Network Working Group
Internet Draft
Intended status: Standards Track
Expires: April 2012

G. Bernstein
Grotto Networking
Y. Lee
D. Li
Huawei
W. Imajuku
NTT

October 31, 2011

Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks

draft-ietf-ccamp-rwa-wson-encode-13.txt

Status of this Memo

Copyright Notice

Abstract

A wavelength switched optical network (WSON) requires that certain key information elements are made available to facilitate path computation and the establishment of label switching paths (LSPs). The information model described in "Routing and Wavelength Assignment Information for Wavelength Switched Optical Networks" shows what information is required at specific points in the WSON. Part of the WSON information model contains aspects that may be of general applicability to other technologies, while other parts are fairly specific to WSONs.

This document provides efficient, protocol-agnostic encodings for the WSON specific information elements. It is intended that protocol-specific documents will reference this memo to describe how information is carried for specific uses. Such encodings can be used to extend GMPLS signaling and routing protocols. In addition these encodings could be used by other mechanisms to convey this same information to a path computation element (PCE).

Conventions used in this document

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 RFC-2119 [RFC2119].

Table of Contents

1. Introduction

A Wavelength Switched Optical Network (WSON) is a Wavelength Division Multiplexing (WDM) optical network in which switching is performed selectively based on the center wavelength of an optical signal.

[RFC6163] describes a framework for Generalized Multiprotocol Label Switching (GMPLS) and Path Computation Element (PCE) control of a WSON. Based on this framework, [WSON-Info] describes an information model that specifies what information is needed at various points in a WSON in order to compute paths and establish Label Switched Paths (LSPs).

This document provides efficient encodings of information needed by the routing and wavelength assignment (RWA) process in a WSON. Such encodings can be used to extend GMPLS signaling and routing protocols. In addition these encodings could be used by other mechanisms to convey this same information to a path computation element (PCE). Note that since these encodings are relatively efficient they can provide more accurate analysis of the control plane communications/processing load for WSONs looking to utilize a GMPLS control plane.

Note that encodings of information needed by the routing and label assignment process applicable to general networks beyond WSON are addressed in a separate document [Gen-Encode].

1.1. Revision History

1.1.1. Changes from 00 draft

Edits to make consistent with update to [RFC6205], i.e., removal of sign bit.

Clarification of TBD on connection matrix type and possibly numbering.

New sections for wavelength converter pool encoding: Wavelength Converter Set Sub-TLV, Wavelength Converter Accessibility Sub-TLV, Wavelength Conversion Range Sub-TLV, WC Usage State Sub-TLV.

Added optional wavelength converter pool TLVs to the composite node TLV.

1.1.2. Changes from 01 draft

The encoding examples have been moved to an appendix. Classified and corrected information elements as either reusable fields or sub-TLVs. Updated Port Wavelength Restriction sub-TLV. Added available wavelength and shared backup wavelength sub-TLVs. Changed the title and scope of section 6 to recommendations since the higher level TLVs that this encoding will be used in is somewhat protocol specific.

1.1.3. Changes from 02 draft

Removed inconsistent text concerning link local identifiers and the link set field.

Added E bit to the Wavelength Converter Set Field.

Added bidirectional connectivity matrix example. Added simple link set example. Edited examples for consistency.

1.1.4. Changes from 03 draft

Removed encodings for general concepts to [Gen-Encode].

Added in WSON signal compatibility and processing capability information encoding.

1.1.5. Changes from 04 draft

Added encodings to deal with access to resource blocks via shared fiber.

1.1.6. Changes from 05 draft

Revised the encoding for the "shared access" indicators to only use one bit each for ingress and egress.

1.1.7. Changes from 06 draft

Removed section on "WSON Encoding Usage Recommendations"

1.1.8. Changes from 07 draft

Section 3: Enhanced text to clarify relationship between pools, blocks and resources. Section 3.1, 3.2: Change title to clarify Pool-Block relationship. Section 3.3: clarify block-resource state.

Section 4: Deleted reference to previously removed RBNF element. Fixed TLV figures and descriptions for consistent sub-sub-TLV nomenclature.

1.1.9. Changes from 08 draft

Fixed ordering of fields in second half of sub-TLV example in Appendix A.1.

