Use Cases for MPLS Network Action Indicators and MPLS Ancillary Data

Abstract

   This document presents a number of use cases that have a common need
   for encoding network action indicators and associated ancillary data
   inside MPLS packets. There has been significant recent interest in
   extending the MPLS data plane to carry such indicators and ancillary
   data to address a number of use cases that are described in this
   document.

   The use cases described in this document are not an exhaustive set,
   but rather the ones that are actively discussed by members of the
   IETF MPLS, PALS and DETNET working groups participating in the MPLS
   Open Design Team.

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1. Introduction

This document describes important cases that require carrying additional ancillary data within the MPLS packets, as well as means to indicate the ancillary data is present, and a specific action needs to be performed on the packet.

These use cases have been identified by the MPLS Working Group Open Design Team working on defining MPLS Network Actions for the MPLS data plane. The MPLS Ancillary Data (AD) can be classified as:

  *implicit, or "no-data" associated with a Network Action (NA) indicator,

*residing within the MPLS label stack and referred to as In Stack
 Data (ISD), and

*residing after the Bottom of MPLS label Stack (BoS) and referred
 to as Post Stack Data (PSD).

The use cases described in this document will be used to assist in
identifying requirements and issues to be considered for future
resolution by the working group.

1.1. Terminology

The following terminology is used in the document:

IETF Network Slice:
    a well-defined composite of a set of endpoints, the connectivity
    requirements between subsets of these endpoints, and associated
    requirements; the term 'network slice' in this document refers to
    'IETF network slice' as defined in
    [I-D.ietf-teas-ietf-network-slices].

Time-Bound Networking:
    Networks that transport time-bounded traffic.

1.2. Acronyms and Abbreviations

ISD: In-stack data

PSD: Post-stack data

MNA: MPLS Network Action

NAI: Network Action Indicator

AD: Ancillary Data

2. Use Cases

2.1. No Further Fastreroute

MPLS Fast Reroute (FRR) [RFC4090], [RFC5286] and [RFC7490] is a
useful and widely deployed tool for minimizing packet loss in the
case of a link or node failure.

Several cases exist where, once FRR has taken place in an MPLS
network and resulted in rerouting a packet away from the failure, a
second FRR that impacts the same packet to rerouting is not helpful,
and may even be disruptive.

For example, in such a case, the packet may continue to loop until its TTL expires. This can lead to link congestion and further packet loss. Thus, the attempt to prevent a packet from being dropped may instead affect many other packets. A proposal to address this is presented in [I-D.kompella-mpls-nffrr].

2.2. In-situ OAM

In-situ Operations, Administration, and Maintenance (IOAM) is used to collect operational and telemetry information while packets traverses a particular path in a network domain.

The term "in-situ" refers to the fact that the IOAM data fields are added to the data packets rather than being sent within the probe packets specifically dedicated to OAM or Performance Measurement (PM).

IOAM can run in two modes Edge-to-Edge (E2E) and Hop-by-Hop (HbH). In E2E mode, only the encapsulating and decapsulating nodes will process IOAM data fields. In HbH mode, the encapsulating and decapsulating nodes as well as intermediate IOAM-capable nodes process IOAM data fields. The IOAM data fields are defined in [I-D.ietf-ippm-ioam-data], and can be used for various OAM use-cases.

Several IOAM Options have been defined:

   *Pre-allocated and Incremental

   *Edge-to-Edge

   *Proof-of-Transit

   *Direct Export (see Section 2.2.1)

[I-D.gandhi-mpls-ioam-sr] defines how IOAM data fields are transported using the MPLS data plane encapsulations, including Segment Routing (SR) with MPLS data plane (SR-MPLS).

The IOAM data may be added after the bottom of the MPLS label stack. The IOAM data fields can be of fixed or incremental size as defined in [I-D.ietf-ippm-ioam-data]. [I-D.gandhi-mpls-ioam] describes the applicability of IOAM to MPLS dataplane. The encapsulating MPLS node needs to know if the decapsulating MPLS node can process the IOAM data before adding it in the packet. In HbH IOAM mode, nodes that are capable of processing IOAM will intercept and process the IOAM data accordingly. The presence of IOAM header and optional IOAM data will betransparent to nodes that do not support or do not participate in the IOAM process.

2.2.1. In-situ OAM Direct Export

IOAM Direct Export (DEX) [I-D.ietf-ippm-ioam-direct-export] is an
IOAM Option-Type in which the operational state and telemetry
information is collected according to the specified profile and
exported in a manner and format defined by a local policy.

