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     **Operating Virtual Concatenation (VCAT) and the Link Capacity
     Adjustment Scheme (LCAS) with Generalized Multi-Protocol Label
                          Switching (GMPLS)**
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Abstract

   This document describes requirements for, and use of, the Generalized
   Multi-Protocol Label Switching (GMPLS) control plane in conjunction

   with the Virtual Concatenation (VCAT) layer 1 inverse multiplexing
   mechanism and its companion Link Capacity Adjustment Scheme (LCAS)
   which can be used for hitless dynamic resizing of the inverse
   multiplex group. These techniques apply to the Optical Transport
   Network (OTN), Synchronous Optical Network (SONET), Synchronous
   Digital Hierarchy (SDH), and Plesiochronous Digital Hierarchy (PDH)
   signals.

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].

Table of Contents

1. **Introduction**

   The Generalized Multi-Protocol Label Switching (GMPLS) suite of
   protocols allows the automated control of different switching
   technologies including SONET/SDH.

   This document describes extensions to RSVP-TE to support the Virtual
   Concatenation (VCAT) layer 1 inverse multiplexing mechanism and its
   companion Link Capacity Adjustment Scheme (LCAS). These extensions
   enable the setup of diversely routed circuits that are members of the
   same VCAT group.

2. **Changes from draft-bernstein-ccamp-gmpls-vcat-lcas-03**

   o Dropped appendices

   o Updated references

   o Fixed error w/r to sessions. The LSPs belong to different sessions

   o Many editorial changes throughout the document

   o Rewrote the introduction

3. **VCAT/LCAS Scenarios and Specific Requirements**

   There are a number of specific requirements for the support of
   VCAT/LCAS in GMPLS that can be derived from the carriers'
   application-specific demands for the use of VCAT/LCAS and from the
   flexible nature of VCAT/LCAS. These are set out in the following
   section.

3.1. **Multiple VCAT Groups per GMPLS Endpoint**

   In general, an LSR can be ingress/egress of one or more VCAT groups.
   VCAT and LCAS are interface capabilities. An LSR may have, for
   example, VCAT-capable interfaces that are not LCAS-capable. It may
   at the same time have interfaces that are neither VCAT nor LCAS-
   capable.

3.2. Component Signal Configuration Requirements

We list in this section the different scenarios that SHOULD be
supported. Here we use the term "VCG" to refer to the entire VCAT
group and the terminology "set" and "subset" to refer to the
collection of potential VCAT group member signals.

o Fixed, co-routed: A fixed bandwidth VCG, transported over a co-
   routed set of member signals. This is the case where the intended
   bandwidth of the VCG does not change and all member signals follow
   the same route and minimize differential delay. The intent here
   is the capability to allocate an amount of bandwidth close to that
   required at the client layer.

o Fixed, diversely routed: A fixed bandwidth VCG, transported over
   at least two diversely routed subsets of member signals. In this
   case, the subsets are link-disjoint over at least one link of the
   route. The intent here is more efficient use of network resources
   (no unique route has the required bandwidth), and additional
   resilience and graceful degradation in the case of failure (note
   that differential delay may be a limiting factor).

o Dynamic, co-routed: A dynamic VCG (bandwidth can be increased or
   decreased via the addition or removal of member signals),
   transported over a co-routed set of members. Intent here is
   dynamic sizing of bandwidth.

o Dynamic, diversely routed: A dynamic VCAT group, transported over
   at least two diversely routed subsets of member signals. The
   intent here is dynamic resizing and resilience (but differential
   delay may be a limiting factor).

3.3. VCAT Operation With or Without LCAS

VCAT capabilities may be present with or without the presence of
LCAS. The use of LCAS is beneficial to the provision of services,
but in the absence of LCAS, VCAT is still a valid technique.
Therefore GMPLS mechanisms for the operation of VCAT are REQUIRED for
both the case where LCAS is available and the case where it is not
available. The GMPLS procedures for the two cases SHOULD be
identical.

4. GMPLS Mechanisms for Signaling VCAT/LCAS

We describe in this section the signaling mechanisms that already
exist in GMPLS using RSVP-TE [RFC3473] and the extensions needed, for
diversely routed paths and in support of the LCAS procedure.

Section 4.1 is included for informational purposes only. It
describes existing procedures and makes no changes.

Section 4.2 describes new procedures to support diversely routed VCAT
groups. Where possible it reuses applicable existing procedures from
section 4.1.

4.1. Co-Routed Signals

Note that this section is for informational purposes only.

