

Network Working Group
Request for Comments: 4652
Category: Informational

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October 2006

Evaluation of Existing Routing Protocols against
Automatic Switched Optical Network (ASON) Routing Requirements

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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 Synchronous Optical Network/Synchronous Digital Hierarchy (SONET/SDH) and Optical Transport Networks (OTNs).

This document provides an evaluation of the IETF Routing Protocols against the routing requirements for an Automatically Switched Optical Network (ASON) as defined by ITU-T.

1. Introduction

Certain capabilities are needed to support the ITU-T Automatically Switched Optical Network (ASON) control plane architecture as defined in [G.8080].

[RFC4258] details the routing requirements for the GMPLS routing suite of protocols to support the capabilities and functionality of ASON control planes identified in [G.7715] and in [G.7715.1]. The ASON routing architecture provides for a conceptual reference architecture, with definition of functional components and common information elements to enable end-to-end routing in the case of protocol heterogeneity and to facilitate management of ASON networks. This description is only conceptual: no physical partitioning of these functions is implied.

However, [RFC4258] does not address GMPLS routing protocol applicability or capabilities. This document evaluates the IETF Routing Protocols against the requirements identified in [RFC4258]. The result of this evaluation is detailed in Section 5. Close examination of applicability scenarios and the result of the evaluation of these scenarios are provided in Section 6.

ASON (Routing) terminology sections are provided in Appendices A and B.

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 [RFC2119].

The reader is expected to be familiar with the terminology introduced in [RFC4258].

3. Contributors

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4. Requirements: Overview

The following functionality is expected from GMPLS routing protocols to instantiate the ASON hierarchical routing architecture realization (see [G.7715] and [G.7715.1]):

- Routing Areas (RAs) shall be uniquely identifiable within a carrier's network, each having a unique RA Identifier (RA ID) within the carrier's network.
- Within a RA (one level), the routing protocol shall support dissemination of hierarchical routing information (including summarized routing information for other levels) in support of an architecture of multiple hierarchical levels of RAs; the number of hierarchical RA levels to be supported by a routing protocol is implementation specific.
- The routing protocol shall 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.
- The routing protocol shall converge such that the distributed Routing DataBases (RDB) become synchronized after a period of time.

To support dissemination of hierarchical routing information, the routing protocol must deliver:

- Processing of routing information exchanged between adjacent levels of the hierarchy (i.e., Level N+1 and N), including reachability and (upon policy decision) summarized topology information.
- Self-consistent information at the receiving level resulting from any transformation (filter, summarize, etc.) and forwarding of information from one Routing Controller (RC) to RC(s) at different levels when multiple RCs are bound to a single RA.
- A mechanism to prevent re-introduction of information propagated into the Level N RA's RC back to the adjacent level RA's RC from which this information has been initially received.

Note: The number of hierarchical levels to be supported is routing protocol specific and reflects a containment relationship.

Reachability information may be advertised either as a set of UNI Transport Resource address prefixes, or as a set of associated Subnetwork Point Pool (SNPP) link IDs/SNPP link ID prefixes, assigned and selected consistently in their applicability scope. The formats of the control plane identifiers in a protocol realization are implementation specific. Use of a routing protocol within a RA should not restrict the choice of routing protocols for use in other RAs (child or parent).

As ASON does not restrict the control plane architecture choice, either a co-located architecture or a physically separated architecture may be used. A collection of links and nodes, such as a sub-network or RA, must be able to represent itself to the wider network as a single logical entity with only its external links visible to the topology database.

5. Evaluation

This section evaluates support of existing IETF routing protocols with respect to the requirements summarized from [RFC4258] in Section 4. Candidate routing protocols are Interior Gateway Protocol (IGP) (OSPF and Intermediate System to Intermediate System (IS-IS)) and BGP. The latter is not addressed in the current version of this document. BGP is not considered a candidate protocol mainly because of the following reasons:

- Non-support of TE information exchange. Each BGP router advertises only its path to each destination in its vector for loop avoidance, with no costs or hop counts; each BGP router knows little about network topology.
- BGP can only advertise routes that are eligible for use (local RIB) or routing loops can occur; there is one best route per prefix, and that is the route that is advertised.
- BGP is not widely deployed in optical equipment and networks.

