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OSPF Extensions in Support of Routing and Wavelength Assignment (RWA) in Wavelength Switched Optical Networks (WSONs)

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Abstract

This document describes OSPF routing protocols extensions to support Routing and Wavelength Assignment (RWA) in Wavelength Switched Optical Networks (WSON) under the control of Generalized MPLS (GMPLS).

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

Wavelength switched optical networks (WSONs) are based on Wavelength Division Multiplexing (WDM) in which user traffic is carried by data channels of different optical wavelengths. In traditional WDM Networks, each wavelength path is statically configured. With the deployment of Reconfigurable Optical Add-Drop Multiplexers (ROADMs), photonic cross-connects (PXCs), and tunable laser, WSONs have become more dynamic, and operators can flexibly set up wavelength paths to carry user traffic.

In WSONs where there are no or a limited number of switches capable of wavelength conversion paths must be set up subject to the "wavelength continuity" constraint. This leads to a path computation problem known as routing and wavelength assignment (RWA). In order to

perform such computations, it is necessary to collect information about the available wavelengths within the network.

[WSON-Frame] provides a framework for applying GMPLS [RFC3945] and the Path Computation Element (PCE) architecture [RFC4655] to the control of WSONs to address the RWA problem. [WSON-Info] describes an information model that specifies the information needed at various points in a WSON in order to compute paths and establish Label Switched Paths (LSPs). Based on the information model of [WSON-Info], [WSON-Encode] provides efficient protocol-independent encodings of the information needed by the RWA process in a WSON. Such encodings can be used to extend GMPLS signaling and routing protocols.

Therefore, in order to enable GMPLS to support Routing and Wavelength Assignment (RWA) in Wavelength Switched Optical Networks (WSON) networks, this document follows on from [WSON-Info], [WSON-Encode], and [WSON-IGP-Eval] to define extensions to the OSPF routing protocol to enhance the Traffic Engineering (TE) properties of GMPLS TE which are defined in [RFC3630], [RFC4202], and [RFC4203]. The enhancements to the Traffic Engineering (TE) properties of GMPLS TE links can be announced in OSPF TE LSAs. The TE LSA, which is an opaque LSA with area flooding scope [RFC3630], has only one top-level Type/Length/Value (TLV) triplet and has one or more nested sub-TLVs for extensibility. The top-level TLV can take one of three values (1) Router Address [RFC3630], (2) Link [RFC3630], (3) Node Attribute [OSPF-Node]. In this document, we enhance the sub-TLVs for the Link TLV and Node Attribute TLV in support of RWA in WSON under the control of GMPLS.

The detail encoding of OSPF extensions is not defined in this document. [WSON-Encode] provides encoding detail.

No consideration of optical impairment routing related information is included in this document.

2. Node Information

According to [WSON-Info] and [WSON-Encode], the node information about WSON nodes includes Node ID, connectivity matrix, wavelength converter pool information. Except for the Node ID which should comply with Routing Address described in [RFC3630], the other pieces of information are defined in this document.

[OSPF-Node] defines a new top TLV named the Node Attribute TLV which carries attributes related to a router/node. This Node Attribute TLV contains one or more sub-TLVs.

Per [WSON-Encode], we have identified the following new Sub-TLVs to the Node Attribute TLV. Detail description for each newly defined Sub-TLV is provided in subsequent sections:

Sub-TLV Type	Length	Name
TBD	variable	Connectivity Matrix
TBD	variable	Wavelength Converter Accessibility
TBD	variable	Wavelength Conversion Range
TBD	variable	WC Usage State

In WSON networks, generally all the sub-TLVs above are optional, which depends on the implementations. Usually, Connectivity Matrix sub-TLV may appear in the LSAs because WSON switches are asymmetric at present. It is assumed that the switches are symmetric switching, if there is no Connectivity Matrix sub-TLV in the LSAs. Wavelength Converter Accessibility, Wavelength Conversion Range and WC Usage State sub-TLVs should appear in the LSAs, if there is wavelength conversion functionality in the WSON networks.

2.1. Connectivity Matrix

It is necessary to identify which ingress ports and wavelengths can be connected to (the same wavelength on) a specific egress port, because the switching devices in a WSON are highly asymmetric.

The Connectivity Matrix is used to identify these restrictions, which can represent either the potential connectivity matrix for asymmetric switches (e.g. ROADMs and such) or fixed connectivity for an asymmetric device such as a multiplexer as defined in [WSON-Info].

The Connectivity Matrix is a sub-TLV (the type is TBD by IANA) of the Node Attribute TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 4.3 of [WSON-Encode]. One sub-TLV contains one matrix. The Connectivity Matrix sub-TLV may occur more than once to contain multi-matrices within the Node Attribute TLV.

2.2. Wavelength Converter Pool

A WSON node may include wavelength converters. The encoding of structure and properties of a general wavelength converter pool utilizes a Converter Accessibility sub-TLV, a Wavelength Converter

Range sub-TLV, and a Wavelength Converter Usage State sub-TLV as described in [WSON-Encode].

2.2.1. Wavelength Converter Accessibility

Wavelength Converter Accessibility represents the ability of an ingress port to reach a wavelength converter and of a wavelength converter to reach a particular egress port as described in [WSON-Encode].

The Wavelength Converter Accessibility is a sub-TLV (the type is TBD by IANA) of the Node Attribute TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 5.2 of [WSON-Encode]. The Wavelength Converter Accessibility sub-TLV may occur at most once within the Node Attribute TLV.

2.2.2. Wavelength Conversion Range

Wavelength converters may have a limited input or output range which can be described using one or more Wavelength Conversion Range sub-TLV as described in [WSON-Encode].

