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Requirements for Generalized MPLS (GMPLS) Routing for Automatically Switched Optical Network (ASON)

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Abstract

The Generalized MPLS (GMPLS) suite of protocols has been defined to control different switching technologies as well as different applications. These include support for requesting TDM connections including SONET/SDH and Optical Transport Networks (OTNs).

This document concentrates on the routing requirements on the GMPLS suite of protocols to support the capabilities and functionalities for an Automatically Switched Optical Network (ASON) as defined by ITU-T.

1. Contributors

This document is the result of the CCAMP Working Group ASON Routing Requirements design team joint effort.

2. 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.

3. Introduction

The GMPLS suite of protocols provides among other capability support for controlling different switching technologies. These include support for requesting TDM connections utilizing SONET/SDH (see ANSI T1.105/ITU-T G.707) as well as Optical Transport Networks (see ITU-T G.709). However, there are certain capabilities that are needed to support the ITU-T G.8080 control plane architecture for the Automatically Switched Optical Network (ASON). Therefore, it is desirable to understand the corresponding requirements for the GMPLS protocol suite. The ASON control plane architecture is defined in [G.8080] and ASON routing requirements are identified in [G.7715] and refined in [G.7715.1] for link state architectures. These recommendations provide functional requirements and architecture, they provide a protocol neutral approach.

This document focuses on the routing requirements for the GMPLS suite of protocols to support the capabilities and functionality of ASON control planes. It discusses the requirements for GMPLS routing that MAY subsequently lead to additional backward compatible extensions to support the capabilities specified in the above referenced documents. A description of backward compatibility considerations is provided in Section 5. Nonetheless, any protocol (in particular, routing) design or suggested protocol extensions is strictly outside the scope of this document. An ASON (Routing) terminology section is provided in Appendix 1 and Appendix 2.

The ASON model distinguishes reference points (representing points of information exchange) defined (1) between an administrative domain and a user (user-network interface or UNI), (2) between administrative domains or within an administrative domain between different control domains (external network-network interface or E-NNI) and, (3) within the same administrative domain between control components (or simply controllers) of the same control domain (internal network-network interface or I-NNI). The ASON model allows for the protocols used within different control domains to be different; and for the protocol used between control domains to be different than the protocols used within control domains. I-NNI control interfaces are located between protocol controllers within a control domain. E-NNI control interfaces are located on protocol controllers between control domains.

The term routing information refers to the abstract representation of network routing related information such as node and link attributes (see Section 4.5). No routing information is passed over the UNI. Routing information exchanged over the NNI is subject to the policy constraints at individual NNIs. The routing information exchanged over the E-NNI encapsulates the common semantics of the individual domain information while allowing different representation within each domain.

The ASON routing architecture is based on the following assumptions:
- A carrier's network is subdivided as Routing Areas (RAs). Each RA shall be uniquely identifiable within a carrier's network (i.e. administrative domain). RAs partitioning provide for routing information abstraction, thereby enabling scalable routing.
- Routing Controllers (RC) provide for the exchange of routing information between and within a RA. The routing information exchanged between RCs is subject to policy constraints imposed at reference points (E-NNI and I-NNI).
- For a RA, the set of RCs is referred to as a routing (control) domain. The RC MAY support more than one routing protocol (i.e. an RC MAY support multiple Protocol Controller (PCs)). There SHOULD NOT be any dependencies on the different routing protocols used.
- The routing information exchanged between routing domains (i.e. inter-domain) is independent of both the intra-domain routing protocol and the intra-domain control distribution choice(s), e.g. centralized, fully distributed.
- The routing adjacency topology (i.e. the associated PC connectivity topology) and the transport network topology SHALL NOT be assumed to be congruent.

