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Segment Routing-Future of IP/MPLS

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I.INTRODUCTION

Segment Routing (SR) is very much similar to the source routing . A node want to send a packet will fallow the segment .Segment is a set of source routing policy & instruction . A segment can represent any instruction, topological or service-based. The source chooses a path and encodes it in the packet header as an ordered list of segments. Segments are identifier for any type of instruction. Each segment is identified by the segment ID (SID) consisting of a flat unsigned 32-bit integer. segment can have a semantic local to an SR node or global within an SR domain. SR supports per-flow explicit routing while maintaining per-flow state only at the ingress nodes to the SR domain.

Segment instruction can be:

• Go to node P using the shortest path (installed by igp –ISIS,OSPF)

• Go to node P over the shortest path to node Q and then follow links Layer 1, Layer 2, and Layer 3

• Apply service S

With segment routing, the network no longer needs to maintain a per-application and per-flow state. Instead, it obeys the forwarding instructions provided in the packet A segment may be associated with a topological instruction. A topological local segment may instruct a node to forward the packet via a specific outgoing interface. A topological global segment may instruct an SR domain to forward the packet via a specific path to a destination. Different segments may exist for the same destination, each with different path objectives (e.g., which metric is minimized, what constraints are specified).

Segment Routing relies on a small number of extensions to Cisco Intermediate System-to-Intermediate System (IS-IS) and Open Shortest Path First (OSPF) protocols. It can operate with an MPLS (Multiprotocol Label Switching) or an IPv6 data plane, and it integrates with the rich multi service capabilities of MPLS, including Layer 3 VPN (L3VPN), Virtual Private Wire Service (VPWS), Virtual Private LAN Service (VPLS), and Ethernet VPN (EVPN). A segment may be associated with a service instruction (e.g. the packet should be processed by a container or VM associated with the segment). A segment may be associated with a QoS treatment (e.g., shape the packets received with this segment at x Mbps).

Segment routing can be directly applied to the Multiprotocol Label Switching (MPLS) architecture with no change in the forwarding plane. Segment routing utilizes the network bandwidth more effectively than traditional MPLS networks and offers lower latency. A segment is encoded as an MPLS label. The SR architecture supports any type of control-plane: distributed, centralized or hybrid.

In a centralized scenario, the segments are allocated and instantiated by an SR controller. The SR controller decides which nodes need to steer which packets on which source-routed policies. The SR controller computes the source-routed policies. The SR architecture does not restrict how the controller programs the network. Likely options are NETCONF, PCEP and BGP. The SR architecture does not restrict the number of SR controllers. Specifically multiple SR controllers may program the same SR domain. The SR architecture allows these SR controllers to discover which SID's are instantiated at which nodes and which sets of local (SRLB) and global labels (SRGB) are available at which node.

A hybrid scenario complements a base distributed control-plane with a centralized controller. For example, when the destination is outside the IGP domain, the SR controller may compute a source-routed policy on behalf of an IGP node. The SR architecture does not restrict how the nodes which are part of the distributed control-plane interact with the SR controller. Likely options are PCEP and BGP.

Hosts MAY be part of an SR Domain. A centralized controller can inform hosts about policies either by pushing these policies to hosts or responding to requests from hosts. The SR architecture can be instantiated on various data planes. This document introduces two data planes instantiations of SR: SR over MPLS (SR-MPLS) and SR over IPv6 (SRv6). In the context of an IGP-based distributed control-plane, two topological segments are defined: the IGP adjacency segment and the IGP prefix segment. In the context of a BGP-based distributed control-plane, two topological segments are defined: the BGP peering segment and the BGP prefix segment. The headend of an SR Policy binds a SID (called Binding segment or BSID) to its policy. When the headend receives a packet with active segment matching the BSID of a local SR Policy, the headend steers the packet into the associated SR Policy.

This document defines the IGP, BGP and Binding segments for the SR-MPLS and SRv6 data planes.

