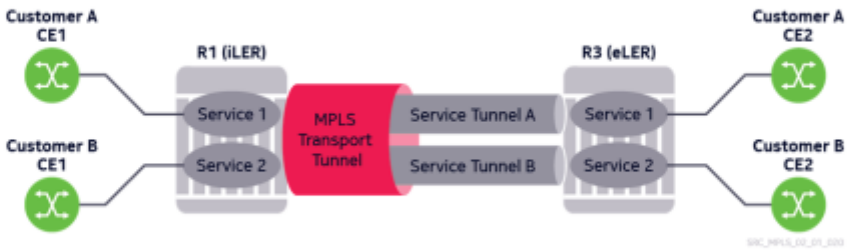
Fundamentals of MPLS

Section 1 - Understanding the Dapa Plane Implementation

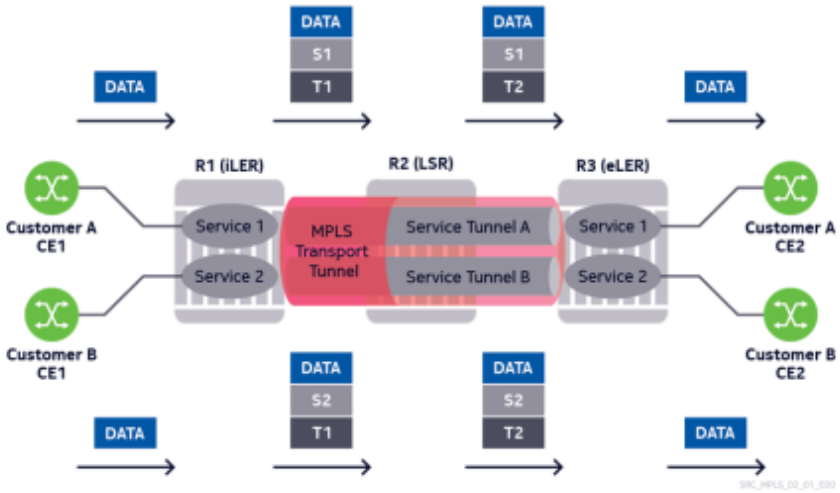
MPLS Label Stack Implementation

- A single data packet or frame can carry multiple MPLS labels
- When that happens, it is said that encapsulated data carries a label stack
- MPLS labels are inserted between OSI Layer 2 and encapsulated data (Payload)
- Labels are used to differentiate different types of services and/or customers from each other.

The Need for a Label Stack for VPN Services

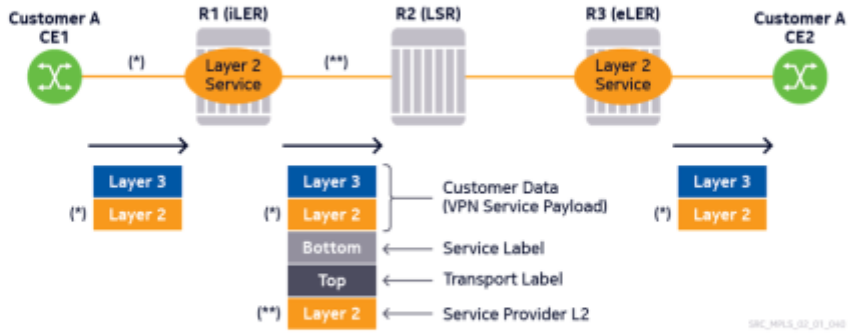


MPLS Label Stack Operation for VPN Services



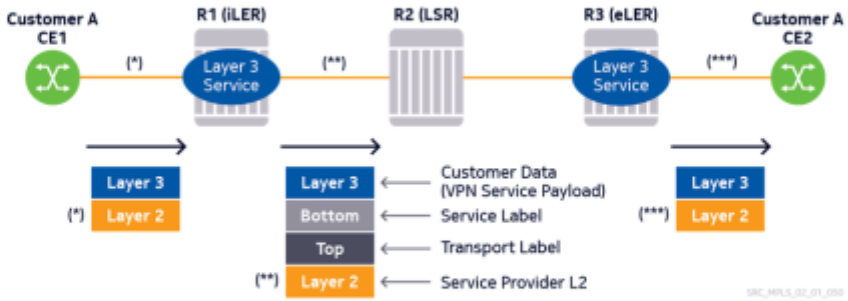
- FEC for MPLS Transport Tunnel is the SYSTEM IP
- FEC for Service Tunnel is Service ID

MPLS Encapsulation for Layer 2 VPN Services



Customer Layer 2 Header is preserved at iLER.

