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Applicability of Generalized Multiprotocol Label Switching (GMPLS) User-Network Interface (UNI)

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Abstract

Generalized Multiprotocol Label Switching (GMPLS) defines a series of protocols for the creation of Label Switched Paths (LSPs) in various switching technologies. The GMPLS User-Network Interface (UNI) was

developed in RFC4208 in order to be applied to an overlay network architectural model.

This document examines a number of GMPLS UNI application scenarios. It shows how techniques developed after the GMPLS UNI can be applied to automate or enable critical processes for these applications. This document also suggested simple extensions to existing technologies to further enable the UNI and points out some existing unresolved issues.

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 [RFC2119].

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1. Introduction

Generalized Multiprotocol Label Switching (GMPLS) defines a series of protocols, including Open Shortest Path Fist - Traffic Engineering (OSPF-TE) [RFC4203] and Resource ReserVation Protocol - Traffic Engineering (RSVP-TE) [RFC3473], which can be used to create Label Switched Paths (LSPs) in a number of deployment scenarios with various transport technologies.

The User-Network Interface (UNI) reference point is defined in the Automatically Switched Optical Network (ASON) [G.8080]. According to [G.8080], the UNI may be implemented as a peering between a client-side entity (UNI-C) and a network-side entity (UNI-N). End-to-end connectivity between UNI-C nodes is achieved across the core network by three components: a UNI request from source UNI-C to source UNI-N; a core network connection from source UNI-N to destination UNI-N; and a UNI request from destination UNI-N to destination UNI-C.

The GMPLS overlay model, as per [RFC4208], can be applied at the UNI, as shown in Figure 1.

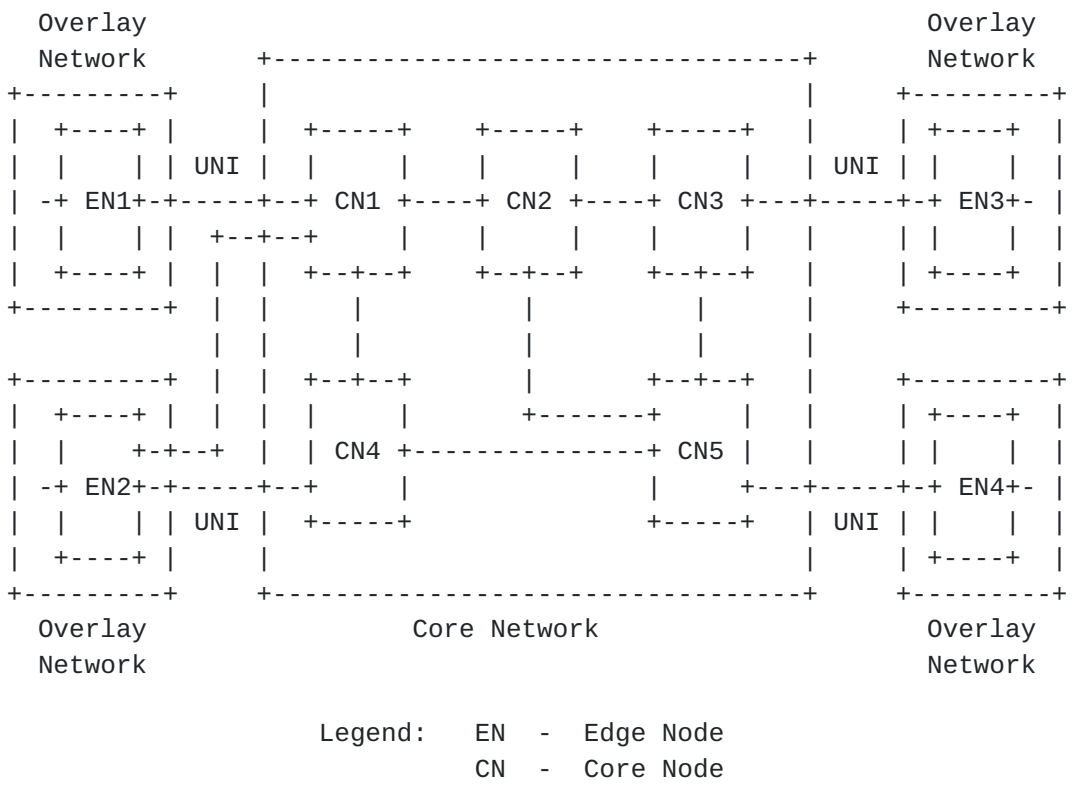


Figure 1 - Applying GMPLS overlay model at UNI

In Figure 1, assume that there is an end-to-end UNI connection passing through EN1-CN1-CN2-CN3-EN3. For convenience, some terms used in this document are defined below:

- "source EN" refers to the edge-node who initiates the connection (e.g., EN1);

- "destination EN" refers to the edge-node where the connection is terminated (e.g., EN3);

- "ingress CN" refers to the core-node to which the source EN is attached (e.g., CN1);

- "egress CN" refers to the core-node to which the destination EN is attached (e.g., CN3).