The following functionality is expected from GMPLS routing to instantiate ASON routing realization (see [G.7715] and [G.7715.1]):
- support multiple hierarchical levels of RAs; the number of hierarchical levels to be supported is routing protocol implementation specific.
- support hierarchical routing information dissemination including

summarized routing information
- support for multiple links between nodes (and between RAs) and for link and node diversity
- support architectural evolution in terms of the number of levels of hierarchies, aggregation and segmentation of RAs
- support routing information based on a common set of information elements as defined in [G.7715] and [G.7715.1], divided between attributes pertaining to links and abstract nodes (each representing either a sub-network or simply a node). [G.7715] recognizes that the manner in which the routing information is represented and exchanged will vary with the routing protocol used.

Also, the behaviour of GMPLS routing is expected to be such that:
- it is scalable with respect to the number of links, nodes and RAs
- in response to a routing event (e.g. topology update, reachability

update), it delivers convergence and damping against flapping
- it fulfils the operational security objectives where required

4. ASON Requirements for GMPLS Routing

The description of the ASON routing components (see Appendix 2) is provided in terms of routing functionality. This description is only conceptual: no physical partitioning of these functions is implied.

The Routing Controller (RC) components receive routing information from their associated Link Resource Manager(s) (LRMs) regarding TE links and store this information in the Routing Information Database (RDB). The RDB is replicated at each RC within the same Routing Area (RA), and MAY contain information about multiple transport plane network layers. Whenever the state of a TE link (or component link) changes, the LRM informs the corresponding RC, which in turn updates its associated RDB. In order to assure RDB synchronization, the RCs co-operate and exchange routing information. In this context, communication between RCs is realized using a particular routing protocol represented by the protocol controller (PC) component and the protocol messages are conveyed over the Signaling Control Network (SCN). The PC MAY convey information for one or more transport network layers. Moreover, as [G7715.1] states and illustrates in its Figure 1, ASON routing protocol requirements deals exclusively with the PC to PC communication of the (RC) routing information; therefore any other communication between any other functional component(s) (e.g. SC, LRM) is also outside the scope of this document.

Note: the RC can be thought of as the function processing the TE database populated by the link local/remote component and TE links (LRM) and by the network wide TE links through the PC which processes the protocol specific routing exchanges. The SCN corresponds to the IP control plane topology enabling routing exchanges between GMPLS controllers (i.e. the routing adjacencies).

4.1 Multiple Hierarchical Levels

[G.8080] introduces the concept of Routing Area (RA). RAs provide for routing information abstraction, thereby enabling scalable routing information representation. Except for the single RA case, RAs are hierarchically contained: a higher level (parent) RA contains lower level (child) RAs that in turn MAY also contain RAs, etc. Thus, RAs contain RAs that recursively define successive hierarchical routing levels.

However, the RA containment relationship describes only an architectural hierarchical organization of RAs. It does not restrict the routing protocol realization (e.g. OSPF multi-areas, path computation, etc.). Moreover, the realization of the routing paradigm to support hierarchical routing and the number of

hierarchical levels to be supported is routing protocol specific and outside the scope of this document.

ASON routing components are identified by values that MAY be drawn from several identifier spaces (see [G.7715.1]). The use of identifiers in a routing protocol realization is implementation specific and outside the scope of this document.

In a multi-level routing hierarchy, it is necessary to distinguish among RCs within a level and RCs at different levels of the routing hierarchy. Before any pair of RCs establishes communication, they MUST verify they belong to the same RA (see Section 4.2). A RA identifier (RA ID) is required to provide the scope within which the RCs can communicate. To distinguish between RCs within the same RA, an RC identifier (RC ID) is required; the RC ID must be unique within its containing RA.

A RA represents a partition of the data plane and its identifier (i.e. RA ID) is used within the control plane as a reference to the data plane partition. RA IDs MAY be associated with a transport plane name space whereas RC IDs are associated with a control plane name space.

4.2 Hierarchical Routing Information Dissemination

Routing information can be exchanged between adjacent levels of the routing hierarchy i.e. Level N+1 and N, where Level N represents the RAs contained by Level N+1. The links connecting RAs MAY be viewed as external links, and the links representing connectivity within an RA MAY be viewed as internal links.