Clarifying edits in section 3 on pools, blocks, and resources.

1.1.10. Changes from 09 draft

Fixed the "Block Shared Access Wavelength Availability sub-TLV" of section 3.4 to use an "RB set field" rather than a single RB ID. Removed all 1st person idioms.

1.1.11. Changes from 10 draft

Removed remaining 1st person idioms. Updated IANA section. Update references for newly issued RFCs.

1.1.12. Changes from 11 draft

Fixed length fields in section 4 to be 16 bits, correcting errors in TLV and field figures. Added a separate section on resources, blocks, sets and the resource pool. Moved definition of the resource block set field to this new section.

1.1.13. Changes from 12 draft

RB Identifier field in Section 3.1 to be 32 bits from 16 bits. Added Editorial changes and updated the contributor list.

2. Terminology

CWDM: Coarse Wavelength Division Multiplexing.

DWDM: Dense Wavelength Division Multiplexing.

FOADM: Fixed Optical Add/Drop Multiplexer.

ROADM: Reconfigurable Optical Add/Drop Multiplexer. A reduced port count wavelength selective switching element featuring ingress and egress line side ports as well as add/drop side ports.

RWA: Routing and Wavelength Assignment.

Wavelength Conversion. The process of converting an information bearing optical signal centered at a given wavelength to one with "equivalent" content centered at a different wavelength. Wavelength conversion can be implemented via an optical-electronic-optical (OEO) process or via a strictly optical process.

WDM: Wavelength Division Multiplexing.

Wavelength Switched Optical Network (WSON): A WDM based optical network in which switching is performed selectively based on the center wavelength of an optical signal.

3. Resources, Blocks, Sets, and the Resource Pool

The optical system to be encoded may contain a pool of resources of different types and properties for processing optical signals. For the purposes here a "resource" is an individual entity such as a wavelength converter or regenerator within the optical node that acts on an individual wavelength signal.

Since resources tend to be packaged together in blocks of similar devices, e.g., on line cards or other types of modules, the fundamental unit of identifiable resource in this document is the "resource block". A resource block may contain one or more resources. As resource blocks are the smallest identifiable unit of processing resource, one should group together resources into blocks if they have similar characteristics relevant to the optical system being modeled, e.g., processing properties, accessibility, etc.

This document defines the following sub-TLVs pertaining to resources within an optical node:

- Resource Pool Accessibility Sub-TLV

- Resource Block Wavelength Constraints Sub-TLV

- Resource Pool State Sub-TLV

- Block Shared Access Wavelength Availability Sub-TLV

- Resource Block Information Sub-TLV

Each of these sub-TLVs works with one or more sets of resources rather than just a single resource block. This motivates the following field definition.

3.1. Resource Block Set Field

In a WSON node that includes resource blocks (RB), denoting subsets of these blocks allows one to efficiently describe common properties the blocks and to describe the structure and characteristics, if non-trivial, of the resource pool. The RB Set field is defined in a similar manner to the label set concept of [RFC3471].

The information carried in a RB set field is defined by:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Action     |C|   Reserved  |         Length                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        RB Identifier 1                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        RB Identifier n                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action: 8 bits

0 - Inclusive List

Indicates that the TLV contains zero or more RB elements that are included in the list.

1 - Reserved

2 - Inclusive Range

Indicates that the TLV contains a range of RBs. The object/TLV contains two WC elements. The first element indicates the start of the range. The second element indicates the end of the range. A value of zero indicates that there is no bound on the corresponding portion of the range.

3 - Reserved

C (Connectivity bit): Set to 0 to denote fixed (possibly multi-cast) connectivity; Set to 1 to denote potential (switched) connectivity. Used in resource pool accessibility sub-TLV. Ignored elsewhere.

Reserved: 7 bits

This field is reserved. It MUST be set to zero on transmission and MUST be ignored on receipt.

Length: 16 bits

The total length of this field in bytes.

RB Identifier:

The RB identifier represents the ID of the resource block which is a 32 bit integer.

Usage Note: the inclusive range "Action" can result in very compact encoding of resource sets and it can be advantages to number resource blocks in such a way so that status updates (dynamic information) can take advantage of this efficiency.

