Possible Network Technologies for Metaverse

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Agenda

- CAN: Computing-aware Networking
- MSR6: Multicast Source Routing over IPv6
- APN: Application-aware Networking
- Generalized IPv6

The influence of network by MEC

MEC changes the structure of networks and ends traffic locally, to provide a low latency and customized service to the user, saving bandwidth at the same time

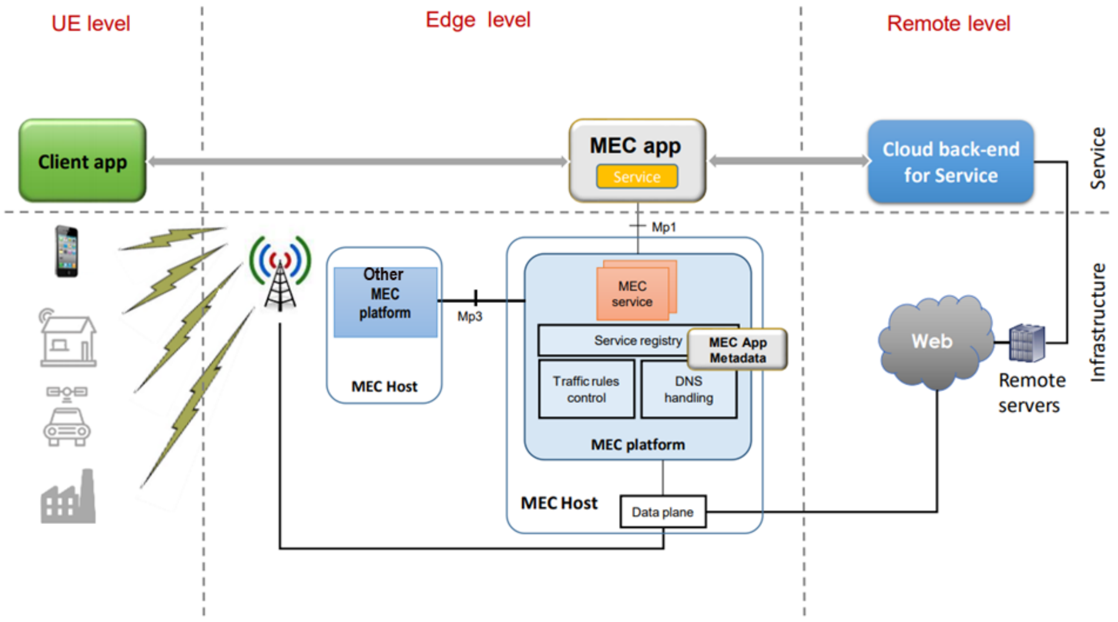


Figure 2: New application development paradigm introduced by MEC.

New issues brought to network by MEC:

- How to **discover edge** by users?
- How dose user **connect** to the edge?
- What could the edge **provide**?
- How to guarantee the **QoS?**
- What if the users **move**?

Completed in 5G domain

Typical Application - AR/VR in MEC: Traffic Steering based on Comprehensive Network and Service Metrics

Upper bound latency for motion-to-photon(MTP): includes frame rendering and requires less than **20 ms** to **avoid motion sickness,** consisted of**:**