The physical location of RCs at adjacent levels, their relationship and their communication protocol are outside the scope of this document. No assumption is made regarding how RCs communicate between levels. If routing information is exchanged between a RC, its parent, and its child RCs, it SHOULD include reachability and MAY include (upon policy decision) node and link topology.

Multiple RCs within a RA MAY transform (filter, summarize, etc.) and then forward information to RCs at different levels. However in this case the resulting information at the receiving level must be self-consistent; this MAY be achieved using a number of mechanisms.

Note: there is no relationship between multi-layer and multi-level routing. The former implies a single routing protocol instance for multiple transport switching layers whereas the latter implies a hierarchical routing topology for one transport switching layer.

4.2.1 Communication between Adjacent Routing Levels

1. Type of Information Exchanged

The type of information flowing upward (i.e. Level N to Level N+1) and the information flowing downward (i.e. Level N+1 to Level N) are used for similar purposes, namely, the exchange of reachability information and summarized topology information to allow routing across multiple RAs. The summarization of topology information may impact the accuracy of routing and MAY require additional path calculation.

The following information exchange are expected:

- Level N+1 visibility to Level N reachability and topology (or upward information communication) allowing RC(s) at level N+1 to determine the reachable endpoints from Level N.
- Level N visibility to Level N+1 reachability and topology (or downward information communication) allowing RC(s) in an RA at Level N to develop paths to reachable endpoints outside of the

RA.

2. Interactions between Upward and Downward Communication

When both upward and downward information exchanges contain endpoint reachability information, a feedback loop could potentially be created. Consequently, the routing protocol MUST include a method to:

- prevent information propagated from a Level N+1 RA into the Level N RA to be re-introduced into the Level N+1 RA, and
- prevent information propagated from a Level N-1 RA into the Level N RA to be re-introduced into the Level N-1 RA.

The routing protocol is required to differentiate the routing information originated at a given level RA from the one derived using the routing information received from its external RAs (regardless of the level of the corresponding RCs). This is a necessary condition to be fulfilled by routing protocols to be loop free.

Also, for ASON, the routing information exchange may generate transient loops at the data plane if no route recording is used during signaling. So, at the data plane, it is not the routing exchange that guarantees (transient) loop avoidance but the signaling protocol by recording the route until the node where computation occurs (by excluding segments already traversed).

3. Method of Communication

Two approaches exist for communication between Level N and N+1.

- The first approach places an instance of a Level N routing function and an instance of a Level N+1 routing function in the same system. The communications interface is within a single system and is thus not an open interface subject to standardization.

- The second approach places the Level N routing function on a separate system from the Level N+1 routing function. In this case, a communication interface must be used between the systems containing the routing functions for different levels. This communication interface and mechanisms are outside the scope of this document.

4.2.2 Configuring the Routing Hierarchy

The RC MUST support static (i.e. operator assisted) and MAY support automated configuration of the information describing its relationship to parent and its child within the hierarchical routing structure (including RA ID and RC ID). When applied recursively, the whole hierarchy is thus configured.

4.2.3 Configuring RC Adjacencies

The RC MUST support static (i.e. operator assisted) and MAY support automated configuration of the information describing its control adjacencies to other RCs within a RA. The routing protocol SHOULD support all the types of RC adjacencies described in Section 9 of [G.7715]. The latter includes congruent topology (with distributed RC) and hubbed topology (with designated RC).

4.3 Evolution

The containment relationships of RAs MAY change, motivated by events such as mergers, acquisitions, and divestitures.

The routing protocol SHOULD be capable of supporting architectural evolution in terms of number of hierarchical levels, as well as aggregation and segmentation of RAs. RA IDs uniqueness within an administrative domain MAY facilitate these operations. The routing protocol is not expected to automatically initiate and/or execute these operations.

4.4 Multiple Links between Nodes and RAs

See Section 4.5.1

4.5 Routing Attributes

Routing for transport networks is performed on a per layer basis, where the routing paradigms MAY differ among layers and within a layer. Not all equipment support the same set of transport layers or the same degree of connection flexibility at any given layer. A server layer trail may support various clients, involving different adaptation functions. Additionally, equipment may support variable adaptation functionality, whereby a single server layer trail dynamically supports different multiplexing structures. As a result, routing information MAY include layer specific, layer independent, and client/server adaptation information.