5.1. Terminology and Identification

- Pi is a physical (bearer/data/transport plane) node.
- Li is a logical control plane entity that is associated to a single data plane (abstract) node. The Li is identified by the TE Router_ID. The latter is a control plane identifier defined as follows:

[RFC3630]: Router_Address (top level) TLV of the Type 1 TE LSA
[RFC3784]: Traffic Engineering Router ID TLV (Type 134)

Note: This document does not define what the TE Router ID is. This document simply states the use of the TE Router ID to identify Li. [RFC3630] and [RFC3784] provide the definitions.

- Ri is a logical control plane entity that is associated to a control plane "router". The latter is the source for topology information that it generates and shares with other control plane "routers". The Ri is identified by the (advertising) Router_ID

[RFC2328]: Router ID (32-bit)
[RFC1195]: IS-IS System ID (48-bit)

The Router_ID, which is represented by Ri and which corresponds to the RC_ID [RFC4258], does not enter into the identification of the logical entities representing the data plane resources such as links. The Routing DataBase (RDB) is associated to the Ri. Note that, in the ASON context, an arrangement consisting of multiple RIs announcing routing information related to a single Li is under evaluation.

Aside from the Li/Pi mappings, these identifiers are not assumed to be in a particular entity relationship except that the Ri may have multiple Lis in its scope. The relationship between Ri and Li is simple at any moment in time: an Li may be advertised by only one Ri at any time. However, an Ri may advertise a set of one or more Lis. Thus, the routing protocol MUST be able to advertise multiple TE Router IDs (see Section 5.7).

Note: Si is a control plane signaling function associated with one or more Lis. This document does not assume any specific constraint on the relationship between Si and Li. This document does not discuss issues of control plane accessibility for the signaling function, and it makes no assumptions about how control plane accessibility to the Si is achieved.

5.2. RA Identification

G.7715.1 notes some necessary characteristics for RA identifiers, e.g., that they may provide scope for the Ri, and that they must be provisioned to be unique within an administrative domain. The RA ID format itself is allowed to be derived from any global address space. Provisioning of RA IDs for uniqueness is outside the scope of this document.

Under these conditions, GMPLS link state routing protocols provide the capability for RA Identification without further modification.

5.3. Routing Information Exchange

In this section, the focus is on routing information exchange Ri entities (through routing adjacencies) within a single hierarchical level. Routing information mapping between levels require specific processing (see Section 5.5).

The control plane does not transport Pi identifiers, as these are data plane addresses for which the Li/Pi mapping is kept (link) local; see, for instance the transport LMP document [RFC4394] where such an exchange is described. Example: The transport plane identifier is the Pi (the identifier assigned to the physical element) that could be, for instance, "666B.F999.AF10.222C", whereas the control plane identifier is the Li (the identifier assigned by the control plane), which could be, for instance, "192.0.2.1".

The control plane exchanges the control plane identifier information, but not the transport plane identifier information (i.e., not "666B.F999.AF10.222C", but only "192.0.2.1"). The mapping Li/Pi is kept local. So, when the Si receives a control plane message requesting the use of "192.0.2.1", Si knows locally that this information refers to the data plane entity identified by the transport plane identifier "666B.F999.AF10.222C".

Note also that the Li and Pi addressing spaces may be identical.

The control plane carries:

- 1) its view of the data plane link end-points and other link connection end-points.
- 2) the identifiers scoped by the Lis, i.e., referred to as an associated IPv4/IPv6 addressing space. Note that these identifiers may be either bundled TE link addresses or component link addresses.
- 3) when using OSPF or ISIS as the IGP in support of traffic engineering, [RFC3477] RECOMMENDS that the Li value (referred to the "LSR Router ID") be set to the TE Router ID value.

Therefore, OSPF and IS-IS carry sufficient node identification information without further modification.

5.3.1. Link Attributes

[RFC4258] provides a list of link attributes and characteristics that need to be advertised by a routing protocol. All TE link attributes and characteristics are currently handled by OSPF and IS-IS (see Table 1) with the exception of Local Adaptation support. Indeed, GMPLS routing does not currently consider the use of dedicated TE link attribute(s) to describe the cross/inter-layer relationships.

In addition, the representation of bandwidth requires further consideration. GMPLS Routing defines an Interface Switching Capability Descriptor (ISCD) that delivers information about the (maximum/ minimum) bandwidth per priority of which an LSP can make use. This information is usually used in combination with the Unreserved Bandwidth sub-TLV that provides the amount of bandwidth not yet reserved on a TE link.

