IPv6 Enhanced (IPE): A New Era of IP Networks for 5G and Cloud

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Founder of SRv6 and IPv6+
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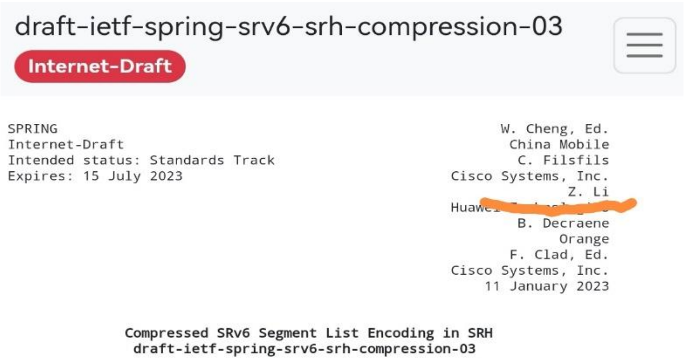
IPv6 Forum Fellow/Vice Chair, APAC IPv6 Council

- 15+ years research and development work in MPLS and SDN Controller as the system architect.
- Be active in standard activities since IETF75 and propose 100+ drafts/RFCs in RTG/OPS areas (www.ipv6plus.net/ZhenbinLi).
- Promoted SDN Transition (Netconf/YANG, BGP/PCEP, etc.) innovation and standard work in the past years.
- Focus on the innovation standard work of SRv6, 5G Transport, Telemetry, Network Intelligence, etc. since 2016.
- Be elected as the IETF IAB member to be responsible for Internet architecture work from 2019 to 2021. Be elected again as the IETF IAB member to be responsible for Internet architecture work from 2021 to 2023.

RFC 8986
Proposed Standard

Internet Engineering Task Force (IETF) — C. Filsfils, Ed., Cisco Systems, Inc.
Request for Comments: 8986 — P. Camarillo, Ed., Cisco Systems, Inc.
Category: Standards Track — J. Leddy, Akamai Technologies
Published: February 2021 — D. Voyer, Bell Canada
ISSN: 2070-1721 — S. Matsushima, SoftBank
Z. Li, Huawei [illegible]

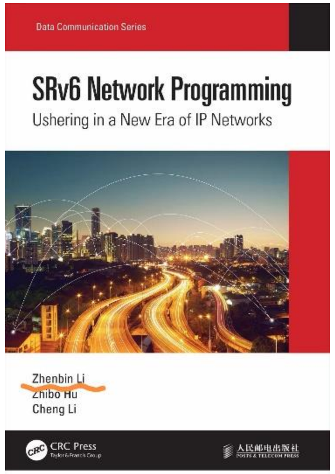
Segment Routing over IPv6 (SRv6) Network Programming



draft-ietf-spring-srv6-srh-compression-03
Internet-Draft

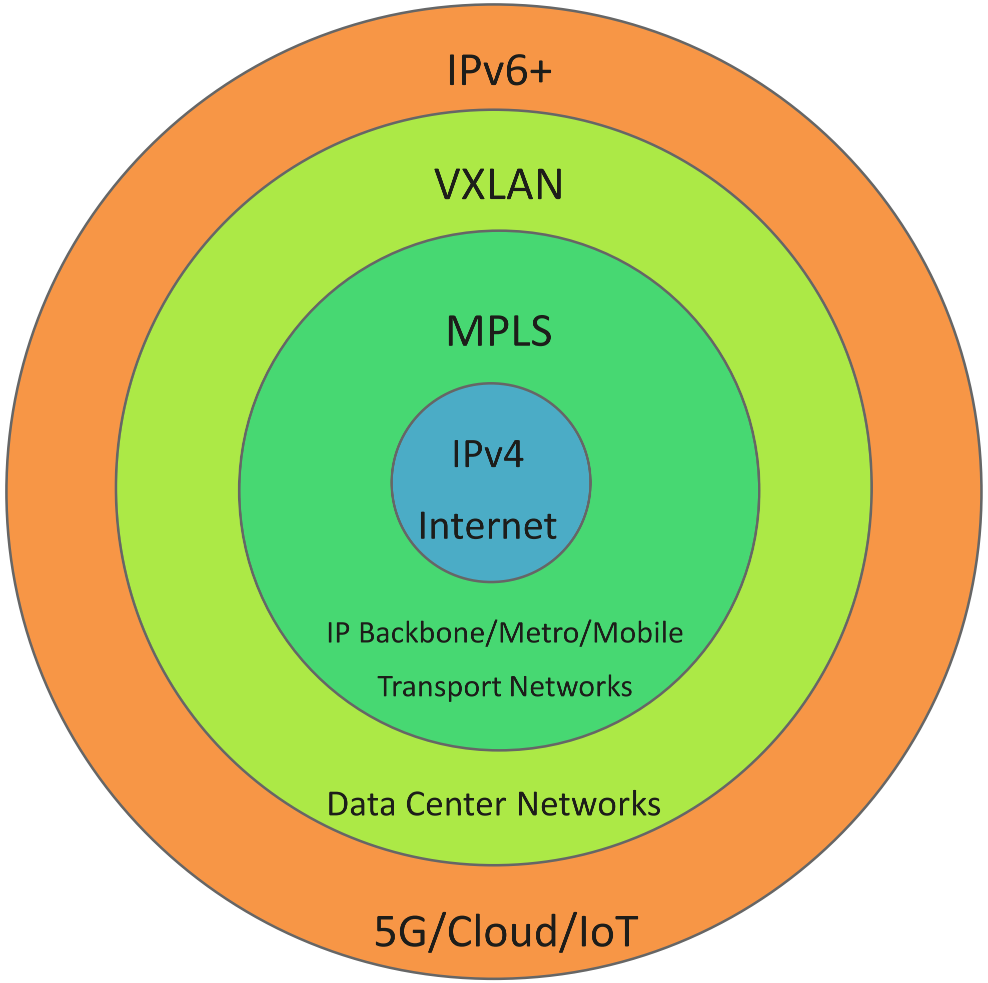
SPRING — W. Cheng, Ed., China Mobile
Internet-Draft — C. Filsfils, Cisco Systems, Inc.
Intended status: Standards Track — Z. Li, Huawei [illegible]
Expires: 15 July 2023 — B. Decraene, Orange
F. Clad, Ed., Cisco Systems, Inc.
11 January 2023

Compressed SRv6 Segment List Encoding in SRH
draft-ietf-spring-srv6-srh-compression-03

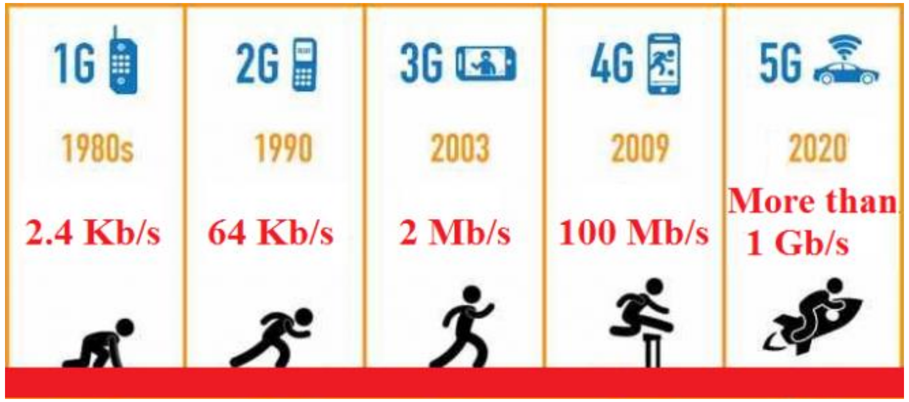


Agenda

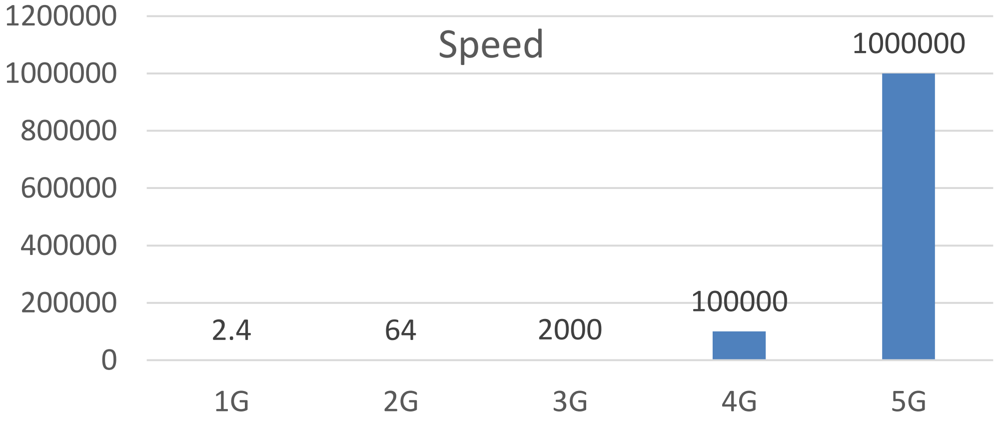
IP Evolutions: Applications Drives the Change of IP Network Architectures



IP



Wireless



Optical

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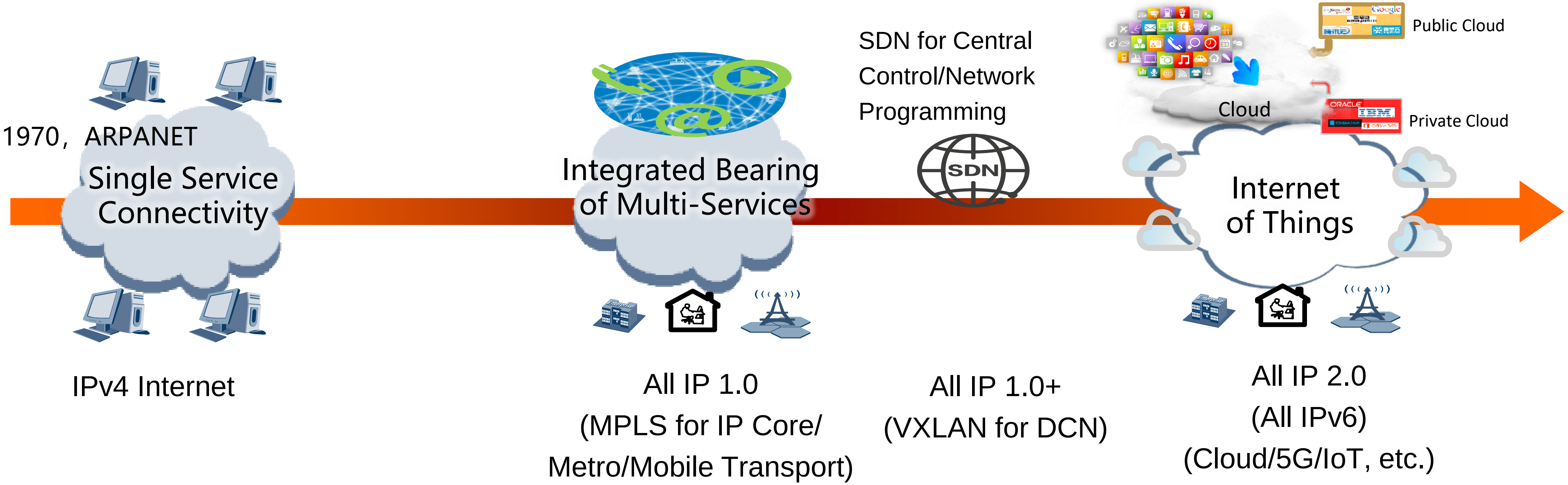
IPv6 Enhanced: A New Era of IP Networks for 5G and Could



- Rethinking on IPv6: Address Space is not enough.
- 5G changes the attributes of connections, and cloud changes their scope.
- Mission of IPv6 Enhanced:
  - Integrate different network easier based on affinity to IP reachability.
  - Provide more encapsulations for new network services such as Network Slicing, DetNet, etc.
  - Cross the chasm between application and network based on affinity to IP and Network Programming conveying application information through IPv6 Extension Header into network.
  - Promote IPv6 combining with requirements on more address spaces.

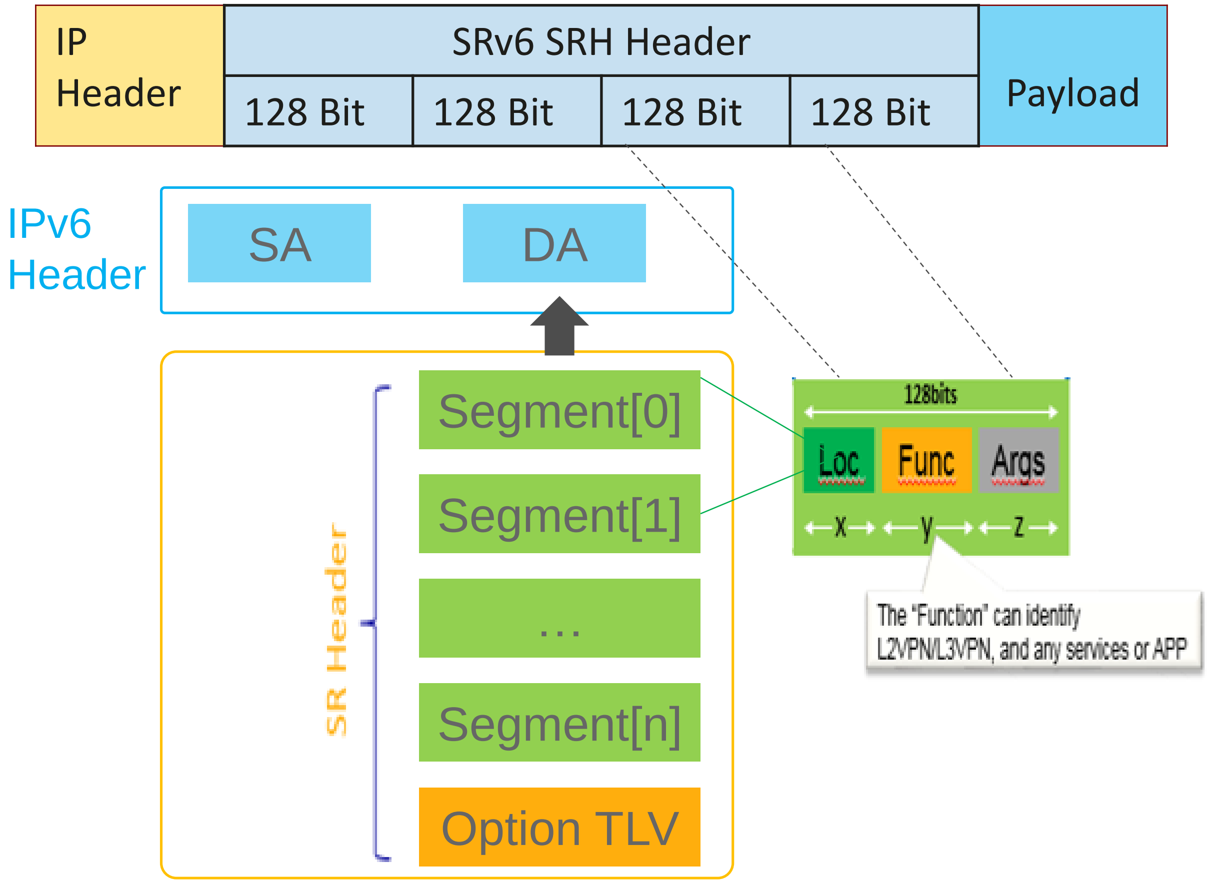
IPv6 Extension Headers and SRv6: Release Network Programming Capabilities

IPv6 Extension Headers

Version	Traffic Class	Flow Label
Pload Length	Next=43	Hop Limit
Source Address		
Destination Address		
Hop-by-Hop Options Header		
Destination Options Header		
Routing Header/SRH		
……		
Destination Options Header		
Payload		

30 years ago, because of limitation of network hardware capabilities, the hardware-friendly design (MPLS: fixed-length packet header) was adopted to extended network functionalities (VPN/TE/FRR, etc.)