4.5.1 Taxonomy of Attributes

Attributes can be organized according to the following categories:

- Node related or link related

- Provisioned, negotiated or automatically configured

- Inherited or layer specific (client layers can inherit some attributes from the server layer while other attributes like Link Capacity are specified by layer).

(Component) link attributes can be statically or automatically configured for each transport network layer. This may lead to unnecessary repetition. Hence, the inheritance property of attributes can also be used to optimize the configuration process.

TE links are configured through grouping of component links. Grouping MAY be based on different link attributes (e.g., SRLG information, link weight, etc).

Two RAs may be linked by one or more TE links. Multiple TE links may be required when component links are not equivalent for routing purposes with respect to the RAs they are attached to, or to the containing RA, or when smaller groupings are required.

4.5.2 Commonly Advertised Information

Advertisements MAY contain the following common set of information regardless of whether they are link or node related:
- RA ID of which the advertisement is bounded
- RC ID of the entity generating the advertisement
- Information to uniquely identify advertisements
- Information to determine whether an advertisement has been updated
- Information to indicate when an advertisement has been derived from a source external to the routing area

4.5.3 Node Attributes

All nodes belong to a RA, hence the RA ID can be considered an attribute of all nodes. Given that no distinction is made between abstract nodes and those that cannot be decomposed any further, the same attributes MAY be used for their advertisement.

The following Node Attributes are defined:

Attribute	Capability	Usage
Node ID	REQUIRED	REQUIRED
Reachability	REQUIRED	OPTIONAL

Table 1. Node Attributes

Reachability information describes the set of endpoints that are reachable by the associated node. It MAY be advertised as a set of associated address prefixes or a set of associated TE link IDs, consistently assigned within an administrative domain.

Note: no distinction is made between nodes that may have further internal details (i.e., abstract nodes) and those that cannot be decomposed any further.

4.5.4 Link Attributes

The following Link Attributes are defined:

Link Attribute	Capability	Usage
Local TE link ID	REQUIRED	REQUIRED
Remote TE link ID	REQUIRED	REQUIRED
TE Link Characteristics	Table 3	

Table 2. Link Attributes

The TE link ID must be sufficient to uniquely identify the corresponding transport plane resource taking into account separation of data and control planes. The TE link ID format is routing protocol specific.

Note: when the remote end of a TE link is located outside of the RA, the remote TE link ID is OPTIONAL.

The following TE link characteristic attributes are defined:

- Signal Type: This identifies the characteristic information of the layer network.

- Link Weight: The metric indicating the relative desirability of a particular link over another e.g. during path computation.

- Resource Class: This corresponds to the set of administrative groups assigned by the operator to this link. A link MAY belong to zero, one or more administrative groups.

- Connection Types: This allows identification of whether the local component link is at a border or within an LSP region (see [HIER])

- Link Capacity: This provides the sum of the available and potential bandwidth capacity for a particular network transport layer. Other capacity measures MAY be further considered.

- Link Availability: This represents the survivability capability such as the protection type associated with the link.

- Diversity Support: This represents diversity information such as

the SRLG information associated with the link.

- Local Adaptation Support: This indicates the set of client layer adaptations supported by the local component link associated to the local TE link. This can only exist when the "Local Connection Type" indicates crossing of an LSP Region or can be flexibly assigned to be at a border or within an LSP region (see [HIER]).

TE link Characteristics	Capability	Usage
Signal Type	REQUIRED	OPTIONAL
Link Weight	REQUIRED	OPTIONAL
Resource Class	REQUIRED	OPTIONAL
Local Connection Types	REQUIRED	OPTIONAL
Link Capacity	REQUIRED	OPTIONAL
Link Availability	OPTIONAL	OPTIONAL
Diversity Support	OPTIONAL	OPTIONAL
Local Adaptation support	OPTIONAL	OPTIONAL

Table 3. TE link Characteristics

Note: separate advertisements of layer specific attributes MAY be chosen. However this may lead to unnecessary duplication. This can be avoided using the inheritance property, so that attributes derivable from the local adaptation information do not need to be advertised.

