub-TLV is associated
that describes each 1:1 relation (i.e., OTN_i-LSC, ETH_i -LSC) (note
that in this figure i=1).

The 1:N relation between the LSC switch and the SDH - OTN - ETH
switches is decomposed as follows:

      - A single IACD sub-TLV describes the 1:1 relation between the LSC
      switch and the PTx

      - A single IACD sub-TLV describes the 1:1 relation between the PTx
      and the ETH, SDH, or OTN switch (one single IACD sub-TLV
      independently from the number of legs between the switches and
      PTx)

   If the hub-and-spoke/star relationships is limited and the PTx
   capability "static", then each OTN-LSC, SDH-LSC, ETH-LSC 1:1
   relationship can be described by a dedicated IACD sub-TLV (like in
   Fig.1).

   Note_2: one ISCD sub-TLV is associated to each ETH, SDH, OTN
   interfaces (left part of the figure)

5.3. **Multistage multiplexing at different levels**

```
                                          +-----------+
                                          |           |
                                          |           |
                                          |           |
                                          |           |
                  PT20                     |           |
   |                    `-.._          OTU3,coherent, |           |
   | OTN/FC/SDH/ETH     +   |   `-+.._+ HD-FEC         |           |
   |      client        '    ---+ | _----------------|  LSC       |
   +-------------------+    |   |.+-'                 | Switch     |
   +--.                   |.-'                        |           |
   | | `-.    `-+.._    |-..PT21       OTU3 ,coherent_|           |OTS line
   +--   +---+ | _-----+   |   `-+.._+ SD-FEC          |        +--------
   +-+   |  |.+-'      -   +---+ | _:----------------|           |
   | |.-'             |  .'   |.+-'                   |           |
   '    PT21          .-'                             |           |
   ETH client                                         |           |
                                                    +|           |
       FC client                                      |           |
   +------------                                      |           |
   | |. PT21                                   +       |           |
   +-+ `-.    `-+.._                                  |           |
   . |   +---+ | _:-----.            OTU4,coherent     |           |
   +-+   |  |.+-'       | `-.   `-+.._+  HD-FEC        |           |
   | |.-'           . .    +---+ | _:----------------|           |
   '                 +-+   |  |.+-'                   |           |
   OTN client        | |.-'                          +-----------+
            ETH '    PT21
                                                       +
```
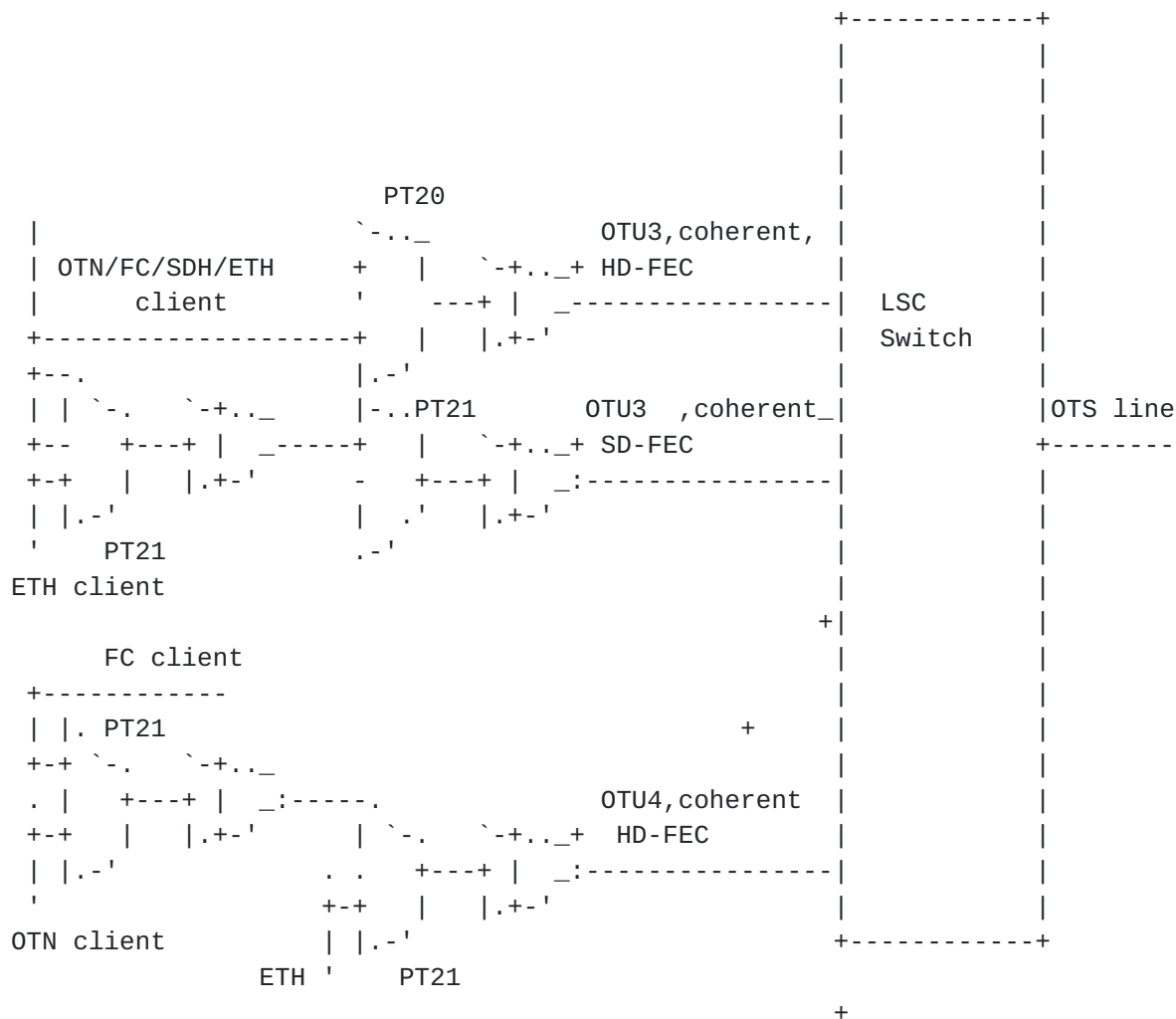
                Figure 9: Multistage multiplexing at different levels