SRH: Three Layers of Programming Spaces



In the new era, breakthrough of network hardware and programming chipset capabilities makes IPv6 extensions (variable-length packet header) possible to support more network services.

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IPv6 Enhanced Research and Standard Planning

IPv6 Enhanced 1.0： SRv6 Basic Capabilities

- SRv6 VPN
- SRv6 TE
- SRv6 FRR

IPv6 Enhanced 2.0 ： New Network Services for 5G/Cloud

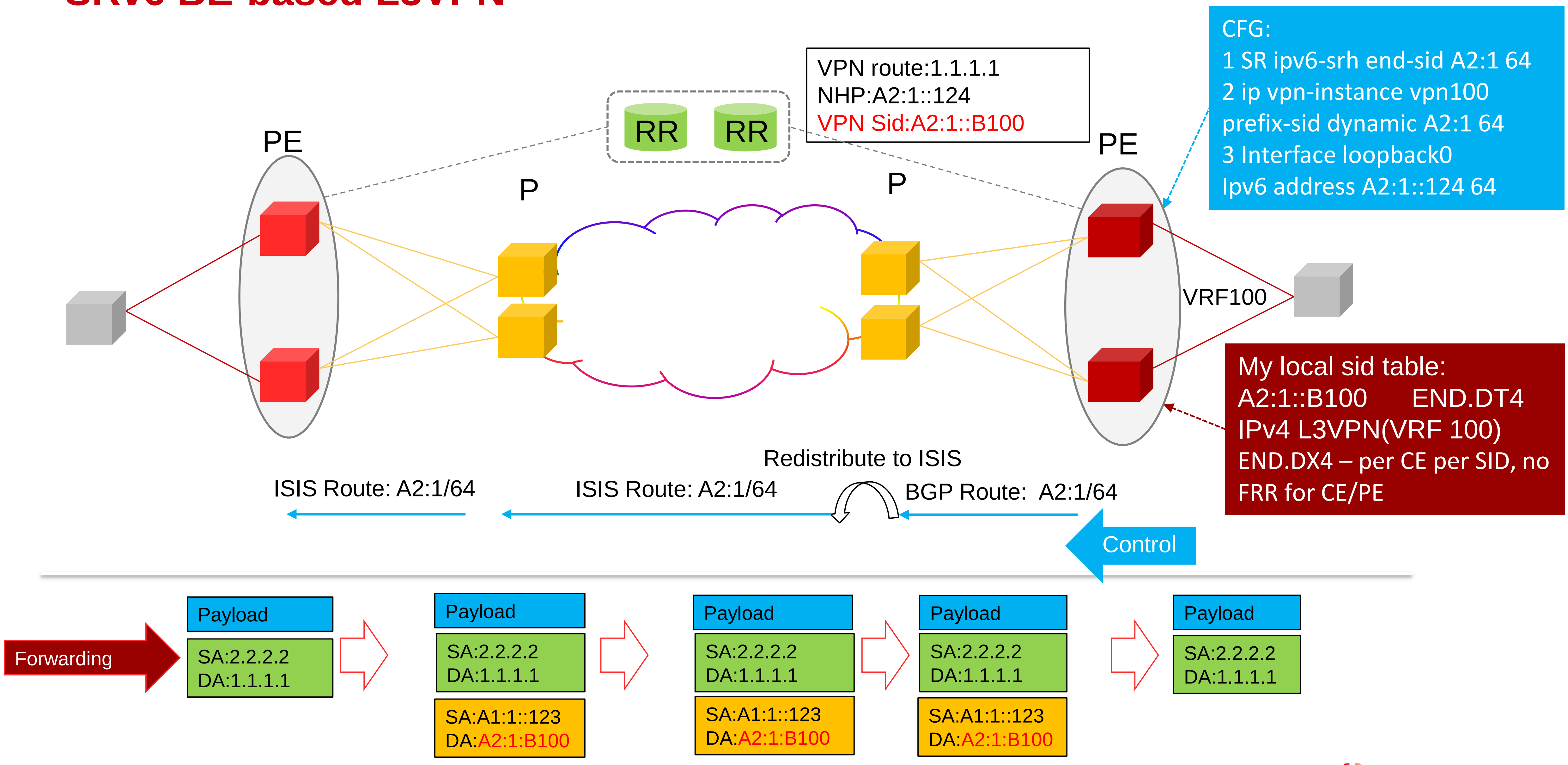
- Network Slicing/VPN+
- In-situ Telemetry/IFIT
- BIERv6
- OAM
- Path Segment
- Detnet
- SFC
- SD-WAN
- SRv6 Compression/G-SRv6

IPv6 Enhanced 3.0： APN6 – App-aware network architecture

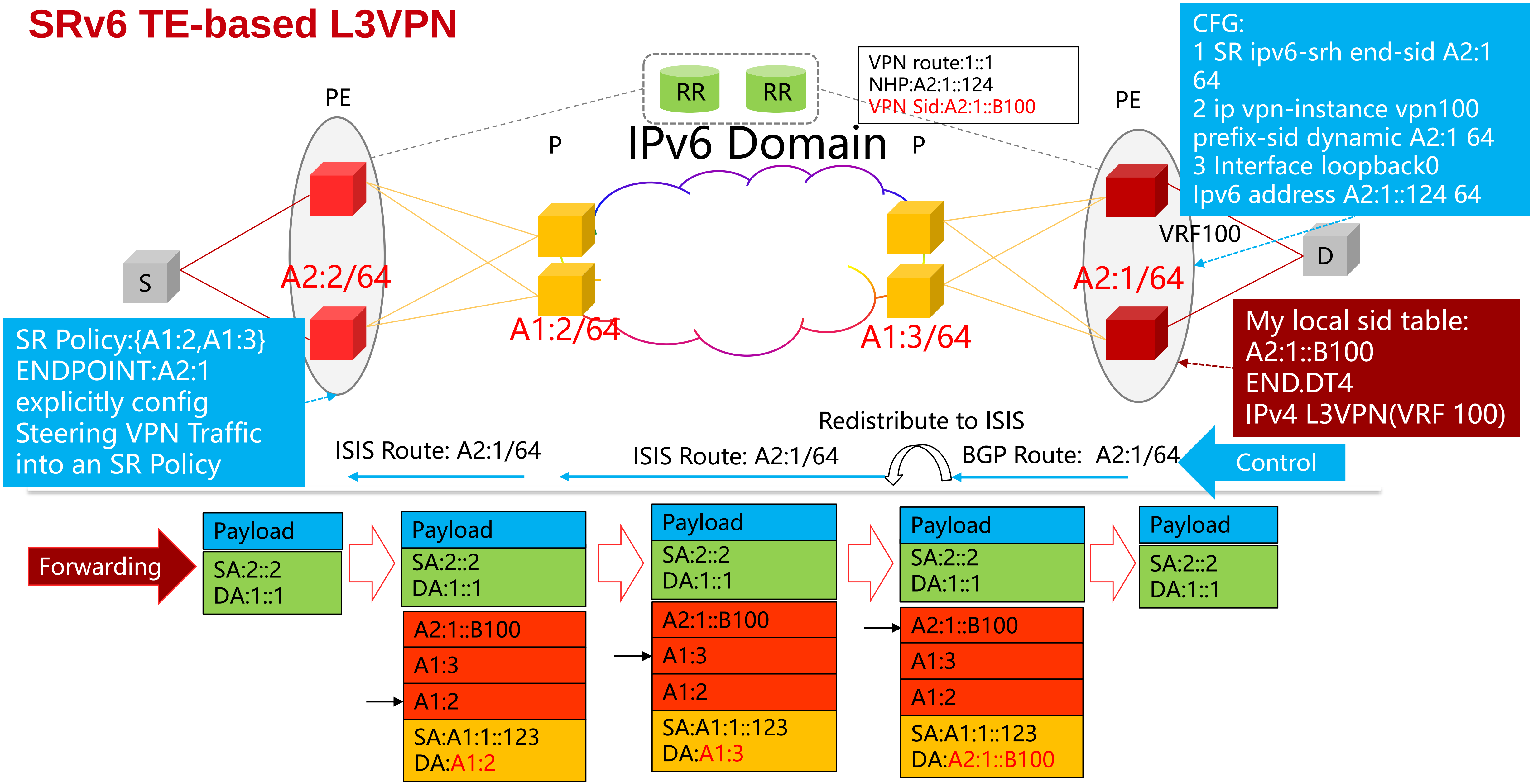
- Forwarding Plane： Conveying Application information via IPv6 extension header
- Control Plane： Exchange Application information through control protocols

Agenda

SRv6 BE-based L3VPN



SRv6 TE-based L3VPN



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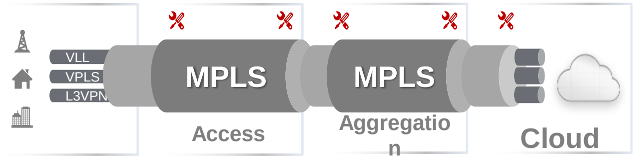
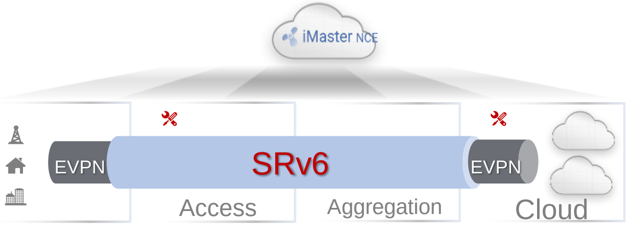
SRv6 is The Best Technology for Future-oriented IP Network

Inter-domain Network Communication

Complex Protocols and Cannot extend to other networks



Unified & simplified Protocols



Experience Differentiated Assurance

Un-routable 20-bits label with Limited capacity

Label	EXP	S	TTL

Programmable Paths & Services

SRv6 Segment List

Programmable segments, enabling service programmability

Locator	Function	Argument
Location info Reachability	Service function definition	Enhancement

Application-aware Networking (APN)

No solutions(MPLS)

Programmable Applications

SRv6 Optional TLV

Programmable Optional TLVs, enabling application programmability

APP ID
User ID
Net Req.

Type
Length
Service Meta

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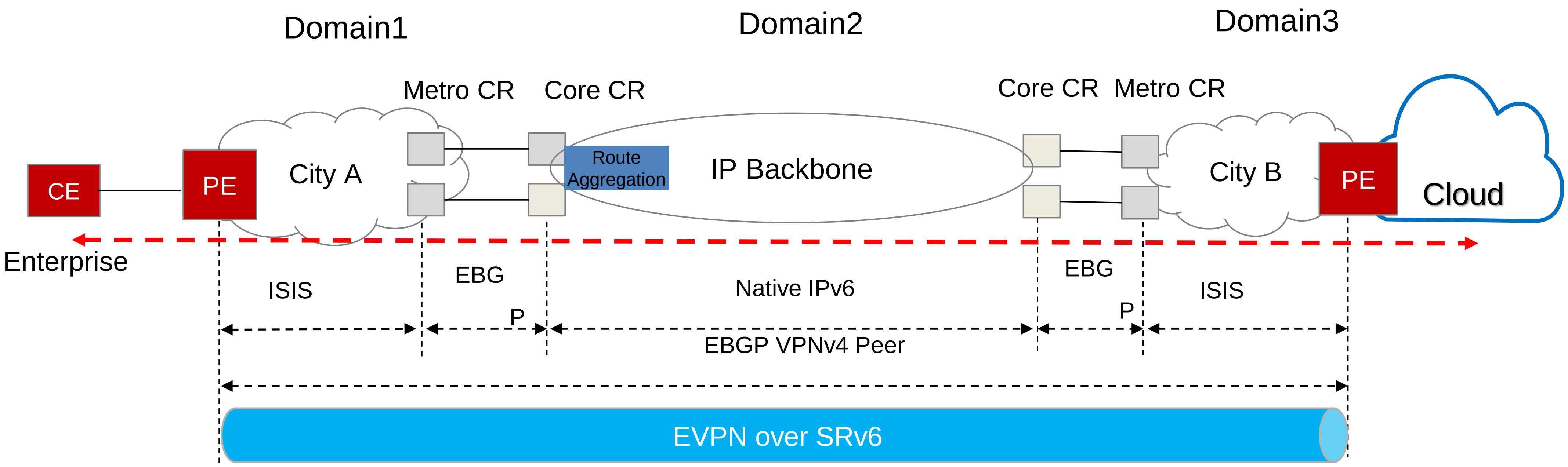
SRv6 Evolution: End-to-end Network Unified Forwarding Process



- Simplicity and Scalability: Work based on IPv6 reachability, no extra signaling. More scalable benefiting form route aggregation.
- Convergence: 10+ Protocols are converged to SRv6 + EVPN to simplify the service provisioning.
- Forward Compatibility and E2E incremental deployment: Unified process to converge different IP network domain. TE and SFC can be deployed incrementally and easily.
- Extensibility: Possibility to be extended to support more new services based on IPv6 as the starting point.