In IOAM DEX, the user data packet is only used to trigger the IOAM
data to be directly exported or locally aggregated without being
pushed into in-flight data packets.

2.3. Network Slicing

An IETF Network Slice service provides connectivity coupled with a
set of network resource commitments and is expressed in terms of one
or more connectivity constructs. A slice-flow aggregate
[I-D.bestbar-teas-ns-packet] refers to the set of traffic streams
from one or more connectivity constructs belonging to one or more
IETF Network Slices that are mapped to a set of network resources
and provided the same forwarding treatment. The packets associated
with a slice-flow aggregate may carry a marking in the packet's
network layer header to identify this association and this marking
is referred to as Flow-Aggregate Selector (FAS). The FAS is used to
map the packet to the associated set of network resources and
provide the corresponding forwarding treatment to the packet.

A router that requires forwarding of a packet that belongs to a
slice-flow aggregate may have to decide on the forwarding action to
take based on selected next-hop(s), and the forwarding treatment
(e.g., scheduling and drop policy) to enforce based on the
associated per-hop behavior.

In this case, the routers that forward traffic over resources that
are shared by multiple slice-flow aggregates need to identify the
slice aggregate packets in order to enforce the associated
forwarding action and treatment.

MNA can be used to indicate the action and carry ancillary data for
packets traversing Label Switched Paths (LSPs). An MNA network
action can be used to carry the FAS in MPLS packets.

2.3.1. Dedicated Identifier as Flow-Aggregate Selector

A dedicated Identifier that is independent of forwarding can be
carried in the packet as a Flow-Aggregate Selector (FAS). This can
be encoded in the MPLS packet as defined in
[I-D.kompella-mpls-mspl4fa], [I-D.li-mpls-enhanced-vpn-vtn-id], and
[I-D.decraene-mpls-slid-encoded-entropy-label-id]. The FAS is used
to associate the packets belonging to Slice-Flow Aggregate to the

underlying Network Resource Partition (NRP) as described in
[I-D.bestbar-teas-ns-packet].

When MPLS packets carry a dedicated FAS identifier, the MPLS LSRs
use the forwarding label to select the forwarding next-hop(s), and
use the FAS in the MPLS packet to infer the specific forwarding
treatment that needs to be applied on the packet.

The FAS can be encoded within an MPLS label carried in the packet's
MPLS label stack. All MPLS packets that belong to the same flow
aggregate MAY carry the same FAS identifier.

2.3.2. Forwarding Label as a Flow-Aggregate Selector

[RFC3031] states in Section 2.1 that: 'Some routers analyze a
packet's network layer header not merely to choose the packet's next
hop, but also to determine a packet's "precedence" or "class of
service"'.

It is possible by assigning a unique MPLS forwarding label to each
flow aggregate (FEC) to distinguish the packets forwarded to the
same destination. from other flow aggregates. In this case, LSRs can
use the top forwarding label to infer both the forwarding action and
the forwarding treatment to be invoked on the packets.

2.4. Generic Delivery Functions

The Generic Delivery Functions (GDF), defined in
[I-D.zzhang-intarea-generic-delivery-functions], provide a new
mechanism to support functions analogous to those supported through
the IPv6 Extension Headers mechanism. For example, GDF can support
fragmentation/reassembly functionality in the MPLS network by using
the Generic Fragmentation Header. MNA can support GDF by placing a
GDF header in an MPLS packet within the Post-Stack Data block
[I-D.ietf-mpls-mna-fwk]. Multiple GDF headers can also be present in
the same MPLS packet organized as a list of headers.

2.5. Delay Budgets for Time-Bound Applications

The routers in a network can perform two distinct functions on
incoming packets, namely forwarding (where the packet should be
sent) and scheduling (when the packet should be sent). IEEE-802.1
Time Sensitive Networking (TSN) and Deterministic Networking provide
several mechanisms for scheduling under the assumption that routers
are time-synchronized. The most effective mechanisms for delay
minimization involve per-flow resource allocation.

Segment Routing (SR) is a forwarding paradigm that allows encoding
forwarding instructions in the packet in a stack data structure,
rather than being programmed into the routers. The SR instructions

are contained within a packet in the form of a First-in First-out
stack dictating the forwarding decisions of successive routers.
Segment routing may be used to choose a path sufficiently short to
be capable of providing a bounded end-to-end latency but does not
influence the queueing of individual packets in each router along
that path.

When carried over the MPLS data plane, a solution is required to
enable the delivery of such packets that can be delivered to their
final destination by a given time budget. One approach to address
this usecase in SR-MPLS was described in [I-D.stein-srtsn].