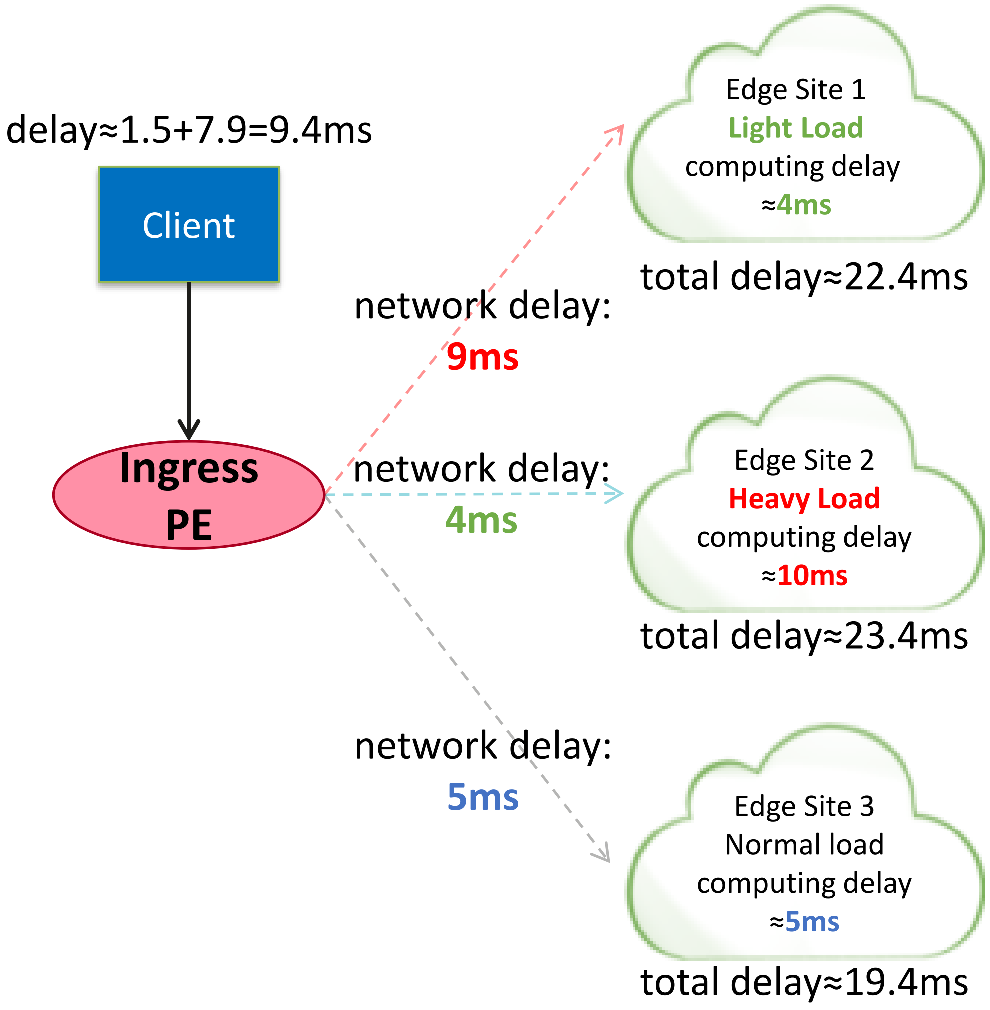
1. sensor sampling delay: <1.5ms (client)
2. display refresh delay: ≈7.9 ms(client)
3. frame rendering computing delay with **GPU≈ 5.5ms** (server)
4. network delay(budget) =20-1.5-7.9-5.5 = **5.1ms**(network)

Budgets for computing delay and network delay are almost equivalent!!

- choose edge site 1 according to load only, total delay≈22.4ms
- choose edge site 2 according to network only, total delay≈23.4ms
- choose edge site 3 according to both, **total delay≈19.4ms**

It can't meet the total delay requirements or find the best choice by either optimize the network or computing resource:

Require to dynamically steer traffic to the appropriate edge to meet the E2E delay requirements considering both network and computing delay



PS: Computing resources have a big difference in different edges, and the 'closest site' may be good for latency but lacks GPU support and should therefore not be chosen.