II.TERMINOLOGY

SID: a segment identifier. Note that the term SID is commonly used in place of the term Segment, though this is technically imprecise as it overlooks any necessary translation

• **Prefix SID**— A segment ID that contains an IP address prefix calculated by an IGP in the service provider core network. Prefix SIDs are globally unique. A node SID is a special form of prefix SID that contains the loopback address of the node as the prefix. It is advertised as an index into the node specific SR Global Block or SRGB.

• **Adjacency SID**— A segment ID that contains an advertising router's adjacency to a neighbor. An adjacency SID is a link between two routers. Since the adjacency SID is relative to a specific router, it is locally unique Note:-SR-MPLS: the instantiation of SR on the MPLS dataplane,SRv6: the instantiation of SR on the IPv6 data plane.

Segment Routing Domain (SR Domain): the set of nodes participating in the source based routing model. These nodes may be connected to the same physical infrastructure (e.g.: a Service Provider's network).

They may as well be remotely connected to each other (e.g.: an enterprise VPN or an overlay). If multiple protocol instances are deployed, the SR domain most commonly includes all of the protocol instances in a single SR domain. However, some deployments may wish to sub-divide the network into multiple SR domains, each of which includes one or more protocol instances. It is expected that all nodes in an SR Domain are managed by the same administrative entity.

PUSH: the instruction consisting of the insertion of a segment at the top of the segment list. In SR-MPLS the top of the segment list is the topmost (outer) label of the label stack. In SRv6, the top of the segment list is represented by the first segment in the Segment Routing

NEXT: when the active segment is completed, NEXT is the instruction consisting of the inspection of the next segment. The next segment becomes active. In SR-MPLS, NEXT is implemented as a POP of the top label. In SRv6, NEXT is implemented as the copy of the next segment from the SRH to the Destination Address of the IPv6 header.

CONTINUE: the active segment is not completed and hence remains active. In SR-MPLS, CONTINUE instruction is implemented as a SWAP of the top label.

SR Global Block (SRGB): the set of global segments in the SR Domain. If a node participates in multiple SR domains, there is one SRGB for each SR domain. In SR-MPLS, SRGB is a local property of a node and identifies the set of local labels reserved for global segments. In SR-MPLS, using the same SRGB on all nodes within the SR Domain is strongly recommended. Doing so eases operations and troubleshooting as the same label represents the same global segment at each node. In SRv6, the SRGB is the set of global SRv6 SIDs in the SR Domain.

SR Local Block (SRLB): local property of an SR node. If a node participates in multiple SR domains, there is one SRLB for each SR domain. In SR-MPLS, SRLB is a set of local labels reserved for local segments. In SRv6, SRLB is a set of local IPv6 addresses reserved for local SRv6 SID's. In a controller-driven network, some controllers or applications MAY use the control plane to discover the available set of local segments.

Global Segment: a segment which is part of the SRGB of the domain. The instruction associated to the segment is defined at the SR Domain level. A topological shortest-path segment to a given destination within an SR domain is a typical example of a global segment.

Local Segment: In SR-MPLS, this is a local label outside the SRGB. It MAY be part of the explicitly advertised SRLB. In SRv6, this can be any IPv6 address i.e., the address MAY be part of the SRGB but used such that it has local significance. The instruction associated to the segment is defined at the node level. IGP Segment: the generic name for a segment attached to a piece of information advertised by a link-state IGP, e.g. an IGP prefix or an IGP adjacency.

IGP-Prefix Segment: an IGP-Prefix Segment is an IGP Segment representing an IGP prefix. When an IGP-Prefix Segment is global within the SR IGP instance/topology it identifies an instruction to forward the packet along the path computed using the routing algorithm specified in the algorithm field, in the topology and the IGP instance where it is advertised. Also referred to as Prefix Segment.