In the ASON context, other bandwidth accounting representations are possible, e.g., in terms of a set of tuples <signal_type; number of unallocated timeslots>. The latter representation may also require definition of additional signal types (from those defined in [RFC3946]) to represent support of contiguously concatenated signals, i.e., STS-(3xN)c SPE / VC-4-Nc, N = 4, 16, 64, 256.

However, the method proposed in [RFC4202] is the most straightforward without requiring any bandwidth accounting change from an LSR perspective (in particular, when the ISCD sub-TLV information is combined with the information provided by the Unreserved Bandwidth sub-TLV).

Link Characteristics	GMPLS OSPF
-----	-----
Local SNPP link ID	Link-local part of the TE link identifier sub-TLV [RFC4203]
Remote SNPP link ID	Link remote part of the TE link identifier sub-TLV [RFC4203]
Signal Type	Technology specific part of the Interface Switching Capability Descriptor sub-TLV [RFC4203]
Link Weight	TE metric sub-TLV [RFC3630]
Resource Class	Administrative Group sub-TLV [RFC3630]
Local Connection Types	Switching Capability field part of the Interface Switching Capability Descriptor sub-TLV [RFC4203]
Link Capacity	Unreserved bandwidth sub-TLV [RFC3630] Max LSP Bandwidth part of the Interface Switching Capability Descriptor sub-TLV [RFC4203]
Link Availability	Link Protection sub-TLV [RFC4203]
Diversity Support	SRLG sub-TLV [RFC4203]
Local Adaptation support	See above

Table 1. TE link attributes in GMPLS OSPF-TE

Link Characteristics	GMPLS IS-IS
-----	-----
Local SNPP link ID	Link-local part of the TE link identifier sub-TLV [RFC4205]
Remote SNPP link ID	Link-remote part of the TE link identifier sub-TLV [RFC4205]
Signal Type	Technology specific part of the Interface Switching Capability Descriptor sub-TLV [RFC4205]
Link Weight	TE Default metric [RFC3784]
Resource Class	Administrative Group sub-TLV [RFC3784]
Local Connection Types	Switching Capability field part of the Interface Switching Capability Descriptor sub-TLV [RFC4205]
Link Capacity	Unreserved bandwidth sub-TLV [RFC3784] Max LSP Bandwidth part of the Interface Switching Capability Descriptor sub-TLV [RFC4205]
Link Availability	Link Protection sub-TLV [RFC4205]
Diversity Support	SRLG sub-TLV [RFC4205]
Local Adaptation support	See above

Table 2. TE link attributes in GMPLS IS-IS-TE

Note: Link Attributes represent layer resource capabilities and their utilization i.e. the IGP should be able to advertise these attributes on a per-layer basis.

5.3.2. Node Attributes

Node attributes are the "Logical Node ID" (described in Section 5.1) and the reachability information described in Section 5.3.3.

5.3.3. Reachability Information

Advertisement of reachability can be achieved using the techniques described in [OSPF-NODE], where the set of local addresses are carried in an OSPF TE LSA node attribute TLV (a specific sub-TLV is defined per address family, e.g., IPv4 and IPv6). However, [OSPF-NODE] is restricted to advertisement of Host addresses and not prefixes, and therefore it requires enhancement (see below). Thus, in order to advertise blocks of reachable address prefixes a summarization mechanism is additionally required. This mechanism may take the form of a prefix length (which indicates the number of significant bits in the prefix) or a network mask.

A similar mechanism does not exist for IS-IS. Moreover, the Extended IP Reachability TLV [RFC3784] focuses on IP reachable end-points (terminating points), as its name indicates.

5.4. Routing Information Abstraction

G.7715.1 describes both static and dynamic methods for abstraction of routing information for advertisement at a different level of the routing hierarchy. However, the information that is advertised continues to be in the form of link and node advertisements consistent with the link state routing protocol used at that level. Hence, no specific capabilities need to be added to the routing protocol beyond the ability to locally identify when routing information originates outside of a particular RA.

The methods used for abstraction of routing information are outside the scope of GMPLS routing protocols.

5.5. Dissemination of Routing Information in Support of Multiple Hierarchical Levels of RAs

G.7715.1 does not define specific mechanisms to support multiple hierarchical levels of RAs beyond the ability to support abstraction as discussed above. However, if RAs bound to adjacent levels of the RA hierarchy are allowed to redistribute routing information in both

directions between adjacent levels of the hierarchy without any additional mechanisms, they would not be able to determine looping of routing information.

