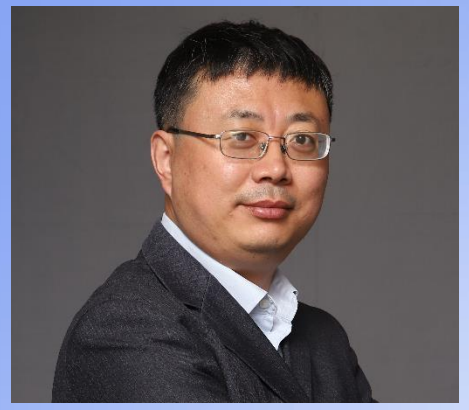
Progress of IPv6 Enhanced Standard and Industry

Zhenbin Li
Huawei Chief IP Protocol Expert
IETF Internet Architecture Board (IAB) Member

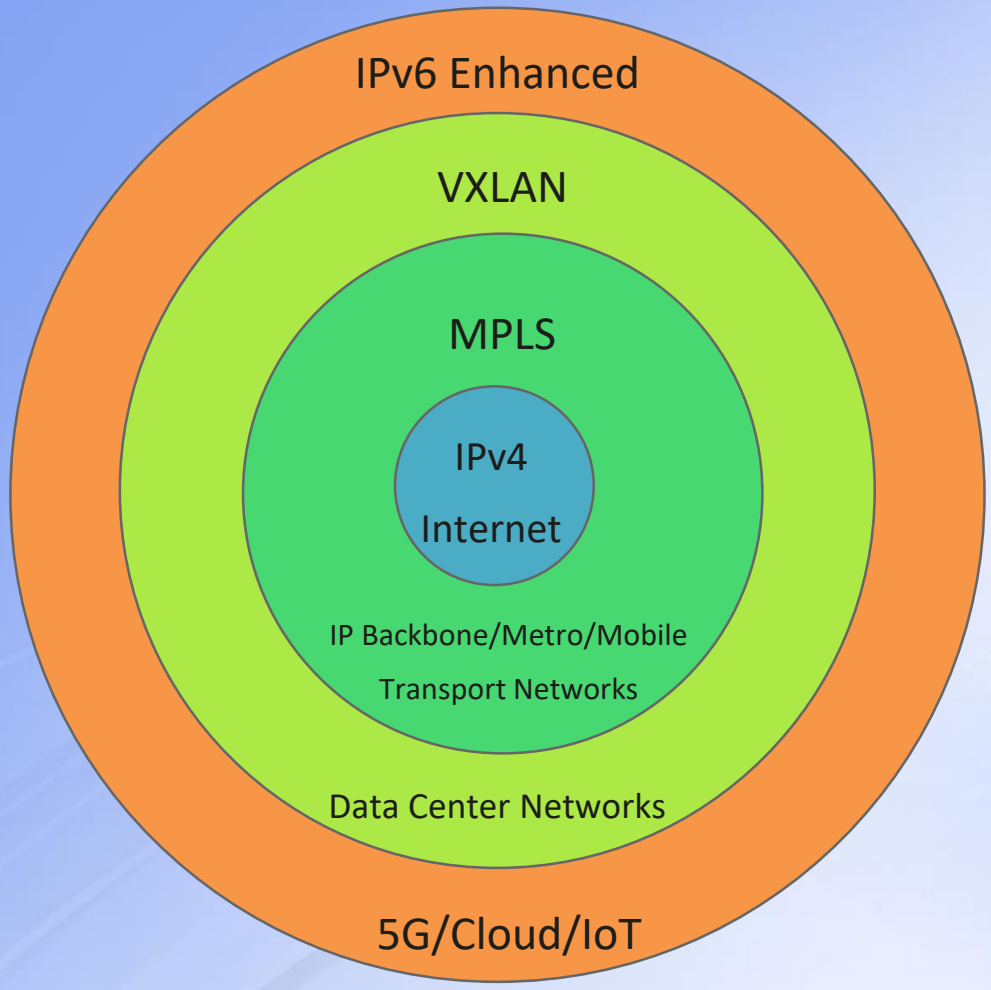


Zhenbin (Robin) Li

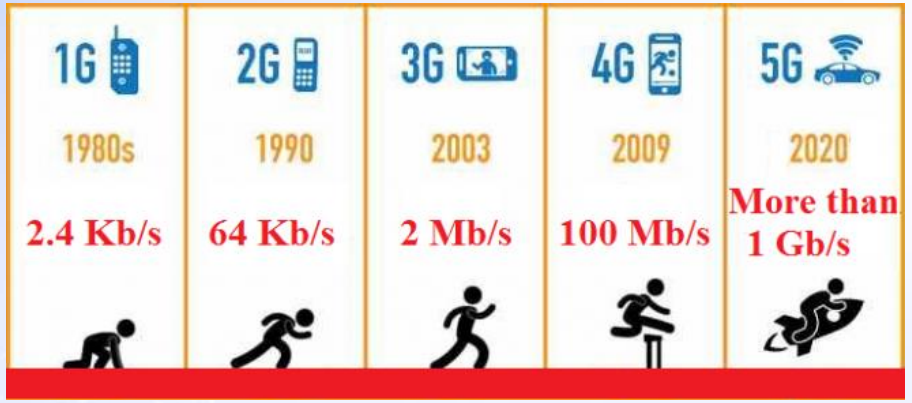
Huawei Chief IP Protocol Expert
IETF Internet Architecture Board (IAB) Member
https://www.iab.org/about/iab-members/

- 15+ years research and development work in IP Operating System 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.
- Publish the book "*SRv6 Network Programming: Ushering in a New Era of IP Networks*"
- Be elected as the IETF IAB member to be responsible for Internet architecture work from 2019 to 2020.
- Be elected again as the IETF IAB member to be responsible for Internet architecture work from 2021 to 2022.

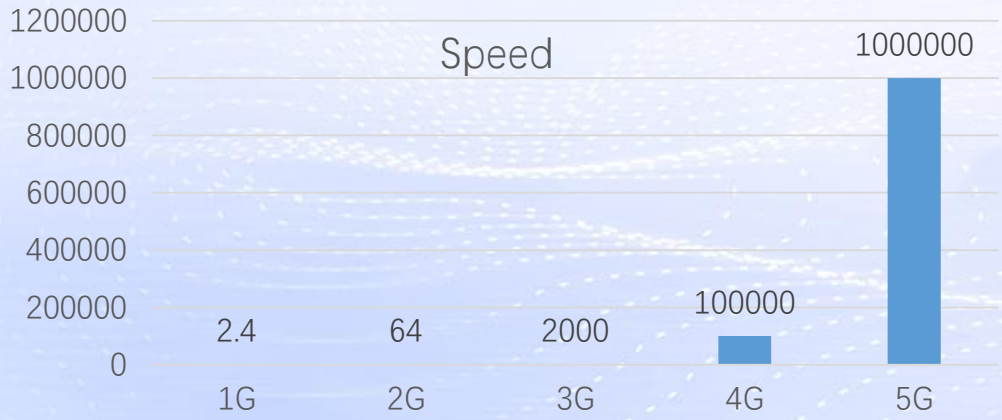
IP Evolutions: Applications Drives the Change of IP Network Architectures