SRv6: Mature Standardization and Rich Eco-system

Mature Standardization

7 RFCs are released

RFC 8402	SR Architecture
RFC 8986	SRv6 Network Programming
RFC 8754	IPv6 Segment Routing Header
RFC 9252	SRv6 VPN
RFC 9256	SR Policy Architecture
RFC 9259	OAM in SRv6
RFC9352	IS-IS Extensions
IESG review	PCEP Extension
IESG review	BGP SR policy
Pre WGLC	SRv6 Compression

Almost All SRv6 Protocol Extension Drafts Become RFC

Mainstream Vendors already support SRv6

…more

EANTC Continuous SRv6 Inter-op Test (2018 – 2023)

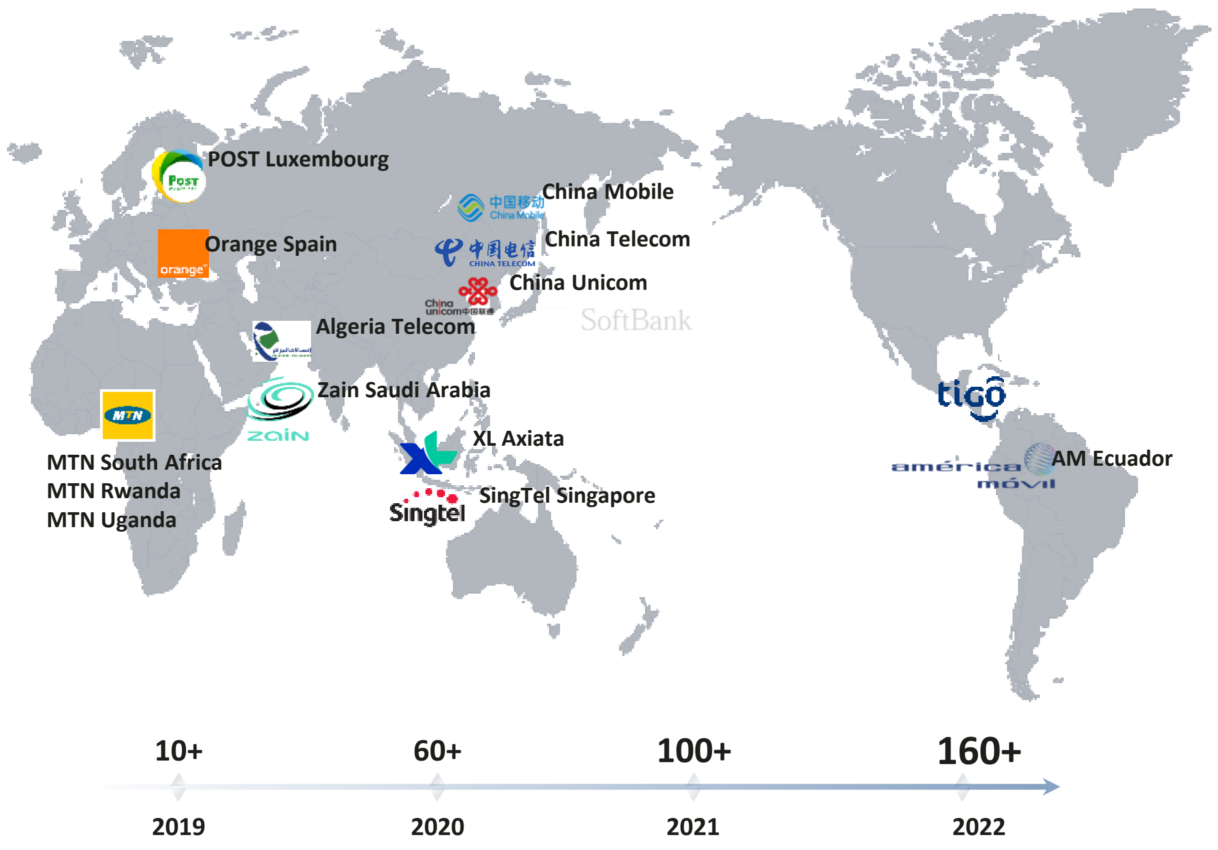
Record-Speed Deployment in Global Carriers

Global Carriers Consensus

(Part of the list)

orange	✓Orange Spain Deployed
T · ·	✓2 Round RFP Released
Telefónica	✓Brazil VIVO IOT Trial
swisscom	✓Already Deployed
中国移动 China Mobile	✓24 network Deployed
SoftBank	✓SRv6 Flex-Algo on 5G Commercial Network
MTN	✓Already Deployed in 3 countries‘
zain	✓Already Deployed in 2 countries‘

Global SRv6 Cases



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SRv6 Deployment with Dual-Vendor Interworking

Challenges

1. Network evolution is complex

IP Network of Orange Spain is built by Huawei, Cisco, Nokia and Juniper.

2. 5G network optimization is complex

Manual optimization based on MPLS/RSVP-TE is complex and takes several days.

Requirements

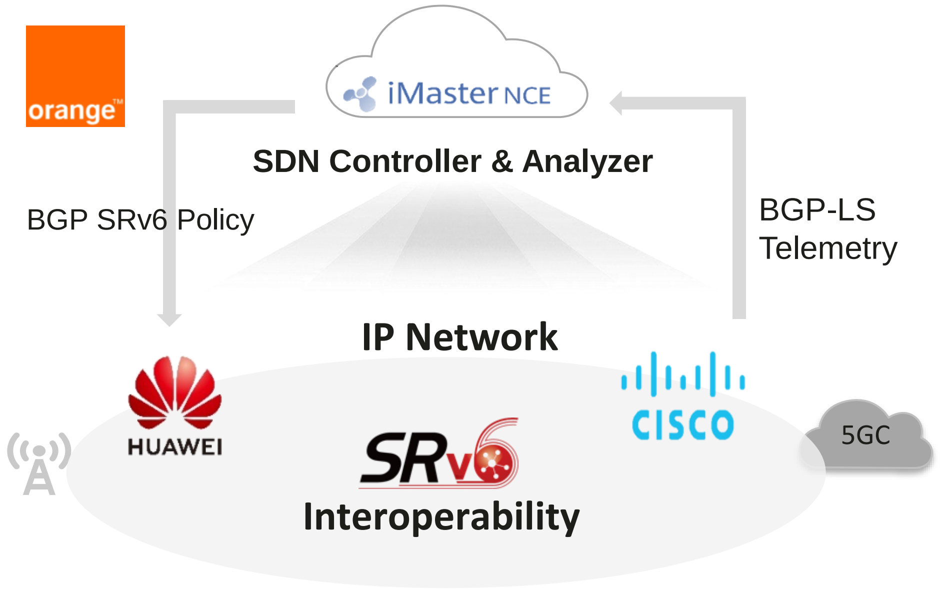
1. Target network architecture for future

- Future services oriented target network
- Evolvable protocol by multi-vendors

2. Flexible network optimization

- Easy network optimization

Implement SRv6 Interworking



Service Scope	Standard Solution		Interworking
5G / LTE	IGP	IS-IS v6	Huawei ATN/NE
SRv6 BE/Policy	TOPO	BGP-LS	PE Node, SRv6 Support
2G / 3G	Forward	SRv6	Cisco NCS
MPLS/RSVP-TE	Control	BGP-SR	P Node, SRv6 Support

Benefit: Flexible Optimization

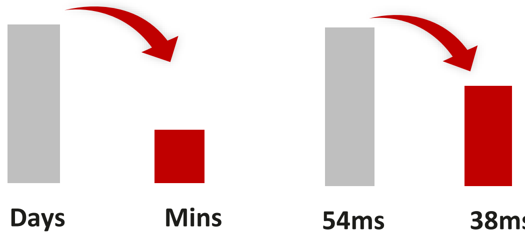
Flexible path optimization on demand

Automation

improve O&M efficiency

Optimization

average lantency reduce 16ms



We expect in 2023 that all the equipments will have a renewal.

— Hector Llorente

IP & Transport Network Manager, Orange Spain

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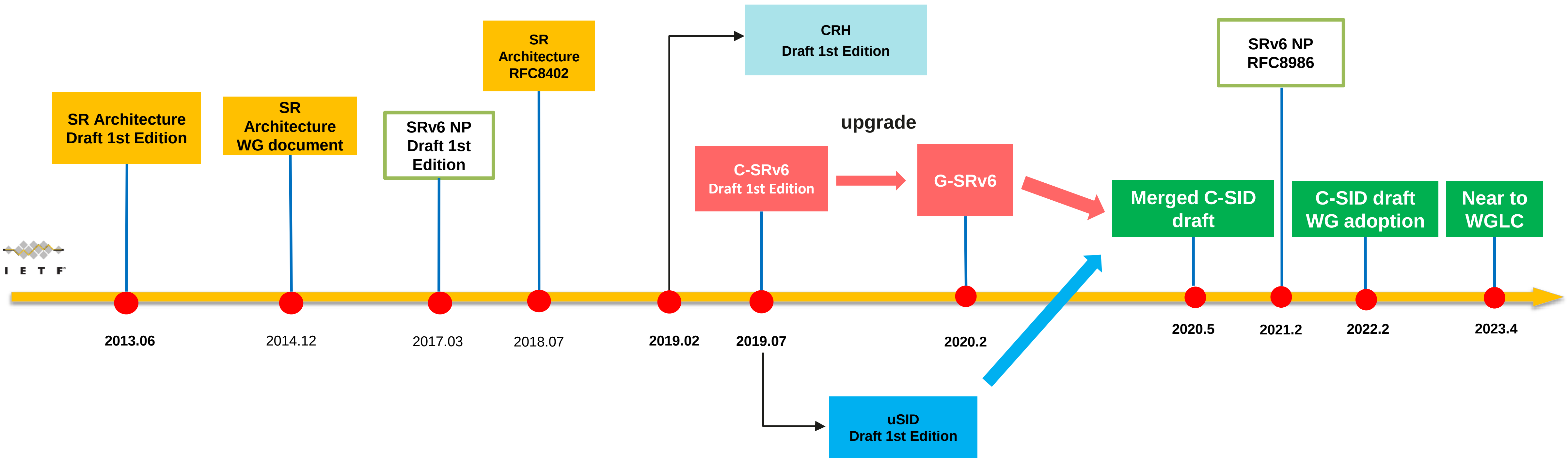
History of SRv6 Compression



- 5 solutions were proposed, and finally merged into one single solution Compressed-SID (C-SID).
- C-SID draft[1] has been adopted as WG draft since Feb, 2022 and near to WGLC now.

[1].https://datatracker.ietf.org/doc/draft-ietf-spring-srv6-srh-compression/

SRv6 Compression: Converged Single Solution and C-SID draft adopted by WG

IETF SPRING WG

- draft-ietf-spring-srv6-srh-compression(C-SID) is adopted.
- C-SID draft defines flavors for the SR endpoint behaviors, which enable a compressed SRv6 Segment-List encoding in the Segment Routing Header (SRH).
  - Replace-C-SID Flavor a.k.a G-SRv6
  - Next-C-SID Flavor a.k.a uSID
  - Next-and-Replace-C-SID Flavor
- All the flavors are defined under the SRv6 network programming architecture RFC8986.
- Replace-C-SID flavor SID and Next-C-SID can be encoded in a single SRH for better interop, and the interop test had been done in 2020.

```
SPRING                                                W. Cheng, Ed.
Internet-Draft                                        China Mobile
Intended status: Standards Track                       C. Filsfils
Expires: 22 September 2022                     Cisco Systems, Inc.
                                                             Z. Li
                                               Huawei Technologies
                                                       B. Decraene
                                                            Orange
                                                            D. Cai
                                                           Alibaba
                                                          D. Voyer
                                                       Bell Canada
                                                       F. Clad, Ed.
                                               Cisco Systems, Inc.
                                                          S. Zadok
                                                          Broadcom
                                                       J. Guichard
                                       Futurewei Technologies Ltd.
                                                          L. Aihua
                                                   ZTE Corporation
                                                         R. Raszuk
                                           NTT Network Innovations
                                                             C. Li
                                               Huawei Technologies
                                                     21 March 2022


              Compressed SRv6 Segment List Encoding in SRH
               draft-ietf-spring-srv6-srh-compression-01
```

C-SID is the recommended solution as per the DT's analysis result, which meet all the compression reqs

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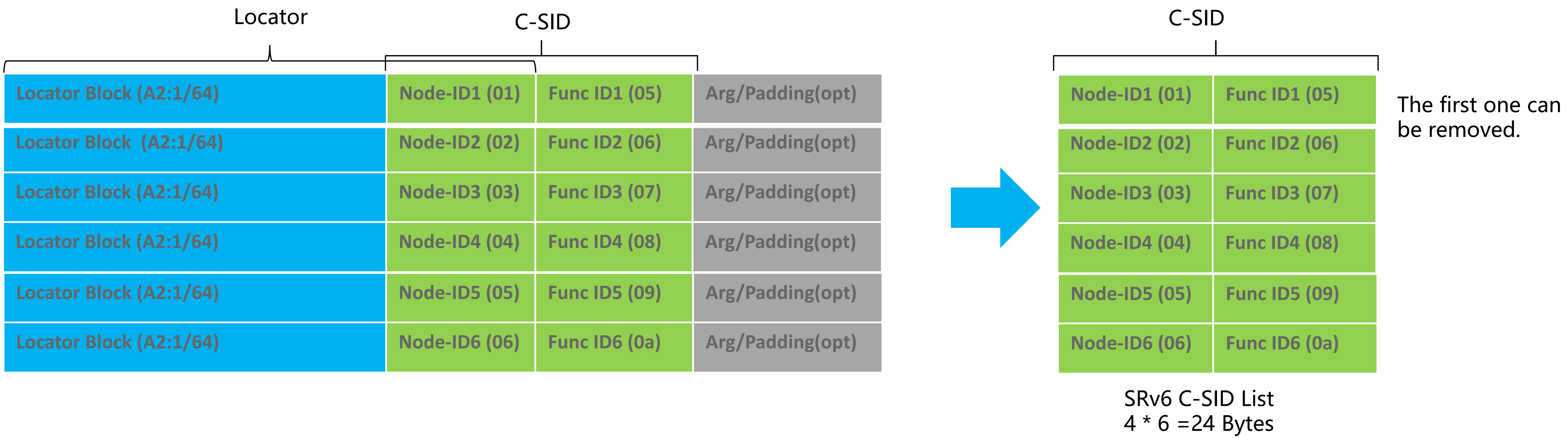
SRv6 Compressed SID (C-SID)

- A normal SRv6 SID is a 128 bits IPv6 address allocated from an address block, called SID Space.
- For the SIDs in the SID list within an SRH， they may share the locator block, and the locator block is redundant that can be deleted to reduce the overhead.
- Each SRv6 SID has the format shown below, we called the different part of the SRv6 SID is compressed SID(C-SID), and the SID is a Compressible SRv6 SID.
- The prefix can be managed according to the real network address planning.
- locator block is included in the first SID in the IPv6 Destination address.