To prevent this looping of routing information between levels, IS-IS [RFC1195] allows only advertising routing information upward in the level hierarchy and disallows the advertising of routing information downward in the hierarchy. [RFC2966] defines the up/down bit to allow advertising downward in the hierarchy the "IP Internal Reachability Information" TLV (Type 128) and "IP External Reachability Information" TLV (Type 130). [RFC3784] extends its applicability for the "Extended IP Reachability" TLV (Type 135). Using this mechanism, the up/down bit is set to 0 when routing information is first injected into IS-IS. If routing information is advertised from a higher level to a lower level, the up/down bit is set to 1, indicating that it has traveled down the hierarchy. Routing information that has the up/down bit set to 1 may only be advertised down the hierarchy, i.e., to lower levels. This mechanism applies independently of the number of levels. However, this mechanism does not apply to the "Extended IS Reachability" TLV (Type 22) used to propagate the summarized topology (see Section 5.3), traffic engineering information as listed in Table 1, as well as reachability information (see Section 5.3.3).

OSPFv2 [RFC2328] prevents inter-area routes (which are learned from area 0) from being passed back to area 0. However, GMPLS makes use of Type 10 (area-local scope) LSAs to propagate TE information [RFC3630], [RFC4202]. Type 10 Opaque LSAs are not flooded beyond the borders of their associated area. It is therefore necessary to have a means by which Type 10 Opaque LSA may carry the information that a particular piece of routing information has been learned from a higher-level RC when propagated to a lower-level RC. Any downward RC from this level, which receives an LSA with this information would omit the information in this LSA and thus not re-introduce this information back into a higher-level RC.

5.6. Routing Protocol Convergence

Link state protocols have been designed to propagate detected topological changes (such as interface failures and link attributes modification). The convergence period is short and involves a minimum of routing information exchange.

Therefore, existing routing protocol convergence involves mechanisms that are sufficient for ASON applications.

5.7. Routing Information Scoping

The routing protocol MUST support a single Ri advertising on behalf of more than one Li. Since each Li is identified by a unique TE Router ID, the routing protocol MUST be able to advertise multiple TE Router IDs. That is, for [RFC3630], multiple Router Addresses and for [RFC3784] multiple Traffic Engineering Router Ids.

The Link sub-TLV that is currently part of the top level Link TLV associates the link to the Router_ID. However, having the Ri advertising on behalf of multiple Lis creates the following issue, as there is no longer a 1:1 relationship between the Router_ID and the TE Router_ID, but a 1:N relationship is possible (see Section 5.1). As the link-local and link-remote (unnumbered) ID association may not be unique per abstract node (per Li unicity), the advertisement needs to indicate the remote Lj value and rely on the initial discovery process to retrieve the {Li;Lj} relationship(s). In brief, as unnumbered links have their ID defined on per Li bases, the remote Lj needs to be identified to scope the link remote ID to the local Li. Therefore, the routing protocol MUST be able to disambiguate the advertised TE links so that they can be associated with the correct TE Router ID.

Moreover, when the Ri advertises on behalf multiple Lis, the routing protocol MUST be able to disambiguate the advertised reachability information (see Section 5.3.3) so that it can be associated with the correct TE Router ID.

6. Evaluation Scenarios

The evaluation scenarios are the following; they are respectively referred to as cases 1, 2, 3, and 4.

In Figure 1, below,

- R3 represents an LSR with all components collocated.
- R2 shows how the "router" component may be disjoint from the node.
- R1 shows how a single "router" may manage multiple nodes.

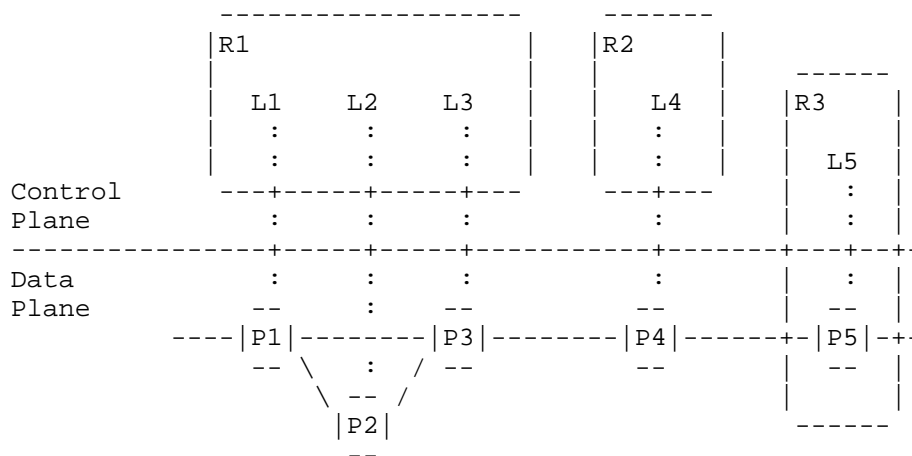


Figure 1. Evaluation Cases 1, 2, and 3

Case 1 as represented refers either to direct links between edges or to "logical links" as shown in Figure 2 (or any combination of them).