SR Policy: an ordered list of segments. The headend of an SR Policy steers packets onto the SR policy. The list of segments can be specified explicitly in SR-MPLS as a stack of labels and in SRv6 as an ordered list of SRv6 SID's. Alternatively, the list of segments is computed based on a destination and a set of optimization objective and constraints (e.g., latency, affinity, SRLG, ...). The computation can be local or delegated to a PCE server. An SR policy can be configured by the operator, provisioned via NETCONF or provisioned via PCEP [RFC5440] . An SR policy can be used for traffic-engineering, OAM or FRR reasons.

How Segment Routing Works

A router in a Segment Routing network is capable of selecting any path to forward traffic, whether it is explicit or Interior Gateway Protocol (IGP) shortest path. Segments represent sub paths that a router can combine to form a complete route to a network destination. Each segment has an identifier (Segment Identifier) that is distributed throughout the network using new IGP extensions. The extensions are equally applicable to IPv4 and IPv6 control planes. Unlike the case for traditional MPLS networks, routers in a Segment Router network do not require Label Distribution Protocol (LDP) and Resource Reservation Protocol - Traffic Engineering (RSVP-TE) to allocate or signal their segment identifiers and program their forwarding information .Each router (node) and each link (adjacency) has an associated segment identifier (SID). Node segment identifiers are globally unique and represent the shortest path to a router as determined by the IGP. The network administrator allocates a node ID to each router from a reserved block. On the other hand, an adjacency segment ID is locally significant and represents a specific adjacency, such as egress interface, to a neighboring router. Routers automatically generate adjacency identifiers outside of the reserved block of node IDs. In an

MPLS network, a segment identifier is encoded as an MPLS label stack entry. Segment IDs direct the data along a specified path. There are two kinds of segment IDS: Within an SR domain, an SR-capable IGP node advertises segments for its attached prefixes and adjacencies. These segments are called IGP segments or IGP SIDs. They play a key role in Segment Routing and use-cases as they enable the expression of any path throughout the SR domain. Such a path is either expressed as a single IGP segment or a list of multiple IGP segments.

The following figure illustrates an MPLS network with five routers using Segment Routing, IS-IS, a label range of 100 to 199 for node IDs, and 200 and higher for adjacency IDs. IS-IS would distribute IP prefix reachability alongside segment ID (the MPLS label) across the network