The existing signaling protocols support co-routed signal setup using
the NVC field as explained in section 2.1 of [RFC3946bis]. In this
case, one single LSP is set up in support of the VCAT group.

There are two options for setting up the VCAT group, depending on
hardware capability, or management preferences: one-shot setup and
incremental setup.

The following sections explain the procedure based on an example of
setting up a VC4-7v SDH VCAT group (corresponding to an STS-3c-7v
SONET VCAT group).

4.1.1. One-shot Setup of Co-Routed Signal

An RSVP-TE Path message is used with the following parameters.

With regards to the traffic parameters, the elementary signal is
chosen (6 for VC-4/STS-3c_SPE). The value of NVC is then set to 7.

A Multiplier Transform greater than 1 (say N>1) is used if the
operator wants to set up N VCAT groups that will belong to, and be
assigned to, one LSP.

SDH or SONET labels in turn have to be assigned for each member of
the VCG and concatenated to form a single Generalized Label
constructed as an ordered list of 32-bit timeslot identifiers of the
same format as TDM labels. [RFC3946bis] requires that the order of
the labels reflect the order of the payloads to concatenate, and not
the physical order of time-slots.

4.1.2. Incremental Setup of Co-Routed Signal

In some cases, it may be necessary or desirable to set up the VCG
members individually, or to add group members to an existing group.

One example of this need is when the hardware that supports VCAT can
only add VCAT elements one at a time or cannot automatically match
the elements at the ingress and egress for the purposes of inverse
multiplexing. Serial or incremental setup solves this problem.

In order to accomplish incremental setup an iterative process is used
to add group members. For each iteration, NVC is incremented up to
the final value required. The iteration consists of the successful
completion of Path and Resv signaling. At first, NVC = 1 and the
label includes just one timeslot identifier

At each of the next iterations, NVC is set to (NVC +1), one more
timeslot identifier is added to the ordered list in the Generalized
Label (in the Path or Resv message). A node that receives a Path
message that contains changed fields will process the full Path
message and, based on the new value of NVC, it will add a component
signal to the VCAT group, and switch the new timeslot based on the
new label information.

Following the addition of the new label to the LSP, LCAS may be used
in-band to add the new label into the existing VCAT group. LCAS
signaling for this function is described in [ITU-T-G.7042].

4.1.3. Removing a Component Signal

The procedure to remove a component signal is similar to that used to
add components as described in Section 4.1.2. The LCAS in-band
signaling step is taken first to take the component out of the group.
LCAS signaling is described in [ITU-T-G.7042].

In this case, the NVC value is decremented by 1 and the timeslot
identifier for the dropped component is removed from the ordered list
in the Generalized Label. This function is not supported without
management intervention for VCAT-only interfaces as removing one
component of the VCG will result in errors in the inverse-
multiplexing procedure of VCAT and result in the teardown of the
whole group. So, this is a feature that only LCAS-capable VCAT
interfaces can support without management intervention at the end
points.

4.1.4. Removing Multiple Component Signals in One Shot

The procedure is similar to 4.1.3. In this case, the NVC value is
changed to the new value and all relevant timeslot identifiers for
the components to be torn down are removed from the ordered list in
the Generalized Label. This is also not supported for VCAT-only
interfaces without management intervention as removing one component

of the VCG will tear down the whole group, but the use of LCAS can
facilitate this procedure.

4.1.5. Use of multiple LSPs for Co-Routed Signals

Co-routed signals may also be supported by distinct LSPs signaled
separately using exactly the techniques described for diversely
routed signals in Section 4.2.

4.1.6. Teardown of Whole VCG

The entire LSP is deleted in a single step (i.e., all components are
removed in one go) using deletion procedures of [RFC3473].

4.2. Diversely Routed Signals

The initial GMPLS specification did not support diversely routed
signals using the NVC construct. In fact, [RFC3946bis] says:

> [...] The standard definition for virtual concatenation allows
> each virtual concatenation components to travel over diverse
> paths. Within GMPLS, virtual concatenation components must
> travel over the same (component) link if they are part of the
> same LSP. This is due to the way that labels are bound to a
> (component) link. Note however, that the routing of components
> on different paths is indeed equivalent to establishing
> different LSPs, each one having its own route. Several LSPs
> can be initiated and terminated between the same nodes and
> their corresponding components can then be associated together
> (i.e., virtually concatenated).

Diverse routing of signals can be a useful capability but requires
the extensions identified in this document.