[RFC4208] provides mechanisms for UNI signaling, which are compatible with GMPLS RSVP-TE signaling ([RFC3471] and [RFC3473]). A single end-to-end RSVP session between source EN and destination EN is used for the user connection, just as it would be for connection creation between two core nodes. However, when considering the isolation of topology information between core network and the overlay network,

additional processing of the RSVP-TE Explicit Route Object (ERO) and Record Route Object (RRO) is required. For example, the ingress CN should verify the ERO it received against its topology database before forwarding the PATH message. And the ingress/egress CN may edit or remove the RRO in order to hide the path segment used inside the core network from the EN.

The UNI can be used in many application scenarios. For example, in a multi-layer network [RFC6001], the interface between client layer node and server layer node can be seen as a UNI. Or, when deploying VPN services such as Layer One Virtual Private Networks (L1VPNs) [RFC4847], [RFC5253], users can connect to a service provider network via a UNI.

This document examines a number of current and future GMPLS application scenarios. It shows how techniques developed after the GMPLS UNI was developed can be used to automate or enable critical aspects of these application scenarios. It points out some potential technology extensions that could improve UNI operation, and highlights some existing unresolved issues.

2. UNI Addressing

In [RFC4208], the GMPLS overlay model is applied at the UNI reference point, and it is required that the edge-node and its attached core-node of the overlay network share the same address space that is used by GMPLS to signal between the edge-nodes across the core network. Under this condition, the user connection can be created using a single end-to-end RSVP session, which is consistent with the RSVP model. Therefore, RSVP-TE defined in [RFC3473] can be used for support GMPLS UNI without any extensions.

However, in the practical deployment of GMPLS UNI, the requirement of sharing the same address space between EN and its attached CN may not be satisfied if the core network and the overlay network are designed and deployed separately, especially if the two networks belong to different carriers. For example, the core network may use IPv6 addresses, while the overlay network uses IPv4 addresses. Or, since the core network is a closed system, the assignment of the IP addresses of the CNs is independent of other IP addresses outside the core network. This implies that the nodes in the core network may use addresses which collide with the edge nodes in the overlay network.

[RFC4208] does not state how to allow that an edge-node and its attached core-node share the same address space, so this document analyzes the addressing deployment scenarios as follows:

1. Overlay network and core network share a common addressing policy. As noted above, there are many situations where this may be impractical, but it might be quite feasible in a multi-layer network operated by a single carrier. In this scenario, end-to-end UNI connectivity may use a single RSVP session, and the core routing information (assuming it is shared and not stripped for confidentiality reasons) will be meaningful to the ENs. Note, however, that the overlay model examined by this document assumes that there is some separation between the overlay and core networks, and this might mean that the overlay network is not able to see the topology or routing information of the core network even when they share a common address space.

2. ENs have visibility into the core network, but overlay and core networks have different address spaces. This is the more common model envisaged by [RFC4208] and for basic mode L1VPN deployments ([RFC5251]), and the previous scenario can be seen to be a special case of this scenario where the two address spaces are complementary. In this deployment, the source EN is aware of the addresses for itself, the ingress CN, the egress CN, and the destination EN in the address space of the core network. It may also have full visibility into the core network, but this is not a requirement.

   In this scenario, the ENs are responsible for performing address mapping between the overlay network's addresses for the ENs, and the core network's addresses for the same nodes and/or its TE links. A typical deployment may assign addresses in the core network address space for the EN and/or its TE links at the EN side, so that EN can use these addresses to communicate with the core network for UNI connection provisioning.

   In this deployment, a single end-to-end RSVP-TE session can still be utilized from source EN to destination EN.

3. ENs do not have any knowledge of the core address space, or do not support the address space the core network is used (e.g., ENs do not support IPv6 that is used by the core network), ENs will have no visibility into the core network.

   In this scenario, the ingress CN is responsible for mapping addresses to the core address space and for filling in any additional routing information. A typical deployment may assign

addresses in the overlay address space for the ingress CN and/or its TE links at the CN side, so that the EN can use overlay addresses to reach the ingress CN and to identify the destination EN.

In this deployment the end-to-end connectivity must be created either using "session stitching" (see Section 5.2) or "session shuffling" (see Section 5.3).

3. UNI Auto Discovery

When the end-to-end connection is set up across the core network it must be targeted at the destination CN so that it can be extended to the destination EN. This means that either the source EN must know the identity of the destination CN to which the destination EN is attached, or the source CN must know this information. This requires some form of "discovery" (possibly including configuration), and depending on the addressing scheme in use (see Section 2) will require address mapping to be performed by the source EN or the source CN.

The discovery problem may be exacerbated when the a variety of services may be requested since the source EN will need to know the capabilities and available resources on the link between the destination CN and the destination EN. It could discover this by attempting to set up a connection and by drawing conclusions from the connection setup failures, but this is not efficient. Furthermore, in the case of a dual-homed destination EN (such as EN2 in Figure 1), a choice of destination CN must be made, and that choice may be influenced by the capabilities and available resources on the CN-EN links leading to the destination EN.