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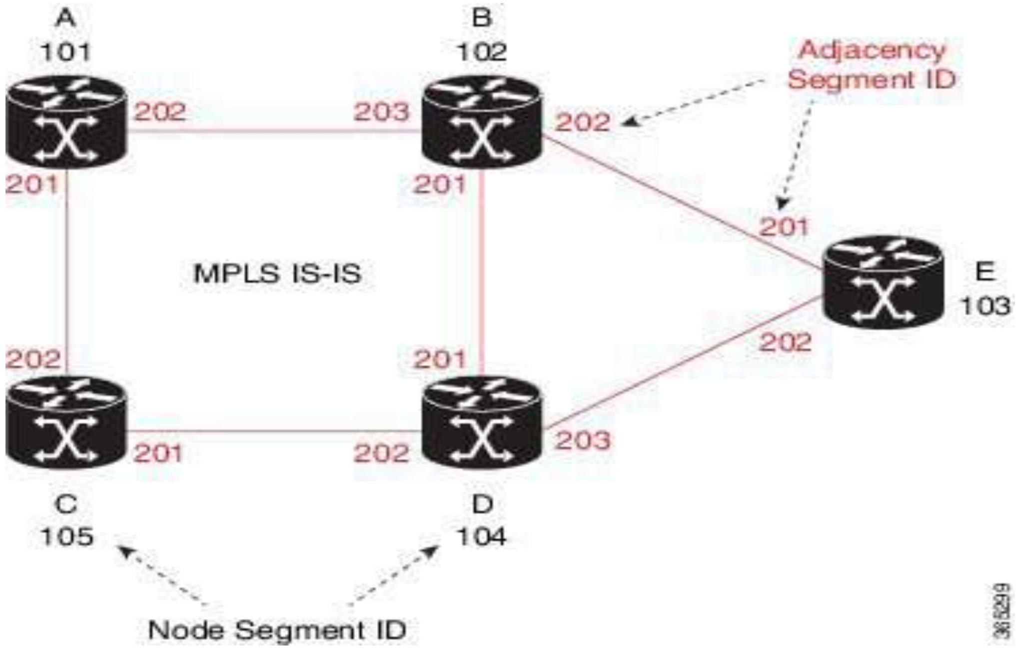
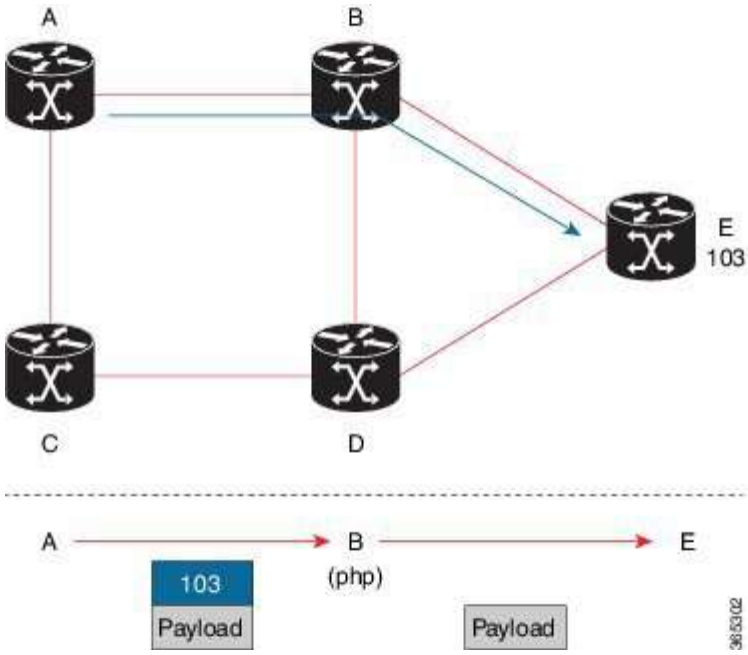


In the previous example, any router sending traffic to router E would push label 103 (router E node segment identifier) to forward traffic using the IS-IS shortest path. The MPLS label-swapping operation at each hop preserves label 103 until the packet arrives at E (Figure 2). On the other hand, adjacency segments behave differently. For example, if a packet arrives at Router D with a top-of-stack MPLS label of 203 (D-to-E adjacency segment identifier), Router D would pop the label and forward the traffic to Router E.



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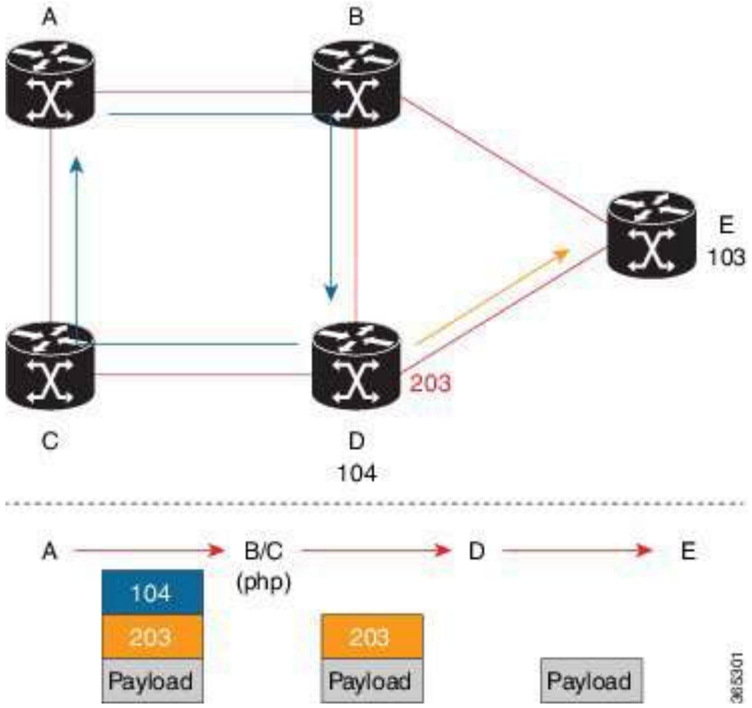
Segment identifiers can be combined as an ordered list to perform traffic engineering. A segment list can contain several adjacency segments, several node segments, or a combination of both depending on the forwarding requirements. In the previous example, Router A could alternatively push label stack (104, 203) to reach Router E using the shortest path and all applicable ECMPs to Router D and then through an explicit interface onto the destination (Figure 3). Router A does not need to signal the new path, and the state information remains constant in the network. Router A ultimately enforces a forwarding policy that determines which flows destined to router E are switched through a particular path.