4. Resource Pool Accessibility/Availability

This section defines the sub-TLVs for dealing with accessibility and availability of resource blocks within a pool of resources. These include the ResourceBlockAccessibility, ResourceWaveConstraints, and RBPoolState sub-TLVs.

4.1. Resource Pool Accessibility Sub-TLV

This sub-TLV describes the structure of the resource pool in relation to the switching device. In particular it indicates the ability of an ingress port to reach sets of resources and of a sets of resources to reach a particular egress port. This is the PoolIngressMatrix and PoolEgressMatrix of [WSON-Info].

The resource pool accessibility sub-TLV is defined by:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     | Connectivity  |                     Reserved                  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                   Ingress Link Set Field A #1                 |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                         RB Set Field A #1                     |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |         Additional Link set and RB set pairs as needed to     |
     :                    specify PoolIngressMatrix                  :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                Egress Link Set Field B #1                     |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |             RB Set B Field #1 (for egress connectivity)       |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |         Additional Link Set and RB set pairs as needed to     |
     :                    specify PoolEgressMatrix                   :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

Connectivity indicates how the ingress/egress ports connect to the resource blocks.

0 -- the device is fixed (e.g., a connected port must go through the resource block)

1 -- the device is switched (e.g., a port can be configured to go through a resource but isn't required)

The Link Set Field is defined in [Gen-Encode].

Note that the direction parameter within the Link Set Field is used to indicate whether the link set is an ingress or egress link set, and the bidirectional value for this parameter is not permitted in this sub-TLV.

See Appendix A.1 for an illustration of this encoding.

4.2. Resource Block Wavelength Constraints Sub-TLV

Resources, such as wavelength converters, etc., may have a limited input or output wavelength ranges. Additionally, due to the structure of the optical system not all wavelengths can necessarily reach or leave all the resources. These properties are described by using one or more resource wavelength restrictions sub-TLVs as defined below:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      RB Set Field                             |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Input Wavelength Set Field                    |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Output Wavelength Set Field                   |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

RB Set Field:

A set of resource blocks (RBs) which have the same wavelength restrictions.

Input Wavelength Set Field:

Indicates the wavelength input restrictions of the RBs in the corresponding RB set.

Output Wavelength Set Field:

Indicates the wavelength output restrictions of RBs in the corresponding RB set.

4.3. Resource Pool State Sub-TLV

The state of the pool is given by the number of resources available with particular characteristics. A resource block set is used to encode all or a subset of the resources of interest. The usage state of resources within a resource block set is encoded as either a list of 16 bit integer values indicating the number of available resources in the resource block, or a bit map indicating whether a particular resource is available or in use. The bit map encoding is appropriate when resource blocks consist of a single resource. This information can be relatively dynamic, i.e., can change when a connection (LSP is established or torn down.

```
 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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | Action        |    Reserved                                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     RB Set Field                              |
 :                                                               :
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                  RB Usage state                               |
 :                                                               :
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Action = 0 denotes a list of 16 bit integers and Action = 1 denotes a bit map. In both cases the elements of the RB Set field are in a one-to-one correspondence with the values in the usage RB usage state area.

```
  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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | Action = 0    |    Reserved                                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     RB Set Field                              |
 :                                                               :
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                  RB#1 state   |      RB#2 state               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 :                                                               :
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                 RB#n-1 state  |   RB#n state or Padding       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Whether the last 16 bits is a wavelength converter (RB) state or padding is determined by the number of elements in the RB set field.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Action = 1    |    Reserved                                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     RB Set Field                              |
    :                                                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                  RB Usage state bitmap                        |
    :                                                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     ......    |         Padding bits          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

RB Usage state: Variable Length but must be a multiple of 4 bytes.

Each bit indicates the usage status of one RB with 0 indicating the RB is available and 1 indicating the RB is in used. The sequence of the bit map is ordered according to the RB Set field with this sub-TLV.