If the UNI is applied in L1VPN scenario, the auto discovery of UNI using OSPFv2 is provided in [RFC5252]. A new L1VPN LSA is introduced to advertise the L1VPN information via the L1VPN info TLV and the TE information of the CE-PE link (in the language of UNI, it's the EN-CN link) via the TE link TLV.

4. UNI Path Computation

End-to-end UNI path computation includes three parts: the selection of the source UNI link, the path computation inside the core network and the selection of the destination UNI link.

The selection of UNI links may not necessary in some scenarios. One example is in case of single-homing with only one UNI link between EN and CN, and another example is manual selection of UNI link when the service is requested. In such cases, the CN to which the source EN is attached, or the path Computation Element (PCE) ([RFC4655]) which is responsible for the core network, can perform the path computation across the core network when the UNI signaling request is sent from the source EN to the source CN.

4.1. UNI Link Selection

This document is specific to the overlay architectural model to the source EN which does not have the topology and TE information of the core network. Therefore, in the case of multi-homing (i.e., the source EN is connected to more than one CN), the source EN does not have enough information to make a correct choice among all the UNI links between itself and the core network for an optimal end-to-end connection.

In this case, a PCE whose computation domain covers both the core network and the ENs attached to it can be used. Note that the GMPLS UNI predates PCE and hence a PCE was not available to solve this problem in early GMPLS UNI deployments. The PCE that has the topology and TE information of the core network can use the UNI discovery mechanism described in Section 3 to learn the EN-CN relationship and the TE information of the UNI links, and therefore has the ability to select the optimal UNI link for the connection.

Figure 2 shows the procedure of UNI path computation using a single PCE with visibility into both networks. When the UNI path computation request is received, the PCE can help the source EN to compute the end-to-end route of the UNI connection based on routing information it learned, so that the source EN can create the UNI connection using the optimal UNI links.

Alternatively, the path can be computed by cooperating PCEs, as shown in Figure 3. The source EN does not experience any difference in behavior in that it sends its computation request to its local PCE, and receives a response telling it what path to use. However, the local PCE may not be aware of the topology of the core network and may need to contact a second PCE to supply the missing information.

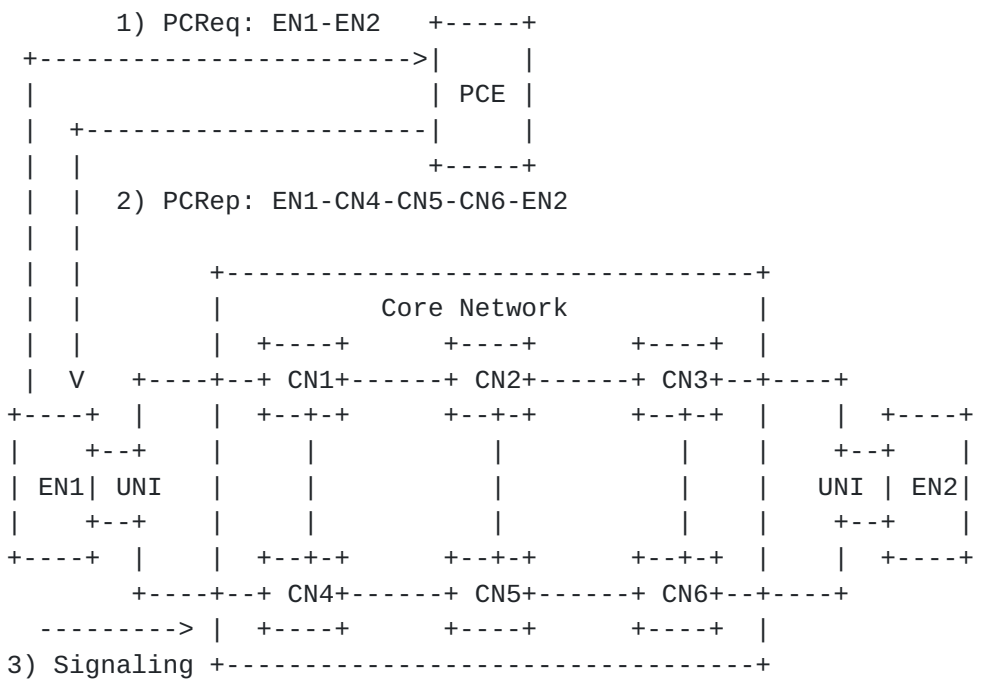
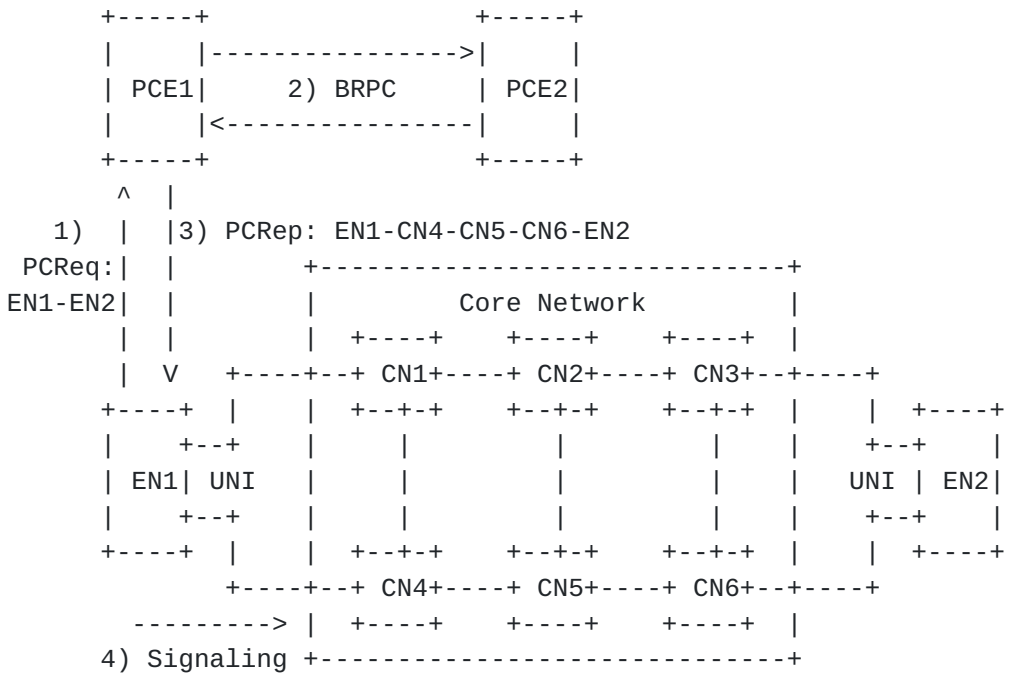