   A single IACD sub-TLV is associated that describes each 1:1 relation
   between the ISCD sub-TLV associated to each interface and the LSC
   switch.

   In case, the PTx tree structure and associated un/used capacity
   varies over time the MAX LSP Bandwidth value(s) is/are to be tuned
   accordingly. Advertising the PTx tree structure (which actually
   instantiates each 1:1 relation) requires structuring the "Adjustment
   Capability-specific information" of the corresponding IACD sub-TLV.

6. Requirements

   In order to deal with all the scenarios depiscted in the previous
   sections, protocol extensions need to take into account the following

set of requirements.

   1. It must be possible to identify from which branch of X to
   which branch of Y the mapping is performed. Due to a restricted
   connectivity to a given switching layer, not all the indicated
   branches are really available. An example of such limitations can
   be seen in figure Figure 6, where for example the SDH client can
   be mapped only on itnerface Y5 of the muxponder board or the
   10GbEth on interface Y6. In figure Figure 4 it is also possible
   to see that the OTN has a hierarchy with 3 branches (i.e.
   ODU1->ODU2->ODU3, ODU2->ODU3 and ODU1->ODU3) and an SDH signal can
   be mapped only over the ODU2->ODU3 branch while an Ethernet one
   can be mapped only on the ODU1->ODU3). So it is not eough to say
   that SDH can be mapped over ODU or Eth over ODU as further info is
   needed. Moreover it is also not enough to say that Eth is mapped
   over ODU1 because in the same example 2 different branches have
   the ODU1 as the top most layer (i.e. ODU1->ODU2->ODU3 and
   ODU1->ODU3) and not both of them can support Eth mapping.

   2. Adaptation information from X to Y to be used both in case of
   Y being switched and X mapped over it or in case of both X and Y
   being switched. Please note that more than one type of adaptation
   might be availble.

   3. Amount of available bandwidth in the mapping between X and Y
   (as per actual IACD definition)

   4. It must be possible to advertise intra-switching capability
   associated to internal links. A typical case is a hierarchy
   gained through the cascade of multiple cards (e.g. trasnponders,
   muxponders) and the link from one board to the other one has a
   given bandwidth.

   5. It must be possible to advertise inter-switching capability
   associated to internal links. A typical case is a M:N client-
   layer hierarchy gained through the cascade of multiple cards (e.g.
   SDH client to a muxponder card) and the link from one board to the
   other one has a given bandwidth.

7. **Evaluation**

   [RFC6001] defined the Interface Adjustment Capability Descriptor
   (IACD) for the advertisement of internal adjustment capability of
   hybrid nodes [RFC5212].