IP

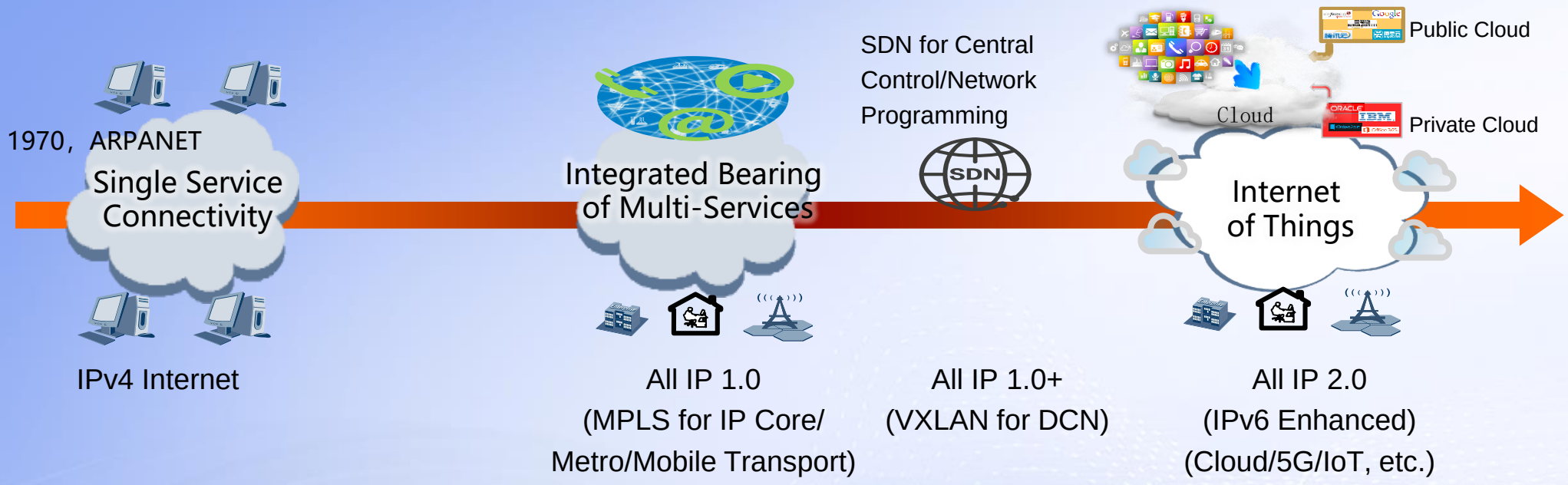


Wireless



Optical

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



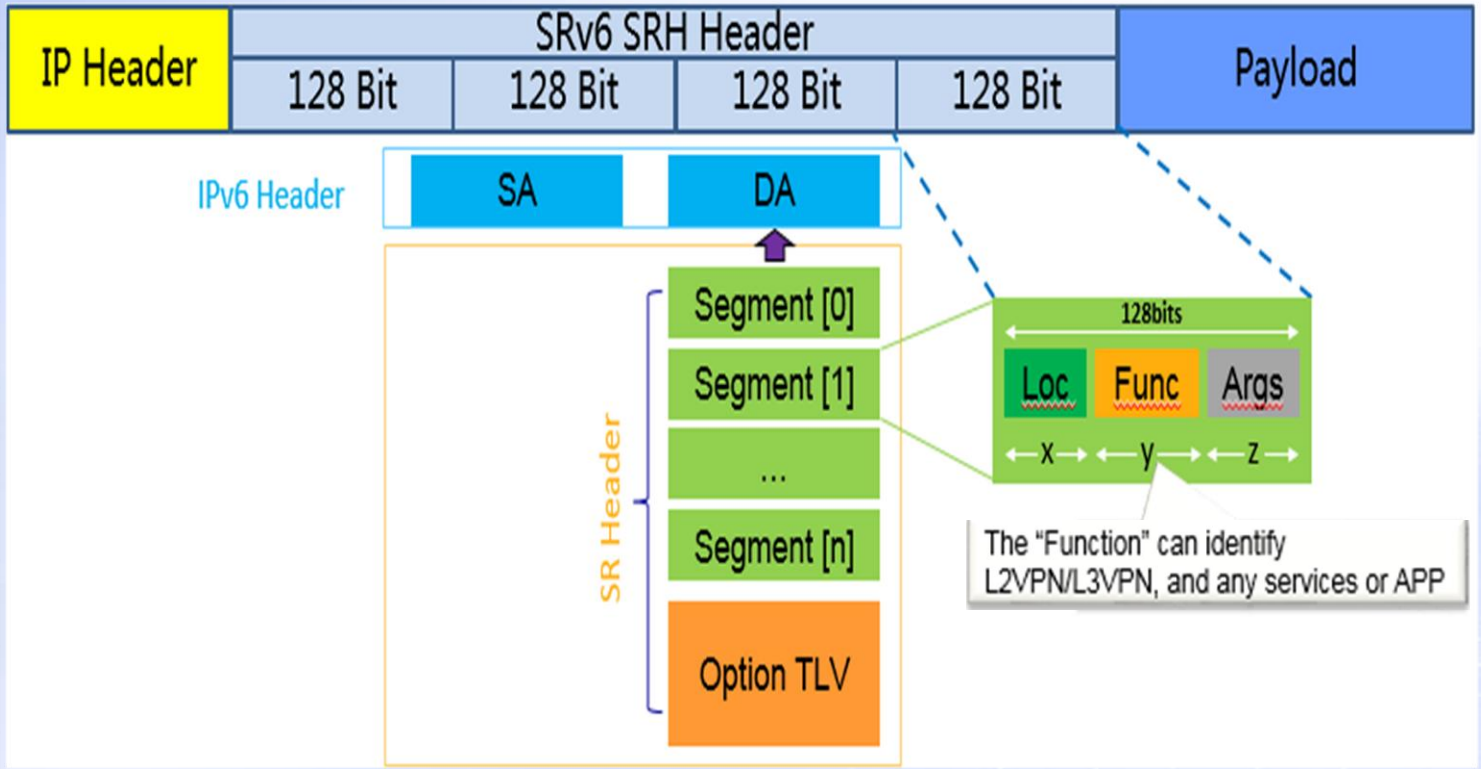
- Rethinking on IPv6: Address Space is not enough.
- New Chance of IPv6: 5G changes the attributes of connections, and cloud changes their scope.
- Mission of IPv6 Enhanced:
  - Integrate different network easier based on affinity to IP reachability.
  - Provide more encapsulations for new network services 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			

SRH: Three Layers of Programming Spaces



IPv6 Enhanced Research and Standard Planning

IPv6 Enhanced 1.0： SRv6 Basic Capabilities

- SRv6 VPN
- SRv6 TE
- SRv6 FRR

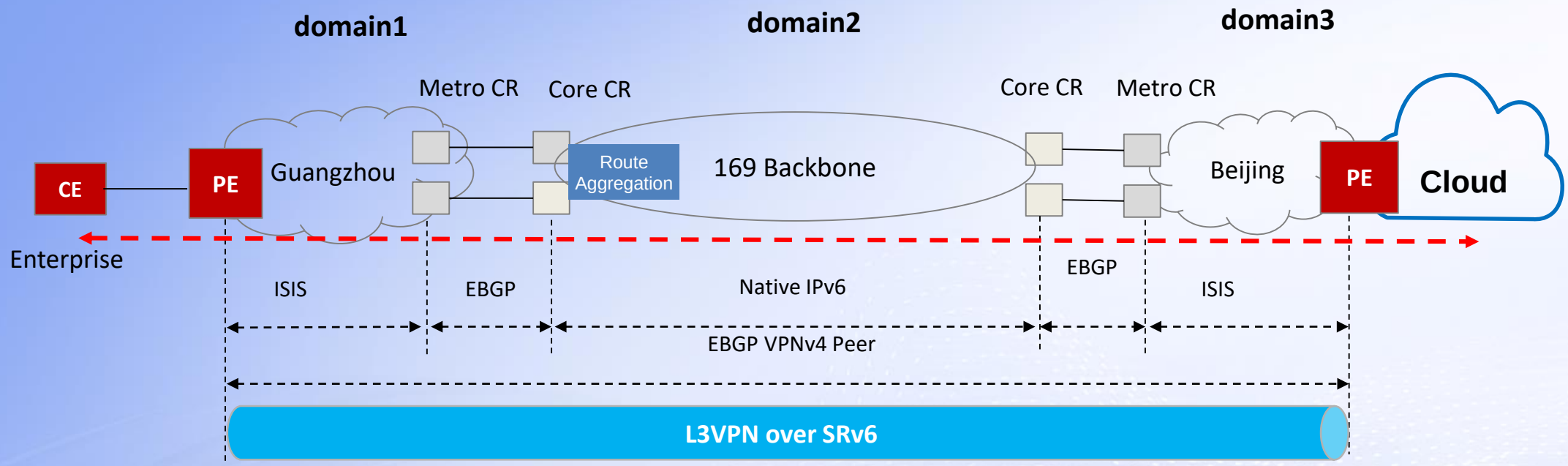
IPv6 Enhanced 2.0 ： New Network Services for 5G/Cloud

