           Requirements for Generalized MPLS (GMPLS) Signaling Usage
      and Extensions for Automatically Switched Optical Network (ASON)

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Abstract

   The Generalized Multi-Protocol Label Switching (GMPLS) suite of
   protocols has been defined to control different switching
   technologies and different applications. These include support for
   requesting Time Division Multiplexing (TDM) connections, including
   Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy
   (SDH) and Optical Transport Networks (OTNs).

   This document concentrates on the signaling aspects of the GMPLS
   suite of protocols. It identifies the features to be covered by the
   GMPLS signaling protocol to support the capabilities of an
   Automatically Switched Optical Network (ASON). This document
   provides a problem statement and additional requirements for the
   GMPLS signaling protocol to support the ASON functionality.

1. Introduction

   The Generalized Multi-Protocol Label Switching (GMPLS) suite of
   protocol specifications provides support for controlling different
   switching technologies and different applications. These include
   support for requesting Time Division Multiplexing (TDM) connections,
   including Synchronous Optical Network (SONET)/Synchronous Digital
   Hierarchy (SDH) (see [ANSI-T1.105] and [ITU-T-G.707], respectively),
   and Optical Transport Networks (see [ITU-T-G.709]). In addition,
   there are certain capabilities needed to support Automatically
   Switched Optical Networks control planes (their architecture is
   defined in [ITU-T-G.8080]). These include generic capabilities such
   as call and connection separation, along with more specific
   capabilities such as support of soft permanent connections.

   This document concentrates on requirements related to the signaling
   aspects of the GMPLS suite of protocols. It discusses the functional
   requirements required to support Automatically Switched Optical
   Networks that may lead to additional extensions to GMPLS signaling
   (see [RFC3471] and [RFC3473]) to support these capabilities. In
   addition to ASON signaling requirements, this document includes GMPLS
   signaling requirements that pertain to backward compatibility
   (Section 5). A terminology section is provided in the Appendix.

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 [RFC2119].

   While [RFC2119] describes interpretations of these key words in terms
   of protocol specifications and implementations, they are used in this
   document to describe design requirements for protocol extensions.

3. Problem Statement

   The Automatically Switched Optical Network (ASON) architecture
   describes the application of an automated control plane for
   supporting both call and connection management services (for a
   detailed description see [ITU-T-G.8080]). The ASON architecture
   describes a reference architecture, (i.e., it describes functional
   components, abstract interfaces, and interactions).

   The ASON model distinguishes reference points (representing points of
   information exchange) defined (1) between a user (service requester)
   and a service provider control domain, a.k.a. user-network interface
   (UNI), (2) between control domains, a.k.a. external network-network
   interface (E-NNI), and, (3) within a control domain, a.k.a. internal

   network-network interface (I-NNI). The I-NNI and E-NNI interfaces
   are between protocol controllers, and may or may not use transport
   plane (physical) links. It must not be assumed that there is a one-
   to-one relationship between control plane interfaces and transport
   plane (physical) links, control plane entities and transport plane
   entities, or control plane identifiers for transport plane resources.

   This document describes requirements related to the use of GMPLS
   signaling (in particular, [RFC3471] and [RFC3473]) to provide call
   and connection management (see [ITU-T-G.7713]). The functionality to
   be supported includes:

       (a) soft permanent connection capability
       (b) call and connection separation
       (c) call segments
       (d) extended restart capabilities during control plane failures
       (e) extended label association
       (f) crankback capability
       (g) additional error cases

4. Requirements for Extending Applicability of GMPLS to ASON

   The following sections detail the signaling protocol requirements for
   GMPLS to support the ASON functions listed in Section 3. ASON
   defines a reference model and functions (information elements) to
   enable end-to-end call and connection support by a protocol across
   the respective interfaces, regardless of the particular choice of
   protocol(s) used in a network. ASON does not restrict the use of
   other protocols or the protocol-specific messages used to support the
   ASON functions. Therefore, the support of these ASON functions by a
   protocol shall not be restricted by (i.e., must be strictly
   independent of and agnostic to) any particular choice of UNI, I-NNI,
   or E-NNI used elsewhere in the network. To allow for interworking
   between different protocol implementations, [ITU-T-G.7713] recognizes
   that an interworking function may be needed.