Figure 2 - PCE for UNI path computation (1)



(BRPC: Backward-Recursive PCE-Based Computation, see [RFC5441])

Figure 3 - PCE for UNI path computation (2)

If confidentiality of the topology within the core network needs to be preserved, the Path Key Subobject (PKS) can be used for either approach outlined here (see [RFC5520] and [RFC5553]). In the PCRep message returned to EN1, the Confidential Path Segment (CPS) (i.e., CN4-CN5-CN6) is encoded as a PKS by the PCE. Therefore, the EN1 only learns the selected UNI link from PCE. When receiving the UNI signaling carrying the PKS from EN1, CN4 can request the PCE to decode the PKS and then continue to create the connection.

Note that in both cases the PCE should be visible to the ENs and there should be control channel between PCE and EN for the transmission of PCEP messages. An alternative implementation could be that the PCE is located inside each CN to which the source EN is attached, so that the source EN can use the UNI control channel to send and receive the PCEP messages.

5. UNI Path Provisioning

The basic GMPLS UNI application is to provide end-to-end connections between edge-nodes through a core network via the overlay model.

5.1. Flat Model

The edge-nodes may have the same switching capability and switching capacity as the nodes in the core network. In this case, one single end-to-end RSVP session through the edge-nodes and a series of core-nodes can be used to create the connection, which forms a flat LSP model, as shown in Figure 4.

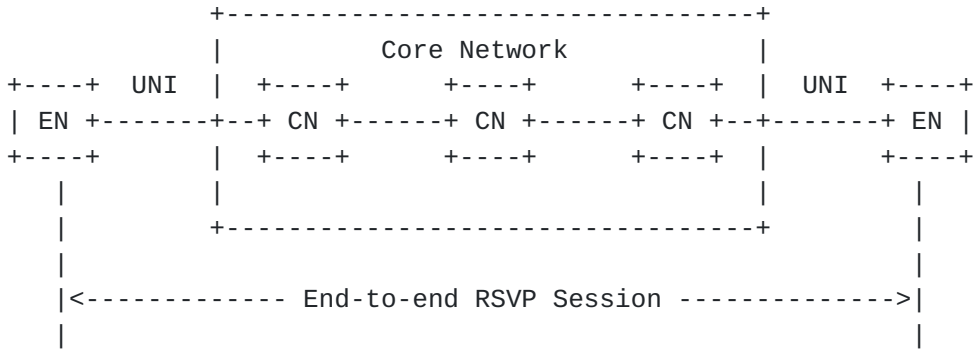


Figure 4 - Flat model

If the edge-nodes and their attached core-nodes share the same address space, or the ENs can perform address mapping into the core network address space, the GMPLS signaling described in [RFC3471], [RFC3473] and other related standards, with special ERO and RRO

processing as described in [RFC4208], can be used to create a connection.

5.2. Stitching Model

Alternatively, the stitching mechanism described in [RFC5150] can be used to create an LSP segment (S-LSP) between the ingress and the egress CN, and to stitch the end-to-end UNI connection to the created S-LSP, as shown in Figure 5.