- 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

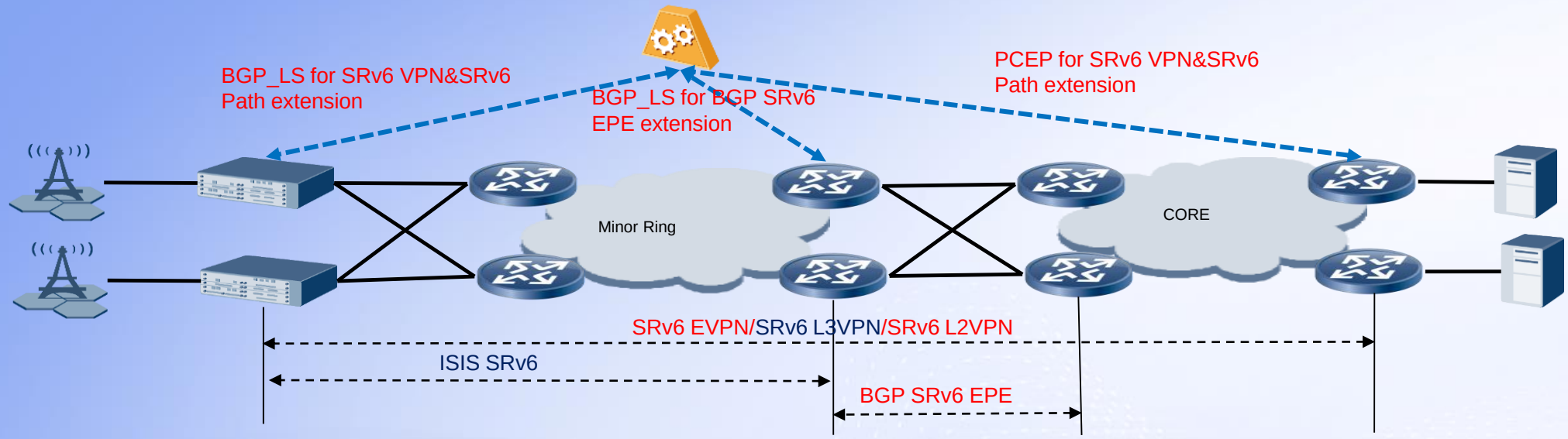
- Forwarding Plane： Conveying Application information via IPv6 extension header
- Control Plane： Exchange Application information through control protocols

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



- **Simplicity: Work based on IPv6 reachability, no extra signaling.**
- **Convergence: 10+ Protocols are converged to SRv6 + EVPN to simplify the service provisioning.**
- **E2E: 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.**

Stable Standards and Large-scale Deployment with Multiple Implementations



SRv6 Standardization on Basic Solutions

Service	Description	Status	IETF RFC/Drafts
Base	SRv6 Arch	○	RFC8986
	SRH	○	RFC8754
VPN	SRv6 VPN	○	WGLC
IGP	ISIS for SRv6	○	WGLC
	OSPFv3 for SRv6	○	WG Draft
SDN Interface	BGP-LS for SRv6	○	WGLC
	BGP Policy for SRv6	○	WGLC
	PCEP for SRv6	○	WG Draft

○: Draft, No Risk △: Draft, With Risk ×: Incomplete Draft

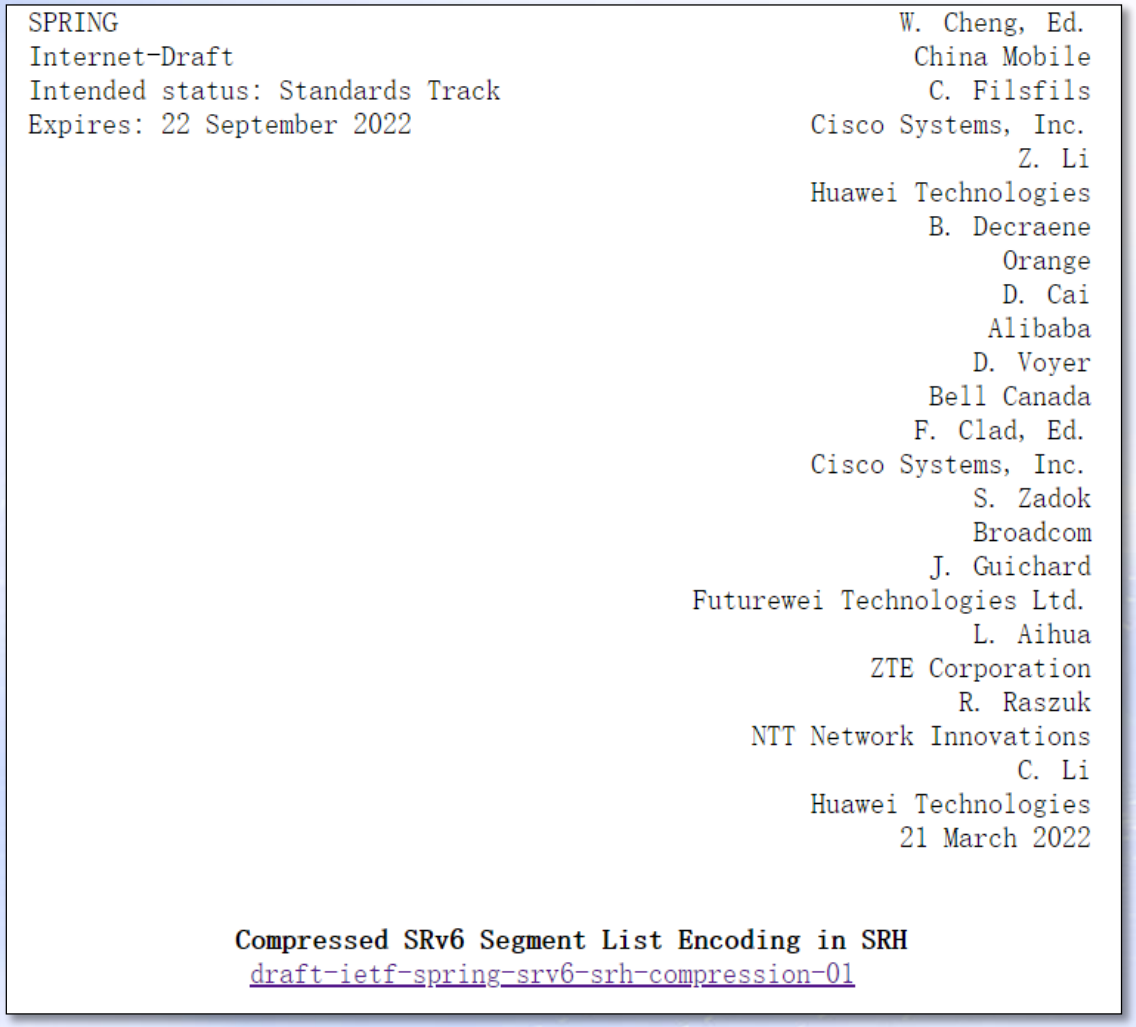
SRv6 Deployment and Implementations

- Deployments:
  - Softbank, China Telecom, Iliad, LINE, China Unicom, CERNET2, MTN, NOIA, Rakuten, Bell Canada, Alibaba, etc.
- Implementations:
  - Open Souce Platforms: Linux, FD.io VPP, P4, etc.
  - Routing Platforms: Huawei, Cisco, Accrus, Nokia, Broadcom, Barefoot, Marvell, Spirent, Ixia, etc.
- Inter-op Test:
  - EANTC 2018 - 2021, etc.
- See draft-matsushima-spring-srv6-deployment-status and draft-tian-spring-srv6-deployment-consideration for details

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
Internet-Draft
Intended status: Standards Track
Expires: 22 September 2022