5. Backward Compatibility

Any particular realization of the ASON routing requirements MUST be backward compatible with the considered routing protocol(s).

Backward compatibility means that at any level of the routing hierarchy, nodes, some of which support the requirements described in this document, and some of which do not, MUST still be capable to operate as mandated by the OSPF, IS-IS, and/or IDR IETF WG and their corresponding GMPLS extensions (as mandated by the CCAMP IETF WG).

Additionally, nodes (that do not support these requirements and) are made part of a multi-level routing hierarchy from their containing RA(s), must be capable of:

- rejecting (or ignoring) any incoming routing information that would be addressed to them in a way that is not detrimental to the network as a whole
- communicating (at a given level) with any other node located at the same level and that implements these requirements

This assumes that such nodes do not communicate directly either with lower or upper level nodes.

Note: backward compatibility with routing protocols is a protocol requirement defined in the IETF context.

6. Security Considerations

ASON routing protocol MUST deliver the operational security objectives where required.

7. Conclusions

This section captures from the identified ASON routing requirements the missing capabilities from the GMPLS routing protocols (e.g. OSPF, IS-IS).

The GMPLS routing protocol is required to support multiple hierarchical levels of RAs and hierarchical routing information dissemination including summarized routing information. However, the number of hierarchical levels to be supported is routing protocol implementation specific. This implies that the GMPLS routing protocol must deliver:

- processing of routing information exchanged between adjacent levels of the routing hierarchy (i.e. Level N+1 and N) including reachability and upon policy decision summarized topology information
- when multiple RCs within a RA transform (filter, summarize, etc.) and then forward information to RC(s) at different levels that the resulting information at the receiving level is self-consistent
- a mechanism to prevent re-introduction of information propagated into the Level N RA back to the external level RA from which this information has been initially received. It is thus expected that advertisements will include information when they have been derived from a source external to the RA. Note that existing routing protocols support mechanisms to identify advertisements of externally derived information and therefore an analysis of their applicability has to be considered on a per-protocol basis.

In order to support operator assisted changes in the containment relationships of RAs, the GMPLS routing protocol is expected to support evolution in terms of number of hierarchical levels of RAs (adding and removing RAs at the top/bottom of the hierarchy), as well as aggregation and segmentation of RAs. These GMPLS routing capabilities are considered of lower priority as they are implementation specific and their method of support should be evaluated on per-protocol basis e.g. OSPF vs IS-IS. In addition, support of non-disruptive operations such as adding or removing a hierarchical level of RAs in or from the middle of the routing hierarchy are considered as the lowest priority requirements. Note also that the number of hierarchical levels to be supported is implementation specific, and reflects a containment relationship e.g. a RA insertion involves supporting a different routing protocol domain in a portion of the network.

Note: some members of the Design Team question if the ASON requirement for supporting architecture evolution is a requirement on the routing protocol (protocol-specific capability) vs. a

capability to be provided by the architecture. For example, ASON allows for supporting multiple protocols within each RA. The multiple protocols share a common routing information database (RDB), and the RDB is the component, which needs to support architecture evolution. The Design Team invites CCAMP input to understand the protocol-specific impacts.

GMPLS routing currently covers all node attributes considered in [G.7715.1]. Assuming that the set of TE link IDs are numbered either from their component/TE links or from the node address that hosts these components/TE links, no additional extensions seem to be required in order to advertise reachable end-points within an ASON control plane. Advertisement of externally reachable prefixes is built in within any routing protocol independently of its usage in/outside GMPLS.

Note: some members of the Design Team noted that reachability information (as described in Section 4.5.3) may be advertised as a set of UNI Transport Resource address prefixes (assigned and selected consistently in their applicability scope). These members of the Design Team raised a concern that existing methods of advertising reachability may need to be examined (on a per-protocol basis) to determine if they are also applicable for UNI Transport Resource addresses. They invite CCAMP discussion on this aspect.