MPLS Encapsulation for Layer 3 (IP) VPN Services



- Customer Layer 2 Header is removed at iLER.
- A new Layer 2 Header is built by eLER.

MPLS Label Header

Field	Name	Size (bits)	Purpose
Label	MPLS Label	20	The MPLS label Value
EXP*	Experimental	3	QoS mapping from TOS/COS bits
S	Bottom of Stack	1	Flag to indicate bottom of MPLS stack
TTL	Time to Live	8	Packet lifetime in MPLS hops

MPLS Label Range Allocation on Nokia OS

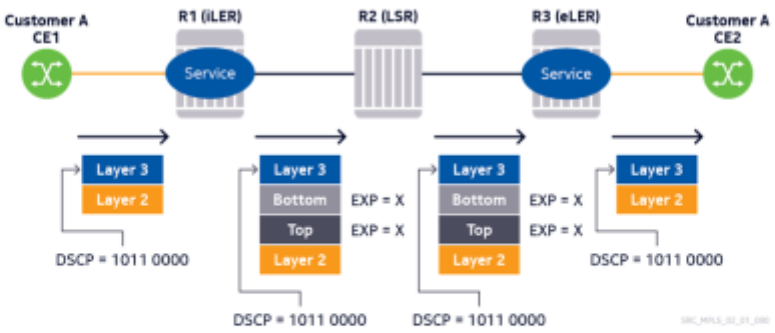
- MPLS Label Field is 20 bits
- Possible values from 0 - 1,048,575

Label Values	Label Usage
0-15	Reserved (Special Use) Labels
16 – 31	Reserved for future use
32 – 18, 431	Reserved for static LSPs, MPLS-TP LSP, static service label
18, 432 – 524, 287	Assigned dynamically by RSVP, LDP, and BGP control planes for both MPLS LSP and service labels
18, 432 – 1, 048, 575	In FP4 system profile B assigned dynamically by RSVP, LDP, and BGP control planes for both MPLS LSP and service labels
524, 288 – 1, 048, 575	Not assigned by SR OS other than in FP4 profile B.

MPLS Header: EXP Field

- Consists of 3 bits
- A.K.A Traffic Class field
- Used solely to convey Quality of Service (QoS) information.
- Only the EXP field inside the top label is significant in processing
- Two approaches
  - Pipe mode
  - Uniform mode
- Nokia SR OS only implements pipe mode

Implementation



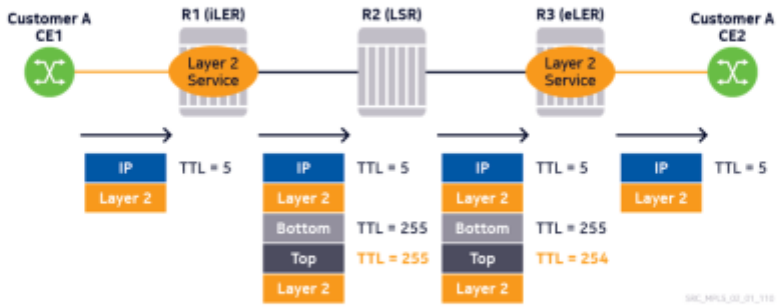
- At iLER, the EXP fields of all MPLS labels are set to the same value, using administrative configuration. This could be a different value from the DSCP field in the customer packet.
- The DSCP value inside the customer packet header is preserved.

MPLS Header - Bottom of Stack (S) Bit

MPLS Header - Time to Live (TTL) Field

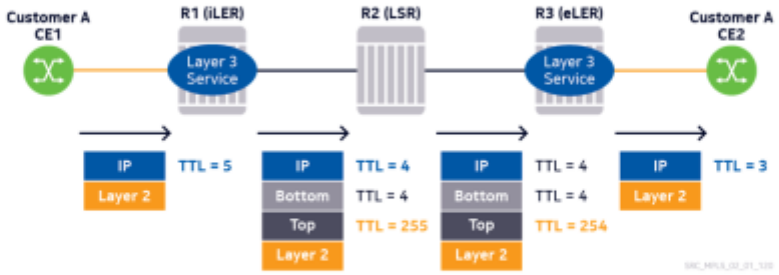
- 8 bit MPLS TTL field functions similarly to IP TTL
- Prevents forwarding loops
- When TTL = 0, packet is not transmitted to next hop
- In *MOST* cases, only the TTL field inside the top label is significant in processing
- Two approaches:
  - Pipe mode
  - Uniform Mode
- Nokia only implementts Pipe mode

TTL Processing for Layer 2 VPN Services in Pipe Mode



- The IP TTL in the customer packet is kept intact.
- The MPLS TTL inside the top label is decremented at each LSR.

