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SRv6: A new approach for the evolution of IP networks

Segment Routing for 5G IP transport networks

5G brings with it the promise of a range of new services from the faster speeds of enhanced mobile broadband to mass deployment of machine-type communications to ultra-reliable low-latency applications. With this range of services comes a pressing need to design network infrastructure that can easily and efficiently support a range of service types. In IP/MPLS networks, deterministic, SLA-based services were traditionally supported by implementing traffic engineering using protocols such as RSVP-TE. This approach, however, was complex and difficult to scale and as a result saw only limited deployment in service provider networks. Segment Routing (SR) was conceived as an approach to solve these problems and provide a foundation for support of SLA services, reliability, and performance in core router networks. Its ability to run over any data plane and to leverage cloud-based path computation has made it a natural complement to the introduction of SDN.

SR is an increasingly mature technology with established standards, a wide ecosystem of vendors that support it, and proven interoperability through extensive third-party testing from organizations such as EANTC. Most importantly, SR is now deployed in production networks around the world with service providers including Bell Canada, Colt, China Unicom, VF Germany, and Comcast.

SRv6 as a new, more powerful approach to SR

Strong interest is emerging in SR with IPv6 as the transport/data plane. SRv6 shares many of the same characteristics, benefits, and target applications of SR deployed on an MPLS data plane (i.e., “SR-MPLS”) but adds some new features with very interesting potential:

- **Increased reachability:** The 128-bit address space supported by IPv6 provides approximately 3.4×10^{38} addresses, more than enough to support the massive growth in network-attached devices expected with the growing adoption of IoT applications.

- **Simplified networking:** SRv6 uses IPv6 extension headers to directly include IPv6-based segment IDs (SIDs) into the IPv6 packet. This implies that separate tunneling protocols such as L2TP, GRE, and even MPLS can be eliminated from the network, simplifying overall network operations and maintenance. The concept can also be extended to mobile networks where SRv6 could replace the GTP protocol, and even in the data center, eliminating the need for VXLAN. In effect, SRv6 can be used as a single unifying protocol from the device through to its destination, be it another device or application in the cloud with the appropriate capacity, latency, and reliability.

- **Network programmability:** One of the most interesting facets of SRv6 is the ability to enable a whole new range of network applications through a concept called "network programming." Special segment IDs (SIDs) can be created and used to include a location, function ID, and state information. An SRv6 packet can then be directed to a network function residing in a particular VM or container in a data center and pass to that application-specific data (state information) to perform that function. This is very similar to how variables are passed to subroutines in computer programming. The network in effect becomes a computer in this paradigm. Network programming can provide an elegant solution to the challenge of providing connectivity to virtualized functions residing in data center locations in a simple, scalable, and secure manner. Other use cases for this approach include VPN services, service chaining, and traffic steering. The concept can also easily be expanded to add an unlimited range of new use cases in the future.

What's ahead for SRv6?

The combined benefits of SRv6 are very compelling: they enable a simplified, unified, and end-to-end transport network leveraging SDN to deliver SLA-based connectivity at scale to connect end-users and devices to a virtualized and distributed services layer. Three operators to date—SoftBank Japan, China Unicom Sichuan, and Iliad Italy—have already announced deployment of SRv6 into their production networks.

Although the story is compelling, mass adoption of SRv6 is not yet assured. There is still a lot of work to be done:

- **Update router hardware:** The introduction of SRv6 requires a hardware upgrade to support SIDs in the IPv6 header and a deep enough SID stack to support large-scale networks. This implies datapath work in the routing NPUs. Vendor platforms with next-generation in-house programmable chipsets are well positioned to move quickly to implement SRv6 features (should they choose). Platforms using merchant silicon may have a longer turnaround. Broadcom is expected to have a solution supporting a deeper SID stack by the end of 2019, with new platforms following 6–9 months after that. Barefoot publicized getting SRv6 up and running on its Tofino chipset with P4 in record time.

- **Optimize to manage header "tax"**: 128-bit addresses may give flexibility for supporting more attached network devices and solve the IPv4 address exhaust issue once and for all, but a large stack of SRv6 SIDs comes with a significant header penalty. This translates into less payload throughput and less efficient use of network capacity resources. Several solutions have been proposed, including SID binding and header compression to address this issue, but there is more work ahead to standardize and implement these enhancements.

- **Finalize key standards:** The basic tools for operationalizing SRv6 networks, including support for resiliency (TI-LFA), testing, monitoring, and other OAM tools, must get through the standardization process and be run through performance and interoperability testing.

- **Grow the vendor ecosystem:** Currently only Huawei and Cisco support SRv6 on their routers. For broader adoption in the industry, a larger vendor ecosystem is required. Nokia, Juniper, and Arista are currently committed to SR-MPLS and have not yet announced any plans regarding SRv6. Nokia is also championing a slightly different variation of SR called unified-SR that supports some of the same additional features of SRv6 but in a dual-stack (IPv4/IPv6) environment. ZTE has announced plans to support SRv6 but has not yet provided timing on availability.

The big barrier: SRv6 needs IPv6

Beyond the "business as usual" work, there is one more fundamental barrier that could make or break SRv6 as a revolutionary technology in router networks: to run SRv6, an IPv6 network is required. However, the world remains mostly IPv4 and/or dual-stack. According to a June 2018 report published by the Internet Society, only 25% of the world's devices advertise IPv6 connectivity. For most service providers, the path to all-IPv6 networks is a challenging one, and the process will not be undertaken lightly.

We expect the initial deployments of SRv6 to align with the countries and/or network operators that have already implemented IPv6 networks, be it for lack of availability of IPv4 address space or because of national imperatives to deploy IPv6. China and Japan have broad availability of IPv6 because of national policy, and the deployments at China Unicom and SoftBank are well aligned with this. Although network operators in India support a mix of IPv4, IPv6, and dual-stack, Reliance/Jio as a large-scale new entrant went all-IPv6. As a result, it is a strong candidate for SRv6 in the future. In the US, mobile network operators Verizon, Sprint, TMO, and AT&T all have high levels of IPv6 traffic and may also be candidates for SRv6. However, there must be broader support for the technology in the incumbent router vendors in these accounts before we will see wider adoption in the US. SR-MPLS may also be considered the preferred path forward if the challenges of migrating to all-IPv6 are too high.

Bottom line

Segment Routing is now a well-accepted evolution path for simplifying IP/MPLS networks and for providing a solution to address the emerging requirements of 5G/IoT and service virtualization. We believe SR-MPLS and SRv6 will be increasingly deployed in service provider, enterprise, and data center networks. However, it is still early days for SRv6, and there is still a lot of work ahead to develop the vendor ecosystem and get to standardized, interoperable implementations of key features and services. More importantly, the ultimate success of SRv6 rests on broader adoption of IPv6-only networks. Will the benefits of SRv6 be compelling enough to drive network operators to convert? They may, but progress will not happen overnight. In the interim, we see a bright future for SR-MPLS and for SR overall as a path forward for the evolution of IP routing and transport.

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