   A common adjustment pool is a pool of reservable and sharable
   resources that are i) allocated on demand/dynamically and ii) either

assigned to a single SC (single adjustment pool model) or multiple SC
(multiple adjustment pool model) or possibly their combination.

In the former case (single pool model), the "lower SC" value of the
IACD sub-TLV (associated to the adjustment pool) is set to the SC
value of ISCD sub-TLV of the interface that interfaces with the
adjustment pool. The "upper" SC value of the IACD (associated to the
adjustment pool) determines the SC capability of the resource pool
itself. In this case the (upper) encoding is set to 0xFF. In other
terms, the capacity of the adjustment pool is not directly accessible
- over the wire - by other nodes belonging to the same TE domain
(assuming homogeneous LSP encoding type along the LSP path). This
model (see Example 1) is typically used when the node matrix
switching capability is not terminating/initiating any LSP (the node
only exposes the capability associated to its I/O) but nodes part of
the same TE domain can still take into account the adjustment
capacity usage on that node.

In the latter case (multiple pool model), the "lower SC" value of the
IACD sub-TLV (associated to the adjustment pool) is set to the SC
value of ISCD sub-TLV of the interface(s) that interfaces with the
adjustment pool. The "upper" SC value of the IACD sub-TLV
(associated to the adjustment pool) determines the SC capability of
the adjustment pool itself. However, the (upper) SC value of the
IACD sub-TLV shall correspond to at least one of the SC values
associated to one of the ISCD sub-TLVs, i.e., the adjustment pool SC
value shall be covered by at least one of the SC values associated to
the ISCD sub-TLVs. In other terms, the capacity of the adjustment
pool is directly accessible compared to the single pool model. This
model (see Example 2) is typically used when nodes expose their full
(multi-level) grooming and initiation/ termination capacity.

Example of single pool model: in the IACD sub-TLV the "upper" SC type
= TDM/HO-SDH, and the "lower" SC type being respectively "L2SC" and
"OTH/TDM". In this example, the capacity associated to the IACD
represents the "interconnection capacity" between the interface X
(L2SC or OTH) to Y = (HO-SDH/TDM). The encoding type associated to
the upper SC is set to 0xFF.

```
                           ^  ^        ^
                           |  |        |
                 +--------------------------------------+
                 | Network       | |  ... |             |
                 | element       | |      |             |
                 |            +---------+                |
                 |      +------|   L2SC  |<----+         |
                 |      |      |         |     |         |
                 |      |      +---------+     |         |
                 |      |                      |         |
                 |      |      +---------+     |         |
                 |      +----->|  HO-SDH |-----+         |
                 |      +------|         |<----+         |
                 |      |      +---------+     |         |
                 |      |                      |         |
                 |      |      +---------+     |         |
                 |      +----->|         |-----+         |
                 |       _     |         |      _        |
                 |      / |     |         |     | \       |
      Fiber 1    |     /  |-----|   OTH   |-----|  \      | Fiber 1
          -----|---|    |-----|         |-----|    |---|----
          ...  |   |    |-----|         |-----|    |...|
          -----|---|    |-----|         |-----|    |---|----
      Fiber N    |    \  |-----|         |-----|  /      | Fiber N
                 |     \_|     +---------+     |_/        |
                 +--------------------------------------+
```
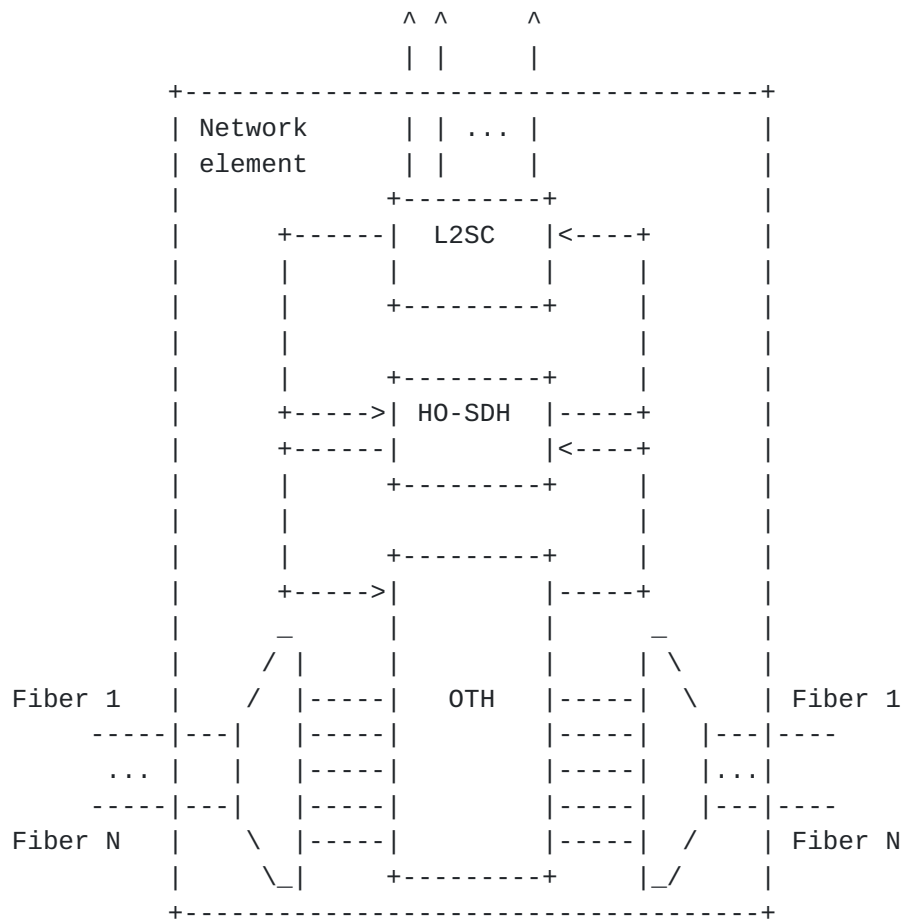
                Figure 10: Example of single pool model