Huawei Implementations on SRv6 C-SID Solutions

NEXT (uSID) + **REPLACE (G-SRv6 32bits)** = **NEXT&REPLACE (G-SRv6 16bits)**

32-bit

NEXT (uSID)

Block	uSID1	uSID2
Block	uSID1	uSID2
Block	uSID1	uSID2
Block	uSID1	uSID2

REPLACE (G-SRv6 32bits)

Block		GSID1	
GSID1	GSID2	GSID3	GSID4
GSID1	GSID2	GSID3	GSID4
GSID1	GSID2	GSID3	GSID4

NEXT&REPLACE (G-SRv6 16bits)

Block		GSID1	GSID2
GSID1	GSID1	GSID1	GSID1
GSID1	GSID1	GSID1	GSID1
GSID1	GSID1	GSID1	GSID1

16-bit

NEXT (uSID)

Block	uSID1	uSID2	uSID3	uSID4
Block	uSID1	uSID2	uSID3	uSID4
Block	uSID1	uSID2	uSID3	uSID4
Block	uSID1	uSID2	uSID3	uSID4

REPLACE (G-SRv6 32bits)

Block				GSID1			
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8

NEXT&REPLACE (G-SRv6 16bits)

Block				GSID1	GSID2	GSID3	GSID4
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8
GSID1	GSID2	GSID3	GSID4	GSID5	GSID6	GSID7	GSID8

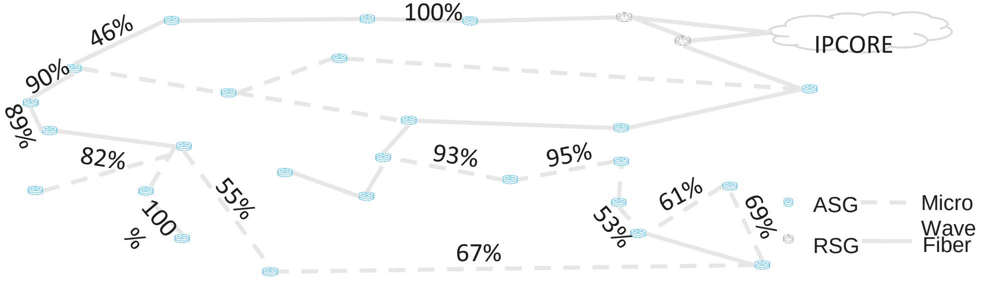
Small locator block, best compression ratio for limited SID list

Flexible locator block, balanced compression ratio and scalability

Flexible locator block, best compression ratio for any SID list

Implements SRv6 Compression to Promote Rapid Traffic Growth

High BW Usage and Insufficient Available Resources



--Typical Aggregation Ring Topology of From Operator U

- To much microwave link: 50% for aggregation(15/30) and 80% for access
- Long service path: 4 aggregation rings have 60 NE on average, and 52 access rings have 8 NE on each ring. The service path is 17 hops on average.
- High bandwidth utilization: 70% on average and over 90% in some cases

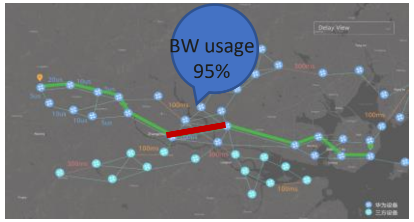
Key Challenge: How to ensure smooth SRv6 cutover without network-wide capacity expansion?

Long service path	High bandwidth utilization	To much microwave link
SRv6 packet carry path info Bandwidth usage definitely increases with SRv6. The longer the path the larger the packet size	High risk of rash cutover Large investment in network expansion unaccepted	The available bandwidth resources is insufficient

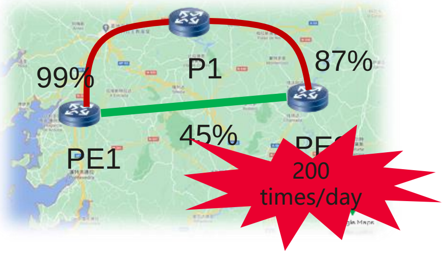
Challenge: How to ensure smooth SRv6 cutover without network-wide capacity expansion?

GSRv6+SDN+precise expansion supports SRv6 successfully deployed

GSRv6 +



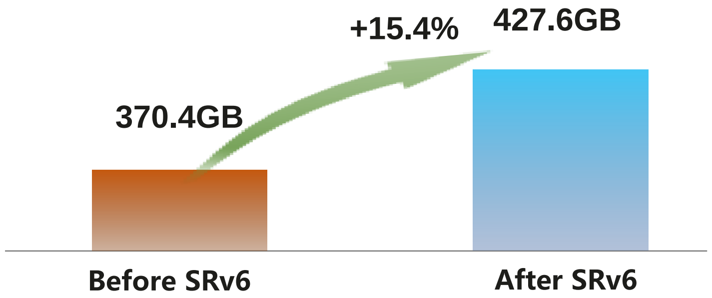
+



Measure 1: Reduce the SRv6 header size with GSRv6

Measure 2: Identify network bottlenecks and perform precise expansion.

Measure 3: SRv6 Based SDN UC Real-time automatic optimization ensuring optimal paths at any time



After SRv6 is deployed in area N
Suppressed traffic is rapidly released

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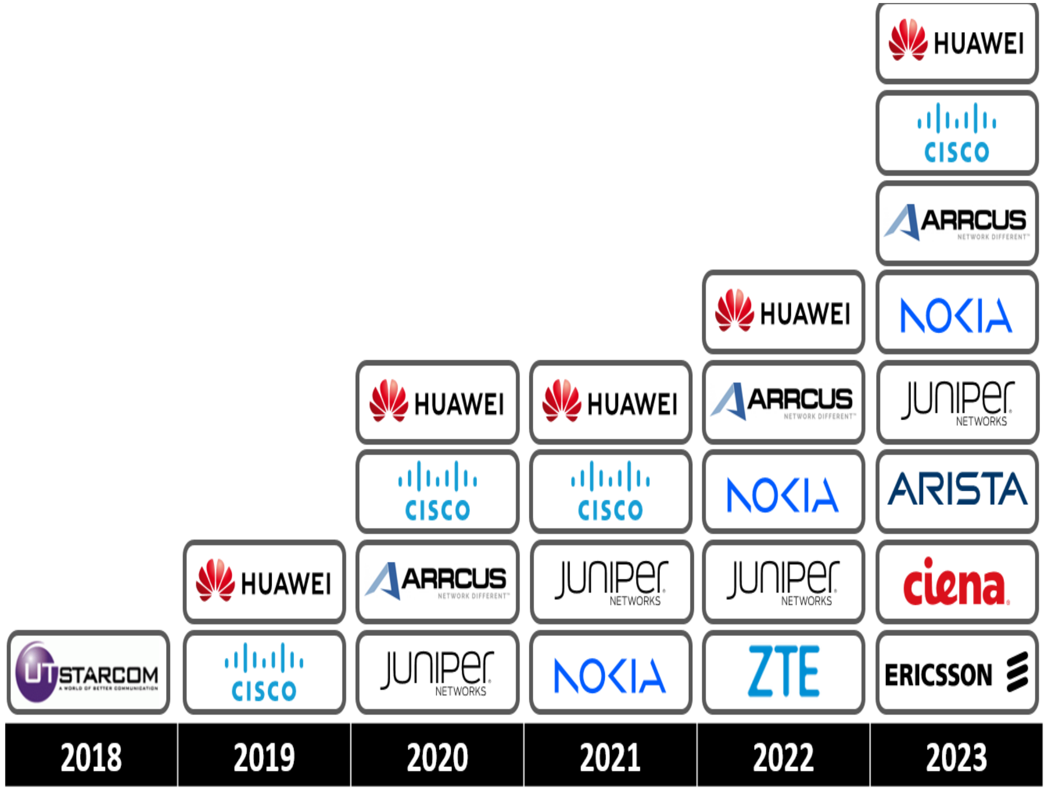
Participating Vendors and Devices in 2023 for EANTC SRv6 Inter-op Test

In 2023, 10 vendors participated in SRv6 interoperability tests



All mainstream vendors participated in the interoperability test

Mainstream | Newcomers

ARISTA	7050 7280Rx	Newcomers
ARRCUS / UfiSpace	UfiSpace S9600 UfiSpace S9710	
Calnex	Paragon-neo/-X Sentry SNE	
ciena	5166	Newcomers
CISCO	C8201 ASR 990x Crosswork NCS 540 NCS 57x1 IOS XRd	Mainstream
ERICSSON	6273 667x	Newcomers
Hewlett Packard Enterprise	Aruba CX83xx Aruba CX9300 Aruba CX10000	Mainstream
HUAWEI	NCE NetEngine 8000 F8 NetEngine 8000 M4	Mainstream
intel	E810-QCDA2T E810-XXVDA4T	
JUNIPER NETWORKS	ACX7024 ACX7100 MX204 Paragon Pathfinder PTX10001-36MR QFX51x0	Mainstream
KEYSIGHT	IxNetwork	
MICROCHIP	TimeProvider 4100	
NOKIA	7750 SR-1 Network Services Platform (NSP)	Mainstream
RARE FreeRtr GÉANT	BF2556X-1T	
ribbon	NPT-2100A	
Spirent	STC	

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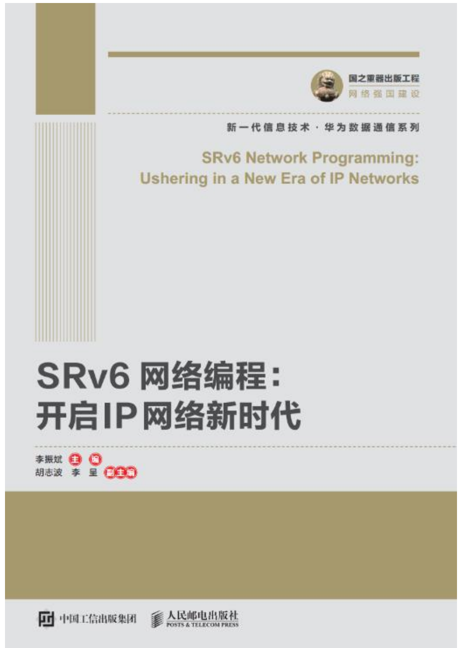
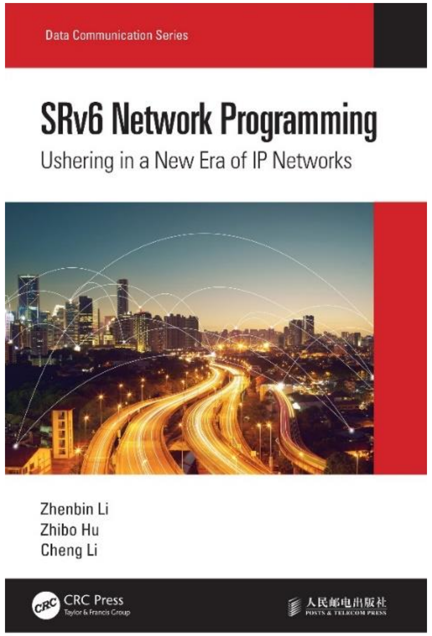
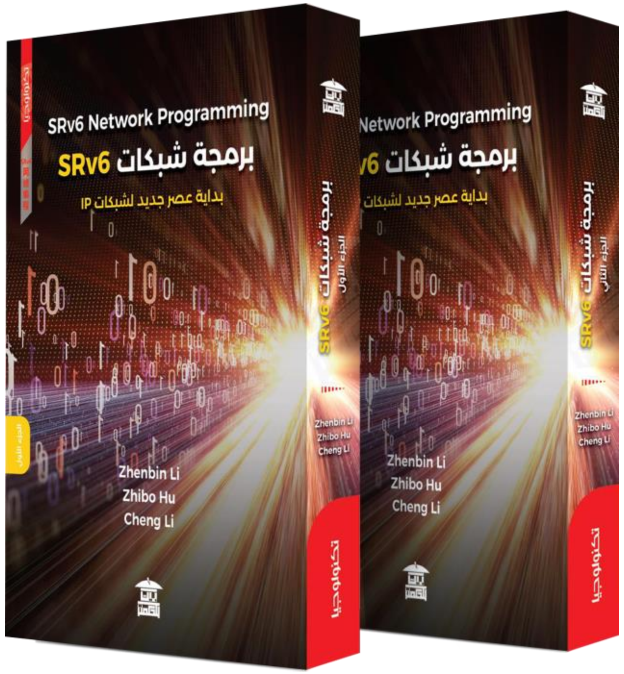
SRv6 Books Published

SRv6 Network Programming: Ushering in a New Era of IP Networks
https://www.routledge.com/SRv6-Network-Programming-Ushering-in-a-New-Era-of-IP-Networks/Li-Hu-Li/p/book/9781032016245







- 2020.07: SRv6 book (Chinese Version) was published.
- 2021.07: SRv6 book (English Version) was published.
- 2022.04: SRv6 book (Arabic Version) was published.