TTL Processing for Layer 3 (IP) VPN Services in Pipe Mode



- The IP TTL in the customer packet is decremented by 1 at iLER and eLER.
- The MPLS TTL inside the top label is decremented at each LSR.

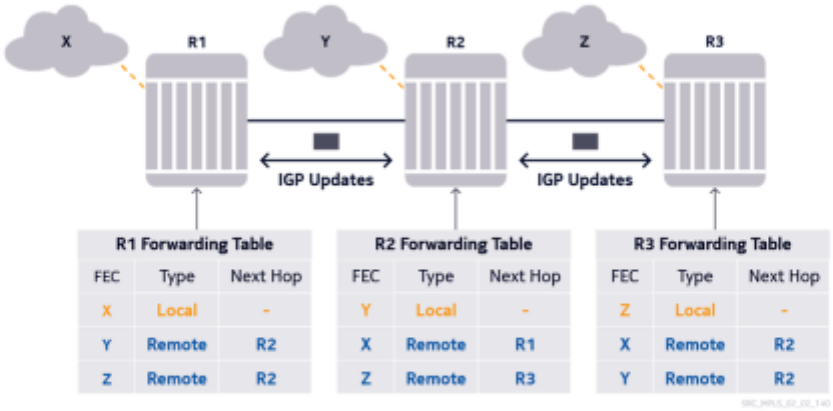
Section 2 - Understanding the Control Plane implementation of MPLS

Requirements for IP/MPLS Control Processes

For tunnels to be estabilshed:

- Routers must know about each other's FECs (Essentially corresponds to an IP prefix)
- Label bindings for FECs mus tbe negotiated between routers.

Requirement for an Interior Gateway Protocol



IGP is responsible for distributing and maintaining network reachability information; that is, the IGP FECs.

Requirements for MPLS Signaling Protocols

- FECs' IP prefixes are exchanged, and the other routers tunnel destinations are known due to IGP
- Signaling protocol is needed to negotiate MPLS labels and establish tunnels

There are two main signaling protocols:

1. Label Distribution Protocol (LDP)
2. Resource Reservation Protocol (RSVP)

MPLS Transport Label Signaling Protocols

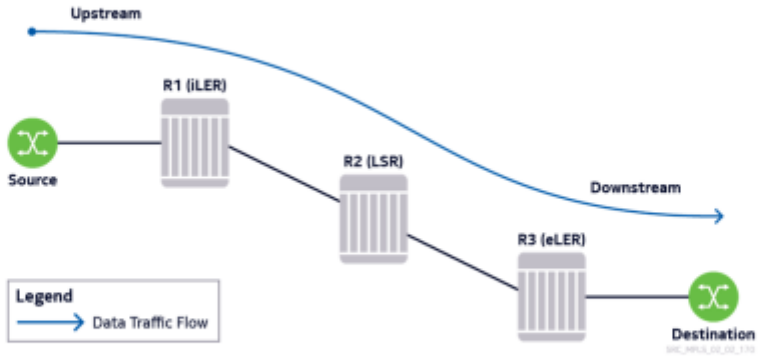
Label Distribution Protocol:

- IGP-based tunnels (only)
- Simple configuration
- No Traffic Engineering Support
- IGP dependednt convergence times
- Also called Link or Interface LDP
- Advertises labels for FECs automatically
- Keeps Labels in memory for all FECs received even if they are not used

Resource Reservation protocol with Traffic Engineering (RSVP-TE):

- Fully customizable tunnel paths
- Ability to run more complex path calculations with additional adminsitrative constraints
- Superior traffic protection mechanisms
- Higher administrative overhead
- Only advertises labels for FECs that are requested by upstream routers
- Deletes Labels for FECs that are not used