Padding bits: Variable Length

4.4. Block Shared Access Wavelength Availability sub-TLV

Resources blocks may be accessed via a shared fiber. If this is the case, then wavelength availability on these shared fibers is needed to understand resource availability.

```
       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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |I|E|                          Reserved                         |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                     RB Set Field                              |
      :                                                               :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |            Ingress Available Wavelength Set Field             |
      :                          (Optional)                           :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |             Egress Available Wavelength Set Field             |
      :                          (Optional)                           :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

I bit:

Indicates whether the ingress available wavelength set field is included (1) or not (0).

E bit:

Indicates whether the egress available wavelength set field is included (1) or not (0).

RB Set Field:

A Resource Block set in which all the members share the same ingress or egress fiber or both.

Ingress Available Wavelength Set Field:

Indicates the wavelengths currently available (not being used) on the ingress fiber to this resource block.

Egress Available Wavelength Set Field:

Indicates the wavelengths currently available (not being used) on the egress fiber from this resource block.

5. Resource Properties Encoding

Within a WSON network element (NE) there may be resources with signal compatibility constraints. These resources be regenerators, wavelength converters, etc... Such resources may also constitute the network element as a whole as in the case of an electro optical switch. This section primarily focuses on the signal compatibility and processing properties of such a resource block.

The fundamental properties of a resource block, such as a regenerator or wavelength converter, are:

(a) Input constraints (shared ingress, modulation, FEC, bit rate, GPID)

(b) Processing capabilities (number of resources in a block, regeneration, performance monitoring, vendor specific)

(c) Output Constraints (shared egress, modulation, FEC)

5.1. Resource Block Information Sub-TLV

Resource Block descriptor sub-TLVs are used to convey relatively static information about individual resource blocks including the resource block compatibility properties, processing properties, and the number of resources in a block.

This sub-TLV has the following format:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      RB Set Field                             |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |I|E|                          Reserved                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Input Modulation Type List Sub-Sub-TLV  (opt)       |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Input FEC Type List Sub-Sub-TLV    (opt)            |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Input Client Signal Type Sub-Sub-TLV      (opt)       |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Input Bit Rate Range List  Sub-Sub-TLV (opt)          |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Processing Capabilities List Sub-Sub-TLV (opt)        |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Output Modulation Type List Sub-Sub-TLV  (opt)        |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Output FEC Type List Sub-Sub-TLV  (opt)               |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where I and E, the shared ingress/egress indicator, is set to 1 if the resource blocks identified in the RB set field utilized a shared fiber for ingress/egress access and set to 0 otherwise.

5.2. Input Modulation Format List Sub-Sub-TLV

This sub-sub-TLV contains a list of acceptable input modulation formats.

Type := Input Modulation Format List

Value := A list of Modulation Format Fields

5.2.1. Modulation Format Field

Two different types of modulation format fields are defined: a standard modulation field and a vendor specific modulation field. Both start with the same 32 bit header shown below.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S|I|      Modulation ID        |          Length               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where S bit set to 1 indicates a standardized modulation format and S bit set to 0 indicates a vendor specific modulation format. The length is the length in bytes of the entire modulation type field.

Where I bit set to 1 indicates it is an input modulation constraint and I bit set to 0 indicates it is an output modulation constraint.

Note that if an output modulation is not specified then it is implied that it is the same as the input modulation. In such case, no modulation conversion is performed.

The format for the standardized type for the input modulation is given by:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|1|       Modulation ID       |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Possible additional modulation parameters depending upon    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:   the modulation ID                                           :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Modulation ID (S bit = 1); Input modulation (I bit = 1)

Takes on the following currently defined values:

0   Reserved

1   optical tributary signal class NRZ 1.25G

      2   optical tributary signal class NRZ 2.5G

      3   optical tributary signal class NRZ 10G

      4   optical tributary signal class NRZ 40G

      5   optical tributary signal class RZ 40G

Note that future modulation types may require additional parameters in their characterization.

The format for vendor specific modulation field (for input constraint) is given by:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0|1|  Vendor Modulation ID     |           Length              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Enterprise Number                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   :   Any vendor specific additional modulation parameters        :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Vendor Modulation ID

  This is a vendor assigned identifier for the modulation type.

Enterprise Number

  A unique identifier of an organization encoded as a 32-bit integer. Enterprise Numbers are assigned by IANA and managed through an IANA registry [RFC2578].

Vendor Specific Additional parameters

  There can be potentially additional parameters characterizing the vendor specific modulation.

5.3. Input FEC Type List Sub-Sub-TLV

This sub-sub-TLV contains a list of acceptable FEC types.

Type := Input FEC Type field List

Value := A list of FEC type Fields

5.3.1. FEC Type Field

The FEC type Field may consist of two different formats of fields: a standard FEC field or a vendor specific FEC field. Both start with the same 32 bit header shown below.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S|I|      FEC ID               |          Length               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Possible additional FEC parameters depending upon           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:   the FEC ID                                                  :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where S bit set to 1 indicates a standardized FEC format and S bit set to 0 indicates a vendor specific FEC format. The length is the length in bytes of the entire FEC type field.

Where I bit set to 1 indicates it is an input FEC constraint and I bit set to 0 indicates it is an output FEC constraint.