W. Cheng, Ed.
China Mobile
C. Filsfils
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

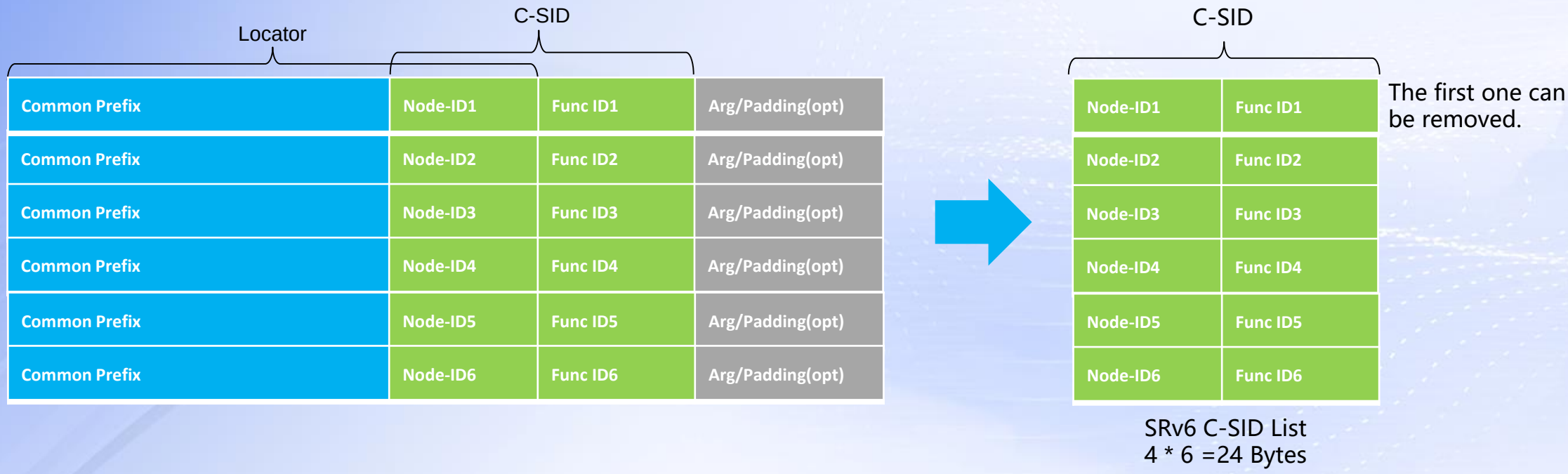
21 March 2022

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

G-SRv6: SRv6 Compressed 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 common prefix, and the common prefix 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.
- Common Prefix is included in the first SID in the IPv6 Destination address.



G-SRv6: Mixed Programming of SID and C-SID

Solution: use SL to index a 128 bit G-SID, use CL to index C-SID inside this G-SID!

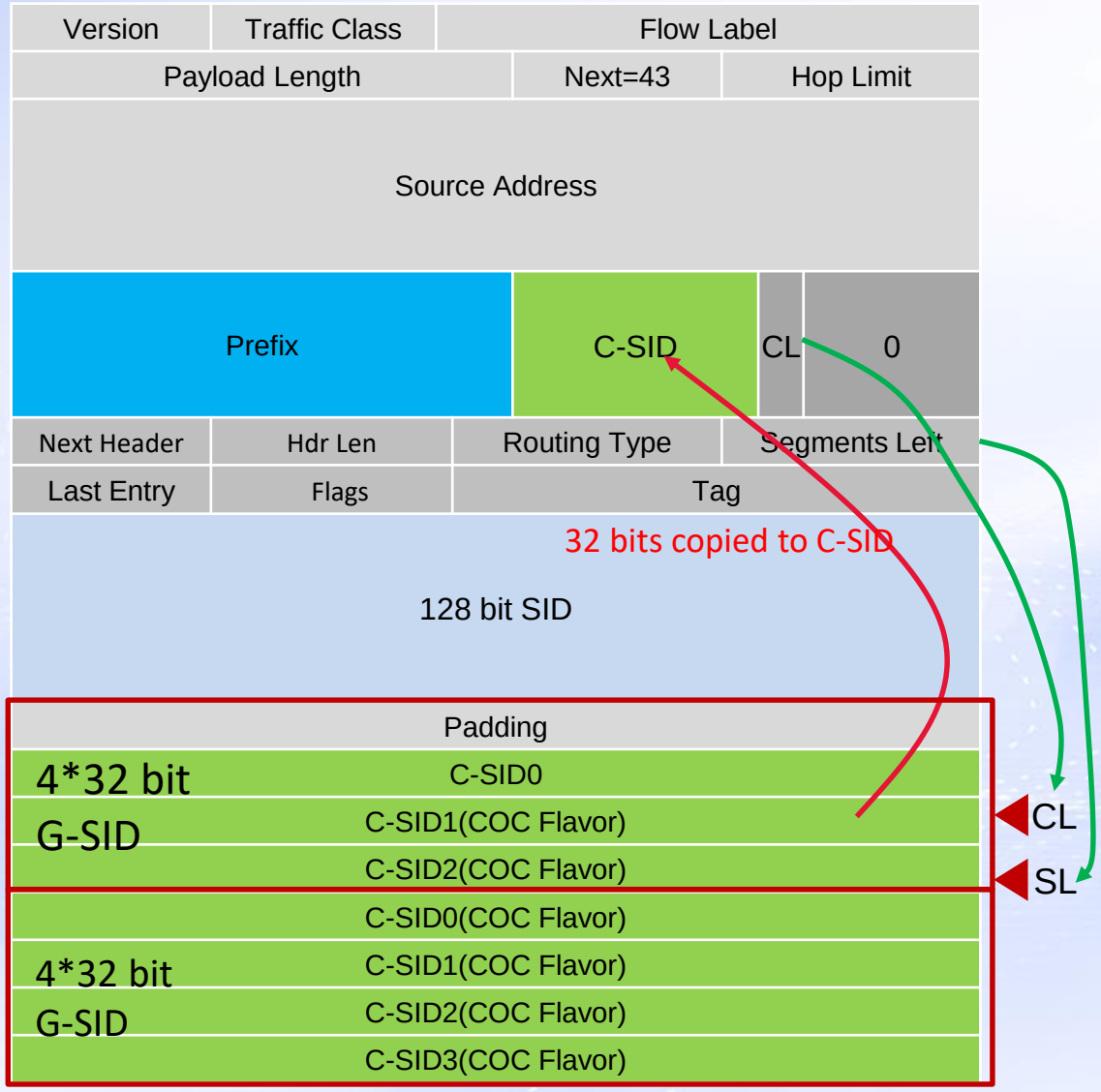
- C-flag in control plane: indicates the format of the SRv6 SID is compressible. The SID can be encoded as 128 or 32 bits in SRH
- COC(Continuation of Compression) flavor indicate the next SID is a 32-bits Compressed SID(C-SID)
- CL （Compressed SID left, the args of the compressible SRv6 SID） indicates the location of C-SID within the G-SID

- Update C-SID from SRH[SL][CL] to IPv6 DA[CP: CP+31]

