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General Network Element Constraint Encoding for GMPLS Controlled Networks

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Abstract

Generalized Multiprotocol Label Switching can be used to control a wide variety of technologies. In some of these technologies network elements and links may impose additional routing constraints such as asymmetric switch connectivity, non-local label assignment, and label range limitations on links.

This document provides efficient, protocol-agnostic encodings for general information elements representing connectivity and label constraints as well as label availability. It is intended that protocol-specific documents will reference this memo to describe how information is carried for specific uses.

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].

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1. Introduction

Some data plane technologies that wish to make use of a GMPLS control plane contain additional constraints on switching capability and label assignment. In addition, some of these technologies must perform non-local label assignment based on the nature of the technology, e.g., wavelength continuity constraint in WSON [WSON-Frame]. Such constraints can lead to the requirement for link by link label availability in path computation and label assignment.

This document provides efficient encodings of information needed by the routing and label assignment process in technologies such as WSON and are potentially applicable to a wider range of technologies. 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).

1.1. Node Switching Asymmetry Constraints

For some network elements the ability of a signal or packet on a particular ingress port to reach a particular egress port may be limited. In addition, in some network elements the connectivity between some ingress ports and egress ports may be fixed, e.g., a simple multiplexer. To take into account such constraints during path computation we model this aspect of a network element via a connectivity matrix.

The connectivity matrix (ConnectivityMatrix) represents either the potential connectivity matrix for asymmetric switches or fixed connectivity for an asymmetric device such as a multiplexer. Note that this matrix does not represent any particular internal blocking behavior but indicates which ingress ports and labels (e.g., wavelengths) could possibly be connected to a particular output port. Representing internal state dependent blocking for a node is beyond the scope of this document and due to it's highly implementation dependent nature would most likely not be subject to standardization in the future. The connectivity matrix is a conceptual M by N matrix representing the potential switched or fixed connectivity, where M represents the number of ingress ports and N the number of egress ports.

1.2. Non-Local Label Assignment Constraints

If the nature of the equipment involved in a network results in a requirement for non-local label assignment we can have constraints based on limits imposed by the ports themselves and those that are implied by the current label usage. Note that constraints such as these only become important when label assignment has a non-local character. For example in MPLS an LSR may have a limited range of labels available for use on an egress port and a set of labels already in use on that port and hence unavailable for use. This information, however, does not need to be shared unless there is some limitation on the LSR's label swapping ability. For example if a TDM node lacks the ability to perform time-slot interchange or a WSON lacks the ability to perform wavelength conversion then the label assignment process is not local to a single node and it may be advantageous to share the label assignment constraint information for use in path computation.

Port label restrictions (PortLabelRestriction) model the label restrictions that the network element (node) and link may impose on a port. These restrictions tell us what labels may or may not be used on a link and are intended to be relatively static. More dynamic information is contained in the information on available labels. Port label restrictions are specified relative to the port in general or to a specific connectivity matrix for increased modeling flexibility. Reference [Switch] gives an example where both switch and fixed connectivity matrices are used and both types of constraints occur on the same port.

1.3. Change Log

Changes from 03 version:

(a) Removed informational BNF from section 1.

(b)   Removed section on "Extension Encoding Usage Recommendations"

Changes from 04,05 versions:

No changes just refreshed document that was expiring.

Changes from 06 version:

Added priority information to available wavelength encodings.

Changes from 07 version:

In port label constraint changed reserved field to Switching Capability and Encoding to allow for self description of labels used and interface capability.

Changes from 08 version:

Switching Capability and Encoding applied to all sub-cases for Port Label Restriction sub-TLV in Section 2.6.

Eliminated A (Availability) Bit from Available Labels Sub-TLV and Shared Backup Labels Sub-TLV.

Changes from 09 version:

Editorial change: Action field can be set to 0x01(Inclusive Range) for Link Set Field Encoding in Section 2.1.

2. Encoding

A type-length-value (TLV) encoding of the general connectivity and label restrictions and availability extensions is given in this section. This encoding is designed to be suitable for use in the GMPLS routing protocols OSPF [RFC4203] and IS-IS [RFC5307] and in the PCE protocol PCEP [PCEP]. Note that the information distributed in [RFC4203] and [RFC5307] is arranged via the nesting of sub-TLVs within TLVs and this document makes use of such constructs. First, however we define two general purpose fields that will be used repeatedly in the subsequent TLVs.