   In support of the G.8080 end-to-end call model across different
   control domains, end-to-end signaling should be facilitated
   regardless of the administrative boundaries, protocols within the
   network, or the method of realization of connections within any part
   of the network. This implies the need for a clear mapping of ASON
   signaling requests between GMPLS control domains and non-GMPLS
   control domains. This document provides signaling requirements for
   G.8080 distributed call and connection management based on GMPLS,
   within a GMPLS based control domain (I-NNI), and between GMPLS based
   control domains (E-NNI). It does not restrict use of other (non
   GMPLS) protocols to be used within a control domain or as an E-NNI or
   UNI. Interworking aspects related to the use of non-GMPLS protocols,

such as UNI, E-NNI, or I-NNI -- including mapping of non-GMPLS
protocol signaling requests to corresponding ASON signaling
functionality and support of non-GMPLS address formats -- is not
within the scope of the GMPLS signaling protocol. Interworking
aspects are implementation-specific and strictly under the
responsibility of the interworking function and, thus, outside the
scope of this document.

By definition, any User-Network Interface (UNI) that is compliant
with [RFC3473] (e.g., [GMPLS-OVERLAY] and [GMPLS-VPN]) is considered
to be included within the GMPLS suite of protocols and MUST be
supported by the ASON GMPLS signaling functionality.

Compatibility aspects of non-GMPLS systems (nodes) within a GMPLS
control domain (i.e., the support of GMPLS systems and other systems
that utilize other signaling protocols or some that may not support
any signaling protocols) is described. For example, Section 4.5,
'Support for Extended Label Association', covers the requirements for
when a non-GMPLS capable sub-network is introduced or when nodes do
not support any signaling protocols.

4.1. Support for Soft Permanent Connection (SPC) Capability

A Soft Permanent Connection (SPC) is a combination of a permanent
connection at the source user-to-network side, a permanent connection
at the destination user-to-network side, and a switched connection
within the network. An Element Management System (EMS) or a Network
Management System (NMS) typically initiates the establishment of the
switched connection by communicating with the node that initiates the
switched connection (also known as the ingress node). The latter
then sets the connection using the distributed GMPLS signaling
protocol. For the SPC, the communication method between the EMS/NMS
and the ingress node is beyond the scope of this document (as it is
for any other function described in this document).

The end-to-end connection is thus created by associating the incoming
interface of the ingress node with the switched connection within the
network, along with the outgoing interface of the switched connection
terminating network node (also referred to as egress node). An SPC
connection is illustrated in the following figure. This shows the
user's node A connected to a provider's node B via link #1, the
user's node Z connected to a provider's node Y via link #3, and an
abstract link #2 connecting the provider's node B and node Y. Nodes
B and Y are referred to as the ingress and egress (respectively) of
the network switched connection.

```
        ---         ---                     ---        ---
       | A |--1--| B |-----2-//------| Y |--3--| Z |
        ---         ---                     ---        ---
```

   In this instance, the connection on link #1 and link #3 are both
   provisioned (permanent connections that may be simple links). In
   contrast, the connection over link #2 is set up using the distributed
   control plane. Thus, the SPC is composed of the stitching of link
   #1, #2, and #3.

   Thus, to support the capability of requesting an SPC connection:

   - The GMPLS signaling protocol MUST be capable of supporting the
      ability to indicate the outgoing link and label information used
      when setting up the destination provisioned connection.

   - In addition, due to the inter-domain applicability of ASON
      networks, the GMPLS signaling protocol SHOULD also support
      indication of the service level requested for the SPC. In cases
      where an SPC spans multiple domains, indication of both source and
      destination endpoints controlling the SPC request MAY be needed.
      These MAY be done via the source and destination signaling
      controller addresses.