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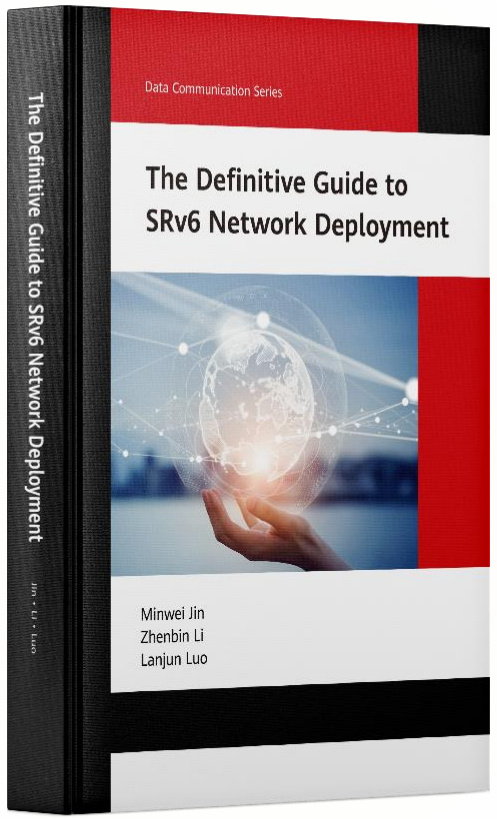
New SRv6 Book: *The Definitive Guide to SRv6 Network Deployment*



Disseminate deployment experience

- Network planning, design and deployment
- Network O&M and application analysis

Table of Contents

- SRv6 enables network innovation
- Strategies for evolution to SRv6
- SRv6 network evaluation and planning suggestions
- SRv6 solution design and deployment (E2E VPN, HoVPN)
- SRv6 O&M guide
- SRv6 transmission efficiency improvement
- SRv6 development prospect

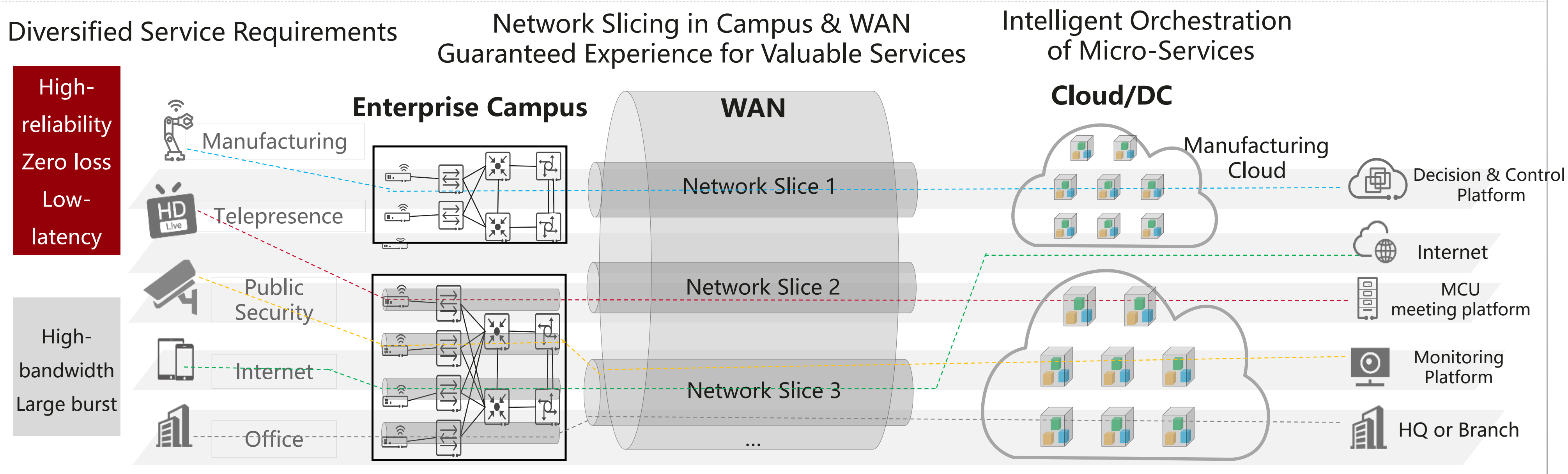
Network Slicing: Commitment to Diverse Services


Manufacturing


Telepresence


Public Security


Smart Office



Flexible on-demand Network Slicing, fulfills diverse service requirements

Independent Service Operation

- Service customization
- KPI visualization
- User management
- Independent upgrade

Security Isolation

- Smart grid
- Industrial control
- Autonomous driving
- Game assurance

Assured SLAs

- Ultra-high bandwidth
- Ultra-low latency
- Massive connections
- Ultra-high reliability

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IPv6 Encapsulation for Network Slice

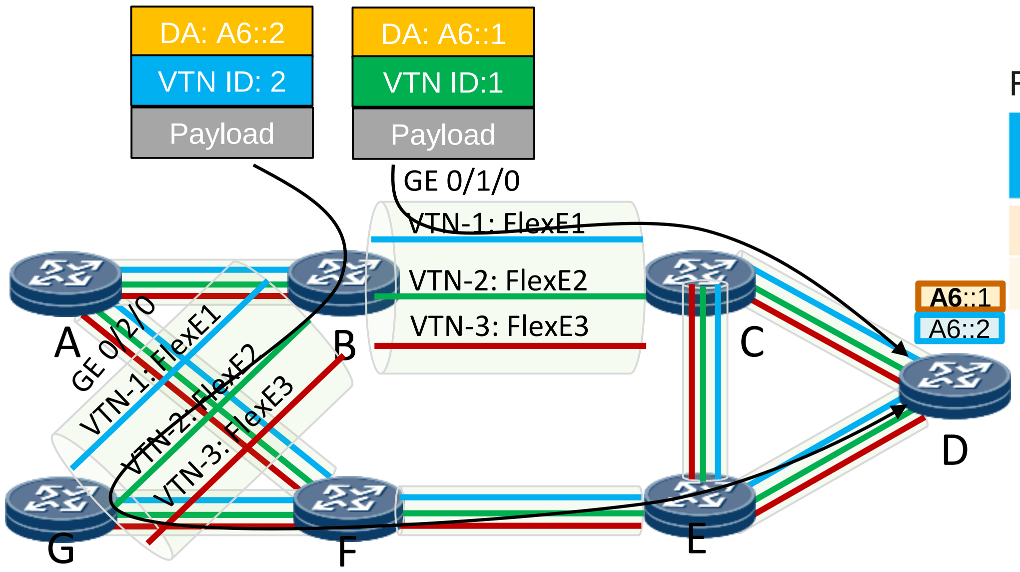
IPv6 Header	Version	Traffic Class	Flow Label	
	Payload Length		Next	Hop Limit
	Source Address (A1::1)			
	Destination Address (A2::11)			
HBH Header	Next Header	Hdr Ext Len	**Slice ID**	
	Next Header	Hdr Ext Len	Routing Type = 4	Segments Left=2
	Last Entry	Flags	Tag	
	Segment List[0] = A6::1			
	Segment List[1] = A4::13			
	Segment List[2] = A2::11			
	Paylod			

Makes use of two separate data plane identifiers for topology and resource specific forwarding treatment

- Use IPv6 destination address to determine the next-hop and outgoing interface in the specified topology
- Use VTN ID field to determine the network resource for packet processing & forwarding

Benefits of this approach:

- Decouple the topology/path identifier and the resource identifier in data packet
- Reduce the number of SRv6 Locator/SID needed for slicing, improve scalability



Forwarding table of node B:

Prefix	Next-hop	OutIf
A6::1	C	GE0/1/0
A6::2	G	GE0/2/0

MainIf	VTN-ID	SubIf
GE0/1/0	1	FlexE1
GE0/1/0	2	FlexE2
GE0/1/0	3	FlexE3
GE0/2/0	1	FlexE1
GE0/2/0	2	FlexE2
GE0/2/0	3	FlexE3

IPv6 Slice-ID Extensions : *tools.ietf.org/html/draft-ietf-6man-enhanced-vpn-vtn-id*

IETF Standards on Network Slicing

Framework

- IETF Network Slice Concept and general framework
- VPN+ framework for network slice realization
- Mapping of 5G E2E network slice to IETF network slices

Management Plane

- IETF Network Slice NBI Service YANG
- IETF Network Slice Realization YANG

SR based Network Slice realization

- SR based VPN+ Data Plane
- SR Resource-aware Segments
- MT based IGP/BGP-LS control plane for SR VPN+

Scalable IETF Network Slice realization

- NRP/VTN scalability
- IPv6 HBH based VPN+ data plane
- MPLS based VPN+ data plane
- Control plane extensions for scalable SR VPN+

End-to-End IETF Network Slice

- E2E IETF network slice realization framework
- SR based E2E IETF network slice realization
- IPv6 based E2E IETF network slice realization
- MPLS based E2E IETF network slice realization

Hierarchical IETF Network Slice

- Hierarchical IETF network slice realization

WG document

Individual draft

IP Network Slice Deployment Cases

80+ Network Slice deployments worldwide

- Multi-industrial network
- Fix-Mobile Convergence
- Premium Private Lines
- Multi-service networks