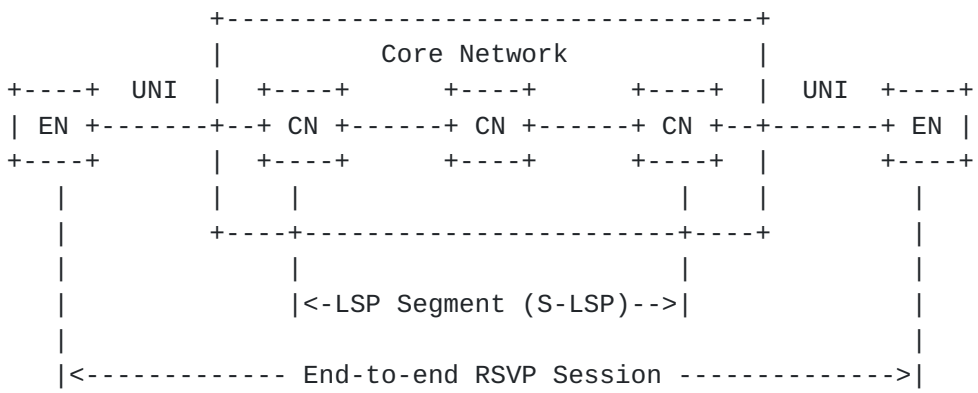


Figure 5 - Stitching model

5.3. Session Shuffling Model

The session shuffling approach ([RFC5251]) is a hybrid of the flat model and the stitching model described in the previous two sections. In this approach a single end-to-end session is established, but as the signaling messages pass through the ingress and egress CNs, address mapping is performed on all addresses carried by the messages to place the addresses into the correct address spaces. The ERO and RRO would normally be stripped (as previously discussed) but the important session identifiers (the source and destination addresses) are changed giving the impression that the session identifiers have been changed.

5.4. Hierarchy Model

In case that the ENs and the CNs have the same switching capability, a tunnel between the ingress and egress core-nodes can be provisioned. The tunnel may have a larger capacity than the end-to-end UNI connection, which may depend on the policies configured at the ingress of the core network. The end-to-end connection can be nested into the tunnel, which forms the LSP hierarchy.

Another case is that the edge-nodes have different switching capabilities with the core network. In such a case, the LSP hierarchy model should also be used.

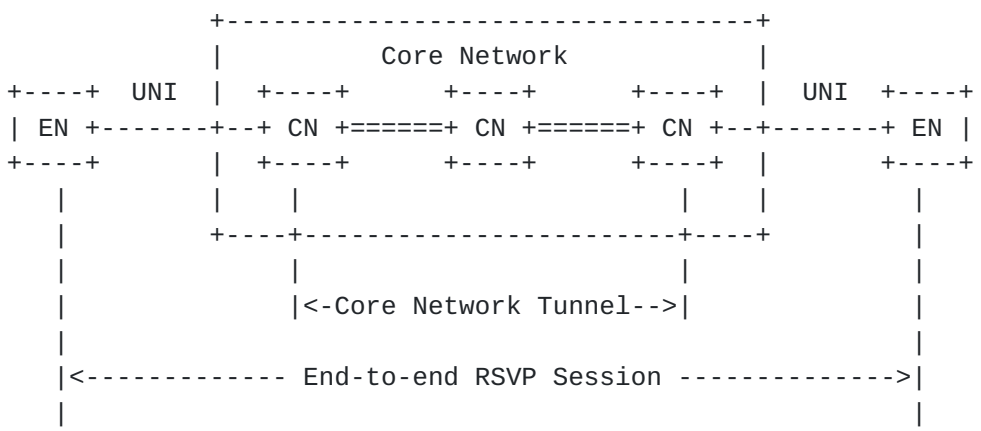


Figure 6 - Hierarchy model

In the hierarchy model, the end-to-end connection can be divided into three hops: one for each UNI link and one hop across the core network. The core network tunnel can be pre-provisioned via network planning, or triggered by the UNI signal. For the latter case, the [RFC5212], [RFC6001] and other multi-layer network related standards are possible to be used to create the hierarchical LSP.

6. UNI Recovery

One of the significant uses of GMPLS is to provide recovery mechanisms for connections, which is also needed in many UNI scenarios.

6.1. End-to-end Recovery

In the case of multi-homing, UNI end-to-end recovery is possible. As shown in Figure 7, the working path (W) and the protection path (P) are disjoint from each other not only inside the core network, but also at both the source and destination sides of the UNI. Mechanisms need to be provided to ensure the selection of disjoint working and backup paths.