From the considered list of link attributes and characteristics, the Local Adaptation support information is missing as TE link attribute. GMPLS routing does not currently consider the use of dedicated TE link attribute(s) to describe the cross/inter-layer relationships. All other TE link attributes and characteristics are currently covered. The need for a "TE metric" per component link needs to be further assessed, in the sense that it can be currently implemented. Further consideration is here needed regarding impacts on TE link bundling capabilities and the increase of the routing advertisement overhead with potentially duplicated information.

Note: ASON does not restrict the architecture choices used, either a co-located architecture or a physically separated architecture may be used. Some members of the Design Team are concerned that GMPLS's concept of the LSR requires a 1-to-1 relationship between the transport plane entity and the control plane entity (Router). They invite CCAMP input on GMPLS capabilities to support multiple architectures i.e. how routing protocols would identify the transport node ID vs. the router or routing controller ID when scoping Link IDs in a link advertisement.

The inheritance property of link attributes used to optimize the component/TE link configuration process is built in within GMPLS.

8. Acknowledgements

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9. Intellectual Property Considerations

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10. References

10.1 Normative References

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Appendix 1 - ASON Terminology

This document makes use of the following terms:

Administrative domain: See Recommendation G.805.

Control plane: performs the call control and connection control functions. Through signaling, the control plane sets up and releases connections, and may restore a connection in case of a failure.

(Control) Domain: represents a collection of entities that are grouped for a particular purpose. G.8080 applies this G.805 recommendation concept (that defines two particular forms, the administrative domain and the management domain) to the control plane in the form of a control domain. The entities that are grouped in a control domain are components of the control plane.

External NNI (E-NNI): interfaces are located between protocol controllers between control domains.

Internal NNI (I-NNI): interfaces are located between protocol controllers within control domains.

Link: See Recommendation G.805.

Management plane: performs management functions for the Transport Plane, the control plane and the system as a whole. It also provides coordination between all the planes. The following management functional areas are performed in the management plane: performance, fault, configuration, accounting and security management

Management domain: See Recommendation G.805.

Transport plane: provides bi-directional or unidirectional transfer of user information, from one location to another. It can also provide transfer of some control and network management information. The Transport Plane is layered; it is equivalent to the Transport Network defined in G.805.

User Network Interface (UNI): interfaces are located between protocol controllers between a user and a control domain.

Appendix 2 - ASON Routing Terminology

This document makes use of the following terms:

Routing Area (RA): a RA represents a partition of the data plane and its identifier is used within the control plane as the representation of this partition. Per [G.8080] a RA is defined by a set of sub-networks, the TE links that interconnect them, and the interfaces representing the ends of the TE links exiting that RA. A RA may contain smaller RAs inter-connected by TE links. The limit of subdivision results in a RA that contains two sub-networks and a TE link with a single component link.

Routing Database (RDB): repository for the local topology, network topology, reachability, and other routing information that is updated as part of the routing information exchange and may additionally contain information that is configured. The RDB may contain routing information for more than one Routing Area (RA).

Routing Components: ASON routing architecture functions. These functions can be classified as protocol independent (Link Resource Manager or LRM, Routing Controller or RC) and protocol specific (Protocol Controller or PC).

Routing Controller (RC): handles (abstract) information needed for routing and the routing information exchange with peering RCs by operating on the RDB. The RC has access to a view of the RDB. The RC is protocol independent.

Note: Since the RDB may contain routing information pertaining to multiple RAs (and hence possibly multiple layer networks), the RCs accessing the RDB may share the routing information.

Link Resource Manager (LRM): supplies all the relevant component and TE link information to the RC. It informs the RC about any state changes of the link resources it controls.

Protocol Controller (PC): handles protocol specific message exchanges according to the reference point over which the information is exchanged (e.g. E-NNI, I-NNI), and internal exchanges with the RC. The PC function is protocol dependent.

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