COC Flavor SRv6 SID in IPv6 DA

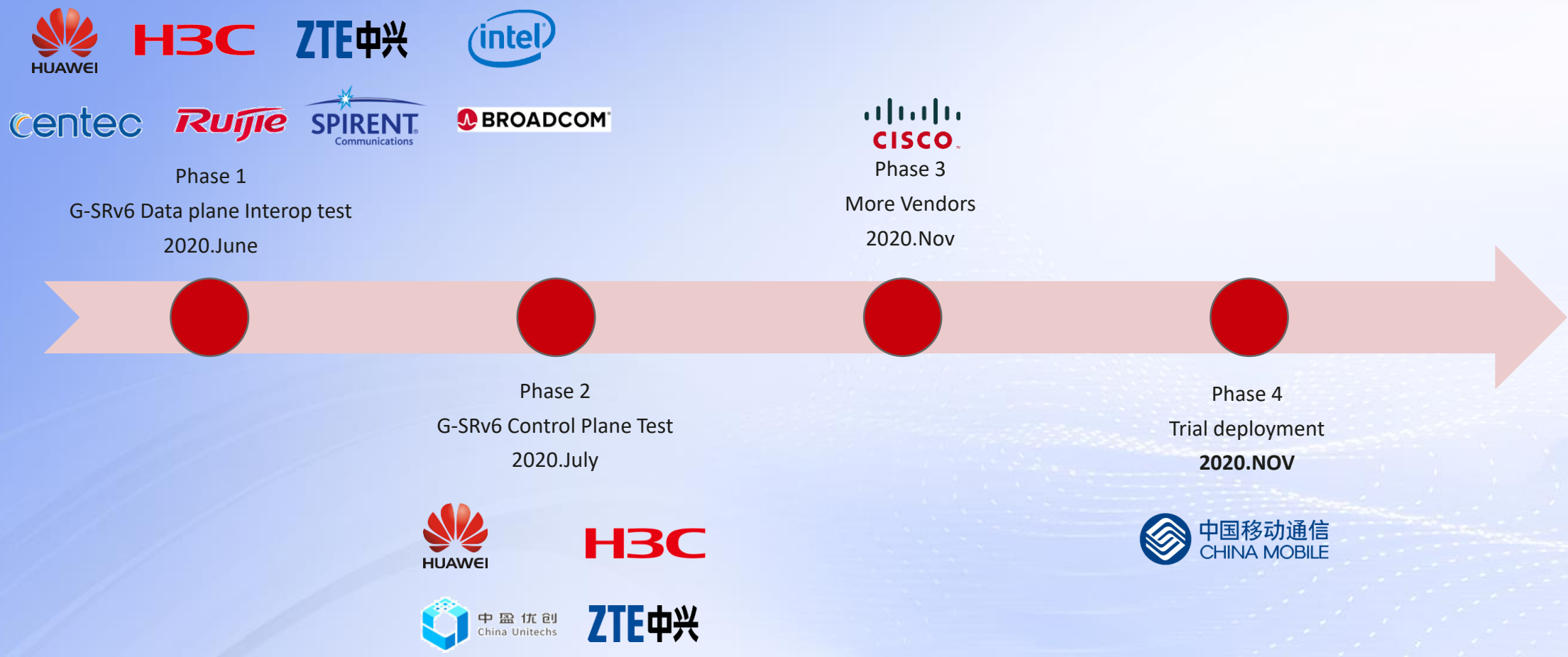
Pros

1. **Fully compatible with SRH, NO modification of SRH**
2. **Fully compatible with SRv6, add COC Flavor endpoint behaviors, no affect of existing SIDs**
3. **Fully compatible with SRv6 control plane: (Can be) No modification of Control Plane**
4. **Address saving & easy to deploy:**
    1. **Flexible address planning, does not require for a short common prefix**
    2. **No new address required when reusing the Locator**
    3. **No new route, no modification of routing scheme(can share the same locator with normal SRv6 SIDs)**
    4. Compressible SRv6 SID can be used as 128 bits or 32 bits. Reduce the number of SIDs.
5. **Less overhead**: A common prefix for a compressed sub-path instead of per 128 bits SID
6. **Smooth upgrade/Incremental deployment**: encode SRv6 SIDs and C-SIDs in a G-SRH
7. **Hardware Friendly:** No index mapping table
8. **Compatible with Micro SID**

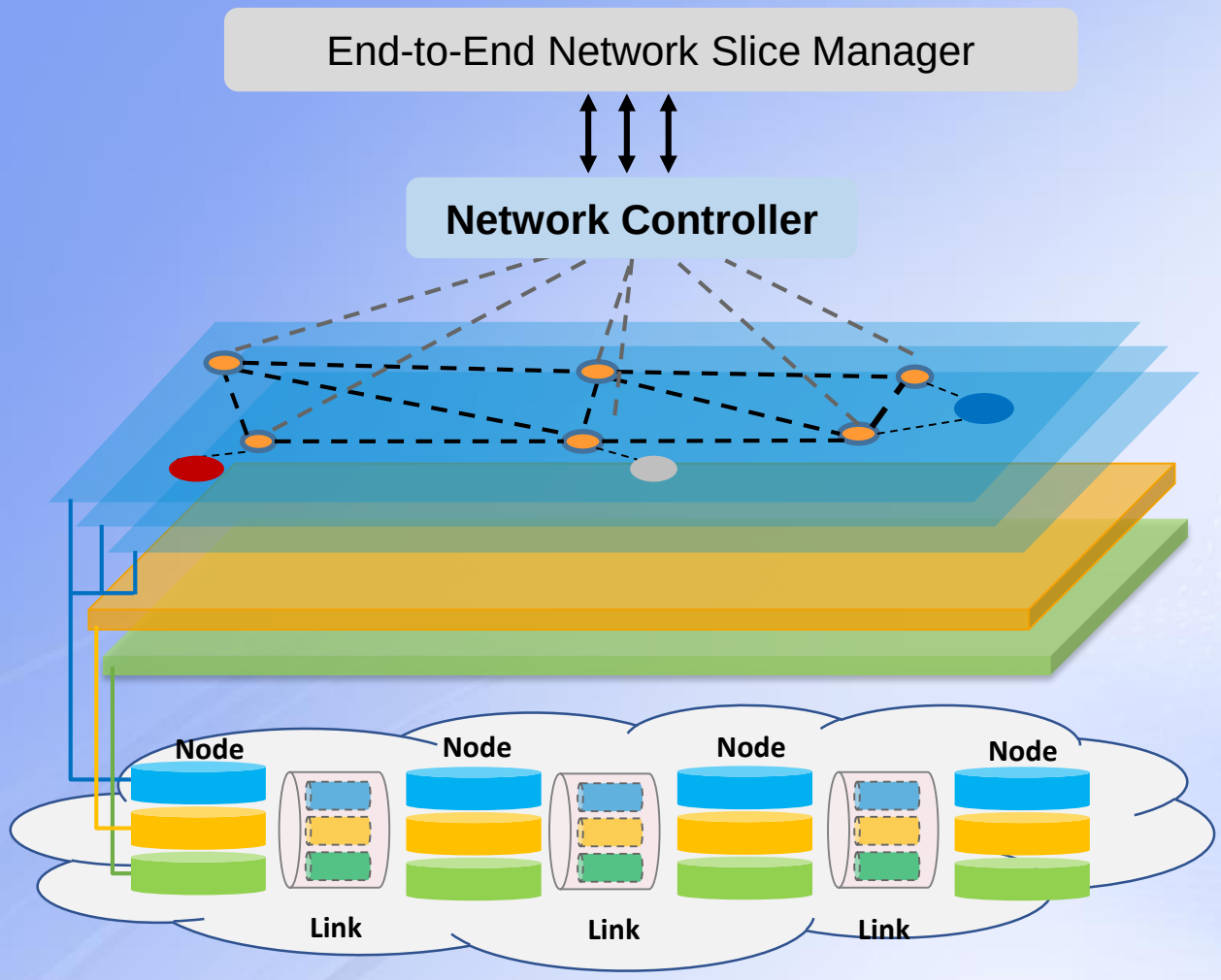


Compression G-SID

G-SRv6 Interop-test and Trial Deployment



IP Network Slicing Architecture



Network Slice Management

- Dynamic/automatic network slice life-cycle management
  - Creation, monitoring, adjustment, deletion
- Network slice planning algorithms

Network Slice Instantiation

- Customize network slice topology and associated attributes
- Integration between overlay connectivity and underlay resource

SRv6/IPv6 based

Network Resource Partitioning

- Flexible Ethernet (FlexE)
- Logical sub-interface
- Dedicated queues
- Time Sensitive Networking (TSN)

https://tools.ietf.org/html/draft-ietf-teas-enhanced-vpn

IPv6 Encapsulation for Network Slice

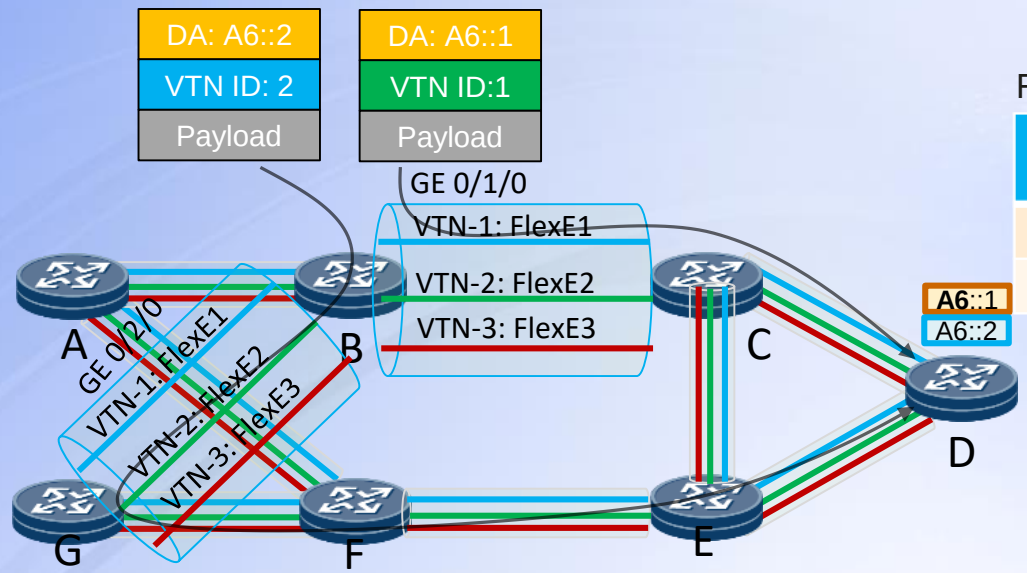
IPv6 Header	Version	Traffic Class	Flow Label	
	Payload Length		Next	Hop Limit
	Source Address (A1::1)			
	Destination Address (A2::11)			
HBH Header	Next Header	Hdr Ext Len	**VTN ID**	
	Next Header	Hdr Ext Len	Routing Type = 4	Segments Left=2
	Last Entry	Flags	Tag	
	Segment List[0] = A6::1			
	Segment 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 VTN-ID Extensions : *tools.ietf.org/html/draft-dong-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