The Wavelength Converter Range is a sub-TLV (the type is TBD by IANA) of the Node Attribute TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 5.3 of [WSON-Encode]. The Wavelength Converter Range sub-TLV may occur more than once within the Node Attribute TLV.

2.2.3. WC Usage State

WC Usage Sate indicates the usage state of wavelength converters as described in [WSON-Encode]

The WC Usage State is a sub-TLV (the type is TBD by IANA) of the Node Attribute TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 5.4 of [WSON-Encode]. The WC Usage State sub-TLV may occur at most once within the Node Attribute TLV.

3. Link Information

The most common link sub-TLVs nested to link top-level TLV are already defined in [RFC3630], [RFC4203]. For example, Link ID, Administrative Group, Interface Switching Capability Descriptor (ISCD), Link Protection Type, Shared Risk Link Group Information

(SRLG), and Traffic Engineering Metric are among the typical link sub-TLVs.

For WSONs, per [WSON-Info] and [WSON-Encode], we add the following additional link sub-TLVs to the link-TLV in this document.

Sub-TLV Type	Length	Name
TBD	variable	WSON Port Wavelength Restrictions
TBD	variable	Available Wavelengths
TBD	variable	Shared Backup Wavelengths

In WSON networks, generally all the sub-TLVs above are optional, which depends on the implementations. It is default no restrictions on wavelength, so WSON Port Wavelength Restrictions sub-TLV may not appear in the LSAs. In order to be able to compute RWA, Available Wavelengths sub-TLV may appear in the LSAs. Without available wavelength information, path computation need guess what lambdas may be available (high blocking probability or distributed wavelength assignment may be used). Shared Backup Wavelengths sub-TLV SHOULD not appear in the LSAs, if there is no wavelength backup functionality in the WSON networks.

3.1. WSON Port Wavelength Restrictions

Port Wavelength Restrictions describes the wavelength (label) restrictions that the link and various optical devices such as OXCs, ROADMs, and waveband multiplexers may impose on a port. These restrictions represent what wavelength may or may not be used on a link and are relatively static. The detailed information about Port wavelength restrictions is described in [WSON-Info].

The WSON Port Wavelength Restrictions is a sub-TLV (the type is TBD by IANA) of the Link TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined Section 4.4 of [WSON-Encode]. The WSON Port Wavelength Restrictions sub-TLV may occur more than once to specify a complex port constraint within the link TLV.

3.2. Available Wavelengths

Available Wavelengths indicates the wavelengths available for use on a link as described in [WSON-Encode].The Available Wavelengths is a

sub-TLV (the type is TBD by IANA) of the Link TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 4.1 of [WSON-Encode]. The Available Wavelengths sub-TLV may occur at most once within the link TLV.

Note that there are five approaches for Wavelength Set which is used to represent the Available Wavelengths described in [WSON-Encode]. Considering that the continuity of the available or unavailable wavelength set can be scattered for the dynamic wavelength availability, so it may burden the routing to reorganize the wavelength set information when the Inclusive (/Exclusive) List (/Range) approaches are used to represent Available Wavelengths information. Therefore, it is RECOMMENDED that only the Bitmap Set be used for representation Available Wavelengths information.

3.3. Shared Backup Wavelengths

Shared Backup Wavelengths indicates the wavelengths available for shared backup use on a link as described in [WSON-Encode].

The Shared Backup Wavelengths is a sub-TLV (the type is TBD by IANA) of the Link TLV. The length is the length of value field in octets. The meaning and format of this sub-TLV are defined in Section 4.2 of [WSON-Encode]. The Shared Backup Wavelengths sub-TLV may occur at most once within the link TLV.

4. Routing Procedures

All the sub-TLVs are nested to top-level TLV(s) and contained in Opaque LSAs. The flooding of Opaque LSAs must follow the rules specified in [RFC2328], [RFC2370], [RFC3630], [RFC4203] and [OSPF-Node].

In the WSON networks, the node information and link information can be classified as two kinds: one is relatively static information such as Node ID, Connectivity Matrix information; the other is dynamic information such as WC Usage State, Available Wavelengths information. [WSON-Encode] give recommendations of typical usage of previously defined sub-TLVs which contain relatively static information and dynamic information. An implementation SHOULD take measures to avoid frequent updates of relatively static information when the relatively static information is not changed. A mechanism MAY be applied such that static information and dynamic information are contained in separate Opaque LSAs to avoid unnecessary updates of static information when dynamic information is changed.

Note that as with other TE information, an implementation SHOULD take measures to avoid rapid and frequent updates of routing information that could cause the routing network to become swamped. A threshold mechanism MAY be applied such that updates are only flooded when a number of changes have been made to the wavelength availability information within a specific time. Such mechanisms MUST be configurable if they are implemented.

5. Security Considerations

This document does not introduce any further security issues other than those discussed in [RFC 3630], [RFC 4203].

6. IANA Considerations

[RFC3630] says that the top level Types in a TE LSA and Types for sub-TLVs for each top level Types must be assigned by Expert Review, and must be registered with IANA.

IANA is requested to allocate new Types for the sub-TLVs as defined in Sections 2.1, 2.2, 3.1, 3.2 and 3.3 as follows:

6.1. Node Information

This document introduces the following sub-TLVs of Node Attribute TLV (Value TBD, see [OSPF-Node])

Type	sub-TLV
TBD	Connectivity Matrix
TBD	Wavelength Converter Accessibility
TBD	Wavelength Conversion Range
TBD	WC Usage State

6.2. Link Information

This document introduces the following sub-TLVs of TE Link TLV (Value 2)

Type	sub-TLV
TBD	WSON Port Wavelength Restrictions
TBD	Available Wavelengths

TBD   Shared Backup Wavelengths

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