Distributed mode: Dyncast for Computing-aware Routing

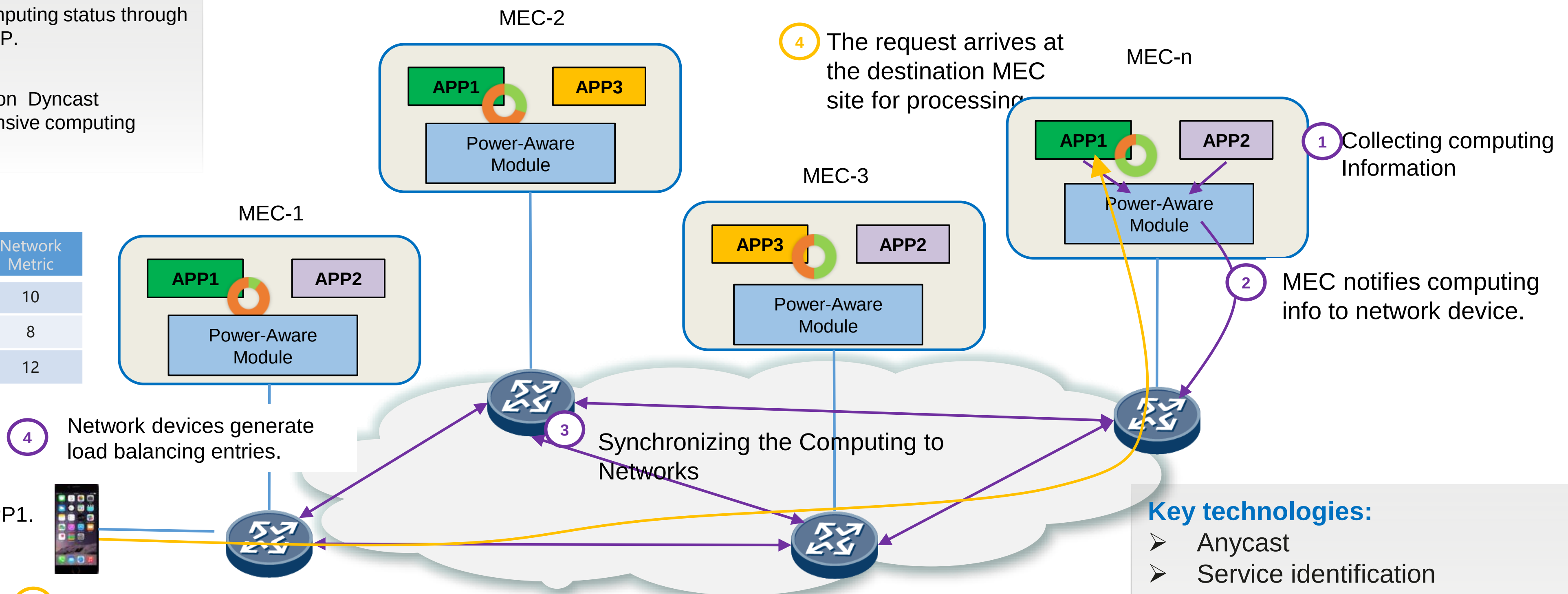
Dyncast (Dynamic Anycast) is a key technology of Computing aware routing. It inherits the advantages of anycast in **fast**, **reliable**, and **anti-DDoS**.

- Distributed computing is the endogenous resource in the computing aware network. Dyncast is used to connect the distributed computing to the network to provide optimal computing allocation and network connection for customers, achieving **high reliability of edge computing and optimal overall system utilization efficiency**.

Control plane: distributes computing status through network protocols, such as BGP.

Data plane: forwards based on Dyncast service identifiers, comprehensive computing status, and network status.

IP Prefix	Nexthop	Computing Metric	Network Metric
APP1 Anycast IP	MEC-1	60	10
	MEC-2	20	8
	MEC-n	10	12



1 Service demands to visit APP1.

2 Network devices select routes based on the computing information and network status of applications at each site.

3 The network device adds an entry to the session table to persist the session

Key technologies:

- Anycast
- Service identification
- Computing metric measurement
- Computing awareness
- scheduling algorithm
- Session persistence