…

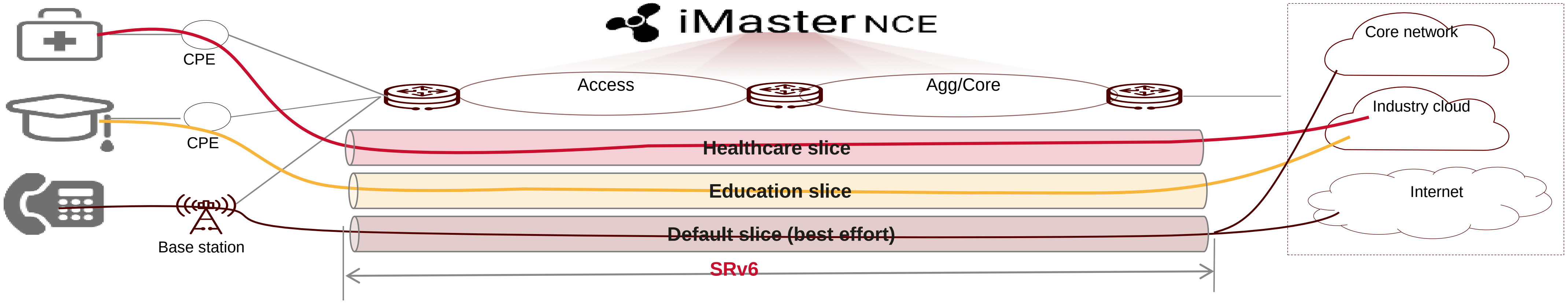
…

Operator N: Network Slicing for Multiple Vertical Industrials

Healthcare

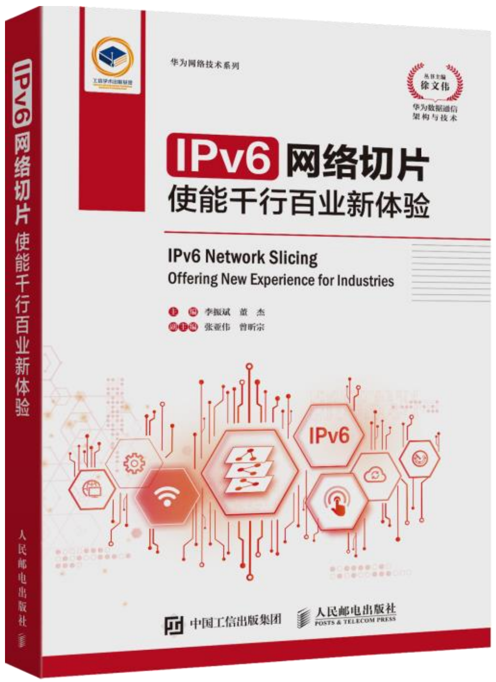
Education

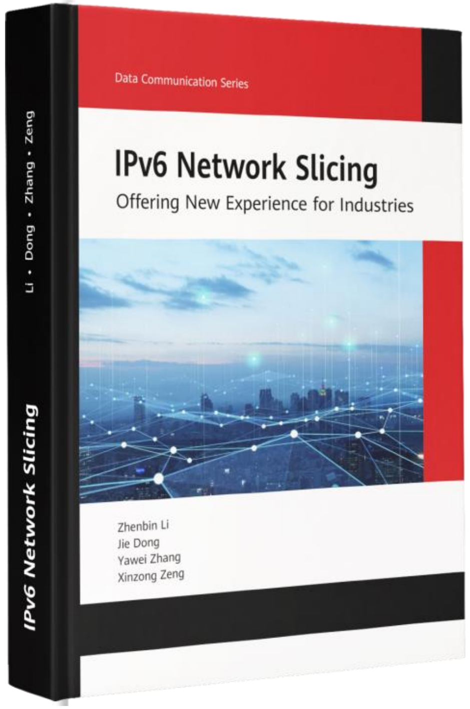
Public Internet

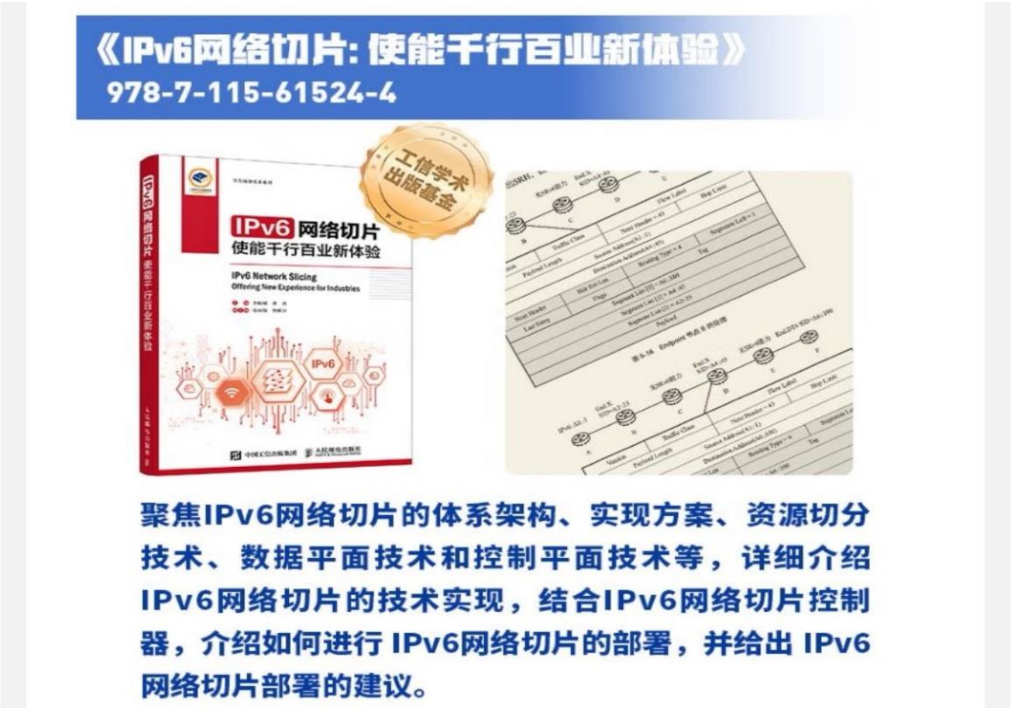


Please refer to visit [draft-ma-teas-ietf-network-slice-deployment] for details

IPv6 Networking Slicing Books Published

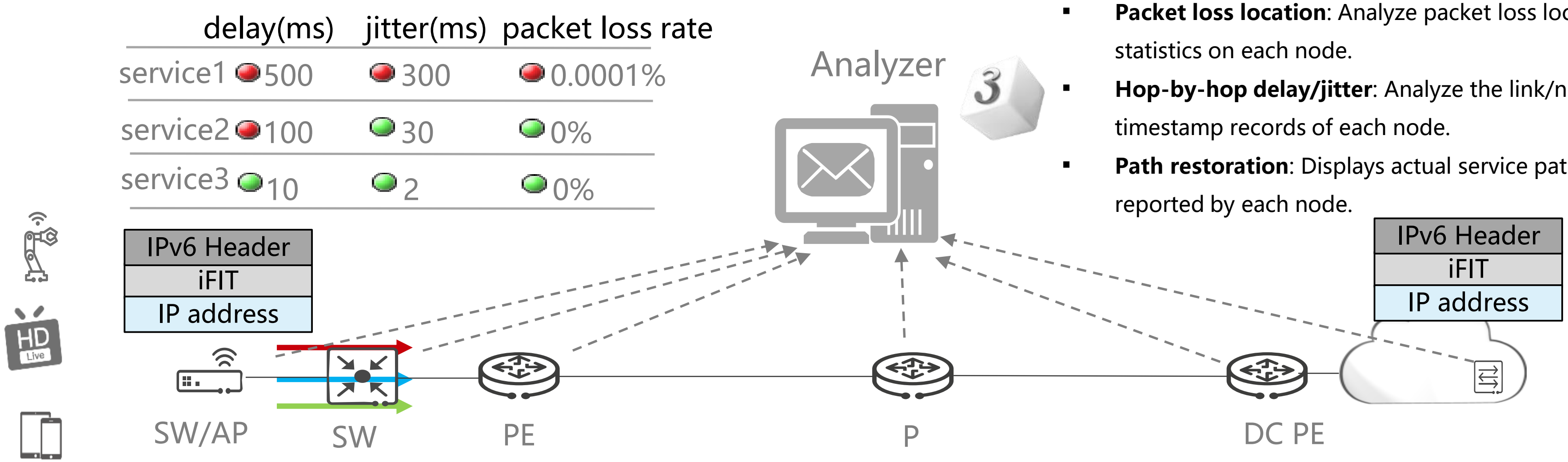






- 2023.06 IPv6 Network Slicing Book (Chinese Version) was published.
- 2023.03 The sample book of *IPv6 Network Slicing* (English Version) was distributed in MWC 2023.

IFIT: In-situ Flow Monitoring, Visualized and Manageable Service Experience



- **Packet loss location**: Analyze packet loss location based on packet statistics on each node.
- **Hop-by-hop delay/jitter**: Analyze the link/node delay based on the timestamp records of each node.
- **Path restoration**: Displays actual service paths based on information reported by each node.

Ingress:

- Customized detection capability
- Performs service-level SLA monitoring by coloring on service packets.

Transit/Egress:

- Automatic statistics: packet statistics and delay
- Periodic Reporting of Statistical Results (Based on Telemetry)

10^{-6} High Precision and Real Services

- Coloring based on real service flows
- High precision: The 10^{-6} packet loss rate

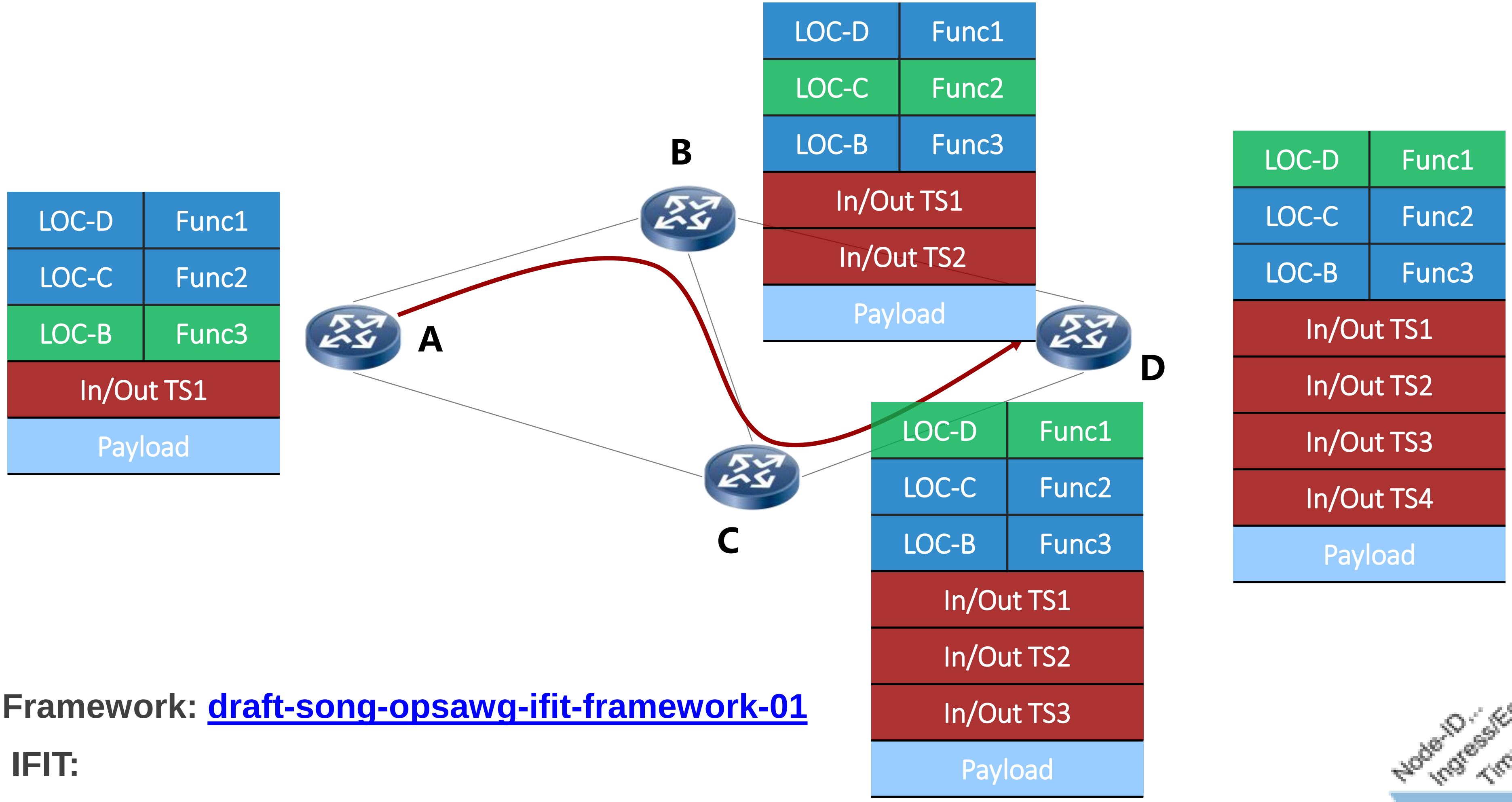
Various Scenarios and Metrics

- KPIs: delay, packet loss rate, jitter, and path restoration
- Service mode: SRv6/L3VPN/EVPN
- Monitoring model: end-to-end, hop-by-hop

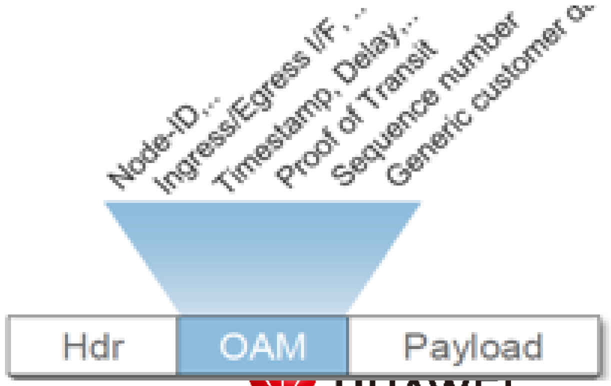
Easy Deployment and O&M

- The ingress node customizes iFIT. The transit and egress nodes are globally enabled with iFIT.
- On-demand monitoring and hop-by-hop demarcation

IPv6 IFIT (In-situ Flow Information Telemetry)



- **IFIT Framework:** [draft-song-opsawg-ifit-framework-01]
- **IPv6 IFIT:**
  - **Alternate Marking:** [RFC9341/RFC9343]
  - **IOAM:** [RFC9197/RFC9326] **and** [draft-ietf-ippm-ioam-ipv6-options]