   Note that the association at the ingress node, between the permanent
   connection and the switched connection, is an implementation matter
   that may be under the control of the EMS/NMS and is not within the
   scope of the signaling protocol. Therefore, it is outside the scope
   of this document.

4.2. Support for Call and Connection Separation

   A call may be simply described as "An association between endpoints
   that supports an instance of a service" [ITU-T-G.8080]. Thus, it can
   be considered a service provided between two end-points, wherein
   several calls may exist between them. Multiple connections may be
   associated with each call. The call concept provides an abstract
   relationship between two users. This relationship describes (or
   verifies) the extent to which users are willing to offer (or accept)
   service to/from each other. Therefore, a call does not provide the
   actual connectivity for transmitting user traffic; it only builds a
   relationship by which subsequent connections may be made.

   A call MAY be associated with zero, one, or multiple connections.
   For the same call, connections MAY be of different types and each
   connection MAY exist independently of other connections (i.e., each
   connection is setup and released with separate signaling messages).

The concept of the call allows for a better flexibility in how end-
points set up connections and how networks offer services to users.
For example, a call allows:

- An upgrade strategy for control plane operations, where a call
   control component (service provisioning) may be separate from the
   actual nodes hosting the connections (where the connection control
   component may reside).

- Identification of the call initiator (with both network call
   controller, as well as destination user) prior to connection,
   which may result in decreasing contention during resource
   reservation.

- General treatment of multiple connections, which may be associated
   for several purposes; for example, a pair of working and recovery
   connections may belong to the same call.

To support the introduction of the call concept, GMPLS signaling
SHOULD include a call identification mechanism and SHOULD allow for
end-to-end call capability exchange.

For instance, a feasible structure for the call identifier (to
guarantee global uniqueness) MAY concatenate a globally unique fixed
ID (e.g., may be composed of country code or carrier code) with an
operator specific ID (where the operator specific ID may be composed
of a unique access point code - such as source node address - and a
local identifier). Other formats SHALL also be possible, depending
on the call identification conventions between the parties involved
in the call setup process.

4.3. Support for Call Segments

   As described in [ITU-T-G.8080], call segmentation MAY be applied when
   a call crosses several control domains. As such, when the call
   traverses multiple control domains, an end-to-end call MAY consist of
   multiple call segments. For a given end-to-end call, each call
   segment MAY have one or more associated connections, and the number
   of connections associated with each call segment MAY be different.

   The initiating caller interacts with the called party by means of one
   or more intermediate network call controllers, located at control
   domain boundaries (i.e., at inter-domain reference points, UNI or
   E-NNI). Call segment capabilities are defined by the policies
   associated at these reference points.

   This capability allows for independent (policy based) choices of
   signaling, concatenation, data plane protection, and control plane
   driven recovery paradigms in different control domains.

4.4. Support for Extended Restart Capabilities

   Various types of failures may occur, affecting the ASON control
   plane. Requirements placed on control plane failure recovery by
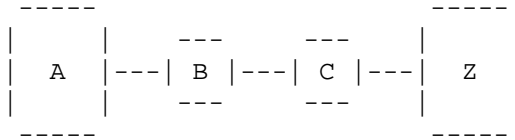   [ITU-T-G.8080] include:

   - Any control plane failure (i.e., single or multiple control
      channel and/or controller failure and any combination thereof)
      MUST NOT result in releasing established calls and connections
      (including the corresponding transport plane connections).

   - Upon recovery from a control plane failure, the recovered control
      entity MUST have the ability to recover the status of the calls
      and the connections established before failure occurrence.

   - Upon recovery from a control plane failure, the recovered control
      entity MUST have the ability to recover the connectivity
      information of its neighbors.

   - Upon recovery from a control plane failure, the recovered control
      entity MUST have the ability to recover the association between
      the call and its associated connections.

   - Upon recovery from a control plane failure, calls and connections
      in the process of being established (i.e., pending call/connection
      setup requests) SHOULD be released or continued (with setup).

   - Upon recovery from a control plane failure, calls and connections
      in the process of being released MUST be released.