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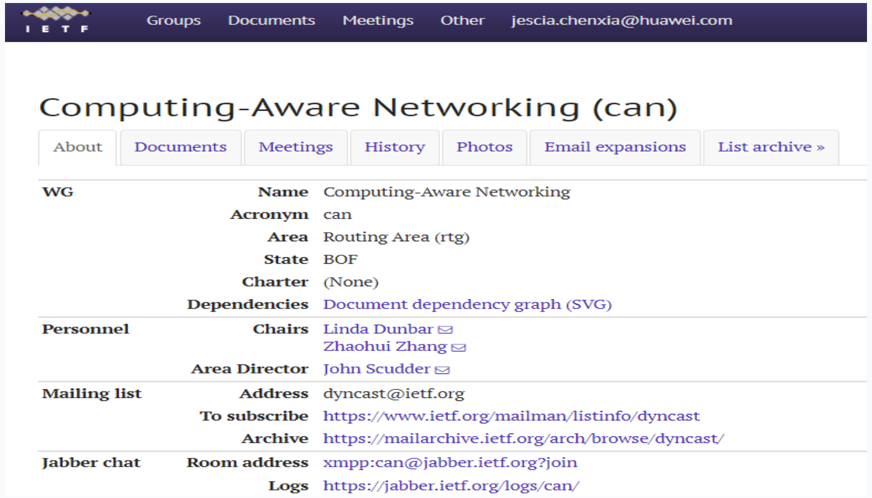
Standard Progress in IETF: CAN BOF of IETF 113

Meeting

- **Dyncast Side Meeting @IETF109 & @IETF110**
  - https://github.com/dyncast/ietf109
  - https://github.com/dyncast/ietf110
- **CAN BOF @IETF113**
  - https://datatracker.ietf.org/group/can/about/



Draft

Draft topic	Draft name
Dynamic-Anycast (Dyncast) Use Cases & Problem Statement	draft-liu-dyncast-ps-usecases
Dynamic-Anycast (Dyncast) Requirements	draft-liu-dyncast-reqs
Dynamic-Anycast Architecture	draft-li-dyncast-architecture
Providing Instance Affinity in Dyncast	draft-bormann-dyncast-affinity
LISP Support for Dynamic Anycast Routing	draft-kjsun-lisp-dyncast
BGP NLRI App Meta Data for 5G Edge Computing Service	draft-dunbar-idr-5g-edge-compute-app-meta-data
Computing-aware Networking Use case of ALTO	draft-liu-alto-can-usecase
Use Cases for Computing-aware Software-Defined Wide Area Network(SD-WAN)	draft-zhang-dyncast-computing-aware-sdwan-usecase

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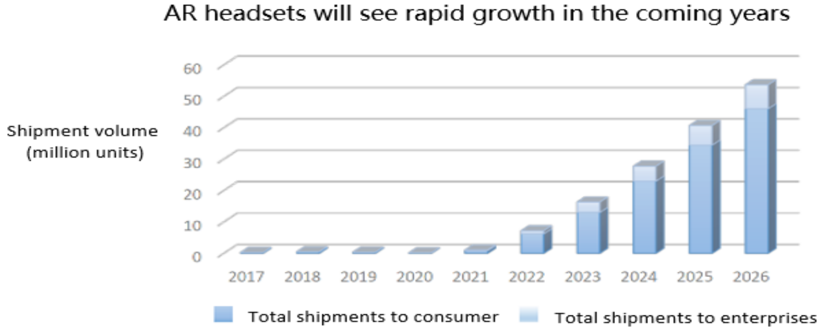
Multicast has great potential in carrying future applications

- Live traffic is rapidly increasing in the network, and will occupy more and more important position
  - Games Live
  - Shopping online
  - Online Meetings/Conferences
- XR heats up and gets attention again
  - Cloud Rendering is important complementary technology besides edge computing, and network plays an important role.
  - XR is one of the most important applications for 5G which is under discussion in 3GPP
- Multicast has great potential in carrying these applications, but…it is not used now.

Taobao's anchor sales list showed that the final sales of Chinese livestream salesman Li Jiaqi on the first live-streaming event of this year's 11.11 Shopping Festival reached 10.653 billion yuan ($1.7 billion), followed by two other female anchors, Viya and Xueli, totaling 8.252 billion yuan and 930 million yuan respectively.



Source: Strategy Analytics

How can multicast evolve gradually to carry more real-time applications?