2.1. Link Set Field

We will frequently need to describe properties of groups of links. To do so efficiently we can make use of a link set concept similar to the label set concept of [RFC3471]. This Link Set Field is used in the <ConnectivityMatrix> sub-TLV, which is defined in Section 2.5. The information carried in a Link Set 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     |Dir|  Format   |         Length                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Link Identifier 1                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    :                               :                               :
    :                               :                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       Link Identifier N                       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action: 8 bits

0 - Inclusive List

Indicates that one or more link identifiers are included in the Link Set. Each identifies a separate link that is part of the set.

1 - Inclusive Range

Indicates that the Link Set defines a range of links. It contains two link identifiers. The first identifier indicates the start of the range (inclusive). The second identifier indicates the end of the range (inclusive). All links with numeric values between the bounds are considered to be part of the set. A value of zero in either position indicates that there is no bound on the corresponding portion of the range. Note that the Action field can be set to 0x01(Inclusive Range) only when unnumbered link identifier is used.

Dir: Directionality of the Link Set (2 bits)

0 -- bidirectional

1 -- ingress

2 -- egress

For example in optical networks we think in terms of unidirectional as well as bidirectional links. For example, label restrictions or connectivity may be different for an ingress port, than for its "companion" egress port if one exists. Note that "interfaces" such as those discussed in the Interfaces MIB [RFC2863] are assumed to be bidirectional. This also applies to the links advertised in various link state routing protocols.

Format: The format of the link identifier (6 bits)

0 -- Link Local Identifier

Indicates that the links in the Link Set are identified by link local identifiers. All link local identifiers are supplied in the context of the advertising node.

1 -- Local Interface IPv4 Address

2 -- Local Interface IPv6 Address

Indicates that the links in the Link Set are identified by Local Interface IP Address. All Local Interface IP Address are supplied in the context of the advertising node.

Others TBD.

Note that all link identifiers in the same list must be of the same type.

Length: 16 bits

This field indicates the total length in bytes of the Link Set field.

Link Identifier: length is dependent on the link format

The link identifier represents the port which is being described either for connectivity or label restrictions. This can be the link local identifier of [RFC4202], GMPLS routing, [RFC4203] GMPLS OSPF routing, and [RFC5307] IS-IS GMPLS routing. The use of the link local identifier format can result in more compact encodings when the assignments are done in a reasonable fashion.

2.2. Label Set Field

Label Set Field is used within the <AvailableLabels> sub-TLV or the <SharedBackupLabels> sub-TLV, which is defined in Section 2.3. and 2.4. ,respectively.

The general format for a label set is given below. This format uses the Action concept from [RFC3471] with an additional Action to define a "bit map" type of label set. The second 32 bit field is a base label used as a starting point in many of the specific formats.

```
   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|    Num Labels         |          Length               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                          Base Label                           |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |     Additional fields as necessary per action                 |
  |
```

Action:

0 - Inclusive List

1 - Exclusive List

2 - Inclusive Range

3 - Exclusive Range

4 - Bitmap Set

Num Labels is only meaningful for Action value of 4 (Bitmap Set). It indicates the number of labels represented by the bit map. See more detail in section 3.2.3.

Length is the length in bytes of the entire field.

2.2.1. Inclusive/Exclusive Label Lists

In the case of the inclusive/exclusive lists the wavelength set format 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 or 1 | Num Labels (not used) |          Length               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Base Label                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Last  Label                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

Num Labels is not used in this particular format since the Length parameter is sufficient to determine the number of labels in the list.

2.2.2. Inclusive/Exclusive Label Ranges

In the case of inclusive/exclusive ranges the label set format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|2 or 3 | Num Labels(not used)  |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Start Label                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     End Label                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Note that the start and end label must in some sense "compatible" in the technology being used.

2.2.3. Bitmap Label Set

In the case of Action = 4, the bitmap the label set format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  4    |   Num Labels          |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Base Label                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Bit Map Word #1 (Lowest numerical labels)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Bit Map Word #N (Highest numerical labels)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where Num Labels in this case tells us the number of labels represented by the bit map. Each bit in the bit map represents a particular label with a value of 1/0 indicating whether the label is in the set or not. Bit position zero represents the lowest label and

corresponds to the base label, while each succeeding bit position represents the next label logically above the previous.