30+ Network Slice deployments worldwide

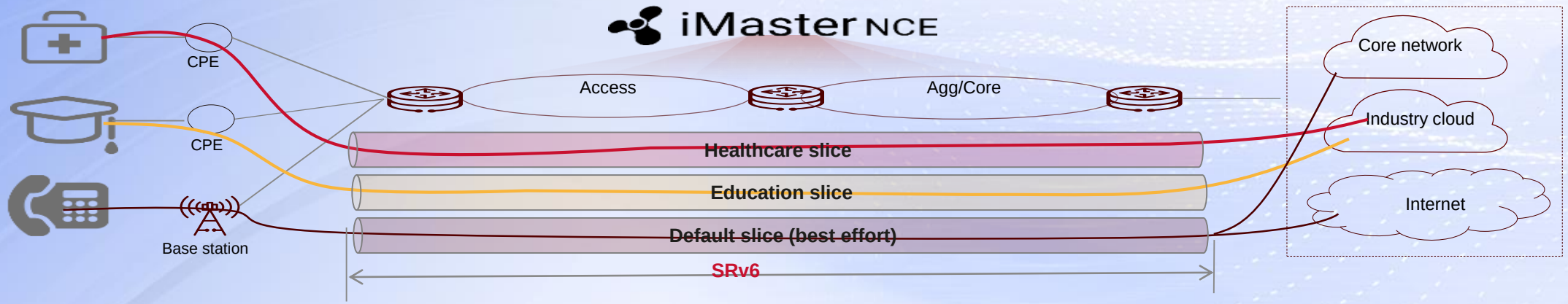
- Multi-industrial network
- Fix-Mobile Convergence
- Premium Private Lines ...
- Multi-service networks ...

Operator N: Network Slicing for Multiple Vertical Industrials

Healthcare

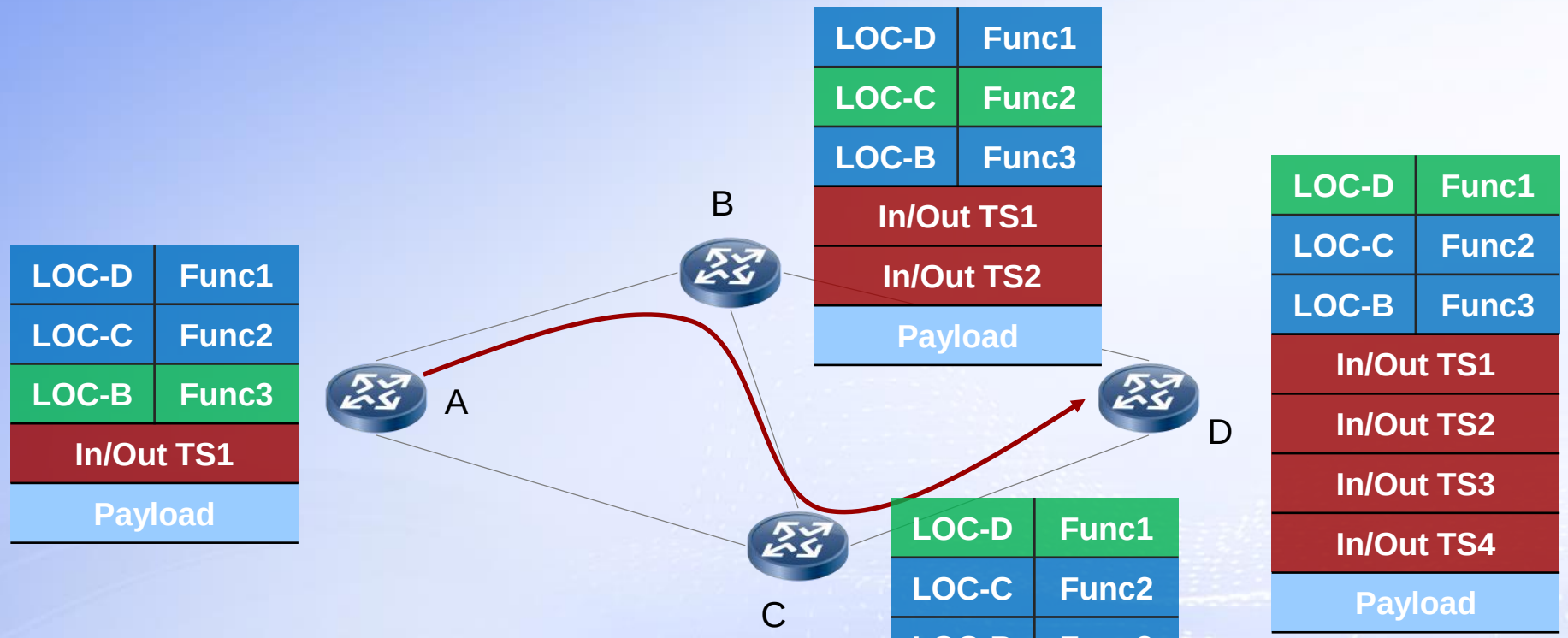
Education

Public Internet



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

IPv6 IFIT (In-situ Flow Information Telemetry)



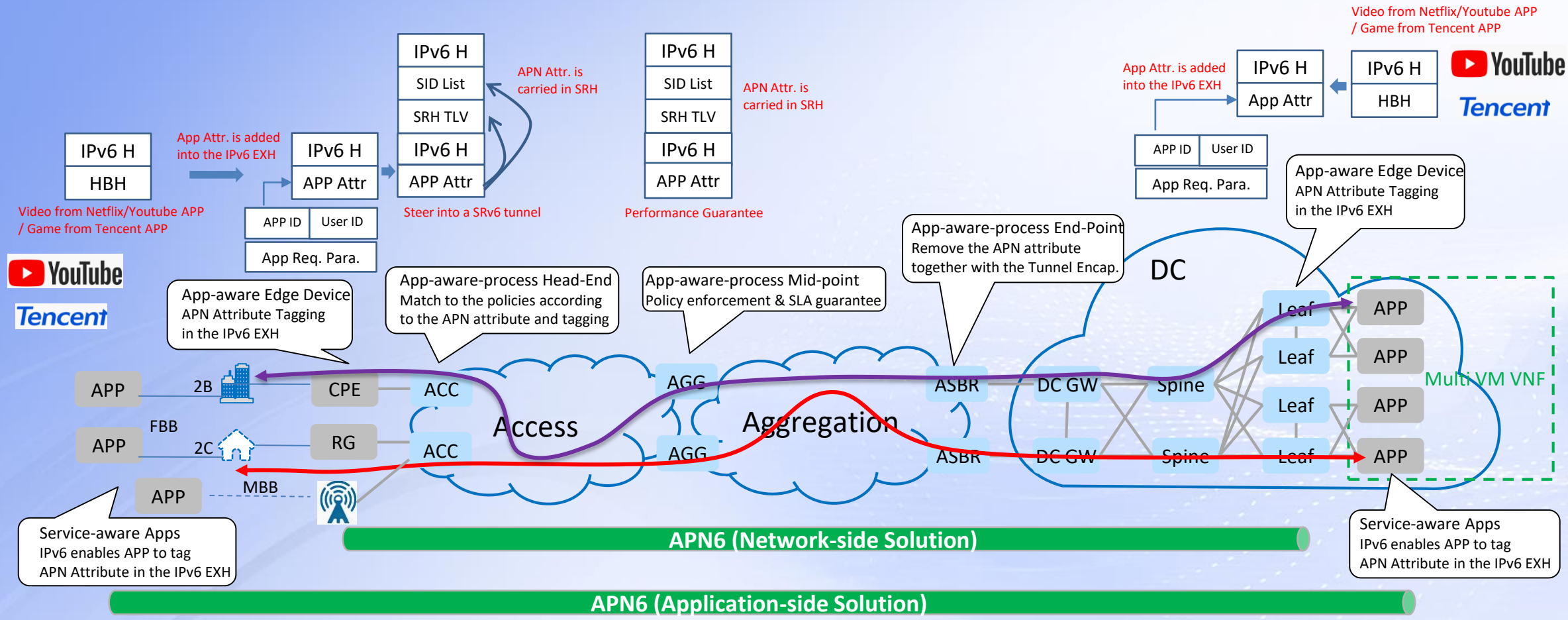
- **IFIT Framework:** draft-song-opsawg-ifit-framework-01
- **IPv6 IFIT:**
  - **Alternate Marking:** draft-ietf-6man-ipv6-alt-mark
  - **IOAM:** draft-ietf-ippm-ioam-data **and** draft-ietf-ippm-ioam-ipv6-options