Note that if an output FEC is not specified then it is implied that it is the same as the input FEC. In such case, no FEC conversion is performed.

The length is the length in bytes of the entire FEC type field.

The format for input standard FEC field is given by:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1|1|       FEC ID              |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Possible additional FEC parameters depending upon           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:   the FEC ID                                                  :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Takes on the following currently defined values for the standard FEC ID:

0   Reserved

1   G.709 RS FEC

2   G.709V compliant Ultra FEC

3   G.975.1 Concatenated FEC (RS(255,239)/CSOC(n0/k0=7/6,J=8))

4   G.975.1 Concatenated FEC (BCH(3860,3824)/BCH(2040,1930))

5   G.975.1 Concatenated FEC (RS(1023,1007)/BCH(2407,1952))

6   G.975.1 Concatenated FEC (RS(1901,1855)/Extended Hamming Product Code (512,502)X(510,500))

7   G.975.1 LDPC Code

8   G.975.1 Concatenated FEC (Two orthogonally concatenated BCH codes)

9   G.975.1 RS(2720,2550)

10   G.975.1 Concatenated FEC (Two interleaved extended BCH (1020,988) codes)

Where RS stands for Reed-Solomon and BCH for Bose-Chaudhuri-Hocquengham.

The format for input vendor-specific FEC field is given by:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |0|1|       Vendor FEC ID       |              Length            |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                        Enterprise Number                       |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     :   Any vendor specific additional FEC parameters                :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Vendor FEC ID

This is a vendor assigned identifier for the FEC type.

Enterprise Number

A unique identifier of an organization encoded as a 32-bit integer. Enterprise Numbers are assigned by IANA and managed through an IANA registry [RFC2578].

Vendor Specific Additional FEC parameters

There can be potentially additional parameters characterizing the vendor specific FEC.

5.4. Input Bit Range List Sub-Sub-TLV

This sub-sub-TLV contains a list of acceptable input bit rate ranges.

Type := Input Bit Range List

Value := A list of Bit Range Fields

5.4.1. Bit Range Field

The bit rate range list sub-TLV makes use of the following bit rate range field:

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                           Starting Bit Rate                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                             Ending Bit Rate                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The starting and ending bit rates are given as 32 bit IEEE floating point numbers in bits per second. Note that the starting bit rate is less than or equal to the ending bit rate.

The bit rate range list sub-TLV is then given by:

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+ Bit Range Field #1  +-+-+-+-+-+-+-+-+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    :                               :                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+ Bit Range Field #M  +-+-+-+-+-+-+-+-+
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

5.5. Input Client Signal List Sub-Sub-TLV

This sub-sub-TLV contains a list of acceptable input client signal types.

Type := Input Client Signal List

Value := A list of GPIDs

The acceptable client signal list sub-TLV is a list of Generalized Protocol Identifiers (GPIDs). GPIDs are assigned by IANA and many are defined in [RFC3471] and [RFC4328].

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |       Number of GPIDs         |           GPID #1             |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     :                               |                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |            GPID #N            |                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where the number of GPIDs is an integer greater than or equal to one.

5.6. Processing Capability List Sub-Sub-TLV

This sub-sub-TLV contains a list of resource block processing capabilities.

Type := Processing Capabilities List

Value := A list of Processing Capabilities Fields

The processing capability list sub-TLV is a list of WSON network element (NE) that can perform signal processing functions including:

1. Number of Resources within the block

2. Regeneration capability

3. Fault and performance monitoring

4. Vendor Specific capability

Note that the code points for Fault and performance monitoring and vendor specific capability are subject to further study.

5.6.1. Processing Capabilities Field

The processing capability field is then given by:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |          Processing Cap ID    |          Length               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   Possible additional capability parameters depending upon    |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     :   the processing ID                                           :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

When the processing Cap ID is "number of resources" the format is simply:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |          Processing Cap ID    |          Length = 8           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                  Number of resources per block                |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

When the processing Cap ID is "regeneration capability", the following additional capability parameters are provided in the sub-TLV:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  T  | C |                  Reserved                           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where T bit indicates the type of regenerator:

T=0: Reserved

T=1: 1R Regenerator

T=2: 2R Regenerator

T=3: 3R Regenerator

Where C bit indicates the capability of regenerator:

C=0: Reserved

C=1: Fixed Regeneration Point

C=2: Selective Regeneration Point

Note that when the capability of regenerator is indicated to be Selective Regeneration Pools, regeneration pool properties such as ingress and egress restrictions and availability need to be specified. This encoding is to be determined in the later revision.

5.7. Output Modulation Format List Sub-Sub-TLV

This sub-sub-TLV contains a list of available output modulation formats.

Type := Output Modulation Format List

Value := A list of Modulation Format Fields

5.8. Output FEC Type List Sub-Sub-TLV

This sub-sub-TLV contains a list of output FEC types.

Type := Output FEC Type field List

Value := A list of FEC type Fields

6. Security Considerations

This document defines protocol-independent encodings for WSON information and does not introduce any security issues.

However, other documents that make use of these encodings within protocol extensions need to consider the issues and risks associated with, inspection, interception, modification, or spoofing of any of this information. It is expected that any such documents will describe the necessary security measures to provide adequate protection.

7. IANA Considerations

This document provides general protocol independent information encodings. There is no IANA allocation request for the TLVs defined in this document. IANA allocation requests will be addressed in protocol specific documents based on the encodings defined here.

8. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

APPENDIX A: Encoding Examples

A.1. Wavelength Converter Accessibility Sub-TLV

Example:

Figure 1 shows a wavelength converter pool architecture know as "shared per fiber". In this case the ingress and egress pool matrices are simply:

```
              +-----+       +-----+
              | 1 1 |       | 1 0 |
          WI =|     |,  WE =|     |
              | 1 1 |       | 0 1 |
              +-----+       +-----+


                    +-----------+                      +------+
                    |           |--------------------->|      |
                    |           |--------------------->|  C   |
              /|    |           |--------------------->|  o   |
             /D+--->|           |--------------------->|  m   |
            + e+--->|           |                      |  b   |=======>
   ========>| M|    |  Optical  |    +-----------+     |  i   | Port E1
   Port I1  + u+--->|   Switch  |    |  WC Pool  |     |  n   |
             \x+--->|           |    |  +-----+  |     |  e   |
              \|    |           +----+->|WC #1|--+---->|  r   |
                    |           |    |  +-----+  |     +------+
                    |           |    |           |     +------+
              /|    |           |    |  +-----+  |     |      |
             /D+--->|           +----+->|WC #2|--+---->|  C   |
            + e+--->|           |    |  +-----+  |     |  o   |
   ========>| M|    |           |    +-----------+     |  m   |=======>
   Port I2  + u+--->|           |                      |  b   | Port E2
             \x+--->|           |--------------------->|  i   |
              \|    |           |--------------------->|  n   |
                    |           |--------------------->|  e   |
                    |           |--------------------->|  r   |
                    +-----------+                      +------+
```

Figure 1 An optical switch featuring a shared per fiber wavelength converter pool architecture.

This wavelength converter pool can be encoded as follows:

```
        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
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       | Connectivity=1|                 Reserved                      |
                   Note: I1,I2 can connect to either WC1 or WC2
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |0 1|0 0 0 0 0 0|            Length = 12        |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                     Link Local Identifier = #1                |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                     Link Local Identifier = #2                |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |1|  Reserved   |            Length = 12        |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                        RB ID = #1                             |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                        RB ID = #2                             |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                         Note: WC1 can only connect to E1
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |1 0|0 0 0 0 0 0|            Length = 8         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                     Link Local Identifier = #1                |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |0|  Reserved   |            Length = 8         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                        RB ID = #1                             |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                      Note: WC2 can only connect to E2
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |1 0|0 0 0 0 0 0|            Length = 8         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                     Link Local Identifier = #2                |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Action=0     |0|  Reserved   |            Length = 8         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                        RB ID = #2                             |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.2. Wavelength Conversion Range Sub-TLV