Global Deployment of IPv6 IFIT

2019 Tokyo Interop

Best of Show Award

IFIT: Intelligent Flow

Information Telemetry

Published On SIGCOMM 2019

RFC9232: Network Telemetry Framework

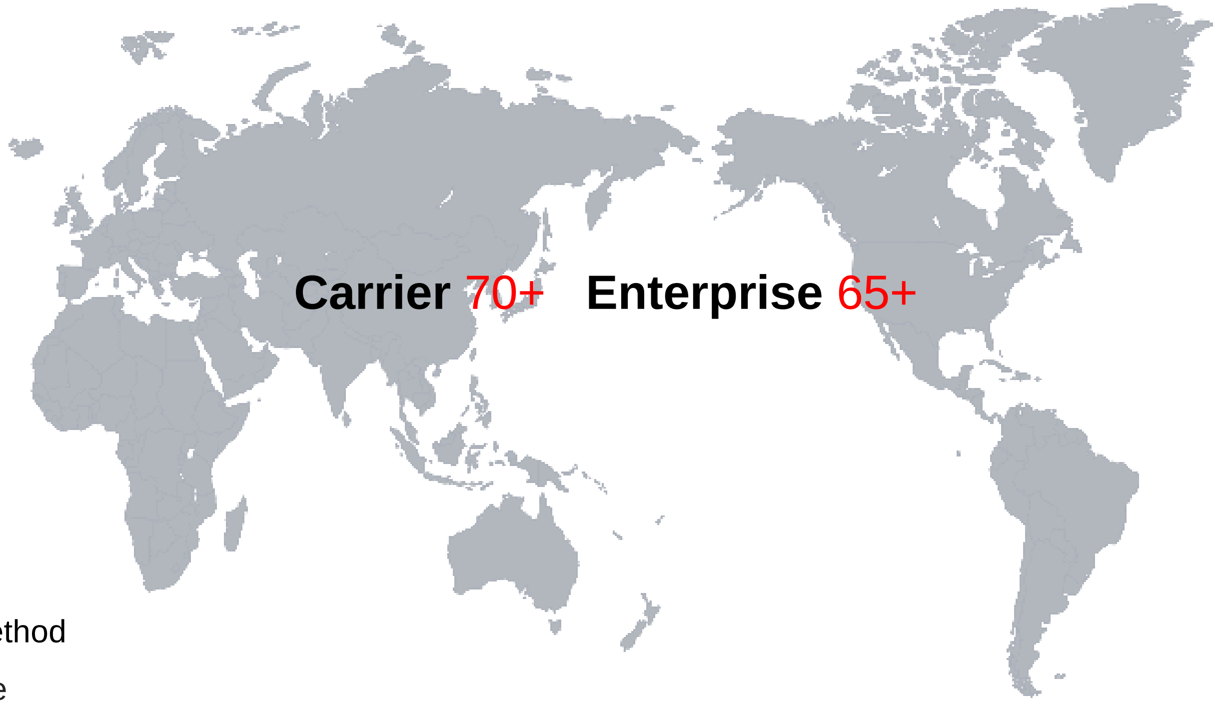
RFC9341: Alternate Marking Method

RFC9342: Clustered Alternate Marking Method

RFC9343: IPv6 Application of the Alternate

Marking Method

Global IFIT Cases

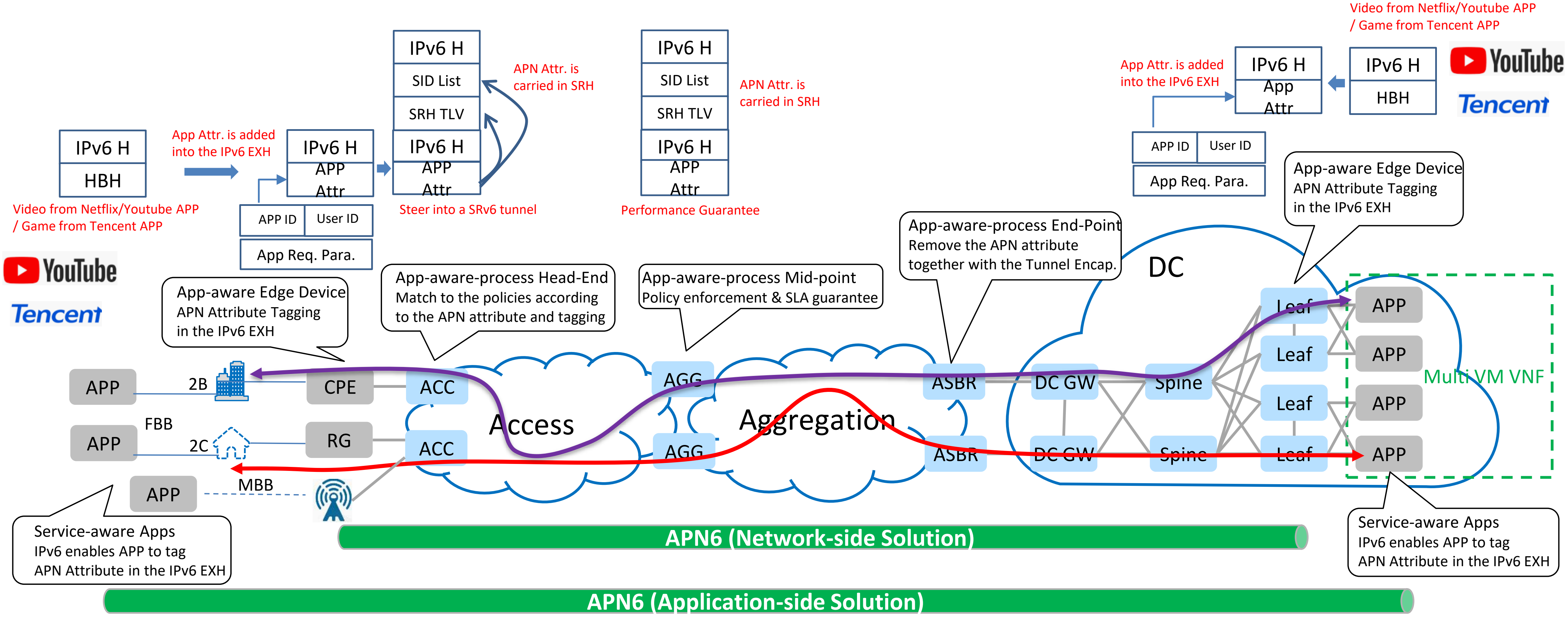


Progress of IFIT Standards

Area	Topic	Drafts	Vendors	Operators
Framework	In-situ Flow Information Telemetry Framework	draft-song-ifit-framework	Huawei	China Mobile/China Telecom/SKT/LGU+
	Clustered Alternate Marking Method	RFC 9342	Huawei	Telecom Italia
Data plane format	Data Fields for In-situ OAM	RFC 9197	Cisco/Huawei	
	In-situ OAM Direct Exporting	RFC 9326	Huawei/Cisco	
	Alternate-Marking Method	RFC 9341	Huawei/Ericsson	Telecom Italia
	Enhanced Alternate Marking Method	draft-zhou-ippm-enhanced-alternate-marking	Huawei	LGU+/China Mobile Telecom Italia
Encap type	IPv6 Application of the Alternate Marking	RFC 9343	Huawei	Telecom Italia, China Mobile, China Unicom
	In-situ OAM IPv6 Options	draft-ietf-ippm-ioam-ipv6-options	Cisco	
	SRH for the Alternate Marking	draft-fz-spring-srv6-alt-mark	Huawei	Telecom Italia
	Multicast On-path Telemetry Solutions	draft-ietf-mboned-multicast-telemetry	Huawei/Ericsson	
Control Plane	BGP SR Policy for IFIT	draft-ietf-idr-sr-policy-ifit	Huawei	China Mobile/Unipay
	Path Computation Element Communication Protocol (PCEP) Extensions to Enable IFIT	draft-ietf-pce-pcep-ifit	Huawei	China Telecom/Unipay
	BGP Extension for Advertising In-situ Flow Information Telemetry (IFIT) Capabilities	draft-ietf-idr-bgp-ifit-capabilities	Huawei	China Telecom
YANG model	A YANG Data Model for In-Situ OAM	draft-ietf-ippm-ioam-yang	Huawei/Cisco	

App-aware IPv6 Networking (APN6) Framework

- Make use of IPv6 extensions header to convey APN attribute along with the packets into the network
- To facilitate the flexible policy enforcement and fine-grained service provisioning



https://datatracker.ietf.org/doc/draft-li-apn-framework/
https://ieeexplore.ieee.org/abstract/document/9162934

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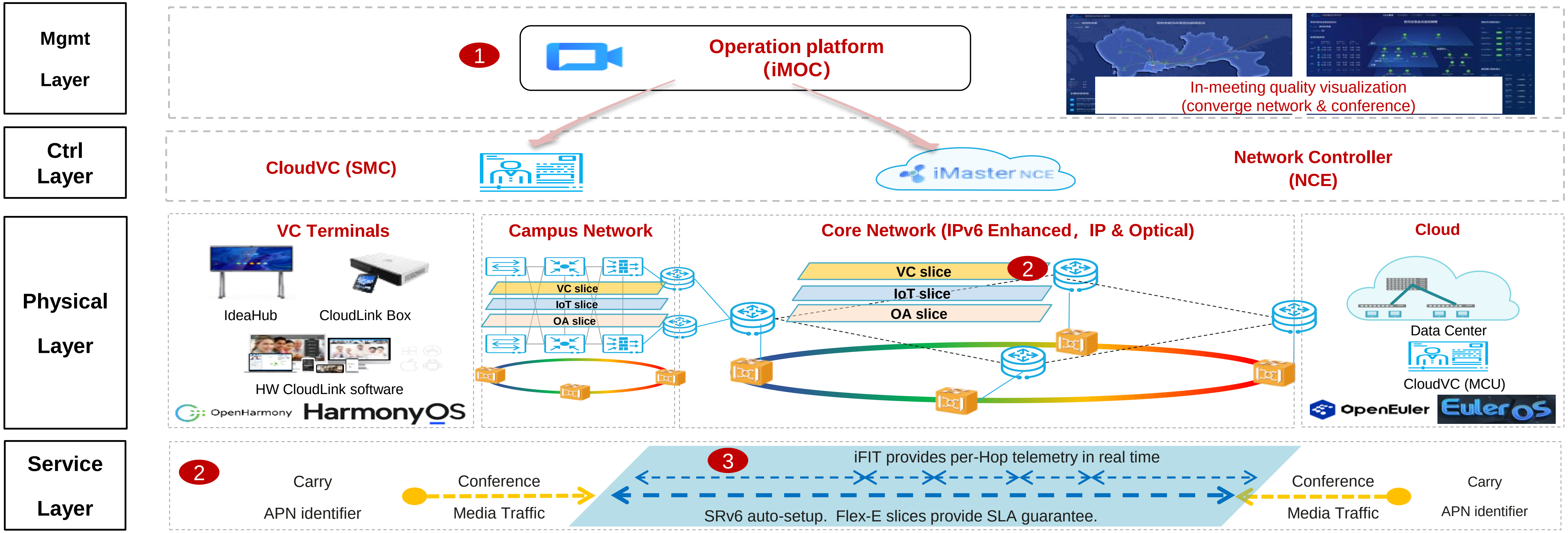
APN6 Demo Cases: Improve User Experience of Video Conference in 2B Services

APN for service-aware, Slicing for SLA ensurance, IFIT for E2E visualization



ICT Product	User Equipment	Network	Cloud
	VC Terminals (Harmony OS)	Network (router & switch) IP & Optical (transport)	iMOC, NCE, CloudVC (EulerOS)

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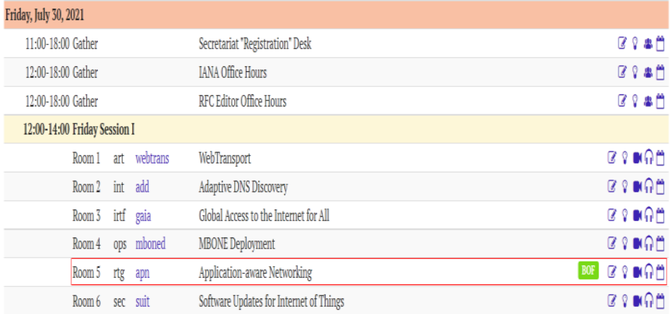
More Industry Consensus on APN and Approved IETF APN BOF

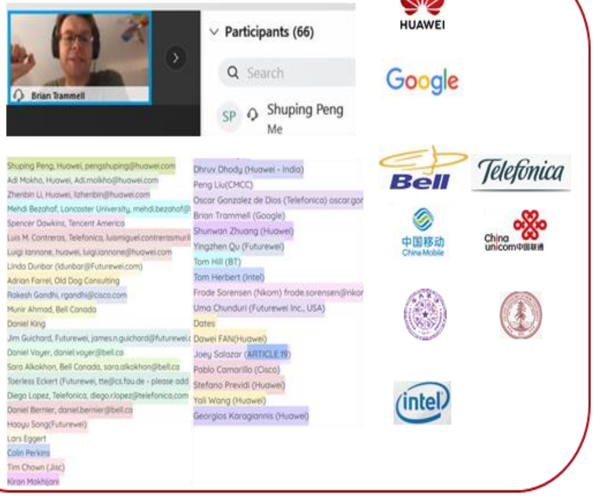
- **Side Meetings** @IETF105 & IETF108
- **Hackathons** @IETF108 & IETF109 & IETF110
- **Demos** @INFOCOM2020 & 2021
- **APN Mailing List** Discussions - apn@ietf.org
- **APN Interim Meeting** @IETF 110-111
- **APN BoF** @IETF111, Approved! 30 July 2021, 1200-1400 PDT

IETF111 APN BoF



IETF105

IETF108



IETF109

IETF110

https://github.com/APN-Community

https://www.ietf.org/blog/ietf109-bofs/
https://www.ietf.org/blog/ietf110-bofs/
https://trac.tools.ietf.org/bof/trac/wiki/WikiStart **(IETF111 BoF)**

Summary of Usage of IPv6 Extension Headers

Functionalities	RFC/Drafts	IPv6 Extension Header		
		HBH Header	Routing Header	DO Header
SRv6	RFC8754		√	
VPN+ (Network Slicing)	1. draft-ietf-spring-resource-aware-segments 2. draft-ietf-6man-enhanced-vpn-vtn-id	√	√	
IFIT (In-situ Flow Telemetry)	1. RFC9197 2. RFC9326 3. RFC9341/RFC9343	√	√	√
MSR6/BIERv6	1. draft-lx-msr6-rgb-segment 2. draft-geng-msr6-traffic-engineering		√	√
APN6	1. draft-li-apn-header 2. draft-li-apn-ipv6-encap	√	√	√

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IPv6 Enhanced Standardization Work Layout

IPE 1.0

SRv6

- RFC8402: SR Architecture
- RFC8754: SRH
- RFC8986: SRv6 Network Programming
- SR Policy RFC9256
- IS-IS RFC queue
- OSPFv3 WGLC
- VPN RFC9252
- BGP-LS WGLC
- BGP SR-Policy WGLC
- PCEP
- Protection
- YANG

IPE 2.0

5G & Cloud

Slicing
- Framework
- SR SID DP
- IPv6 Slice ID DP
- SR SID CP
- IPv6 Slice ID CP
- Inter-Domain Slicing
- Hierarchical Slicing
- YANG

IFIT
- Framework
- Alternate Marking
- IOAM
- IGP
- BGP-LS
- BGP SR-Policy
- PCEP
- YANG

SRv6 Compression
- Requirements
- Analysis
- Framework

MSR6/ BIERv6
- Requirements
- Problem Statement
- Encapsulation

- OAM
- **Path Segment**
- **Path MTU**
- DETNET
- **SFC**

IPE 3.0:

APN

- Problem Statement
- Use cases
- Framework
- Encapsulation
- Protocol Extensions

Legend: RFC | WG Draft | Potential WG Draft | Individual Draft

Please visit www.ipv6plus.net for the latest progress

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IPv6 Enhanced Industry Activities

ETSI/IPv6 Forum IPE SIG Founded (100+ Members)

IPv6 Enhanced Innovation

APAC：APAC V6 Alliance Founded (50+ Members)

Africa: The 2nd IPv6 Enhanced Summit

Latin America: The 1st IPv6 Enhanced Summit

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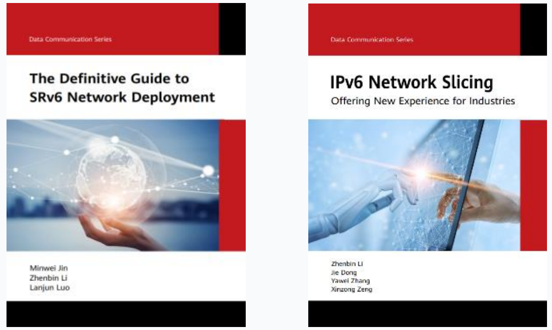
IPv6 Enhanced Series Books and Videos

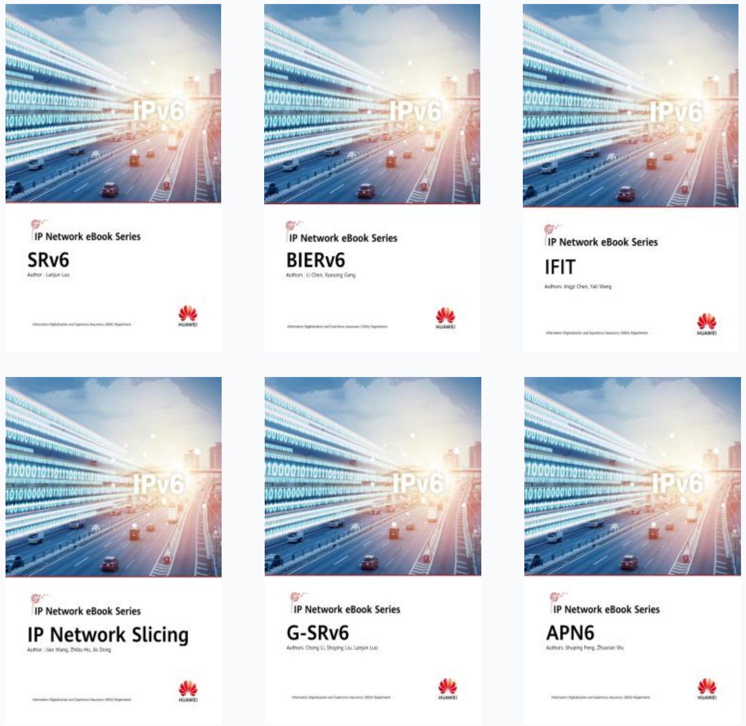
IPv6 Enhanced Books

To be published in 2023



https://www.amazon.com/SRv6-Network-Programming-Ushering-Communication/dp/1032016248