Progress of IFIT Standards

Area	Topic	Drafts
Framework	In-situ Flow Information Telemetry Framework	draft-song-ifit-framework
Basic Encap	Data Fields for In-situ OAM	draft-ietf-ippm-ioam-data
	In-situ OAM Direct Exporting	draft-ietf-ippm-ioam-direct-export
	Enhanced Alternate Marking Method	draft-zhou-ippm-enhanced-alternate-marking
Encap type	IPv6 Application of the Alternate Marking	draft-ietf-6man-ipv6-alt-mark
	SRH for the Alternate Marking	draft-fz-spring-srv6-alt-mark
	In-situ OAM Processing in Tunnels	draft-song-ippm-ioam-tunnel-mode
Control Plane	BGP SR Policy for IFIT	draft-ietf-idr-sr-policy-ifit
	PCEP SR Policy for IFIT	draft-chen-pce-sr-policy-ifit
	IGP/BGP-LS for IFIT	draft-wang-lsr-ifit-node-capability-advertisement
YANG model	A YANG Data Model for In-Situ OAM	draft-ietf-ippm-ioam-yang

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

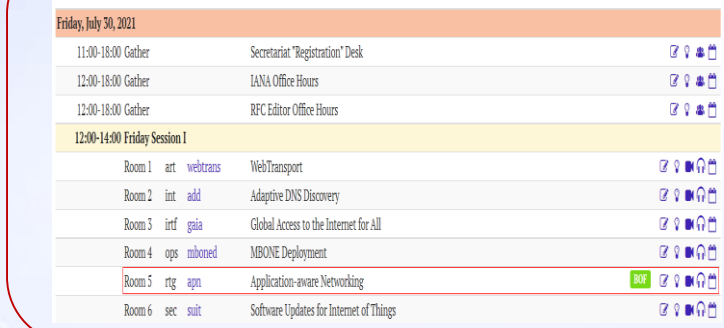


https://datatracker.ietf.org/doc/draft-li-apn-framework/
https://ieeexplore.ieee.org/abstract/document/9162934

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 @30th July 2021 1200-1400 PDT

IETF111 APN BoF



Friday, July 30, 2021				
11:00-18:00 Gather			Secretariat "Registration" Desk	
12:00-18:00 Gather			IANA Office Hours	
12:00-18:00 Gather			RFC Editor Office Hours	
12:00-14:00 Friday Session 1				
Room 1	art	webtrans	WebTransport	
Room 2	int	add	Adaptive DNS Discovery	
Room 3	irtf	gaia	Global Access to the Internet for All	
Room 4	ops	mboned	MBONE Deployment	
Room 5	rtg	apn	Application-aware Networking	BOF
Room 6	sec	suit	Software Updates for Internet of Things	

IETF105

IETF108

IETF109

IETF110

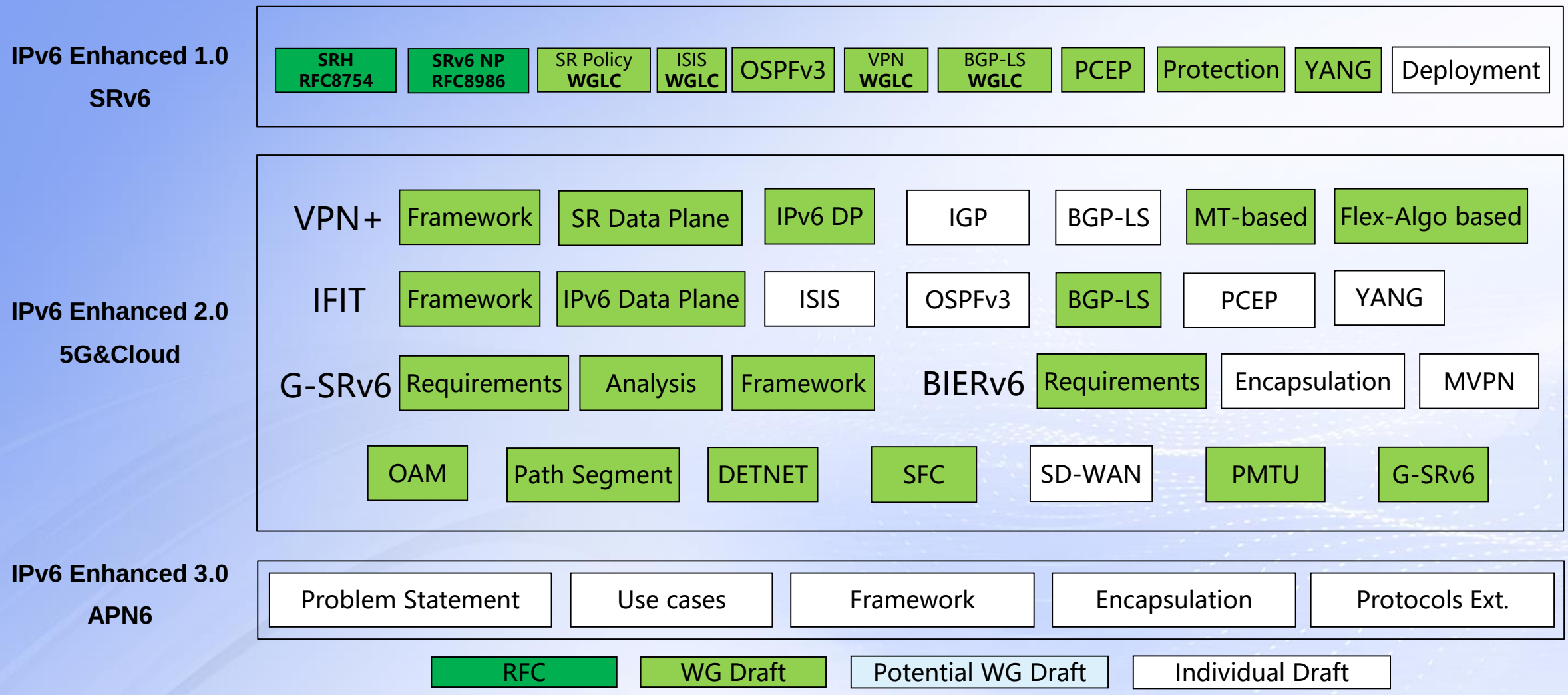
https://github.com/APN-Community

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 Enhanced 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. draft-ietf-6man-ipv6-alt-mark 2. draft-ietf-ippm-ioam-data 3. draft-ietf-ippm-ioam-ipv6-options	√	√	√
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	√	√	√