   The advertisement for the node interfaces will be:

       + L2SC interfaces

          - ISCD sub_TLV 1 for L2SC interface

          - IACD sub_TLV 1 for L2SC to HO-SDH (1) in figure above

       + OTH inferfaces

          - ISCD sub_TLV 1 for OTH interface

          - IACD sub_TLV 1 for OTH to HO-SDH (2) in figure above

   Example of multiple pool model: In this case we will show two
   examples, the first of which does not foresee any interconnection
   between the L2SC and the HO-SDH matrices, while the second one does.

In the former case there is at least one ISCD sub-TLV of SC = X
corresponding to the lower SC value (HO-SDH/TDM) of the IACD sub-TLV
associated to the first adjustment pool (HO-SDH/TDM), and one ISCD
sub-TLV of type SC = Y corresponding to the lower SC value (L2SC) of
the IACD sub-TLV associated to the second adjustment pool Y (L2SC).
In this example, the capacity associated to the IACD represents the
"interconnection capacity" between the pool of SC = X (HO-SDH/TDM) to
Y (L2SC). Each TE Link 1...N is able to get access to this
adjustment capacity.

```
           +----------------------------------------------------+
           | Network                                            |
           | element                                            |
           |                        +---------+                 |
           |            +---------|   L2SC    |<---------+       |
           |            |       **|           |**        |       |
           |            |        * +---------+ *         |       |
           |            |        *             *         |       |
           |            |        * +---------+ *         |       |
           |            |       **|           |**        |       |
           |            | +-------|  HO-SDH   |<-------+  |       |
           |            | |       |           |        |  |       |
           |            | |       +---------+         |  |       |
           |            | |                           |  |       |
           |            | |       +---------+         |  |       |
           |            | |       |           |        |  |       |
           |          _ | |       |           |        |  | _     |
           |         / |<- |       |           |        | +| \     |
   Fiber 1 |    /  |<--+   |  OTH  |           |   +--|  \   | Fiber 1
     -----|--|   |----------|       |----------|   |---|----
     ... | |   |----------|       |----------|   |...|
     -----|--|   |----------|       |----------|   |---|----
   Fiber N |   \  |----------|       |----------| /   | Fiber N
           |    \_|       +---------+            |_/    |
           +----------------------------------------------------+
```

       Figure 11: Example of multiple pool model - No interconnection
                        between OTH and HO-SDH

   In this case the advertisement, which is the same for each of the N
   TE Link is:

      - ISCD sub_TLV for LSC

      - ISCD sub_TLV for HO-SDH

        - ISCD sub_TLV for OTH

        - IACD sub_TLV for LSC to HO-SDH (starred link)