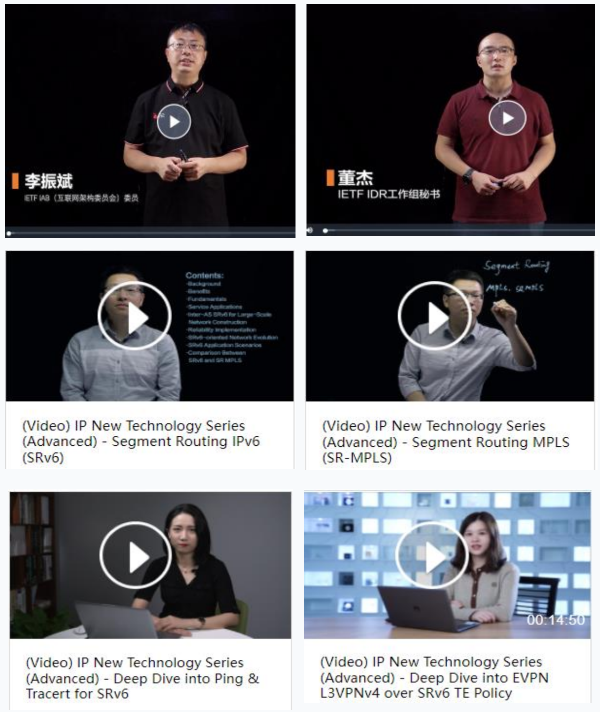
IPv6 Enhanced Series e-Books



IPE Series eBook

Scan to obtain the electronic version

IPv6 Enhanced Series Videos



https://support.huawei.com/enterprise/en/routers/netengine-8000-pid-252772223/multimedia

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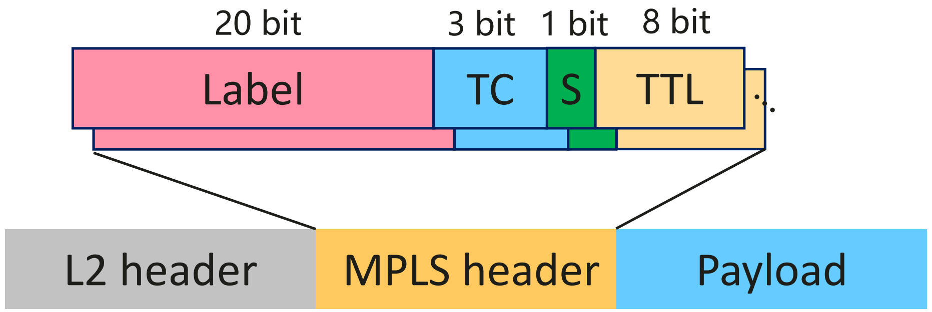
MPLS Network Actions (MNA) : Background

- The success of MPLS is built on **Simple Data Plane**



- Fixed-size label and label stack entry (LSE)
- Simple format
- Simple label processing
  - PUSH, SWAP, POP
- Coupled with flexible control plane and management plane

- Since 2020, there are emerging use cases which require additional actions and data to be carried in MPLS packets
  - Network Slicing
  - IOAM
  - Detnet
  - More use cases are described in draft-ietf-mpls-mna-usecases
- This requires new extensions to MPLS
  - Data plane and corresponding control & management plane mechanisms
- MPLS Open Design Team (Open DT) was established in 2021 for the design of MNA
  1. MNA use cases, requirements, framework
  2. MNA general solutions ← We are here
  3. MNA applications

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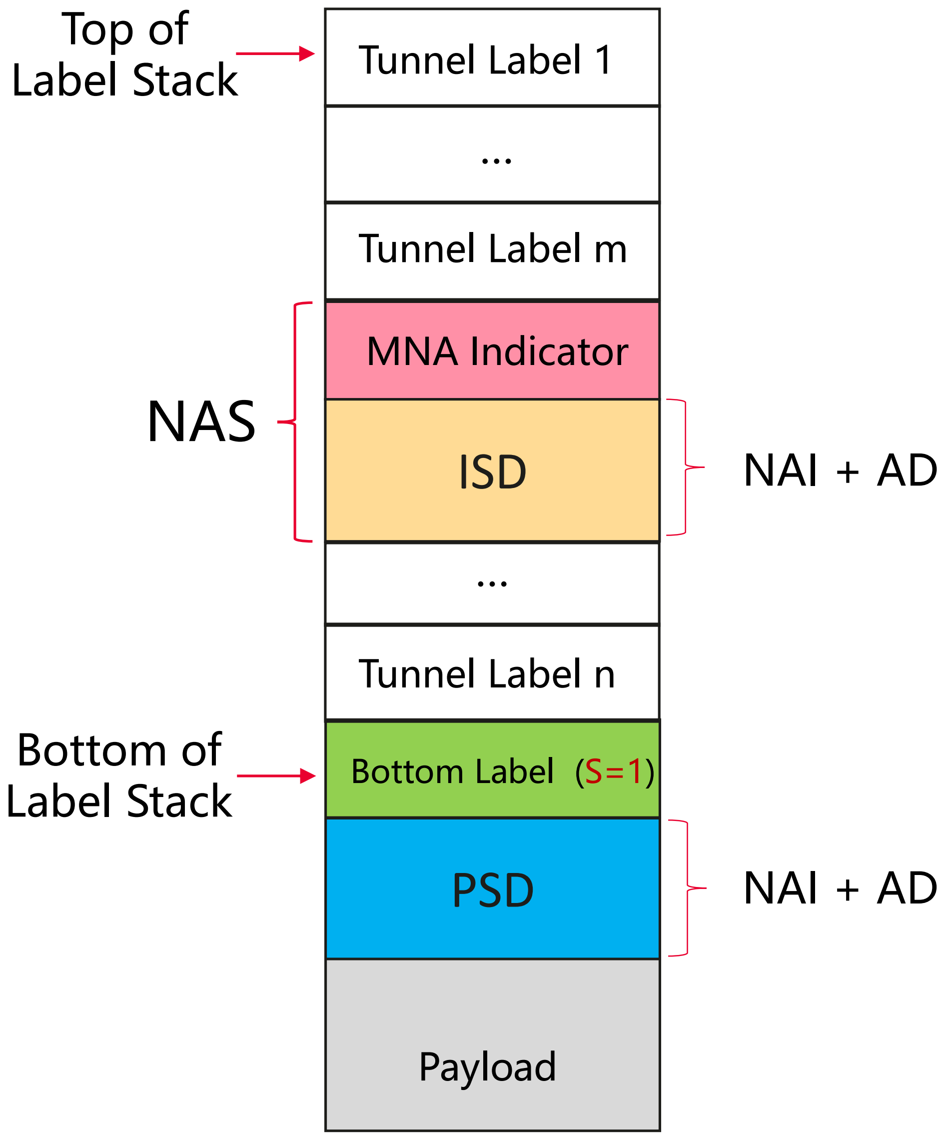
MNA Components and Terms



- **MNA indicator**
  - An MPLS Special Purpose label (SPL) to indicate the existence of MNA
- **Network Action Indication (NAI)**
  - Indicate a specific network action
- **Ancillary Data (AD)**
  - Optional data associated with a given network action
- **Network Action Sub-stack (NAS)**
  - A continuous set of label stack entries for MNA
- **In-stack Data (ISD)**
  - NAIs and AD carried in the label stack
- **Post-stack Data (PSD)**
  - NAIs and AD carried after the label stack

MNA Solutions: ISD and PSD

- There have been endless discussion about the comparison between ISD and PSD
- Both ISD and PSD have pros and cons, while for a complete solution it turns out that **both would be needed**

Comparison	ISD	PSD
Position	Closer to the top of stack	After the whole label stack
Encoding	Limitations both in format and size	Flexible format and size
Encapsulation Efficiency	Low (duplicated ISDs)	High
Processing	Significant changes to MPLS label processing	Independent of MPLS label processing
Backward Compatibility	Must not be exposed to legacy MPLS nodes	Must not be sent to legacy LSP egress nodes

- It is inevitable that the MNA solution would be complex, and operators need to be cautious about the compatibility with legacy MPLS networks

Huawei's Work on MNA Standards

- Huawei realized the limitation of MPLS early and started the research on possible extensions. The first version of MPLS extension header draft was submitted in 2018
  - https://datatracker.ietf.org/doc/html/draft-song-mpls-extension-header-00
- Huawei analyzed the extensibility of IPv6 and MPLS, and believe that IPv6 is more promising for network programmability, thus focus on IPv6 based innovations, such as SRv6, etc.
- Huawei joined the IETF MPLS MNA Design Team from the beginning, and leads the analysis and discussion about MNA solutions to help improve the quality of MNA specifications
- If MPLS has to be extended, Huawei consider that PSD is better than ISD. The PSD solution in MPLS Open DT was based on the MPLS extension header mechanism proposed by Huawei, although it was not adopted due to IPR declarations

Huawei's Contribution to MNA Standards

Topics	Documents	Huawei's Position
Use Cases	draft-ietf-mpls-mna-usecases	Contributor
Requirements	draft-ietf-mpls-mna-requirements	Contributor
Framework	draft-ietf-mpls-mna-fwk	Coauthor
Encapsulation	draft-ietf-mpls-mna-hdr	Contributor
	draft-jags-mpls-ps-mna-hdr	Coauthor
	draft-song-mpls-extension-header	Coauthor
Architecture	draft-andersson-mpls-mna-operation-architecture	Coauthor
Operation	draft-andersson-mpls-mna-label-stack-operations	Coauthor

Summary of MNA

- The purpose of MNA is to enable programmability for MPLS
  - Similar to the capability of extension headers in IPv6/SRv6
- This is a fundamental change to MPLS, equivalent to the significance of RFC 8200 to IPv6
  - But need additional backward compatibility considerations with legacy MPLS
- MNA standards are still in progress, will take time to bring to the market
  - Until now there is no implementation from mainstream vendors
- If there is requirement for network programmability, a better choice would be IPv6/SRv6 both for now and for the future
  - Stable architecture
  - Flexibility and extensibility for real programmability
  - Forward compatibility for easy incremental deployment
  - Leverage the momentum and ubiquitousness of IPv6 (terminals, network & Cloud)

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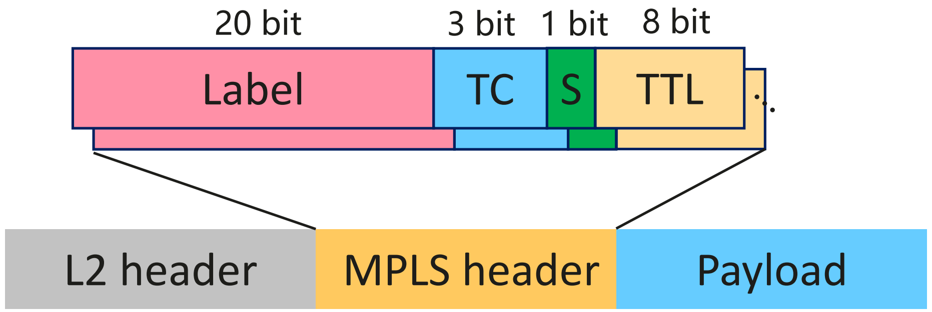

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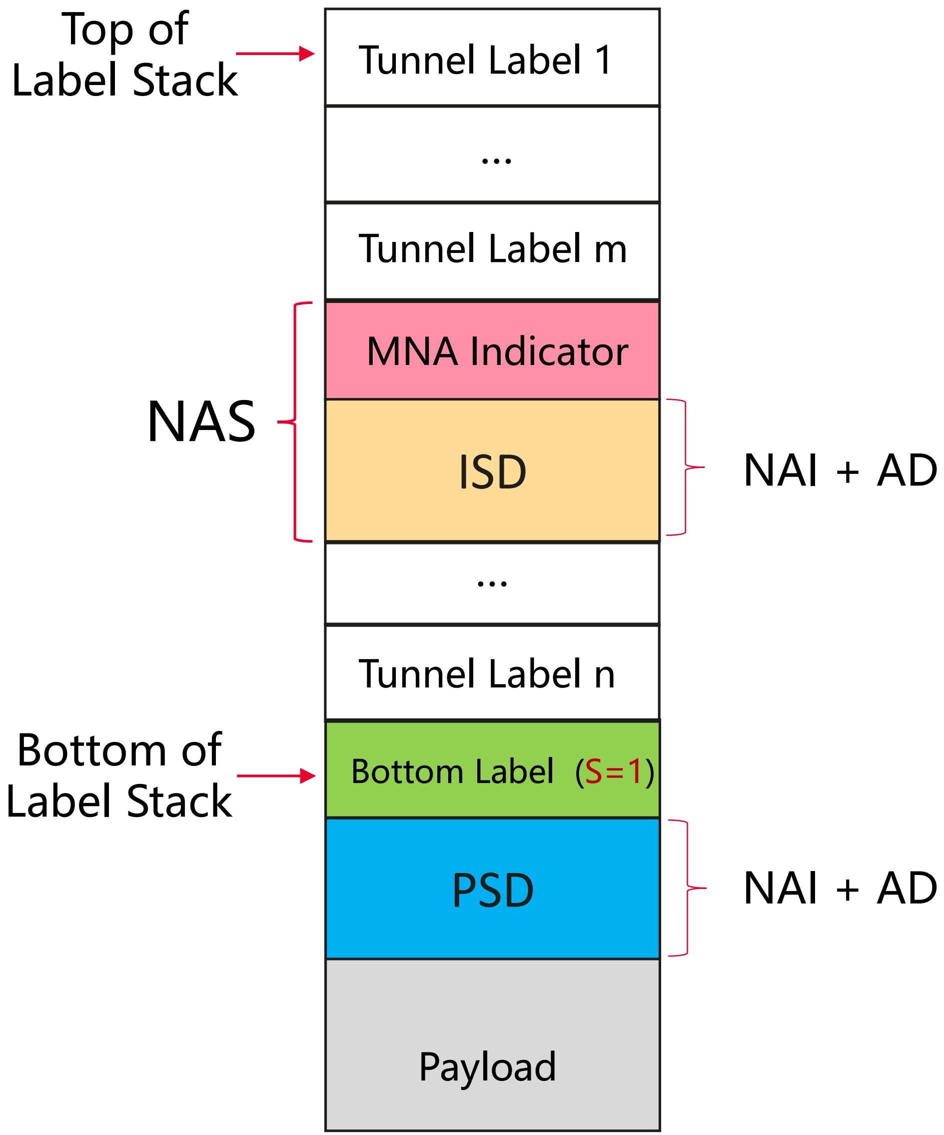

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THANK YOU

www.huawei.com