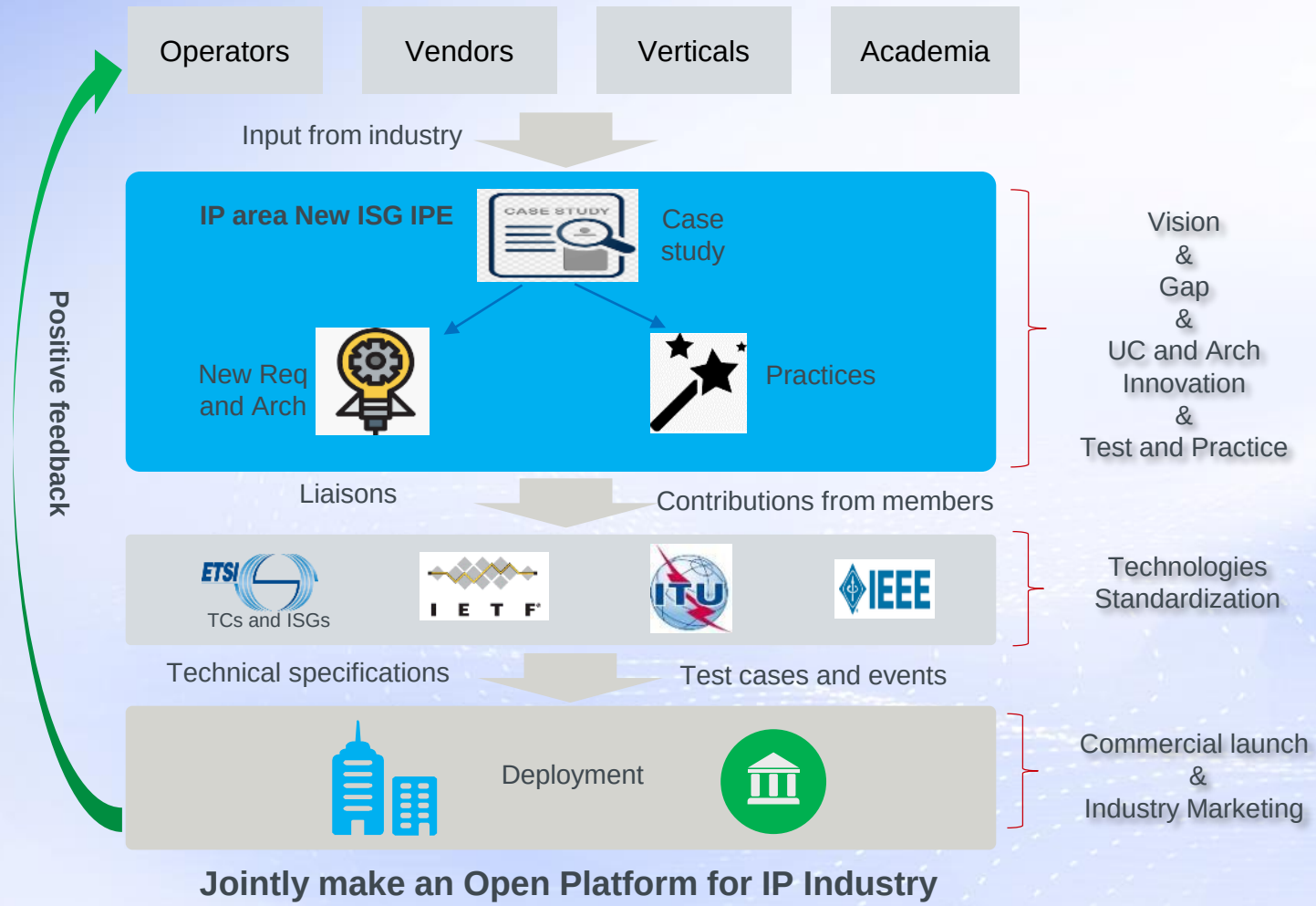
IPv6 Enhanced Standardization Work Layout



Please visit www.ipv6plus.net for the latest progress

ETSI New ISG IPE (IPv6 Enhanced)

25 Members, 63 Participants, 1 Counsellor (2022-03)

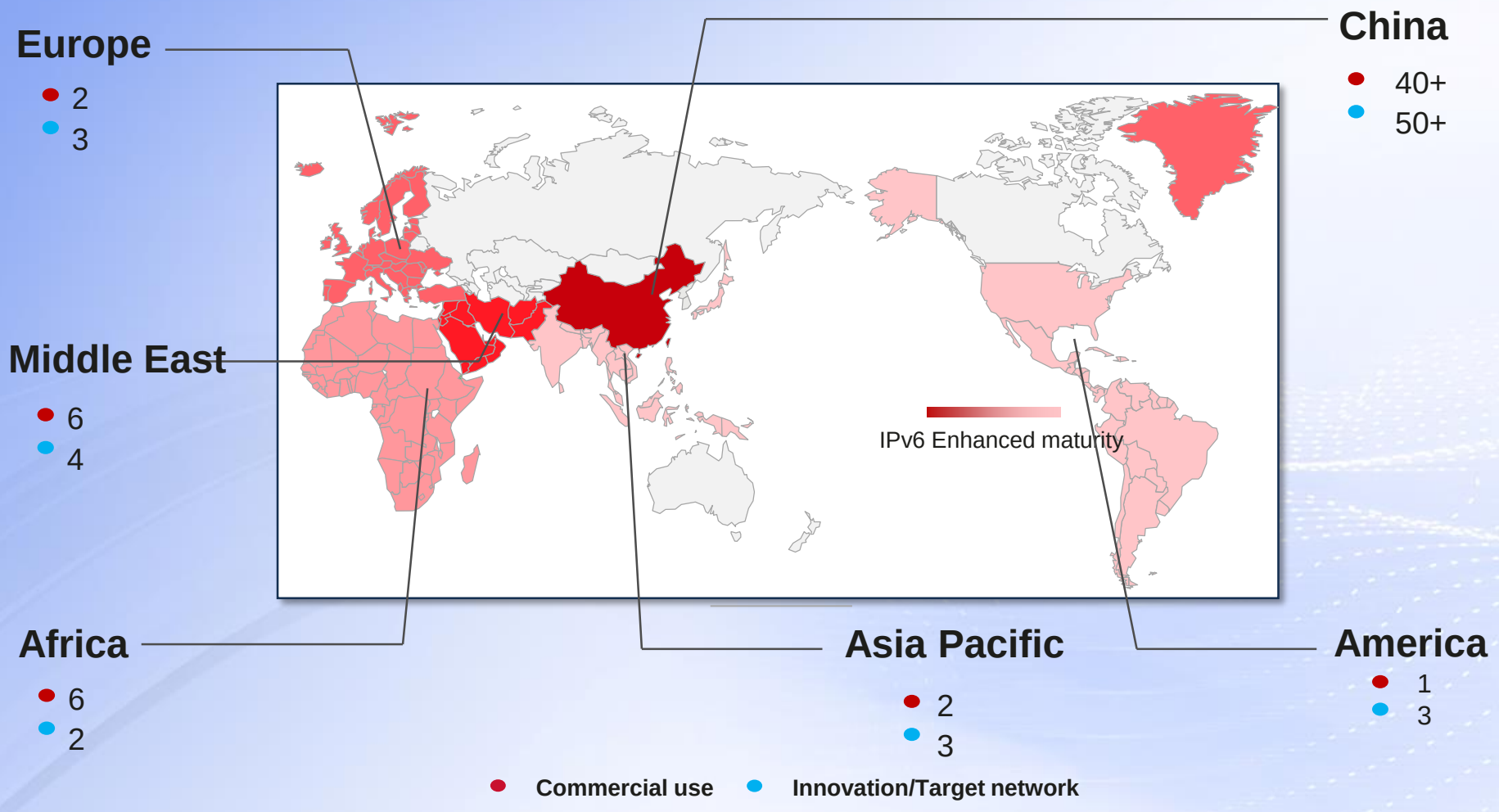


Jointly make an Open Platform for IP Industry

Complete industry chain in ISG IPE: Operators from different reality, Major Device Vendors, Verticals and Academia

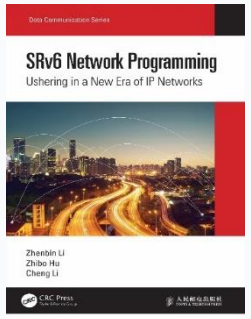
World-Wide IPv6 Enhanced Deployments are Booming

IPv6 Enhanced Deployment: 100+ SRv6; 30+ IP Network Slicing



IPv6 Enhanced Series Books and Videos

IPv6 Enhanced Books

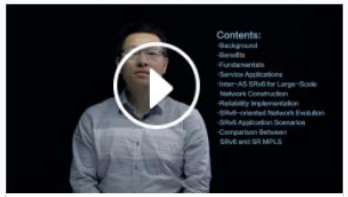


IPv6 Network Slicing
(To be Published on 2022)

IPv6 Enhanced Series Books

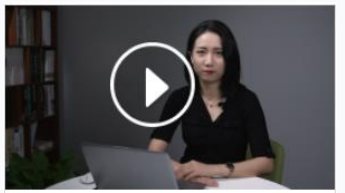
IPv6 Enhanced Series Videos

(Video) IP New Technology Series (Advanced) - Deep Dive into EVPN L3VPNv4 over SRv6 TE Policy



(Video) IP New Technology Series (Advanced) - Segment Routing IPv6 (SRv6)

(Video) IP New Technology Series (Advanced) - Segment Routing MPLS (SR-MPLS)



(Video) IP New Technology Series (Advanced) - Deep Dive into Ping & Tracert for SRv6

IPv6 Enhanced Series Books and Videos

IPv6 Enhanced Books

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

IPv6 Enhanced Series eBooks

Scan to obtain
the electronic version

https://e.huawei.com/en/material/bookshelf/bookshelfview/202109/29105716

IPv6 Enhanced Series Videos

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

THANKS !