   On the other side, if we consider the same scenario including the
   inteconnection between the OTH and HO-SDH matrices, as shown in
   figure below, the advertisement changes as follows.


```
                +-------------------------------------------------+
                | Network                                         |
                | element                                         |
                |                     +---------+                 |
                |         +---------|   L2SC    |<---------+      |
                |         |       **|           |**         |      |
                |         |        * +---------+ *          |      |
                |         |        *             *          |      |
                |         |        * +---------+ *          |      |
                |         |       **|           |**         |      |
                |       +-------|  HO-SDH  |<-------+ |      |
                |       | |       ..|           |..       | |      |
                |       | |       : +---------+ .        | |      |
                |       | |       :             :        | |      |
                |       | |       : +---------+ :        | |      |
                |       | |       : |           | :        | |      |
                |    _  | |       :.|           |.:       | | _    |
                |   /  |<- |       |             |       | +| \    |
    Fiber 1     |  /   |<--+       |    OTH    |         +--|  \   | Fiber 1
        -----|--|   |-----------|         |-----------|   |---|----
        ...  |  |   |----------|         |-----------|   |...|
        -----|--|   |-----------|         |-----------|   |---|----
    Fiber N     |  \   |-----------|         |-----------|  /   | Fiber N
                |   \_|       +---------+         |_/     |
                +-------------------------------------------------+
```


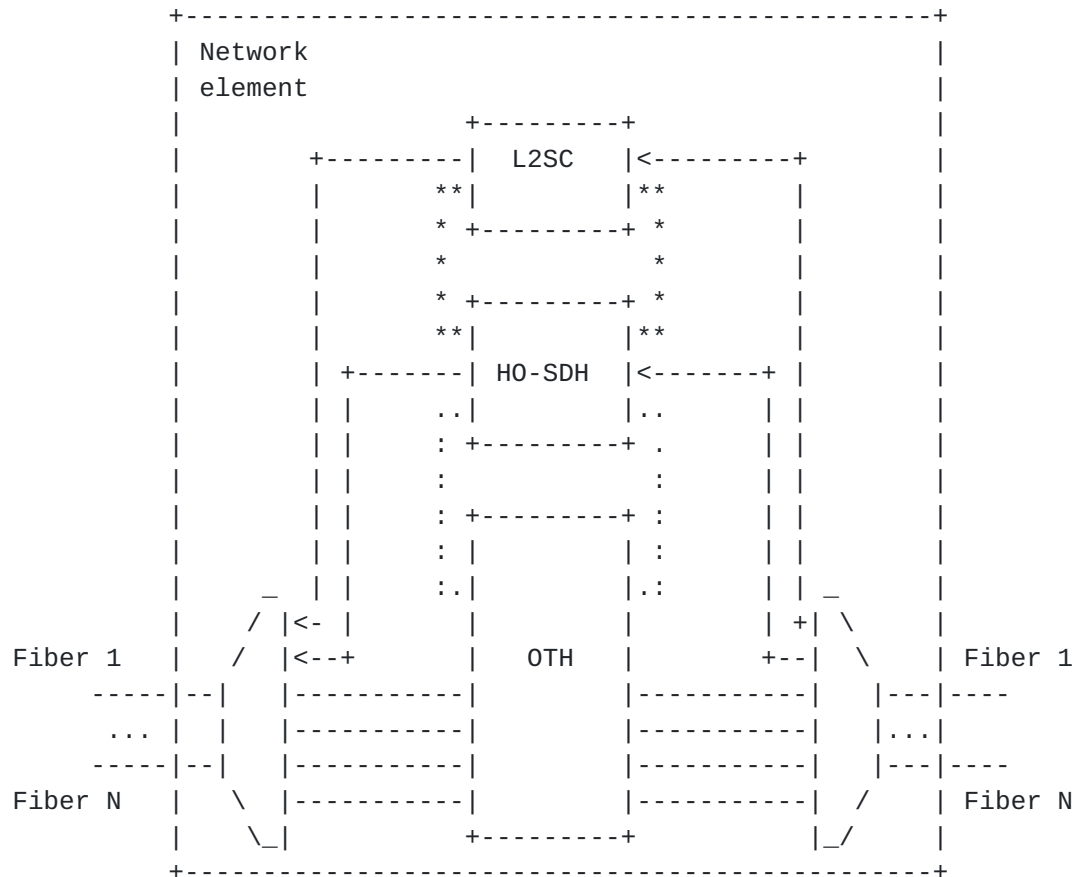   Figure 12: Example of multiple pool model - With interconnection
                          between OTH and HO-SDH

   This time the advertisement is modified as follows:

        - ISCD sub_TLV 1 for LSC

        - ISCD sub_TLV 2 for HO-SDH

        - ISCD sub_TLV 3 for OTH

      - IACD sub_TLV 1 for LSC to HO-SDH (starred link)

