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2. Abstract

Optical rings provide an efficient and robust mechanism for failure protection. The significance of ring architecture in the evolution of optical networks is also due to the proliferation of multi-level SONET (SDH) rings, especially in metropolitan and regional areas. However, the IP-based MPLS framework for optical networks is largely based upon (optical) mesh, due to the latter’s connection flexibility. In this draft, we propose a hybrid mesh-ring optical network architecture of mixing rings together with meshes, either by embedding rings into meshes or by connecting rings with meshes. A hybrid mesh-ring network provides both connection flexibility and robust failure protection. After briefly discussing the unique architecture of hybrid mesh-ring networks, this draft focuses on defining new attributes and methods for mesh-ring’s topology discovery and routing information distribution. We utilize the IS-IS/OSPF opaque LSA mechanism, defined in RFC 2370. Finally, we discuss our work in the context of MPLS traffic engineering and network service protection and restoration.
3. Introduction

As operators move to deploy more advanced optical networks, various important issues arise with respect to network migration. One of these concerns is with regards to network topologies, and specifically migration strategies from existing infrastructures to expanded offerings. It is well-understood that many networks today are based upon fiber ring infrastructures, as seen by the proliferation of multi-level SONET/SDH ring technologies, especially in the access and metro/regional space. Furthermore, optical ring networks allow for inherently efficient and robust protection switching (i.e., "self-healing") mechanisms. Given the entrenched base of ring fiber-plants and the scale of such infrastructure investments, it is clear that ring topologies will remain an integral part of many networks for some time to come. Operators also start to adopt dynamic optical ring architectures, i.e., extending SONET/SDH uni-direction path switching (UPSR) and bi-directional line (BLSR) switching concepts (see [GHANI] for complete details) to optical ring networks. Ring networks will allow network operators to immediately leverage their current fiber layouts and thereby provide a cost-effective initial migration step from SONET/SDH (TDM-based) ring networks.

We foresee that the networks consisting of hybrid rings and meshes are of particular importance for operators to migrate to next generation optical networks. The reasons are as follows. Although optical rings allows fast and robust protection mechanisms, it suffers from reduced inter-node connectivity (degree two). Consequently, some carriers have proposed the deployment of mesh network topologies to counter the deficiency of ring topologies due to the fact that mesh networks can offer richer connectivity. However, mesh networks still lack well-defined protection and restoration capabilities. This raises a significant concern to network operators who have paid tremendous attentions to service reliability. All these motivate us to investigate the architecture of hybrid ring and mesh networks, termed mesh-rings. A hybrid mesh-ring network provides both connection flexibility and fast/robust failure protection and restoration. Some carriers who have end-to-end networks covering metro/regional and long haul space have expressed the similar views [STRANDYUE] [YUELAZER]. The architecture of hybrid mesh-ring networks fits well for them to build end-to-end metro(Ring)-long haul(mesh)-metro(ring) networks.

With regards to hybrid mesh-ring networks, there are two key scenarios, namely "virtual" ring embedding or mesh-ring interconnection:

- Ring emulation basically entails operating (multiple) "virtual" rings on top of mesh (network) topologies. The capability of embedding multiple "virtual" rings on top of a mesh topology is attractive to operators, since this permits the re-use of well-defined ring protection mechanisms (UPSR, BLSR, etc). For operators accustomed to operating ring networks, this capability will allow them to gradually migrate to mesh services provisioning.
Traditional SONET ring network operators may start with the same ring topology. As new services emerge, the ring operators may choose to gradually phase in expansions to existing ring topologies (e.g., by adding fibers between non-adjacent ring nodes to "break" the ring to offer new services). This "pay-as-you-grow" approach is more cost-effective than undertaking the deployment of altogether new (i.e., "greenfield-type") mesh fiber-plants. The network ends up with a hybrid ring and mesh topology.

Clearly, hybrid ring-mesh networks will present various unique concerns regarding network control, provisioning, resource discovery, and protection. This draft first briefly discusses the unique architecture of hybrid mesh-ring networks. We then focus on defining new attributes and methods for mesh-ring's topology discovery and routing information distribution. Of particular importance is an identifier field for ring networks (ring ID) and the ability to indicate different types of protection. We utilize the IS-IS/OSPF Opaque LSA mechanism as defined in RFC 2370. The new attributes will be used by lightpath routing algorithms for provisioning purposes in mesh-ring networks. We also briefly discuss our work in the context of MPLS traffic engineering and network service restoration (failure protection).