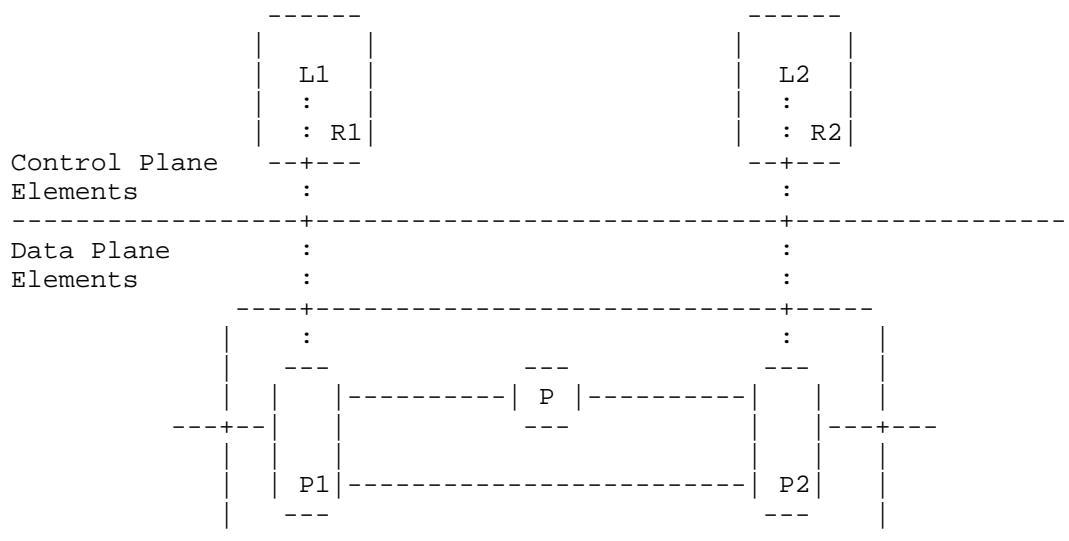


Figure 2. Case 1 with Logical Links

Another case (referred to as Case 4) is constituted by the Abstract Node as represented in Figure 3. There is no internal structure associated (externally) to the abstract node.

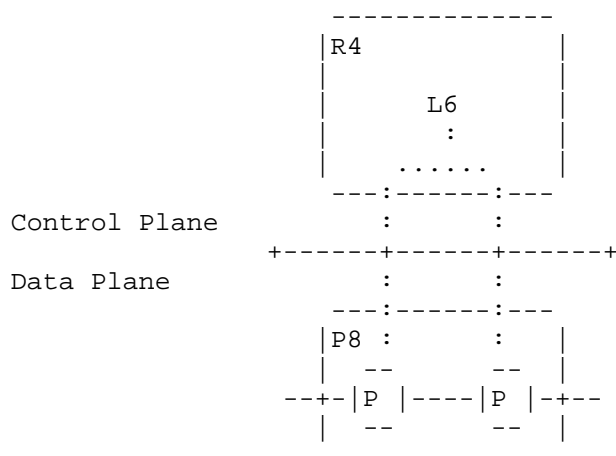


Figure 3. Case 4: Abstract Node

Note: the "signaling function" referred to as Si, i.e., the control plane entity that processes the signaling messages, is not represented in these figures.

7. Summary of Necessary Additions to OSPF and IS-IS

The following sections summarize the additions to be provided to OSPF and IS-IS in support of ASON routing.

7.1. OSPFv2

Reachability	Extend Node Attribute sub-TLVs to support address prefixes (see Section 5.3.3).
Link Attributes	Representation of cross/inter-layer relationships in link top-level link TLV (see Section 5.3.1). Optionally, provide for per-signal-type bandwidth accounting (see Section 5.3.1).
Scoping	TE link advertisements to allow for retrieving their respective local-remote TE Router_ID relationship(s) (see Section 5.7). Prefixes part of the reachability advertisement (using Node Attribute top-level TLV) needs to be associated to its respective local TE Router_ID (see Section 5.7).