Upstream and Downstream Reference

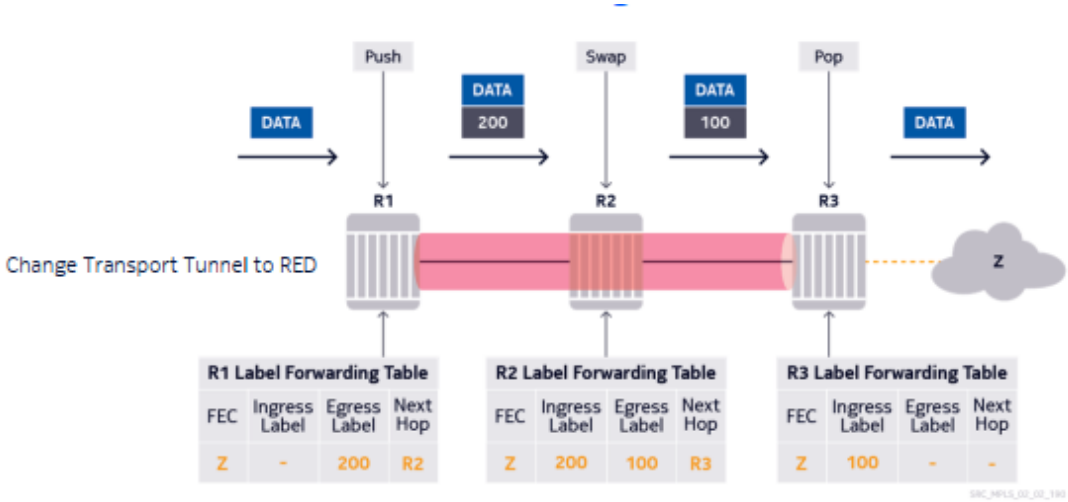


- Direction of the Data Traffic Flow provides the reference points.
- The router that is closer to the source is called Upstream.
- The router that is closer to the destination is called Downstream.

Upstream Label Distribution

- Routers advertise label bindings for their FECs, which are propogated to the upstream routers
- Each router selects the label value that it will advertise, associated with each FEC.

Result of Label Distribution (Data Forwarding)



- Label Forwarding Information Base (LFIB) tables are populated and the LSP gets established
- Encapsulated data can then be transmitted in the downstream direction.

MPLS Service Label Signaling Protocols

Targeted LDP (T-LDP)

- Used for Layer 2 VPN Services
- RFC 4447 specifies its use
- Creates an end-to-end session between two PE routers

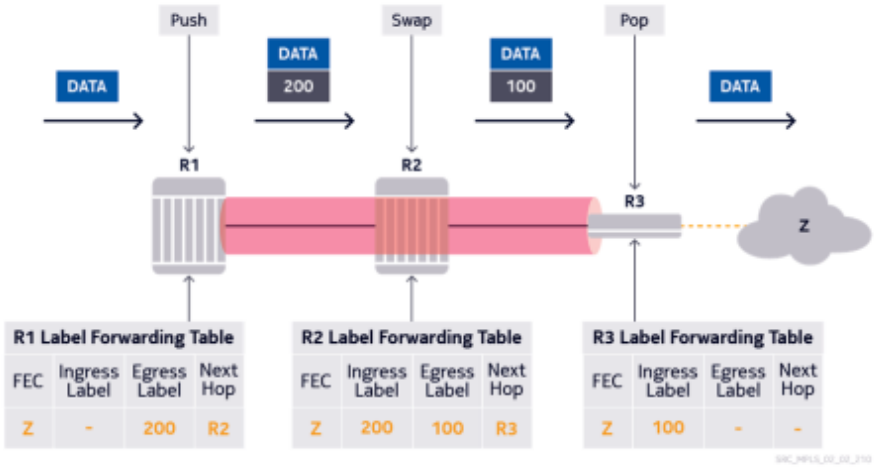
Multi-Protocol Border Gateway Protocol (MP-BGP)

- Used for Layer 3 (IP) VPN Services
- Called Multi-Protocol due to its support for different address families other than standard IPv4
- Based on RFC 4364

MPLS Special Use Labels

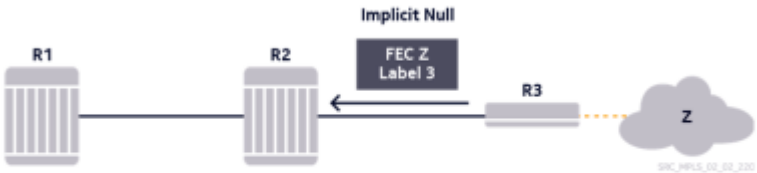
Label Value	Label Usage
0	IPv4 Explicit Null
2	Router Alert
3	IPv6 Explicit Null
4-15	Reserved for future use

Before Implicit Null - Normal Operation



R3 receives packets destined fro FEC Z with a label of 100 and always pops them.