4. Hybrid Mesh-Ring Networks Architecture

4.1 Network Architecture Description

A hybrid mesh-ring network is loosely defined as a network mixing rings with meshes. There are many ways to form a hybrid mesh-ring network:

a. Mesh links are added to an optical ring. For example, in Fig. 1.a, a network operator decides to add a mesh link between node W and node Y. The flexibility for adding mesh links is attractive to operators who have a ring network but want to expand their networks for offering other types of services.

b. Multiple optical rings are connected by a mesh (see Fig. 1.b). For example, two mesh links are added to connect ring R1 and ring R2.

c. In a network with a mesh topology, we embed one or more logical rings. For example, in Fig 1.c, we define two logical rings (A-B-C-D-I-H-A) and (I-D-E-F-I). This approach is called ring emulation. These embedded logical rings are also called "virtual rings." The links on virtual rings are also part of the mesh network. For network operators accustomed to operating ring networks, ring emulations are particularly attractive. On a mesh network, they can provision a virtual private optical ring for those large clients who demand premium services.
Each of the optical rings in a mesh-ring network is considered as a routing entity. We propose to introduce a unique ring identifier (Ring ID) for each ring in a hybrid mesh-ring network. A ring ID is 32-bit integer field. In the case where multiple rings form a hierarchical structure, a ring ID field can be sub-divided into 2 or more sub-fields, which represents the ring hierarchy.

We also propose to associate each link in a hybrid mesh-ring network with a link protection type. Various types of optical protected rings have been defined in ITU-T and ANSI T1X1.5 (see [ITU], [GR2979]). These include Optical Channel Dedicated Protection Rings (OCh-DPRing), Optical Channel Shared Protection Rings (OCh-SPRing), Optical Multiplex-Section Dedicated Rings (OMS-DPRing), and Optical Multiplex-Section Shared Rings (OMS-SPRing). One important reason for identifying link protection types in a hybrid mesh-ring networks is to take advantage of rings’ protection and self-healing properties. For an architectural framework on this topic, refer to [GHANI] for details.

There are other important traffic engineering attributes which can be introduced in a hybrid mesh-ring networks. One example is the Class of Services (CoS). When provisioning lightpath across a hybrid mesh-ring network, operators may want to offer various level of services, based on the protection features and other quality agreements.

For example, the operator of a hybrid mesh-ring network may offer a client a lightpath which traverses the ring links only. This type of ring-only lightpaths may be protected either by a dedicated protection path by a shared protection path.

### 4.2 Routing Considerations in the Hybrid Mesh-Ring Networks

In a hybrid mesh-ring optical networks, there are unique requirements for resource discovery and maintenance as well as for lightpath routing.

- We need differentiate links in a ring from links in a mesh. Certain traffic such as voice traffic need to be routed along the ring links due to their fast (sub 50-ms) and robust protection capability;

- We also need identify the direction of a ring-link for a given node on a ring. The direction can be either clock-wise or counter clock-wise.
For a hierarchical hybrid mesh-ring network, multiple rings may be interconnected by a mesh or a ring in a hierarchical structure. Ring identifiers (Ring IDs) may contain a hierarchical structure for facilitating the inter-ring routing.

5. Opaque LSA for Mesh-Ring Optical Networks

In this section, we describe the enhancements to IS-IS/OSPF in support of hybrid mesh-ring networks. These are in addition to the previous extensions:

- for supporting the MPLS traffic engineering ([OSPF-TE], [ISIS-TE]);
- for supporting MPL(ambda)S & optical routing ([KOMPELLA], [WANG]).

In particular, our LSA format follows closely the description in [OSPF-TE], a de-facto standard.

5.1 LSA Type

This draft makes use of the Opaque LSA [OSPF-Opaque] (RFC2370). Opaque LSAs are introduced as a means of distributing additional OSPF routing information. Three types of Opaque LSA exist:

- Type 9: link-local scope
- Type 10: area-local scope
- Type 11: Autonomous System (AS) scope

We use only Type 10 LSAs for area flooding scope.

5.2 LSA Header

In Opaque LSAs, the payload of the LSA could contain information that has meaning only within a certain application and will be ignored otherwise. The type of the application is identified by the Opaque Type, contained in the LSA ID.

The LSA ID of an Opaque LSA is defined as having eight bits of opaque type and 24 bits of type-specific data. The new Opaque type number for mesh-rings is TBD. The remaining 24 bits are broken up into eight bits of reserved space (which must be zero) and sixteen bits of instance. A maximum of 65536 LSAs may be sourced by a single node.