2.5.1. Stack Based Methods for Latency Control

One efficient data structure for inserting local deadlines into the
headers is a "stack", similar to that used in Segment Routing to
carry forwarding instructions. The number of deadline values in the
stack equals the number of routers the packet needs to traverse in
the network, and each deadline value corresponds to a specific
router. The Top-of-Stack (ToS) corresponds to the first router's
deadline while the Bottom-of-Stack (BoS) refers to the last's. All
local deadlines in the stack are later or equal to the current time
(upon which all routers agree), and times closer to the ToS are
always earlier or equal to times closer to the BoS.

The ingress router inserts the deadline stack into the packet
headers; no other router needs to be aware of the requirements of
the time-bound flows. Hence admitting a new flow only requires
updating the information base of the ingress router.

MPLS LSRs that expose the Top of Stack (ToS) label can also inspect
the associated "deadline" carried in the packet (either in MPLS
stack as ISD or after BoS as PSD).

2.6. NSH-based Service Function Chaining

[RFC8595] describes how Service Function Chaining (SFC) can be
realized in an MPLS network by emulating the NSH by using only MPLS
label stack elements.

The approach in [RFC8595] introduces some limitations that are
discussed in [I-D.lm-mpls-sfc-path-verification]. This approach,
however, can benefit from the framework introduced with MNA in
[I-D.ietf-mpls-mna-fwk].

For example, it may be possible to extend NSH emulation using MPLS
labels [RFC8595] to support the functionality of NSH Context
Headers, whether fixed or variable-length. One of the use cases
could support Flow ID [I-D.ietf-sfc-nsh-tlv] that may be used for

load-balancing among Service Function Forwarders (SFFs) and/or the
Service Function (SF) within the same SFP.

2.7. Network Programming

In SR, an ingress node steers a packet through an ordered list of
instructions, called "segments". Each one of these instructions
represents a function to be called at a specific location in the
network. A function is locally defined on the node where it is
executed and may range from simply moving forward in the segment
list to any complex user-defined behavior.

Network Programming combines Segment Routing (SR) functions to
achieve a networking objective that goes beyond mere packet routing.

It may be desirable to encode a pointer to function and its
arguments within an MPLS packet transport header. For example, in
MPLS we can encode the FUNC::ARGs within the label stack or after
the Bottom of Stack to support the equivalent of FUNC::ARG in SRv6
as described in [RFC8986].

3. Existing MPLS Use cases

There are serveral services that can be transported over MPLS
networks today. These include providing Layer-3 (L3) connectivity
(e.g. for unicast and multicast L3 services), and Layer-2 (L2)
connectivity (e.g. for unicast Pseudo-Wires (PWs), multicast E-Tree,
and broadcast E-LAN L2 services). In those cases, the user service
traffic is encapsulated as the payload in MPLS packets.

For L2 service traffic, it is possible to use A Control Word (CW)
[RFC4385] and [RFC5085] immediately after the MPLS header to
disambiguate the type of MPLS payload, prevent possible packet
misordering, and allow for fragmentation. In this case, the first
nibble the data that immediately follows after MPLS bottom of stack
is set to 0000b to identify the presence of PW CW.

In addition to providing connectivity to user traffic, MPLS may also
transport OAM data (e.g. over MPLS G-AChs [RFC5586]). In this case,
the first nibble of the data that immediately follows after MPLS
bottom of stack is set to 0001b, it indicates the presence of a
control channel associated witha PW, LSP, or Section.

Bit Index Explicit Replication (BIER) [RFC8296] traffic can also be
encapsulated over MPLS. In this case, BIER has defined 0101b as the
value for the first nibble in the data that immediately appears
after the bottom of the label stack for any BIER encapsulated packet
over MPLS.

For pseudowires, the G-ACh uses the first four bits of the PW
control word to provide the initial discrimination between data
packets and packets belonging to the associated channel, as
described in [RFC4385].

It is expected that new use cases described in this document and
within the MNA framework [I-D.ietf-mpls-mna-fwk] will allow for the
co-existance and backward compatibility with all such existing MPLS
services.

4. Co-existence of Usecases

Two or more of the aforementioned use cases MAY co-exist in the same
packet. This may require the presence of multiple ancilary data
(whether In-stack or Post-stack ancillary data) to be present in the
same MPLS packet.

For example, IOAM may provide key functions along with network
slicing to help ensure that critical network slice SLOs are being
met by the network provider. In this case, IOAM is able to collect
key performance measurement parameters of network slice traffic
flows as it traverses the transport network.

5. IANA Considerations

This document has no IANA actions.

6. Security Considerations

This document introduces no new security considerations.

7. Acknowledgement

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