Realizing Network Slices in IP/MPLS Networks

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Tarek Saad  Juniper Networks
Vishnu Pavan Beeram  Juniper Networks

Contributors: Colby Barth, Srihari Sangli, Chandra Ramachandran

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Agenda

- Introduction
- Slice Per Hop Definition
- Solution approaches
- Next Steps
Introduction

- Solution to realize network slicing in IP/MPLS networks
  - Based on DiffServ principles
    - Slicing from a device and network resource level perspective
  - Ensure proper placement of paths and respective treatment of traffic traversing network slice resources
    - Agnostic to the path control technique used in the network slicing domain

- Multiple network slices can be realized on top of a shared physical IP/MPLS infrastructure network
  - Dynamically created and managed

- Traffic traversing shared network resources may require specific treatment to meet target SLOs
  - A Slice Selector within a packet identifies slice traffic
  - Device specific slice resources instantiated on-demand: Slice Queues and Slice PHB

- Placement of traffic on slice resources optimized based on network slice resource utilization
  - Slice-aware TE

- Differentiation of traffic within same network slice is also possible
  - Diffserv Class Selector (CS) in the packet distinguishes traffic within same slice
Solution Overview

- Approaches to network resource slicing:
  - Control plane slicing, Data plane slicing, mix of Control and Data plane slicing
  - Hybrid options possible

- An integral Slice Per Hop Definition, encompassing:
  - Data plane Slice Selector
  - Data plane resources (H-QoS PHBs)
  - Control plane resources (bandwidths, priorities, shared-resource groups)
  - Slice specific topology facilitating Slice aware TE

- Multiple options for Slice Per Hop Definition dissemination
  - Programmed via Netconf/gRPC interface(s)
  - Exchanged in IGP and/or BGP
  - Configured directly on device(s)

- Multiple options for path selection and control techniques within a Slice (SR Policy, Flex-algo, RSVP-TE LSP, ...)
Slice Per-Hop Definition (1/2)

- **Data plane Slice Selector**
  - A range of MPLS forwarding labels (for each destination) mapping to a Slice
  - A range of MPLS VPN service labels mapping to a single Slice
  - A single Global label mapping to a Slice
  - A set of IP destinations mapped to a slice
  - A multi-field packet selector

- **Data plane resources (H-QoS PHBs)**
  - A Slice QoS profile or a reference to device local profile
  - Different profiles to multiple interfaces possible
Slice Per-Hop Definition (2/2)

- Control-plane resources management
  - Slice-aware Bandwidth Engineering
  - Preference-based preemption of Slice-aware TE paths
  - Resource sharing
  - Protection

- Slice topology for Slice aware TE
  - Slice Membership: Topological elements (link/node) participating in a slice
  - Single Topology can cater to multiple slices

Diagram:
- Max Guaranteed BW
- Max Shared BW
- Control plane slice Selector variants
- Priority
- 4 slices, over-booked max reservable BW
- 4 slices, 2 resource-sharing groups, over booked max reservable BW
- Max BW
Data plane only network slicing

- Data plane network resource slicing
  - Slice Selector – identifies packets belonging to a specific slice
  - Per slice CoS profile is applied on participating links and nodes
  - Transit nodes classify incoming traffic (e.g. using Slice label) and apply per slice scheduling

- Control plane
  - No control plane awareness of slice resources
  - No slice-aware path placement/TE

- Use-case
  - Suitable when no BW engineering is required and ECMP is leveraged between endpoints (e.g. Spine/Leaf deployment)
  - Does not address all network slice SLOs being standardized at IETF
Control plane only network slicing

- **Control plane network resource slicing**
  - Link resources are sliced in control plane
    - Per slice link maximum and available BW
    - Ingress router/PCE forms per slice TED using the link-state
  - Slice-aware path computation and path placement
    - CSPF uses the slice aware TED to select optimal TE path
  - Control plane preemption in case of contention on a specific link resource
    - In case of degradation of LAG, control plane can preempt LSP(s) to avoid congestion

- **Data plane**
  - No per slice classification of traffic or per slice PHB on transit routers
  - Policing can happen on slice incoming traffic
Control and data plane network slicing