Example:

This example, based on figure 1, shows how to represent the wavelength conversion range of wavelength converters. Suppose the wavelength range of input and output of WC1 and WC2 are {L1, L2, L3, L4}:

```
    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
                          Note: WC Set
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Action=0     |1| Reserved    |     Length = 12               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          WC ID = #1                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          WC ID = #2                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                          Note: wavelength input range
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | 2   | Num Wavelengths = 4     |          Length = 8           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |     Reserved    |  n for lowest frequency = 1   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                          Note: wavelength output range
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | 2   | Num Wavelengths = 4     |          Length = 8           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |     Reserved    |  n for lowest frequency = 1   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.3. An OEO Switch with DWDM Optics

Figure 2 shows an electronic switch fabric surrounded by DWDM optics. In this example the electronic fabric can handle either G.709 or SDH signals only (2.5 or 10 Gbps). To describe this node, the following information is needed:

<Node_Info> ::= <Node_ID>[Other GMPLS sub-TLVs][<ConnectivityMatrix>...] [<ResourcePool>][<RBPoolState>]

In this case there is complete port to port connectivity so the <ConnectivityMatrix> is not required. In addition since there are

sufficient ports to handle all wavelength signals the <RBPoolState> element is not needed.

Hence the attention will be focused on the <ResourcePool> sub-TLV:

<ResourcePool> ::=
<ResourceBlockInfo>[<ResourceBlockAccessibility>...][<ResourceWaveConstraints>...]

```
           /|    +-----------+    +-------------+   +------+
          /D+--->|           +--->|Tunable Laser|-->|      |
         + e+--->|           |    +-------------+   |  C   |
========>| M|    |           |        ...           |  o   |=======>
Port I1  + u+--->|           |    +-------------+   |  m   | Port E1
          \x+--->|           |--->|Tunable Laser|-->|  b   |
           \|    |  Electric |    +-------------+   +------+
                 |   Switch  |
           /|    |           |    +-------------+   +------+
          /D+--->|           +--->|Tunable Laser|-->|      |
         + e+--->|           |    +-------------+   |  C   |
========>| M|    |           |        ...           |  o   |=======>
Port I2  + u+--->|           |    +-------------+   |  m   | Port E2
          \x+--->|           +--->|Tunable Laser|-->|  b   |
           \|    |           |    +-------------+   +------+
                 |           |
           /|    |           |    +-------------+   +------+
          /D+--->|           |--->|Tunable Laser|-->|      |
         + e+--->|           |    +-------------+   |  C   |
========>| M|    |           |        ...           |  o   |=======>
Port I3  + u+--->|           |    +-------------+   |  m   | Port E3
          \x+--->|           |--->|Tunable Laser|-->|  b   |
           \|    +-----------+    +-------------+   +------+
```

Figure 2 An optical switch built around an electronic switching fabric.

The resource block information will tell us about the processing constraints of the receivers, transmitters and the electronic switch. The resource availability information, although very simple, tells us that all signals must traverse the electronic fabric (fixed connectivity). The resource wavelength constraints are not needed since there are no special wavelength constraints for the resources that would not appear as port/wavelength constraints.

<ResourceBlockInfo>:

```
       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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                     RB Set Field                              |
      :  (only one resource block in this example with shared         |
      |                     input/output case)                        |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |0|0|                         Reserved                          |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |           Input Modulation Type List Sub-Sub-TLV              |
      :        (The receivers can only process NRZ)                   :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |           Input FEC Type List Sub-Sub-TLV                     |
      :           (Only Standard SDH and G.709 FECs   )               :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         Input Client Signal Type Sub-TLV                      |
      :              (GPIDs for SDH and G.709)                        :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         Input Bit Rate Range List  Sub-Sub-TLV                |
      :                          (2.5Gbps, 10Gbps)                    :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         Processing Capabilities List Sub-Sub-TLV              |
      :                    Fixed (non optional) 3R regeneration       :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         Output Modulation Type List Sub-Sub-TLV               |
      :                          NRZ                                  :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |         Output FEC Type List Sub-Sub-TLV                      |
      :                 Standard SDH, G.709 FECs                      :
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Since there is fixed connectivity to resource blocks (the electronic switch) the <ResourceBlockAccessibility> is:

```
        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
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       | Connectivity=1|Reserved       |                               |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                    Ingress Link Set Field A #1                |
       :                    (All ingress links connect to resource)    :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                          RB Set Field A #1                    |
       :              (trivial set only one resource block)            :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                Egress Link Set Field B #1                     |
       :                    (All egress links connect to resource)     :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2578] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.

[RFC3471] Berger, L., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description", RFC 3471, January 2003.

[RFC4328] Papadimitriou, D., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control", RFC 4328, January 2006.

[G.694.1] ITU-T Recommendation G.694.1, "Spectral grids for WDM applications: DWDM frequency grid", June, 2002.

9.2. Informative References

[G.694.1] ITU-T Recommendation G.694.1, Spectral grids for WDM applications: DWDM frequency grid, June 2002.

[G.694.2] ITU-T Recommendation G.694.2, Spectral grids for WDM applications: CWDM wavelength grid, December 2003.

[Gen-Encode]   G. Bernstein, Y. Lee, D. Li, W. Imajuku, "General Network Element Constraint Encoding for GMPLS Controlled Networks", work in progress: draft-ietf-ccamp-general-constraint-encode.

[RFC6205]   T. Otani, H. Guo, K. Miyazaki, D. Caviglia, "Generalized Labels for G.694 Lambda-Switching Capable Label Switching Routers", RFC 6205, March 2011.

[RFC6163] Y. Lee, G. Bernstein, W. Imajuku, "Framework for GMPLS and PCE Control of Wavelength Switched Optical Networks", RFC 6163, April 2011.

[WSON-Info] G. Bernstein, Y. Lee, D. Li, W. Imajuku, "Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks", work in progress: draft-ietf-ccamp-rwa-info, March 2009.

10. Contributors

Diego Caviglia
Ericsson
Via A. Negrone 1/A 16153
Genoa Italy
Phone: +39 010 600 3736
Email: diego.caviglia@(marconi.com, ericsson.com)

Anders Gavler
Acreo AB
Electrum 236
SE - 164 40 Kista Sweden
Email: Anders.Gavler@acreo.se

Jonas Martensson
Acreo AB
Electrum 236
SE - 164 40 Kista, Sweden
Email: Jonas.Martensson@acreo.se

Itaru Nishioka
NEC Corp.
1753 Simonumabe, Nakahara-ku, Kawasaki, Kanagawa 211-8666
Japan
Phone: +81 44 396 3287
Email: i-nishioka@cb.jp.nec.com

Cyril Margaria
Nokia Siemens Networks
St Martin Strasse 76
Munich,   81541
Germany
Phone: +49 89 5159 16934
Email: cyril.margaria@nsn.com

Authors' Addresses

Greg M. Bernstein (ed.)
Grotto Networking
Fremont California, USA

Phone: (510) 573-2237
Email: gregb@grotto-networking.com

Young Lee (ed.)
Huawei Technologies
1700 Alma Drive, Suite 100
Plano, TX 75075
USA

Phone: (972) 509-5599 (x2240)
Email: ylee@huawei.com

Dan Li
Huawei Technologies Co., Ltd.
F3-5-B R&D Center, Huawei Base,
Bantian, Longgang District
Shenzhen 518129 P.R.China

Phone: +86-755-28973237
Email: danli@huawei.com

Wataru Imajuku
NTT Network Innovation Labs
1-1 Hikari-no-oka, Yokosuka, Kanagawa
Japan

Phone: +81-(46) 859-4315
Email: imajuku.wataru@lab.ntt.co.jp

Jianrui Han
Huawei Technologies Co., Ltd.
F3-5-B R&D Center, Huawei Base,
Bantian, Longgang District
Shenzhen 518129 P.R.China

Phone: +86-755-28972916
Email: hanjianrui@huawei.com

Intellectual Property Statement

Acknowledgment

Funding for the RFC Editor function is currently provided by the Internet Society.