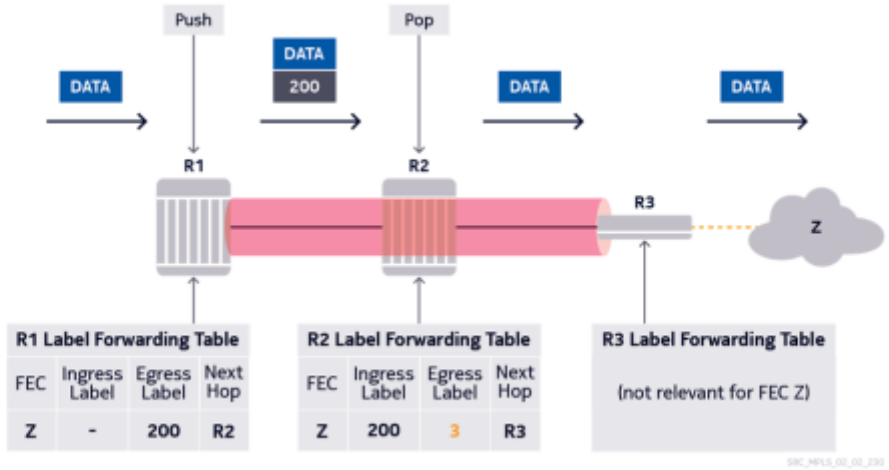
MPLS Implicit Null



- On R3, the result of the label lookup process for packets destined fro FEC Z is always a "pop" action.

- If R3 wants to save some processing resources, it can request the penultimate router (R2) to send the packets with no transport label.
- R3 expresses this by advertising a label binding for FEC Z with a value of 3.

Penultimate Hop Popping (Result of Implicit Null Advertisement)

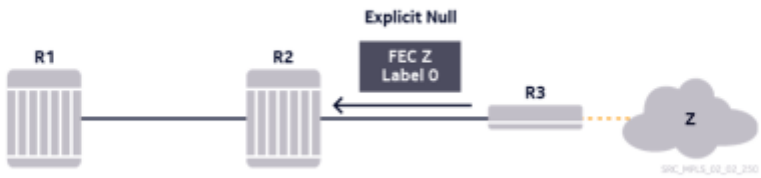


- Penultimate hop (R2) honors the request of R3 and pops the transport label
- Although the egress label value is displayed as 3, this value can never exist in the MPLS label of a data packet.

Nokia Support for Penultimate Hop Popping (PHP)

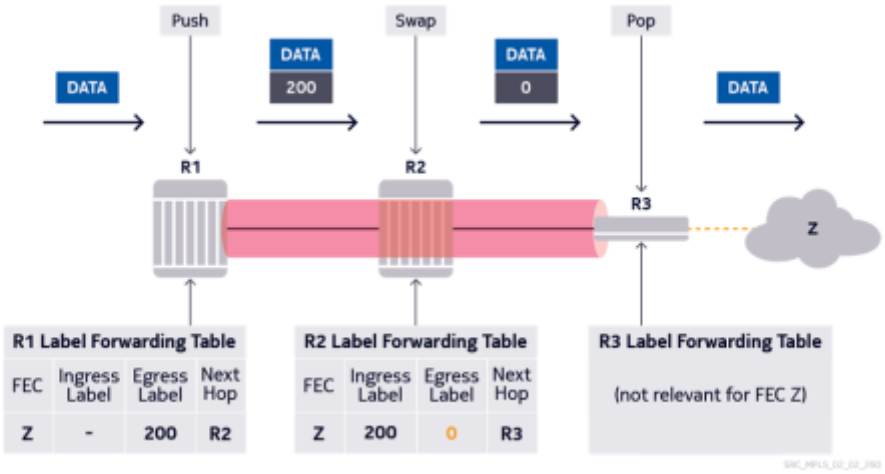
- As a penultimate router, Nokia routers have always had inherent support to honor any PHP request.
- Its possible to configure an SR OS router to advertise impllicit null as the last hop router
- It is supported for both LDP and RSVP-TE
- Introduced for small-scale MPLS nodes.

MPLS Explicit Null



- R3 still wants to sav esome CPU resources but needs the QoS information included in the EXP bits.
- R3 sends a lebl value of 0 to router R2
- R3 pops the label directly without doing a label lookup; R3 records the EXP bit value for QoS processing.

Result of Explicit Null Advertisement



- R2 honors the request of R3 and sends the packet with a label value of 0
- R3 immediately pops the label when it sees a value of 0.

Nokia SR OS Support for Explicit Null

- As the penultimate router, Nokia Routers have always had the inherent support to honor any explicit null request
- Service Router does not send any explicit null requests as the last hop
- CPU utilization is not a concern on the service router.

MPLS Router Alert Label

- Used in several OAM (Operational, Adminsitration, Maintenance) applications.
- Indicates to the receiving router that the packet must be passed to the control plane for processing.