Change frist from the network side?

- Simple protocol
- Flexible to support a variety of application scenarios
- Easy to be used end-to-end

IETF Experience and existing work

- Segment Routing
- Network Programming
- IPv6

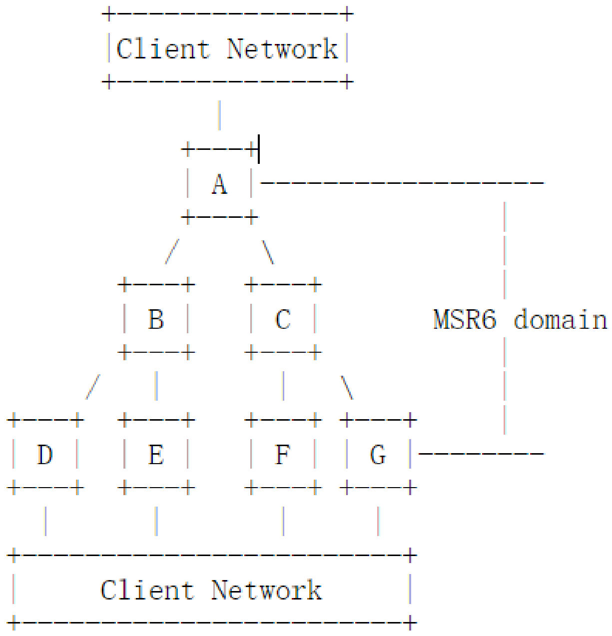
And then…

Application Ecosystem (not yet)?

So We Propose the requirement of : MSR6 (Multicast Segment Routing over IPv6)

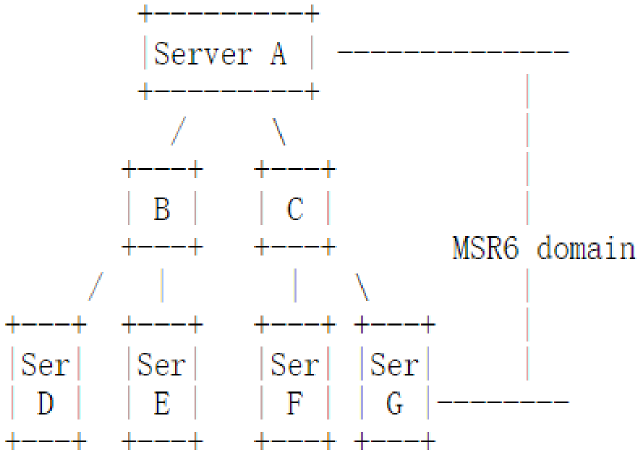
- Key Features of MSR6:
  - IPv6:
    - Allowing Host-Initiated multicast with IPv6 encapsulation;
    - Transit through unicast nodes in the network
    - Easy to support inter-domain deployment
  - Network Programming
    - Flexible encoding based on different scenarios/use cases
    - Able to program the packet at the ingress node, controlling leaf to join or leave a multicast tree. No multicast state is supposed to be maintained in the network domain;
    - Able to steer the multicast traffic over different trees according to service requirement; Path optimization is allowed based on network status;