The new LSA for mesh-ring optical networks starts with the LSA header:

```
+---------------------------+---------------------------+---------------------------+---------------------------+
|            LS age           |    Options    |      10       |
+---------------------------+---------------------------+---------------------------+
|      TBD      |    Reserved   |           Instance            |
+---------------------------+---------------------------+---------------------------+
|                     Advertising Node ID                       |
+---------------------------+---------------------------+---------------------------+
|                     LS sequence number                        |
+---------------------------+---------------------------+---------------------------+
|         LS checksum           |             length            |
+---------------------------+---------------------------+---------------------------+
```

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5.3 New Opaque LSA Payload

The LSA payload consists of one or more nested Type/Length/Value (TLV) triplets for extensibility. They are used in path computation algorithm to compute optical paths in the mesh-ring optical networks. The format of each TLV is:

```
|              Type             |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Value...                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The new opaque LSA describe the nodes and links in a mesh-ring networks. We define two top-level TLVs: Optical Node TLV and Link TLV.

5.4 Link TLV

Link TLV describes a single unidirectional link. The link TLV is type 2, the length is variable. It is constructed as a set of sub-TLVs. There are no ordering requirements for the sub-TLVs.

The following sub-TLVs are defined:
1 - Link type (1 octet)
2 - Link ID (4 octets)
3 - Local interface IP address (4 octets)
4 - Remote interface IP address (4 octets)
5 - Available link resource information
6 - Ring ID (4 octets)
7 - Link protection type (4 octets)
8 - Shared Link Risk Group ID (4 octets)

In [OSPF-TE] and [WANG], many sub-TLVs are described. Here, we put our emphasis on new sub-TLVs unique to the hybrid mesh-ring optical networks.

5.4.1 Link Type

Link type sub-TLV defines the type of the link (as describe in [WANG]):

3 - Service transparent (a point to point physical optical link)
4 - Service aware (a point to point logical optical link)

By using this link type, we can represent both physical and logical link and their connection type in optical domain.

5.4.2 Link ID

The Link ID sub-TLV identifies the optical link exactly as the point to point case in [OSPF-TE].
5.4.3 Local and Remote Interface IP Addresses

The local interface IP address sub-TLV specifies the IP address of the interface corresponding to this link. The remote interface IP address sub-TLV specifies the IP address of the neighbor’s interface corresponding to this link. This and the local address are used to discern multiple parallel links between two nodes.

5.4.4 Available Link Resource Information

Refer to [WANG] for descriptions.

5.4.5 Ring ID

When a link belongs to a ring, 2 sub-TLVs are added. Ring ID sub-TLV is TLV type 6, and has four octets in length. Ring ID is unique within an IGP domain.

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type(6)          |             4                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             Ring ID                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

For a link not belonging to a ring, this sub-TLV is omitted. A link may belong to multiple rings, in which cases multiple sub-TLVs are included.

5.4.6 Link Protection Type

The link protection type sub-TLV is TLV type 7 and also have 4 octets in length.

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Type(7)          |             4                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Link protection code                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The link protection code is 32-bit flagged field. It represents various protection types defined in ITU-T [GR-2979], including OCh-DPRing, OCh-SPRing, OMS-DPRing and OMS-DPRing. Furthermore, other protection and restoration properties can also be encoded in this field.

When a link belongs to multiple rings, multiple sub-TLVs are included.
5.4.7 Shared Link Risk Group

The shared link risk group sub-TLV specifies group membership for "shared risk link group" (SRLG). A set of links may constitute a "shared risk link group" if they share a resource whose failure may affect all links in the set. An example would be two fibers in the same conduit. Also, a link may be part of more than one SRLG. Refer to [KOMPELLA] for more descriptions.

6. Routing and Signaling Requirement for Mesh-Ring Networks

New opaque LSAs are subsequently used by the constrained shortest path first (CSPF) algorithm. It may be desirable for network operators to specify the type of light path from a source to a destination:

- Path P passes a BWPSR ring, or
- Path P passes a BLSR ring, or
- Path P passes a UPSR ring;

Exactly how the CSPF algorithm incorporates the information contained in new opaque LSAs is proprietary in nature and beyond the scope of this document.

After obtaining an explicit lightpath from a source to a destination, we use GMPLS [GMPLS] to provision this lightpath. When setting up a light path in RSVP-TE or CR-LDP, we may treat a ring as an abstract node. More treatments will follow in this area.

7. Failure Protection and Restoration for Mesh-Ring Networks

There are clearly advantages in supporting failure protection and restoration by identifying the rings in a hybrid mesh-ring network. We propose to develop a light-weighted dedicated protection-switching protocol, namely optical APS (O-APS) protocol, for hybrid mesh-ring networks. This new protocol is preferred to use the similar operation model of SONET APS [SONET-APS]. This topic deserves more detailed treatment, due to its primary importance. More discussions can be found in [GHANI].

8. Security Considerations

There is no known security problem caused by this draft.

9. Acknowledgements

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10. References

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