Network Working Group
Internet Draft
Intended status: Standards Track
Expires: June 2015

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February 23, 2015

General Network Element Constraint Encoding for GMPLS Controlled Networks

draft-ietf-ccamp-general-constraint-encode-20.txt

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.

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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 Wavelength Switched Optical Networks (WSON) [RFC6163]. 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 input port to reach a particular output port may be limited. In addition, in some network elements the connectivity between some input ports and output 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 input ports and labels (e.g., wavelengths) could possibly be connected to a particular output port and label pair. Representing internal state dependent blocking for a node is beyond the scope of this document and, due to its highly implementation-dependent nature, would most likely not be subject to standardization in the future. The connectivity matrix is a conceptual M*m by N*n matrix where M represents the number of input ports each with m labels and N the number of output ports each with n labels.

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 output 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. In this case, 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.

2. Encoding

This section provides encodings for the information elements defined in [RWA-Info] that have applicability to WSON. The encodings are designed to be suitable for use in the GMPLS routing protocols OSPF [RFC4203] and IS-IS [RFC5307] and in the PCE protocol (PCEP) [RFC5440]. Note that the information distributed in [RFC4203] and [RFC5307] is arranged via the nesting of sub-TLVs within TLVs and this document defines elements to be used within such constructs. Specific constructs of sub-TLVs and the nesting of sub-TLVs of the information element defined by this document will be defined in the respective protocol enhancement documents.

2.1. Connectivity Matrix Field

The Connectivity Matrix Field represents how input ports are connected to output ports for network elements. The switch and fixed connectivity matrices can be compactly represented in terms of a minimal list of input and output 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.

The Connectivity Matrix is uniquely identified only by the advertising node. There may be more than one Field associated with a node as a node can partition the switch matrix into several sub-matrices. This partitioning is primarily to limit the size of any individual information element used to represent the matrix and to enable incremental updates. When the matrix is partitioned into sub-matrices, each sub-matrix will be mutually exclusive to one another in representing which ports/labels are associated with each sub-matrix. This implies that two matrices will not have the same {src port, src label, dst port, dst label}.

Each sub-matrix is identified via a different Matrix ID which MUST represent a unique combination of {src port, src label, dst port, dst label}.

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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Conn  |   MatrixID    |            Reserved                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set A #1                         |
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Link Set B #1                         :
:                               :                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Additional Link set pairs as needed     |
:                     to specify connectivity                   :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where

Connectivity (Conn) (4 bit) 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 label 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. See Section 2.3. for a detail description of the link set field. There are two permitted combinations for the link set field parameter "dir" for Link Set A and B pairs:

o Link Set A dir=input, Link Set B dir=output

In this case, the meaning of the pair of link sets A and B in this case is that any signal that inputs a link in set A can be potentially switched out of an output 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 inputs on the links in set A can potentially output on a link in set B, and any input signal on the links in set B can potentially output on a link in set A. If link set A is an input and link set B is an output for a signal, then it implies that link set A is an output and link set B is an input for that signal.