4.5. Support for Extended Label Association

   It is an ASON requirement to enable support for G.805 [ITU-T-G.805]
   serial compound links. The text below provides an illustrative
   example of such a scenario, and the associated requirements.

   Labels are defined in GMPLS (see [RFC3471]) to provide information on
   the resources used on a link local basis for a particular connection.
   The labels may range from specifying a particular timeslot,
   indicating a particular wavelength, or to identifying a particular
   port/fiber. In the ASON context, the value of a label may not be
   consistent across a link. For example, the figure below illustrates

the case where two GMPLS capable nodes (A and Z) are interconnected
across two non-GMPLS capable nodes (B and C), where all of these
nodes are SONET/SDH nodes, providing, for example, a VC-4 service.

```
        -----                           -----
       |     |     ---         ---     |     |
       |  A  |---| B |---| C |---|  Z  |
       |     |     ---         ---     |     |
        -----                           -----
```

Labels have an associated implicit imposed structure based on
[GMPLS-SONET] and [GMPLS-OTN]. Thus, once the local label is
exchanged with its neighboring control plane node, the structure of
the local label may not be significant to the neighbor node, as the
association between the local and the remote label may not
necessarily be the same. This issue does not present a problem in
simple point-to-point connections between two control plane-enabled
nodes in which the timeslots are mapped 1:1 across the interface.
However, if a non-GMPLS capable sub-network is introduced between
these nodes (as in the above figure, where the sub-network provides
re-arrangement capability for the timeslots), label scoping may
become an issue.

In this context, there is an implicit assumption that the data plane
connections between the GMPLS capable edges already exist prior to
any connection request. For instance, node A's outgoing VC-4's
timeslot #1 (with SUKLM label=[1,0,0,0,0]), as defined in
[GMPLS-SONET]), may be mapped onto node B's outgoing VC-4's timeslot
#6 (label=[6,0,0,0,0]), or may be mapped onto node C's outgoing VC-
4's timeslot #4 (label=[4,0,0,0,0]). Thus, by the time node Z
receives the request from node A with label=[1,0,0,0,0], node Z's
local label and timeslot no longer correspond to the received label
and timeslot information.

As such, to support this capability, a label association mechanism
SHOULD be used by the control plane node to map the received (remote)
label into a locally significant label. The information necessary to
allow mapping from a received label value to a locally significant
label value can be derived in several ways including:

- Manual provisioning of the label association

- Discovery of the label association

Either method MAY be used. In case of dynamic association, the
discovery mechanism operates at the timeslot/label level before the
connection request is processed at the ingress node. Note that in
the case where two nodes are directly connected, no association is

required. In particular, for directly connected TDM interfaces, no
mapping function (at all) is required due to the implicit label
structure (see [GMPLS-SONET] and [GMPLS-OTN]). In these instances,
the label association function provides a one-to-one mapping of the
received to local label values.

4.6. Support for Crankback

Crankback has been identified as an important requirement for ASON
networks. Upon a setup failure, it allows a connection setup request
to be retried on an alternate path that detours around a blocked link
or node (e.g., because a link or a node along the selected path has
insufficient resources).

Crankback mechanisms MAY also be applied during connection recovery
by indicating the location of the failed link or node. This would
significantly improve the successful recovery ratio for failed
connections, especially in situations where a large number of setup
requests are simultaneously triggered.

The following mechanisms are assumed during crankback signaling:

- The blocking resource (link or node) MUST be identified and
   returned in the error response message to the repair node (that
   may or may not be the ingress node); it is also assumed that this
   process will occur within a limited period of time.

- The computation (from the repair node) of an alternate path around
   the blocking link or node that satisfies the initial connection
   constraints.

- The re-initiation of the connection setup request from the repair
   node (i.e., the node that has intercepted and processed the error
   response message).

The following properties are expected for crankback signaling:

- Error information persistence: the entity that computes the
   alternate (re-routing) path SHOULD store the identifiers of the
   blocking resources, as indicated in the error message, until the
   connection is successfully established or until the node abandons
   rerouting attempts. Since crankback may happen more than once
   while establishing a specific connection, the history of all
   experienced blockages for this connection SHOULD be maintained (at
   least until the routing protocol updates the state of this
   information) to perform an accurate path computation that will
   avoid all blockages.