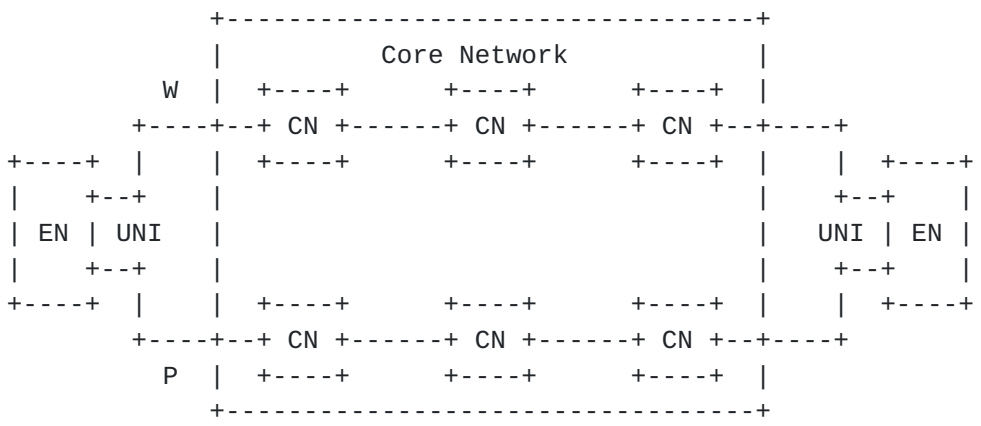


Figure 7 - UNI end-to-end recovery

6.1.1. Serial Provisioning of Working & Protection Path

In the case that the working path is computed and created before the protection path, path computation needs to compute a disjoint (or maximally disjoint) protection path given this existing working path.

If the information concerning the working path segment traversing the core network is known by the EN without considering the confidentiality, then the EN can easily use the RRO to collect the working path information, and use the XRO to exclude the working path when creating the protection path, as described in [RFC4874].

But in most cases, in order to preserve the confidentiality of topology within the core network, the information of path segment traversing the core network should be hidden from the EN. In such case, the RRO & XRO mechanism in [RFC4874] cannot be used. An alternative would be to only collect the Shared Risk Group (SRG) information but not the full path information. This is because the SRG information is normally less confidential than the information of node ID and link ID.

In an application scenario where a PCE is involved inside the core network, then the Path Key mechanism can be used. The confidential path segment, i.e., the working path segment traversing the core network, is encoded as a PKS by the PCE when computing the working path. This PKS can be brought to the source EN, so when it request that the PCE compute a protection path, the PKS can be used to exclude the working path segment inside the core network.

[RFC5520] provides a mechanism to hide the CPS using PKS in the PCEP message, while [RFC5553] makes extensions to RSVP-TE to carry the PKS in ERO and RRO objects. It is required that the PKS should also be

allowed to be carried in the XRO in both PCEP message and RSVP-TE signaling.

6.1.2. Concurrent Computation of Working & Protection Path

Alternatively, the working and protection path can be computed at the same time (e.g., by PCE or by one of the CNs to which the source EN is attached).

[PCE-GMPLS] allows requesting the PCE for path computation with specified protection type defined in [RFC4872]. Therefore, it's possible that the source EN requests the edge CN or PCE to compute both the working and the protection path at the same time. At this time, the disjunction problem can be resolved inside the path computation server.

Same as described in the previous section, the path segment traversing the core network can be encoded as a PKS if confidentiality is requested.

6.2. Segment Recovery

The UNI connection may only request protection inside the core network, especially in case of single-homing. One UNI segment protection example is shown in Figure 8.

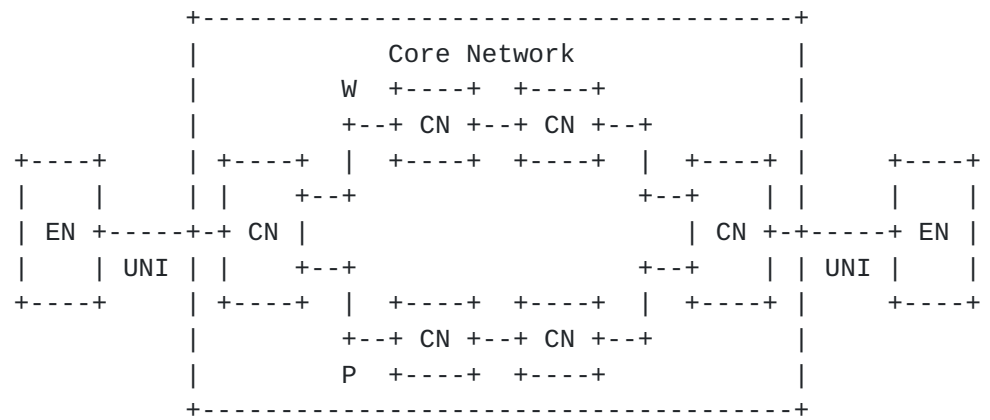


Figure 8 - UNI segment recovery

[RFC4873] provides the mechanism of segment recovery, in which the PROTECTION Object is extended to indicate the segment recovery, and

the SERO object is introduced for the explicit control of the protection LSP between the branch node and the merge node.