The size of the bit map is Num Label bits, but the bit map is padded out to a full multiple of 32 bits so that the TLV is a multiple of four bytes. Bits that do not represent labels (i.e., those in positions (Num Labels) and beyond SHOULD be set to zero and MUST be ignored.

2.3. Available Labels Sub-TLV

The Available Labels sub-TLV link consists of an availability flag, priority flags, and a single variable length label set field 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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      PRI      |              Reserved                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Label Set Field                           |
   :                                                               :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

PRI (Priority Flags, 8 bits): Indicates priority level applied to Label Set Field. Bit 8 corresponds to priority level 0 and bit 15 corresponds to priority level 7.

Note that Label Set Field is defined in Section 2.2. See Appendix A.5. for illustrative examples.

2.4. Shared Backup Labels Sub-TLV

The Shared Backup Labels sub-TLV consists of an availability flag, priority flags, and single variable length label set field 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     PRI       |             Reserved                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Label Set Field                          |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

PRI (Priority Flags, 8 bits): Indicates priority level applied to Label Set Field. Bit 8 corresponds to priority level 0 and bit 15 corresponds to priority level 7.

2.5. Connectivity Matrix Sub-TLV

The Connectivity Matrix represents how ingress ports are connected to egress ports for network elements. The switch and fixed connectivity matrices can be compactly represented in terms of a minimal list of ingress and egress port set pairs that have mutual connectivity. As described in [Switch] such a minimal list representation leads naturally to a graph representation for path computation purposes that involves the fewest additional nodes and links.

A TLV encoding of this list of link set pairs 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  |   MatrixID    |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set A #1                         |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set B #1                         :
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Additional Link set pairs as needed     |
:                     to specify connectivity                   :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

Connectivity is the device type.

0 -- the device is fixed

1 -- the device is switched(e.g., ROADM/OXC)

MatrixID represents the ID of the connectivity matrix and is an 8 bit integer. The value of 0xFF is reserved for use with port wavelength constraints and should not be used to identify a connectivity matrix.

Link Set A #1 and Link Set B #1 together represent a pair of link sets. There are two permitted combinations for the link set field parameter "dir" for Link Set A and B pairs:

- o Link Set A dir=ingress, Link Set B dir=egress

  The meaning of the pair of link sets A and B in this case is that any signal that ingresses a link in set A can be potentially switched out of an egress link in set B.

- o Link Set A dir=bidirectional, Link Set B dir=bidirectional

  The meaning of the pair of link sets A and B in this case is that any signal that ingresses on the links in set A can potentially egress on a link in set B, and any ingress signal on the links in set B can potentially egress on a link in set A.

See Appendix A for both types of encodings as applied to a ROADM example.

2.6. Port Label Restriction sub-TLV

Port Label Restriction tells us what labels may or may not be used on a link.

The port label restriction of section 1.2. can be encoded as a sub-TLV as follows. More than one of these sub-TLVs may be needed to fully specify a complex port constraint. When more than one of these sub-TLVs are present the resulting restriction is the intersection of the restrictions expressed in each sub-TLV. To indicate that a restriction applies to the port in general and not to a specific connectivity matrix use the reserved value of 0xFF for the MatrixID.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   MatrixID    |RestrictionType| Switching Cap |     Encoding  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |     Additional Restriction Parameters per RestrictionType    |
    :                                                               :
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

MatrixID: either is the value in the corresponding Connectivity Matrix sub-TLV or takes the value OxFF to indicate the restriction applies to the port regardless of any Connectivity Matrix.

RestrictionType can take the following values and meanings:

0: SIMPLE_LABEL (Simple label selective restriction)

1: CHANNEL_COUNT (Channel count restriction)

2: LABEL_RANGE1 (Label range device with a movable center label and width)

3: SIMPLE_LABEL & CHANNEL_COUNT (Combination of SIMPLE_LABEL and CHANNEL_COUNT restriction. The accompanying label set and channel count indicate labels permitted on the port and the

maximum number of channels that can be simultaneously used on the port)

4: LINK_LABEL_EXCLUSIVITY (A label may be used at most once amongst a set of specified ports)

Switching Capability is defined in [RFC4203] and Encoding in [RFC3471]. The combination of these fields defines the type of labels used in specifying the port label restrictions as well as the interface type to which these restrictions apply.