   - Rerouting attempts limitation: to prevent an endless repetition of
      connection setup attempts (using crankback information), the
      number of retries SHOULD be strictly limited. The maximum number
      of crankback rerouting attempts allowed MAY be limited per
      connection or per node:

      - When the number of retries at a particular node is exceeded,
         the node that is currently handling the failure reports the
         error message upstream to the next repair node, where further
         rerouting attempts MAY be performed. It is important that the
         crankback information provided indicate that re-routing through
         this node will not succeed.

      - When the maximum number of retries for a specific connection
         has been exceeded, the repair node that is handling the current
         failure SHOULD send an error message upstream to indicate the
         "Maximum number of re-routings exceeded". This error message
         will be sent back to the ingress node with no further rerouting
         attempts. Then, the ingress node MAY choose to retry the
         connection setup according to local policy, using its original
         path, or computing a path that avoids the blocking resources.

      Note: After several retries, a given repair point MAY be unable to
      compute a path to the destination node that avoids all of the
      blockages. In this case, it MUST pass the error message upstream
      to the next repair point.

4.7. Support for Additional Error Cases

   To support the ASON network, the following additional category of
   error cases are defined:

   - Errors associated with basic call and soft permanent connection
      support. For example, these MAY include incorrect assignment of
      IDs for the Call or an invalid interface ID for the soft permanent
      connection.

   - Errors associated with policy failure during processing of the new
      call and soft permanent connection capabilities. These MAY
      include unauthorized requests for the particular capability.

   - Errors associated with incorrect specification of the service
      level.

5. Backward Compatibility

   As noted above, in support of GMPLS protocol requirements, any
   extensions to the GMPLS signaling protocol, in support of the
   requirements described in this document, MUST be backward compatible.

   Backward compatibility means that in a network of nodes, where some
   support GMPLS signaling extensions to facilitate the functions
   described in this document, and some do not, it MUST be possible to
   set up conventional connections (as described by [RFC3473]) between
   any arbitrary pair of nodes and to traverse any arbitrary set of
   nodes. Further, the use of any GMPLS signaling extensions to set up
   calls or connections that support the functions described in this
   document MUST not perturb existing conventional connections.

   Additionally, when transit nodes that do not need to participate in
   the new functions described in this document lie on the path of a
   call or connection, the GMPLS signaling extensions MUST be such that
   those transit nodes are able to participate in the establishment of a
   call or connection by passing the setup information onwards,
   unmodified.

   Lastly, when a transit or egress node is called upon to support a
   function described in this document, but does not support the
   function, the GMPLS signaling extensions MUST be such that they can
   be rejected by pre-existing GMPLS signaling mechanisms in a way that
   is not detrimental to the network as a whole.

6. Security Considerations

   Per [ITU-T-G.8080], it is not possible to establish a connection in
   advance of call setup completion. Also, policy and authentication
   procedures are applied prior to the establishment of the call (and
   can then also be restricted to connection establishment in the
   context of this call).

   This document introduces no new security requirements to GMPLS
   signaling (see [RFC3471]).

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Appendix - Terminology

   This document makes use of the following terms:

   Administrative domain: See Recommendation G.805 [ITU-T-G.805].

   Call: Association between endpoints that supports an instance of a
   service.

   Connection: Concatenation of link connections and sub-network
   connections that allows the transport of user information between the
   ingress and egress points of a sub-network.

   Control Plane: Performs the call control and connection control
   functions. The control plane sets up and releases connections
   through signaling, 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. Entities grouped in a control
   domain are components of the control plane.

   External NNI (E-NNI): Interfaces are located between protocol
   controllers that are situated between control domains.

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

   Link: See Recommendation G.805 [ITU-T-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 [ITU-T-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 and is equivalent to the Transport
   Network defined in G.805 [ITU-T-G.805].

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

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