      - IACD sub_TLV 2 for HO-SDH to OTH (dotted link)

   The IACD is the only object defined in routing for the management of
   hybrid nodes. It provides the information for the forwarding/
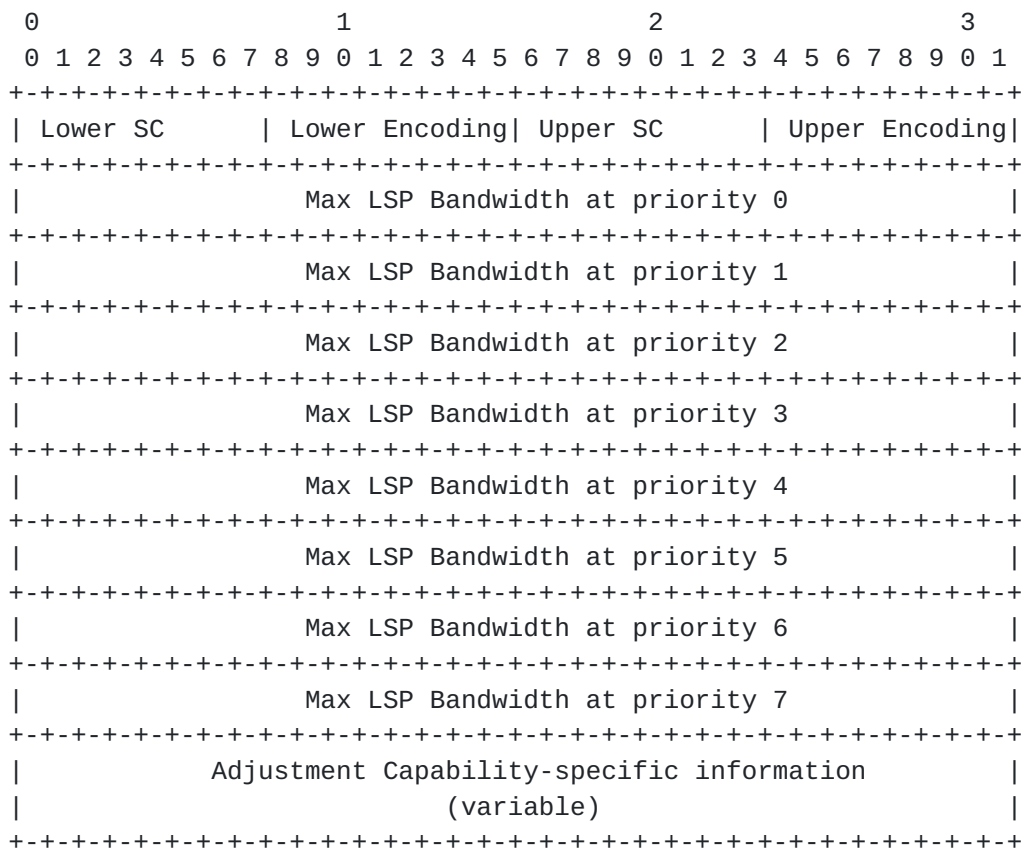   switching capability and is used in addition to the ISCD.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Lower SC      | Lower Encoding| Upper SC      | Upper Encoding|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 0              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 1              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 2              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 3              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 4              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 5              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 6              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Max LSP Bandwidth at priority 7              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Adjustment Capability-specific information         |
   |                          (variable)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                        Figure 13: IACD format

8. Missing information

   The pieces of information needed for addressing the requirements
   listed in Section 6 are:

      - Mapping information from a client to a server layer. E.g. an
      ethernet client could be mapped over and OTN hierarchy using a
      GFP-F or GFP-T adaptation.

- Connectivity constraints: need to describe optical transponder muxing scheme with positioning and restricted connectivity in order to provide end to end connectivity. In the example shown in picture Figure 4, the capability of muxing an SDH hierarchy is shown, but the SDH cannot be injected in any branch of the OTN hierarchy. There is the need to specify that the SDH hierarchy can be only muxed into the ODU->ODU3 branch of the OTN hierarchy and not in all of them.

- Multistage interswitching capability: The IACD already allows advertising the multiplexing of single and multi-stage muxing scenarios like the one in the reference muxing tree, where an SDH hierarchy is muxed over an OTN hierarchy, which is againg muxed over an OCh (two levels of muxing).

9. IANA Considerations

   TBD

10. Contributors

   TBD

11. Acknowledgements

   TBD

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