III.PREFIX-SID ALGORITHM

Segment Routing supports the use of multiple routing algorithms i.e, different constraint based shortest path calculations can be supported. An algorithm identifier is included as part of a Prefix-SID advertisement.

This document defines two algorithms:

- "Shortest Path": this algorithm is the default behavior. The packet is forwarded along the well known ECMP-aware SPF algorithm employed by the IGPs. However it is explicitly allowed for a midpoint to implement another forwarding based on local policy. The "Shortest Path" algorithm is in fact the default and current behavior of most of the networks where local policies may override the SPF decision.
- "Strict Shortest Path": This algorithm mandates that the packet is forwarded according to ECMP-aware SPF algorithm and instructs any router in the path to ignore any possible local policy overriding the SPF decision. The SID advertised with "Strict Shortest Path" algorithm ensures that the path the packet is

going to take is the expected, and not altered, SPF path. Note that Fast Reroute (FRR) [RFC5714] mechanisms are still compliant with the Strict Shortest Path. In other words, a packet received with a Strict-SPF SID may be rerouted through a FRR mechanism.

An IGP-Prefix Segment identifies the path, to the related prefix, computed as per the associated algorithm. A packet injected anywhere within the SR domain with an active Prefix-SID is expected to be forwarded along a path computed using the specified algorithm. Clearly, if not all SR capable nodes in an SR Domain support a given algorithm it is not possible to guarantee that the packet will follow a path consistent with the associated algorithm.

A router MUST drop any SR traffic associated with an SR algorithm, if the nexthop router has not advertised support for the SR algorithm.

The ingress node of an SR domain SHOULD validate that the path to a prefix, advertised with a given algorithm, includes nodes all supporting the advertised algorithm. If this constraint cannot be met the packet SHOULD be dropped by the ingress node. Note that in the special case of "Shortest Path", all nodes (SR Capable or not) are assumed to support this algorithm.

Benefits of Segment Routing

• **Ready for SDN**— Segment Routing is a compelling architecture conceived to embrace Software-Defined Network (SDN) and is the foundation for Application Engineered Routing (AER). It strikes a balance between network-based distributed intelligence, such as automatic link and node protection, and controller-based centralized intelligence, such as traffic optimization. It can provide strict network performance guarantees, efficient use of network resources, and very high scalability for application-based transactions. The network uses minimal state information to meet these requirements. Segment routing can be easily integrated with a controller-based SDN architecture. Below figure illustrates a sample SDN scenario where the controller performs centralized optimization, including bandwidth admission control. In this scenario, the controller has a complete picture of the network topology and flows. A router can request a path to a destination with certain characteristics, for example, delay, bandwidth, diversity. The controller computes an optimal path and returns the corresponding segment list, such as an MPLS label stack, to the requesting router. At that point, the router can inject traffic with the segment list without any additional signaling in the network.

• In addition, segment lists allow complete network virtualization without adding any application state to the network. The state is encoded in the packet as a list of segments. Because the network only maintains segment state, it can support a large number - and a higher frequency - of transaction-based application requests without creating any burden on the network.