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

2.2. Port Label Restriction Field

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

The port label restriction can be encoded as follows: More than one of these fields may be needed to fully specify a complex port constraint. When more than one of these fields are present, the resulting restriction is the union of the restrictions expressed in each field. The use of the reserved value of 0xFF for the MatrixID indicates that a restriction applies to the port, and not to a specific connectivity matrix.

```
 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    |  SwitchingCap |    Encoding   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Additional Restriction Parameters per Restriction Type   |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

MatrixID: either is the value in the corresponding Connectivity Matrix field or takes the value 0xFF to indicate the restriction applies to the port regardless of any Connectivity Matrix.

RstType (Restriction Type) can take the following values and meanings:

0: SIMPLE_LABEL (Simple label selective restriction; See Section 2.2.1 for details)

1: CHANNEL_COUNT (Channel count restriction; See Section 2.2.2 for details)

2: LABEL_RANGE (Label range device with a movable center label and width; See Section 2.2.3 for details)

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; See Section 2.2.4 for details)

4: LINK_LABEL_EXCLUSIVITY (A label may be used at most once amongst a set of specified ports; See Section 2.2.5 for details)

SwitchingCap (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.

Additional Restriction Parameters per RestrictionType field is an optional field that describes additional restriction parameters for each RestrictionType pertaining to specific protocols.

2.2.1. SIMPLE_LABEL

In the case of the SIMPLE_LABEL, 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 = 0   |  SwitchingCap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Label Set Field                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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

See Section 2.6 for the definition of label set.

2.2.2. 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   | SwitchingCap  |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MaxNumChannels                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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

MaxNumChannels is a 32-bit integer.

2.2.3. LABEL_RANGE

In the case of the LABEL_RANGE, 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 = 2   | Switching Cap |  Encoding     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          MaxLabelRange                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Label Set Field                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This is a generalization of the waveband device. The MaxLabelRange indicates the maximum width of the waveband in terms of the channels spacing given in the Label Set Field. The corresponding label set is used to indicate the overall tuning range.

MaxLabelRange is a 32-bit integer.

See Section 2.6.2 for the explanation of label range.

2.2.4. 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   |  SwitchingCap |   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.

See Section 2.6 for the definition of label set.

2.2.5. 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   |  SwitchingCap |   Encoding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Link Set Field                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In this case the accompanying link set indicates that a label may be used at most once among the ports in the link set field. See Section 2.3 for the definition of link set.

2.3. 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>, which is defined in Section 2.1. 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. The second identifier indicates the end of the range. 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 identifier for unnumbered link is used.

Dir: Directionality of the Link Set (2 bits)

0 -- bidirectional

1 -- input

2 -- output

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 input port, than for its "companion" output 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.

Others -- Reserved for future use.

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.

2.4. Available Labels Field

The Available Labels Field consists of 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): A bitmap used to indicate which priorities are being advertised. The bitmap is in ascending order, with the leftmost bit representing priority level 0 (i.e., the highest) and the rightmost bit representing priority level 7 (i.e., the lowest). A bit MUST be set (1) corresponding to each priority represented in the sub-TLV, and MUST NOT be set (0) when the corresponding priority is not represented. If a label is available at priority M it MUST be advertised available at each priority N < M. At least one priority level MUST be advertised.

The PRI field indicates the availability of the labels for use in LSP set up and pre-emption as described in [RFC3209].

When a label is advertised as available for priorities 0, 1, ... M it may be used by any LSP of priority N <= M. When a label is in use by an LSP of priority M it may be used by an LSP of priority N < M if LSP preemption is supported.

When a label was initially advertised as available for priorities, 0, 1, ... M and once a label is used for an LSP at a priority, say N (N<=M), then this label is advertised as available for 0, ... N-1.

Note that Label Set Field is defined in Section 2.6. See Appendix A.5. for illustrative examples.

2.5. Shared Backup Labels Field

The Shared Backup Labels Field consists of 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): A bitmap used to indicate which priorities are being advertised. The bitmap is in ascending order, with the leftmost bit representing priority level 0 (i.e., the highest) and the rightmost bit representing priority level 7 (i.e., the lowest). A bit MUST be set (1) corresponding to each priority represented in the sub-TLV, and MUST NOT be set (0) when the corresponding priority is not represented. If a label is available at priority M it MUST be advertised available at each priority N < M. At least one priority level MUST be advertised.

The same LSP set up and pre-emption rules specified in Section 2.4 apply here.

Note that Label Set Field is defined in Section 2.6. See Appendix A.5. for illustrative examples.

2.6. Label Set Field

Label Set Field is used within the <AvailableLabels> or the <SharedBackupLabels>, which is defined in Sections 2.4. and 2.5., respectively. It is also used within the <SIMPLE_LABEL>, <LABEL_RANGE>, <SIMPLE_LABEL> or <CHANNEL_COUNT>, which is defined in Sections 2.1.1. - 2.1.4., 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. Labels are variable in length. Action specific fields are 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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Action|    Num Labels = N     |          Length               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          Base Label                           |
    |                             . . .                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      (Action specific fields)                 |
    |                              . . . .                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action:

0 - Inclusive List

1 - Exclusive List

2 - Inclusive Range

3 - Exclusive Range

4 - Bitmap Set

Num Labels is generally the number of labels. It has a specific meaning depending on the action value. See Sections 2.6.1 - 2.6.3 for details. Num Labels is a 12 bit integer.

Length is the length in bytes of the entire label set field.

2.6.1. 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 = 2        |          Length               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                         Label #1                              |
 |                            . . .                              |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 :                                                               :
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                         Label #N                              |
 |                            . . .                              |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

Label #1 is the first Label to be included/excluded and Label #N is the last Label to be included/excluded. Num Labels MUST match with N.

2.6.2. 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          |             Length              |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                    Start Label                                |
 |                       . . .                                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     End Label                                 |
 |                       . . .                                   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Note that Start Label is the first Label in the range to be included/excluded and End Label is the last label in the same range. Num Labels MUST be two.

2.6.3. 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 Labels bits, but the bit map is padded out to a full multiple of 32 bits so that the field 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.

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. A general discussion on security in GMPLS networks can be found in [RFC5920].

4. IANA Considerations

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

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 input 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 input 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

Using the label format defined in [RFC6205], with the Grid value set to indicate an ITU-T A/2 [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 Labels = 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 Labels = 7        |    Length = 32 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

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
                     Input added to    Output dropped from
                     West Line Output    East Line Input
                           vvvvv          ^^^^^
                          | |||.|        | |||.|
                    +-----| |||.|--------| |||.|------+
                    |    +---------------------+     |
                    |    |                     |     |
        Output      |    | Unidirectional ROADM |     |    Input
   -----------------+    |                     |     +--------------
   <=====================|                     |===================<
   -----------------+    +---------------------+     +--------------
                    |                                |
        Port #1     |                                |   Port #2
   (West Line Side) |                                |(East Line Side)
   -----------------+    +---------------------+     +--------------
   >=====================|                     |===================>
   -----------------+    | Unidirectional ROADM |     +--------------
          Input     |    |                     |     |    Output
                    |    |              _      |     |
                    |    +---------------------+     |
                    +-----| |||.|--------| |||.|------+
                          | |||.|        | |||.|
                           vvvvv          ^^^^^
                     (Tributary) Ports #43-#82
                Output dropped from    Input added to
                West Line Input      East Line Output
```