2.6.1. SIMPLE_LABEL

In the case of the SIMPLE_LABEL the GeneralPortRestrictions (or MatrixSpecificRestrictions) format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 0   | Switching Cap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Label Set Field                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying label set indicates the labels permitted on the port.

2.6.2. CHANNEL_COUNT

In the case of the CHANNEL_COUNT the format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 1   | Switching Cap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MaxNumChannels                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying MaxNumChannels indicates the maximum number of channels (labels) that can be simultaneously used on the port/matrix.

2.6.3. LABEL_RANGE1

In the case of the LABEL_RANGE1 the GeneralPortRestrictions (or MatrixSpecificRestrictions) format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 2   |Switching Cap |   Encoding     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          MaxLabelRange                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Label Set Field                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying MaxLabelRange indicates the maximum range of the labels. The corresponding label set is used to indicate the overall label range. Specific center label information can be obtained from dynamic label in use information. It is assumed that both center label and range tuning can be done without causing faults to existing signals.

2.6.4. SIMPLE_LABEL & CHANNEL_COUNT

In the case of the SIMPLE_LABEL & CHANNEL_COUNT the format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 3   | Switching Cap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MaxNumChannels                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Label Set Field                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying label set and MaxNumChannels indicate labels permitted on the port and the maximum number of labels that can be simultaneously used on the port.

2.6.5.   Link Label Exclusivity

In the case of the Link Label Exclusivity the format 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| MatrixID      | RstType = 4   | Switching Cap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set Field                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying port set indicate that a label may be used at most once among the ports in the link set field.

3. 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.

4. IANA Considerations

TBD. Once our approach is finalized we may need identifiers for the various TLVs and sub-TLVs.

5. Acknowledgments

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

APPENDIX A: Encoding Examples

Here we give examples of the general encoding extensions applied to some simple ROADM network elements and links.

A.1. Link Set Field

Suppose that we wish to describe a set of ingress ports that are have link local identifiers number 3 through 42. In the link set field we set the Action = 1 to denote an inclusive range; the Dir = 1 to denote ingress links; and, the Format = 0 to denote link local identifiers. In particular we have:

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Action=1     |0 1|0 0 0 0 0 0|            Length = 12        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Link Local Identifier = #3                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Link Local Identifier = #42               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.2. Label Set Field

Example:

A 40 channel C-Band DWDM system with 100GHz spacing with lowest frequency 192.0THz (1561.4nm) and highest frequency 195.9THz (1530.3nm). These frequencies correspond to n = -11, and n = 28 respectively. Now suppose the following channels are available:

Frequency (THz)	n Value	bit map position
192.0	-11	0
192.5	-6	5
193.1	0	11
193.9	8	19
194.0	9	20
195.2	21	32
195.8	27	38

With the Grid value set to indicate an ITU-T G.694.1 DWDM grid, C.S. set to indicate 100GHz this lambda bit map set would then 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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |  4    | Num Wavelengths = 40  |    Length = 16 bytes          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = -11 |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0|
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1 0 0 0 0 0 1 0|   Not used in 40 Channel system (all zeros)   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

To encode this same set as an inclusive list we would have:

```
      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    | Num Wavelengths = 40  |    Length = 20 bytes          |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = -11 |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = -6  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = -0  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = 8   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = 9   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = 21  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |Grid |  C.S. |      Reserved    | n  for lowest frequency = 27  |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.3. Connectivity Matrix Sub-TLV

Example:

Suppose we have a typical 2-degree 40 channel ROADM. In addition to its two line side ports it has 80 add and 80 drop ports. The picture

below illustrates how a typical 2-degree ROADM system that works with bi-directional fiber pairs is a highly asymmetrical system composed of two unidirectional ROADM subsystems.