• **Simplified**—When applied to the MPLS data plane, Segment Routing offers the ability to tunnel MPLS services (VPN, VPLS, and VPWS) from an ingress provider edge to an egress provider edge without any other protocol than an IGP (ISIS or OSPF). Simpler operation without separate protocols for label distribution (for example, no LDP or RSVP).No complex LDP or IGP synchronization to troubleshoot

.Better utilization of installed infrastructure, for lower capital expenditures (Cap Ex), withECMP-aware shortest path forwarding (using node segment IDs).

• **Supports Fast Reroute (FRR)—** Deliver automated FRR for any topology. In case of link or node failures in a network, MPLS uses the FRR mechanism for convergence. With segment routing, the convergence time is sub-50-msec.

• **Large-scale Data Center-Segment Routing simplifies MPLS-**enabled data center designs using Border Gateway Protocol (BGP) RFC 3107 - IPv4 labeled unicast among Top-of-the-Rack/Leaf/Spine switches. BGP distributes the node segment ID, equivalent to IGP node SID. Any node within the topology allocates the same BGP segment for the same switch. The same benefits are provided as for IGP node SID: ECMP and automated FRR (BGP PIC(Prefix Independent Convergence).This is a building block for traffic engineering - SR TE data center fabric optimization.

• **Scalable**—Segment Routing Configuration Guide, Cisco IOS XE Release 3S 5 Introduction to Segment Routing Avoid thousands of labels in LDP database. Avoid thousands of MPLS Traffic Engineering LSP's in the network. Avoid thousands of tunnels to configure.

• **Dual-plane Networks**—Segment Routing provides a simple solution for disjointness enforcement within a so-called "dual-plane" network, where the route to an edge destination from a given plane stays within the plane unless the plane is partitioned. An additional SID "anycast" segment ID allows the expression of macro policies such as: "Flow 1 injected in node A toward node Z must go via plane 1" and "Flow 2 injected in node A towards node Z must go via plane 2."

• **Centralized Traffic Engineering**—Controllers and orchestration platforms can interact with Segment Routing traffic engineering for centralized optimization, such as WAN optimization. Network changes such as congestion can trigger an application to optimize (recompute) the placement of segment routing traffic engineering tunnels .Segment Routing tunnels are dynamically programmed onto the network from an orchestrator using southbound protocols like PCE .Agile network programming is possible since Segment Routing tunnels do not require signaling and per-flow state at midpoints and tail end routers.

• **Egress Peering Traffic Engineering (EPE)—**Segment Routing allows centralized EPE.A controller instructs an ingress provider edge and content source to use a specific egress provider edge and specific external interface to reach a destination. BGP "peering" segment IDs are used to express source-routed inter-domain paths .Controllers learn BGP peering SIDs and the external topology of the egress border router through BGP Link Status (BGP-LS) EPE routes. Controllers program ingress points with a desired path.

• **Plug-and-Play deployment**— Segment routing tunnels are interoperable with existing MPLS control and data planes and can be implemented in an existing deployment

IV.CONCLUSION

The segment routing has good significant advantages over ip/mpls network .It also support large ISP ,TE,FRR and other serval services. Segment Routing: An Architecture build with SDN in mind and addressing the evolving network requirements . SR can be seen as alternative for LDP and RSVP-TE. This means that the same scaling requirements will remain in case of an E2E MPLS coverage in a multi-area/instance domain. • Seamless MPLS could be used to cross area or AS boundary, similar to what is available today with LDP and/or RSVP-TE. This approach has some clear advantages: - Smooth migration with existing MPLS domains - BGP is a field-proven scalable protocol - Non-SR nodes can still connect to a SR MPLS domain Public Use case 7: Seamless MPLS and segment routing (1) End-to-end scaling integrating SR/LDP/RSVP-TE.

V. ACKNOWLEDGEMENTS

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