Referring to the figure we see that the Input direction of ports #3-#42 (add ports) can only connect to the output on port #1. While the Input side of port #2 (line side) can only connect to the output on ports #3-#42 (drop) and to the output on port #1 (pass through). Similarly, the input direction of ports #43-#82 can only connect to the output on port #2 (line). While the input direction of port #1 can only connect to the output on ports #43-#82 (drop) or port #2 (pass through). We can now represent this potential connectivity matrix as follows. This representation uses only 29 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 Output    East Line Input
                           vvvvv          ^^^^^
                          | |||.|        | |||.|
                    +-----| |||.|--------| |||.|------+
                    |    +----------------------+     |
                    |    |                      |     |
        Output      |    | Unidirectional ROADM |     |    Input
   -----------------+    |                      |     +--------------
   <====================|                      |===================<
   -----------------+    +----------------------+     +--------------
                    |                                 |
        Port #1     |                                 |   Port #2
   (West Line Side) |                                 |(East Line Side)
   -----------------+    +----------------------+     +--------------
   >====================|                      |===================>
   -----------------+    | Unidirectional ROADM |     +--------------
        Input     |    |                      |     |    Output
                    |    |             _        |     |
                    |    +----------------------+     |
                    +-----| |||.|--------| |||.|------+
                          | |||.|        | |||.|
                           vvvvv          ^^^^^
                     Ports #3-#42            Ports #43-82
                Output dropped from    Input added to
                West Line Input      East Line Output
```

```
     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

If one wants to make a set of labels (indicated by Label Set Field #1) available only for the highest priority level (Priority Level 0) while allowing a set of labels (indicated by Label Set Field #2) available to all priority levels, 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 0 0 0 0 0 0 0|             Reserved                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Label Set Field #1                        |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 1 1 1 1 1 1 1|             Reserved                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Label Set Field #2                        |
:                                                               :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

6. References

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