However, due to the overlay model, the source EN may not have the information concerning the CN to which the destination EN is attached. In other words, the source EN does not know which node is the merge node of the UNI segment protection, so the SERO object cannot be used to request the edge CN for the UNI segment recovery. Therefore, segment recovery may not be controlled explicitly by the source EN.

7. UNI Call

The Call is a fundamental component of the ASON model [G.8080]. It is used to maintain the association between one or more user applications and the network to control the set-up, release, modification and maintenance of sets of connections. In simple cases, the Call and Connection can be established at the same time and in a strict one-to-one ratio. In this case, Call signaling is simple and requires only minor extensions to connection signaling. However, if Calls are to be handled separately from Connections, or if more than one Connection can be associated with a single Call, additional Call signaling is required.

The GMPLS Call, defined in [RFC4974], provides a mechanism to negotiate agreement between endpoints possibly in cooperation with the nodes that provide access to the network. Typically the GMPLS Call can be applied in the UNI scenario for access link capability exchange, policy, authorization, security, and so on.

7.1. Exchange of UNI Link Information

It is possible that the TE attributes of the access link (i.e., the UNI link) are not shared across the core network. So the source EN may not have the TE information of the destination access link as well as the capability of the destination EN. For example, in case of TDM network, the Virtual Concatenation (VCAT) and Link Capacity Adjustment Scheme (LCAS) capability of the destination EN may not be known.

In this case, the source EN can raise a Call carrying the LINK_CAPABILITY object to have a capability exchange with the destination EN, as described in [RFC4974].

7.2. Control of Call Route

When applying the Call, it's possible that there are multiple core network domains between the source EN (Call initiator) and the destination EN (Call terminator), or there is more than one Call manager in the core network (e.g., in the multi-homing scenario where the CNs to which the ENs are attached act as the Call managers).

In the both cases, when establishing the Call, there may be multiple alternative routes for the Call message to reach the destination EN. One can simply use the hop-by-hop manner (i.e., each Call manager determines the next Call manager to which the Call message will be sent by itself) to control the path of the Call.

However, in the practical deployment of UNI Call, commercial and policy motivations normally play an important role in selecting the Call route, especially in the multi-domain scenario. In this case, the hop-by-hop manner is not practical because the route of the Call needs to be pre-determined in consideration of commercial and policy factors before establishing the Call.

Therefore, it is desirable to allow full control of the Call by the source EN. That is, the source EN can identify the full Call route and signal it explicitly, so that the Call message can be forwarded along the desired route. Moreover, the management plane needs to be able to identify the Call route explicitly as an instruction to the source EN.

8. UNI Multicast

Data plane multicasting is supported in the existing Traffic-Engineering networks. GMPLS provides extensions to the RSVP-TE to support provisioning of point-to-multipoint (P2MP) TE LSPs via control plane, as described in [RFC4461] and [RFC4875].

In the scenarios where the overlay architectural model is used, it's a requirement to transport signals from one source EN to multiple destination ENs which are located in other overlay networks. One could create multiple point-to-point connections between the source EN and each destination EN, but it will be a waste of bandwidth resource of both UNI links and the core network.

Therefore, there are some scenarios required to support point-to-multipoint (P2MP) TE LSPs from one source EN to multiple leaf ENs.

8.1. UNI Multicast Connection Model

There are two cases for the UNI multicast. For the first case, only the ingress and egress CNs in the core network support the multicast. The core network has to provide multiple P2P connections between ingress CN and each egress CN for the end-to-end UNI multicast, as shown in Figure 9.