4.2.1. Associating Diversely Routed Signals

The feature that needs to be added is the functionality to associate
the components of the same VCG. For this purpose, we use the
Association Object that was defined in [E2E-RECOVERY] to associate
working and recovery LSPs.

A diversely routed VCG uses a number of routes R <= VCG size, as some
routes may be the same for several components. A number of LSPs, L
(VCG >= L >= R) are used with each LSP establishing at least one
component of the VCG, and at most all of the co-routed members of the
group. For a set of c components using the same route, we set up the
LSP with NVC = c exactly as explained in section 4.1.1. Therefore,

the association of group members or of sub-groups to form the VCG
requires the association of the LSPs used to establish the group
members.

To be able to distinguish the LSPs in the VCG each must have a unique
identifier. LSPs are identified by the combination of Session and
Sender Template fields. It is common practice when make-before-break
[RFC3209] is supported to allow LSPs with the same Session, but
different Sender Templates (specifically with different LSP IDs) to
share resources. Since resource sharing between VCG members must not
be allowed (because we want each LSP to contribute capacity to the
VCG), but since we want to continue to support make-before-break for
each group member, it is necessary to distinguish the LSPs in the VCG
by varying the fields in the Session object. Specifically, a
different Tunnel ID is used to identify each LSP in the VCG.

Thus, VCG members cannot be associated through the Session object,
and the Association object is used instead.

The assignment of the Association ID is outside the scope of GMPLS
but MUST be unique for each VCAT group.

Note that the use of the Association object to associate members of a
VCG does not preclude the use of another instance of the object with
a different Association ID to indicate the association of working and
recovery LSPs, as [E2E-RECOVERY] allows the use of multiple
Association objects. We differentiate between the Association
objects used for the VCAT group and other Association objects through
the definition of a new association type to indicate that this is a
VCG association.

Association Type: 16 bits

               Value   Type
               -----   ----

                 3   VCAT group

See [E2E-RECOVERY] for the definition of other fields and values of
the Association object.

4.2.2. Procedures for VCG Setup Using Diversely Routed Components

For every route R, use the procedure outlined in section 4.1.1 or
4.1.2 depending on the capability of the equipment or local policy.
The Path message MUST include the Association object with type set to
3, and each Path message MUST use the same Association ID.

Following the addition of each new LSP (i.e., once the RESV message has been received by the ingress LSR), LCAS signaling is used in-band to hitlessly add the new label into the existing group [ITU-T-G.7042].

4.2.3. Procedures for VCG Reduction/Teardown Using Diversely Routed Components

To remove the component circuits on any route, LCAS signaling is used in-band to remove the labels associated with the LSP from the group. LCAS signaling is defined in [ITU-T-G.7042].

In addition, the procedures outlined in section 4.1.3 or 4.1.4 are used to tear down the unwanted LSP.

Again, this can only be done on LCAS-capable interfaces. If the procedure is attempted on VCAT-only interfaces, then the whole VCG is torn down (this is not a graceful teardown so ingress/egress initiate a Path Tear/Resv Tear) on all routes.

4.2.4. Update of Already Established LSPs

Established co-routed VCAT groups currently do not support the Association object. If a co-routed VCAT Group size is to be increased with new diversely routed members, we use the LSP modification procedure described in [RFC2205]. An Association object is added to the Path message for the existing LSP(s). That Association object can then be used to set up new diversely routed group members.

The same applies to SONET/SDH LSPs. An operator may decide to use an already cross-connected SONET/SDH LSP for diversely-routed VCAT. In this case the modification procedure described in [RFC2205] is used as well.

4.2.5. One LSP per Circuit

These procedures can support the use of as many LSPs as there are circuits in the VCG. This can be done when each circuit is separately routed, or when some of the circuits are co-routed, and each LSP will be used to set up one element of the VCG. The Association object is used to indicate the VCG association.

5. **IANA Considerations**

   This document requests from IANA the assignment of a new Association
   Type within the Association object. This object was defined in [E2E-
   RECOVERY].

   The value 3 "VCAT group" is suggested in section 4.2.1.

6. **Security Considerations**

   This document introduces a new use of the Association object for
   GMPLS signaling [RFC3473] to associate diversely routed VCAT group
   members. It does not introduce any new signaling messages, nor
   change the relationship between LSRs that are adjacent in the control
   plane. This association information in the event of an interception
   may indicate that there are members of the same VCAT group that take
   a different route and may indicate to an interceptor that the network
   may be more robust.

   Otherwise, this document does not introduce any additional security
   considerations.

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