Hierarchy Provide a mechanism by which Type 10 Opaque LSA may carry the information that a particular piece of routing information has been learned from a higher-level RC when propagated to a lower-level RC (so as not to re-introduce this information into a higher-level RC).

7.2. IS-IS

Reachability Provide for reachability advertisement (in the form of reachable TE prefixes).

Link Attributes Representation of cross/inter-layer relationships in Extended IS Reachability TLV (see Section 5.3.1).

Optionally, provide for per-signal-type bandwidth accounting (see Section 5.3.1).

Scoping Extended IS Reachability TLVs to allow for retrieving their respective local-remote TE Router_ID relationship(s) (see Section 5.7).

Prefixes part of the reachability advertisement needs to be associated to its respective local TE Router_ID (see Section 5.7).

Hierarchy Extend the up/down bit mechanisms to propagate the summarized topology (see Section 5.3) and traffic engineering information as listed in Table 1, as well as reachability information (see Section 5.3.3).

8. Security Considerations

The introduction of a dynamic control plane to an ASON network exposes it to additional security risks that may have been controlled or limited by the use of management plane solutions. The routing protocols play a part in the control plane and may be attacked so that they become unstable or provide incorrect information for use in path computation or by the signaling protocols.

Nevertheless, there is no reason why the control plane components cannot be secured, and the security mechanisms developed for the routing protocol and used within the Internet are equally applicable within an ASON context.

[RFC4258] describes the requirements for security of routing protocols for the Automatically Switched Optical Network. Reference is made to [M.3016], which lays out the overall security objectives of confidentiality, integrity, and accountability. These are well discussed for the Internet routing protocols in [THREATS].

A detailed discussion of routing threats and mechanisms that are currently deployed in operational networks to counter these threats is found in [OPSECPRACTICES]. A detailed listing of the device capabilities that can be used to support these practices can be found in [RFC3871].

9. Acknowledgements

The authors would like to thank Adrian Farrel for having initiated the proposal of an ASON Routing Solution Design Team and the ITU-T SG15/Q14 for their careful review and input.

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Appendix A. ASON Terminology

This document makes use of the following terms:

Administrative domain (see Recommendation G.805): For the purposes of [G.7715.1], an administrative domain represents the extent of resources that belong to a single player such as a network operator, a service provider, or an end-user. Administrative domains of different players do not overlap amongst themselves.

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 (control) entities that are grouped for a particular purpose. The control plane is subdivided into domains matching administrative domains. Within an administrative domain, further subdivisions of the control plane are recursively applied. A routing control domain is an abstract entity that hides the details of the RC distribution.

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): A "topological component" that describes a fixed relationship between a "subnetwork" or "access group" and another "subnetwork" or "access group". Links are not limited to being provided by a single server trail.

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): A management domain defines a collection of managed objects that are grouped to meet organizational requirements according to geography, technology, policy, or other structure, and for a number of functional areas such as fault, configuration, accounting, performance, and security (FCAPS), for the purpose of providing control in a consistent manner. Management domains can be disjoint, contained, or overlapping. As such, the resources within an administrative domain can be distributed into several possible overlapping management domains.

The same resource can therefore belong to several management domains simultaneously, but a management domain shall not cross the border of an administrative domain.

Subnetwork Point (SNP): The SNP is a control plane abstraction that represents an actual or potential transport plane resource. SNPs (in different subnetwork partitions) may represent the same transport resource. A one-to-one correspondence should not be assumed.

Subnetwork Point Pool (SNPP): A set of SNPs that are grouped together for the purposes of routing.

Termination Connection Point (TCP): A TCP represents the output of a Trail Termination function or the input to a Trail Termination Sink function.

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 Recommendation.

User Network Interface (UNI): Interfaces are located between protocol controllers between a user and a control domain. Note: There is no routing function associated with a UNI reference point.

Appendix B. ASON Routing Terminology

This document makes use of the following terms:

Routing Area (RA): An 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], an RA is defined by a set of sub-networks, the links that interconnect them, and the interfaces representing the ends of the links exiting that RA. An RA may contain smaller RAs inter-connected by links. The limit of subdivision results in an RA that contains two sub-networks interconnected by a single 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 that 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 being 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 possibly to 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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Acknowledgement

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).