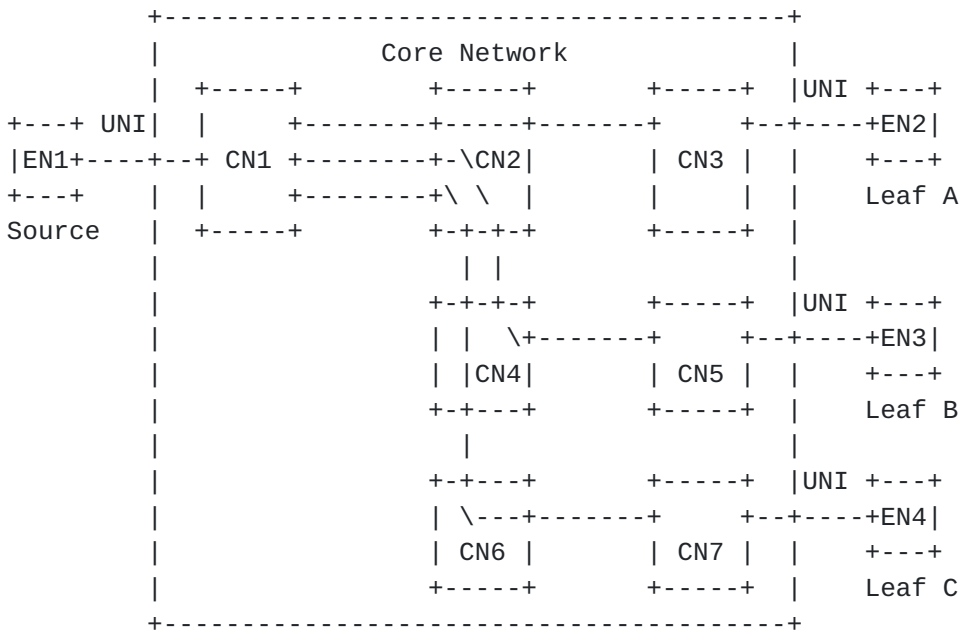


Figure 9 - Only ingress/egress CNs support multicast

For example, in the PSC over TDM multi-layer scenario, the ingress/egress CNs may have the packet multicast capability and therefore can adapt the packets from EN into multiple TDM connections inside the core network, while other CNs inside the core network may only support point-to-point (P2P) TDM connections.

In another case, all the CNs in the core network can support multicast, so that the core network can create a P2MP LSP to provide the end-to-end UNI multicast, as shown in Figure 10.

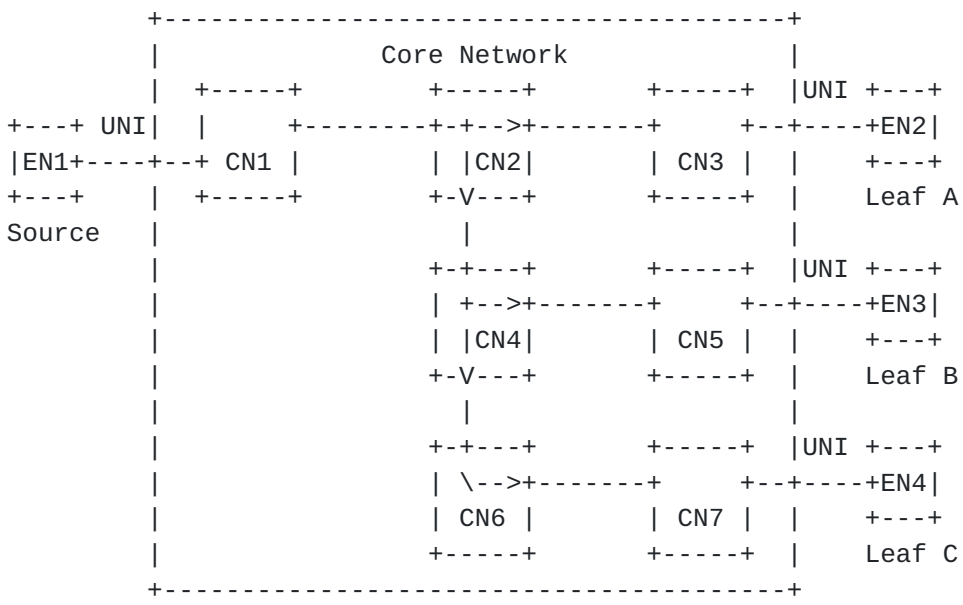


Figure 10 - All CNs support multicast

For example, in the Ethernet over OTN scenario, if the core network can support ODU0 multicast, then an ODU0 P2MP LSP can be created inside the core network to carry the client Gigabit Ethernet (GE) signal for the ENs.

Note that the branching of the multicast may also happen at the source EN in the multi-homing scenario. In this case, each branch of the source EN uses a separate UNI link connecting the source EN to the core network. For each UNI branch, the connection model inside the core network is the same as described in this section.

8.2. UNI Multicast Connection Provisioning

The four UNI connection provisioning models, as described in Section 5, should also be applied in the UNI multicast scenario.

For the flat model, one end-to-end P2MP session as described in [RFC4875] can be used directly to create the P2MP LSP from source EN to leaf ENs.

For the stitching model, multiple P2P LSP segments or one P2MP LSP segment between the ingress CN and each egress CNs needs to be created and then stitched to the UNI P2MP LSP. GMPLS UNI signaling should have the capability to convey the multicast information by using stitching model.

For the session shuffling model, one end-to-end P2MP session can be used to create the P2MP LSP, with an address mapping performed at both ingress and egress CNs.

For the hierarchy model, multiple P2P LSP tunnels or one P2MP LSP tunnel between the ingress CN and each egress CNs needs be triggered by the UNI signaling for creating P2MP LSP. GMPLS UNI signaling should have the capability to convey the multicast information by using hierarchy model.

9. Security Considerations

[RFC5920] provides an overview of security vulnerabilities and protection mechanisms for the GMPLS control plane, which is applicable to this document.

The details of the specific security measures of the overlay network architectural model are provided in [RFC4208], which permits the core network to filter out specific RSVP objects to hide its topology from the EN.

Furthermore, if PCE is used, the security issues described in [RFC4655] and other related standards should also be considered.

Additionally, when the PKS mechanism is applied, the security issues can be dealt with using [RFC5520] and [RFC5553].

10. IANA Considerations

This informational document does not make any requests for IANA action.

11. Acknowledgments

TBD.

12. References

12.1. Normative References

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