```
                      (Tributary) Ports #3-#42
                  Ingress added to    Egress dropped from
                  West Line Egress    East Line Ingress
                        vvvvv          ^^^^^
                       | |||.|       | |||.|
                 +-----| |||.|--------| |||.|------+
                 |    +----------------------+     |
                 |    |                      |     |
     Egress      |    | Unidirectional ROADM |     |    Ingress
-----------------+    |                      |     +--------------
<=====================|                      |===================<
-----------------+    +----------------------+     +--------------
                 |                                 |
     Port #1     |                                 |   Port #2
(West Line Side) |                                 |(East Line Side)
-----------------+    +----------------------+     +--------------
>=====================|                      |===================>
-----------------+    | Unidirectional ROADM |     +--------------
     Ingress     |    |                      |     |    Egress
                 |    |               _      |     |
                 |    +----------------------+     |
                 +-----| |||.|--------| |||.|------+
                       | |||.|        | |||.|
                        vvvvv          ^^^^^
                  (Tributary) Ports #43-#82
             Egress dropped from    Ingress added to
             West Line ingress      East Line egress
```

Referring to the figure we see that the ingress direction of ports #3-#42 (add ports) can only connect to the egress on port #1. While the ingress side of port #2 (line side) can only connect to the egress on ports #3-#42 (drop) and to the egress on port #1 (pass through). Similarly, the ingress direction of ports #43-#82 can only connect to the egress on port #2 (line). While the ingress direction of port #1 can only connect to the egress on ports #43-#82 (drop) or port #2 (pass through). We can now represent this potential connectivity matrix as follows. This representation uses only 30 32-bit words.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Conn = 1   |    MatrixID   |      Reserved                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Note: adds to line
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=1     |0 1|0 0 0 0 0 0|          Length = 12          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #3                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #42               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |1 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #1                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to drops
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 1|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #2                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=1     |1 0|0 0 0 0 0 0|          Length = 12          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #3                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #42               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to line
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 1|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #2                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |1 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #1                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                Note: adds to line
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=1     |0 1|0 0 0 0 0 0|          Length = 12          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #43               |
```

```
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #82               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Action=0     |1 0|0 0 0 0 0 0|          Length = 8           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #2                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    Note: line to drops
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Action=0     |0 1|0 0 0 0 0 0||          Length = 8          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #1                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Action=1     |1 0|0 0 0 0 0 0|          Length = 12          |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #43               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #82               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                    Note: line to line
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Action=0     |0 1|0 0 0 0 0 0|          Length = 8           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #1                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Action=0     |1 0|0 0 0 0 0 0|          Length = 8           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Local Identifier = #2                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.4. Connectivity Matrix with Bi-directional Symmetry

If one has the ability to renumber the ports of the previous example as shown in the next figure then we can take advantage of the bi-directional symmetry and use bi-directional encoding of the connectivity matrix. Note that we set dir=bidirectional in the link set fields.

```
                                (Tributary)
                     Ports #3-42         Ports #43-82
                     West Line Egress    East Line Ingress
                           vvvvv          ^^^^^
                          | |||.|        | |||.|
                    +-----| |||.|--------| |||.|------+
                    |    +----------------------+     |
                    |    |                      |     |
        Egress      |    | Unidirectional ROADM |     |    Ingress
   -----------------+    |                      |     +--------------
   <=====================|                      |===================<
   -----------------+    +----------------------+     +--------------
                    |                                 |
        Port #1     |                                 |   Port #2
   (West Line Side) |                                 |(East Line Side)
   -----------------+    +----------------------+     +--------------
   >=====================|                      |===================>
   -----------------+    | Unidirectional ROADM |     +--------------
        Ingress     |    |                      |     |    Egress
                    |    |              _       |     |
                    |    +----------------------+     |
                    +-----| |||.|--------| |||.|------+
                          | |||.|        | |||.|
                           vvvvv          ^^^^^
                     Ports #3-#42            Ports #43-82
                Egress dropped from    Ingress added to
                West Line ingress      East Line egress
```

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Conn = 1   |    MatrixID   |      Reserved                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                          Add/Drops #3-42 to Line side #1
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=1     |0 0|0 0 0 0 0 0|          Length = 12          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #3                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #42               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #1                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line #2 to add/drops #43-82
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #2                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=1     |0 0|0 0 0 0 0 0|          Length = 12          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #43               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #82               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Note: line to line
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #1                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Action=0     |0 0|0 0 0 0 0 0|          Length = 8           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     Link Local Identifier = #2                |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A.5. Priority Flags in Available/Shared Backup Labels sub-TLV

If one wants to make a set of labels (indicated by Label Set Field #1) available for all priority levels (level 0 to 7) while allowing

a set of labels (indicated by Label Set Field #2) only to available to the highest priority (Priority Level 7), the following encoding will express such need.

```
      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 0 0|                        Reserved                         |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Label Set Field #1                        |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1 1 1|                        Reserved                         |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                     Label Set Field #2                        |
     :                                                               :
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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