- Control plane and data plane network slicing
  - Combination of the previous two
  - Slice-aware TE enables ingress/PCE to do proper placement of LSPs based on per slice link available BW
  - Data plane Per-Hop Behavior on transit nodes provides guarantees in case of congestion on a link
  - Covers strict and shared resource slice isolation requirements
Next Steps

- Slice-aware TE
  - Protocol Extensions -- Coordination with relevant drafts
- Request review and feedback
YANG Data Model for Network Slice Per-Hop Definition

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Overview

- YANG data model for programming Network Slice Per Hop Definition (Slice-PHD) on IP/MPLS devices
  - Multiple Slice Selector options
  - Flexible and hierarchical Slice PHB(s)
  - Covers resource management in control plane and data plane
  - Mapping of a slice to a logical topology
Network Slice Per Hop Definition Model

Model Structure

```
module: ietf-network-slice-phd
  +--rw network-slicing!
    +--rw network-slice-phbs
      |   +--rw network-slice-phb* [id]
      |       ............
    +--rw network-slices
      +--rw network-slice* [name]
         |   ............
      +--rw slice-resource-reservation
         |   ............
      +--rw slice-selectors
         |   +--rw slice-selector* [id]
         |       ............
      +--rw slice-phb? ns-phb-ref
         |       ............
      +--rw slice-membership
                     ............
```

Slice-PHDs

*network-slices* container

- Key elements
  - Slice Resource Reservation
  - Slice Selectors
  - Slice PHB
  - Slice Membership

Slice-PHBs

*network-slice-phbs* container

- Referenced by Slice-PHDs
Network Slice Per Hop Definition Model

Slice Per-Hop-Behaviors

```
+--rw network-slice-phbs
 | | +--rw network-slice-phb* [id]
 | | | +--rw id uint16
 | | | +--rw (profile-type)?
 | | | | +--:(profile)
 | | | | | +--rw profile? string
 | | | | +--:(custom-profile)
 | | | | ............
```

Slice-PHBs container (network-slice-phbs)

- Carries a list of Slice-PHB entries
- Slice-PHB entry
  - Referenced by one or more Slice-PHD
  - Options:
    - Reference to a generic PHB profile
    - Custom PHB profile
Network Slice Per Hop Definition Model

S slice-resource-reservation Container
- Slice-aware Bandwidth Engineering
- Preference-based preemption of Slice-aware TE paths
- Sharing of resources amongst a group of slices
- Slice Protection
Network Slice Per Hop Definition Model

Slice Selectors

slice-selectors Container
- Set of data plane field selectors
- Slice Selector (SS)
  - Identify packets belonging to the given network slice
  - 16-bit ID
    - SS with the lowest ID is the default used by all the topological elements that are members of the given network slice
    - Other entries are used to override the default on select topological elements
Network Slice Per Hop Definition Model

Slice Membership

```
+-rw slice-membership
  +--rw filter-policies
    +--rw filter-policy* [id]
    +--rw id
      |      uint16
    +--rw (filter-type)?
      |    +--:(topology-ref)
      |    |    +--rw (topo-ref-type)?
      |    |    |    +--:(algo-id)
      |    |    |    |    +--rw algo-id?    uint8
      |    |    |    +--:(te-topo-id)
      |    |    |        +--rw te-topology-identifier
      |    |    |        +--rw provider-id?  te-global-id
      |    |    |        +--rw client-id?   te-global-id
      |    |    |        +--rw topology-id? te-topology-id
      |    +--:(custom-topology)
      |    |    +--rw include
      |    |    |    +--rw link-affinity*   string
      |    |    |    +--rw link-name*       string
      |    |    |    +--rw node-prefix*     inet:ip-prefix
      |    |    |    +--rw as*              inet:as-number
      |    |    +--rw exclude
      |    |    |    +--rw link-affinity*   string
      |    |    |    +--rw link-name*       string
      |    |    |    +--rw node-prefix*     inet:ip-prefix
      |    |    |    +--rw as*              inet:as-number
    +--rw slice-selector?
      |      ns-ss-ref
    +--rw slice-phb?
      |      ns-phb-ref
```

slice-membership Container

- Set of filtering policies
  - Determine which topological elements belong the specific network slice
- Filtering Policy
  - Reference a predefined topology (or)
  - Specify rules to construct customized topology
- Slice members can optionally override the default Slice-PHB and/or the default slice selector.
Next Steps

- Request review and feedback