MSR6 Possible Deployment Modes



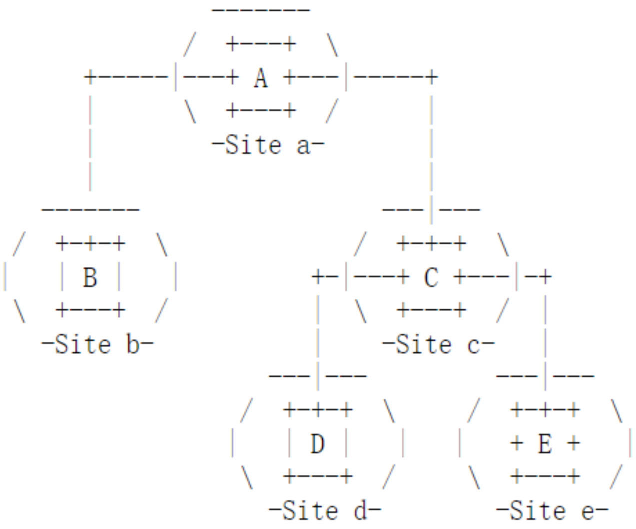
Conventional Multicast Deployment

E.g., IPTV, live video



Host-Initiated Multicast Deployment

E.g., MSDC (Massively Scalable Data Center), Cloud for Tenant Multicast



Multicast Overlay Network

E.g., SD-WAN

Host-Initiated Multicast maybe an very important requirement for the Metaverse. Currently many applications which would have adopted multicast take methods of using unicast to simulate multicast. It is OK for the existing videos adopting 4M/8M transmission. But for the Metaverse, it may take up to 10G ~ 20G transmission. Using unicast to simulate multicast means great waste of network resources. Host-initiated multicast and interworking between host-initiated multicast and network-based multicast maybe a must for the metaverse.

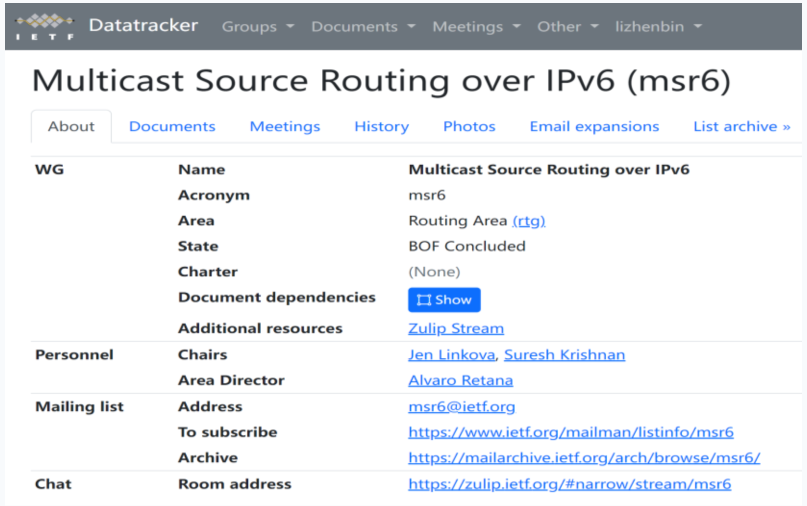
MSR6 Requirements

- Path Programming
- Resource Assurance
- Deterministic Delay
- Performance Measurement
- Reliability
- Forwarding Efficiency
- Host Initiated Multicast
- Scalability for Large-scale Receivers

Standard Progress in IETF: MSR6 BOF of IETF 114

Meeting

- **MSR6 Side Meeting @IETF112**
  - https://github.com/XuesongGeng/IETF-112-MSR6-Side-Meeting
- **MSR6 BOF @IETF114**
  - https://datatracker.ietf.org/group/msr6/about/



Draft

Draft topic	Draft name
Problem Satement of IPv6 Multicast Source Routing (MSR6)	draft-liu-msr6-problem-statement
Yet another Problem Statement for IPv6 Multicast Source Routing (MSR6)	draft-eckert-msr6-problem-statement
MSR6(Multicast Source Routing over IPv6) Use Cases	draft-liu-msr6-use-cases
Design Consideration of IPv6 Multicast Source Routing (MSR6)	draft-cheng-msr6-design-consideration
RGB (Replication through Global Bitstring) Segment for Multicast Source Routing over IPv6	draft-lx-msr6-rgb-segment
Recursive Bitstring Structure (RBS) for Multicast Source Routing over IPv6 (MSR6)	draft-eckert-msr6-rbs
IPv6 Multicast Source Routing Traffic Engineering	draft-geng-msr6-traffic-engineering
RLB (Replication through Local Bitstring) Segment for Multicast Source Routing over IPv6	draft-geng-msr6-rlb-segment

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Challenges of IP-based Transport Network Services

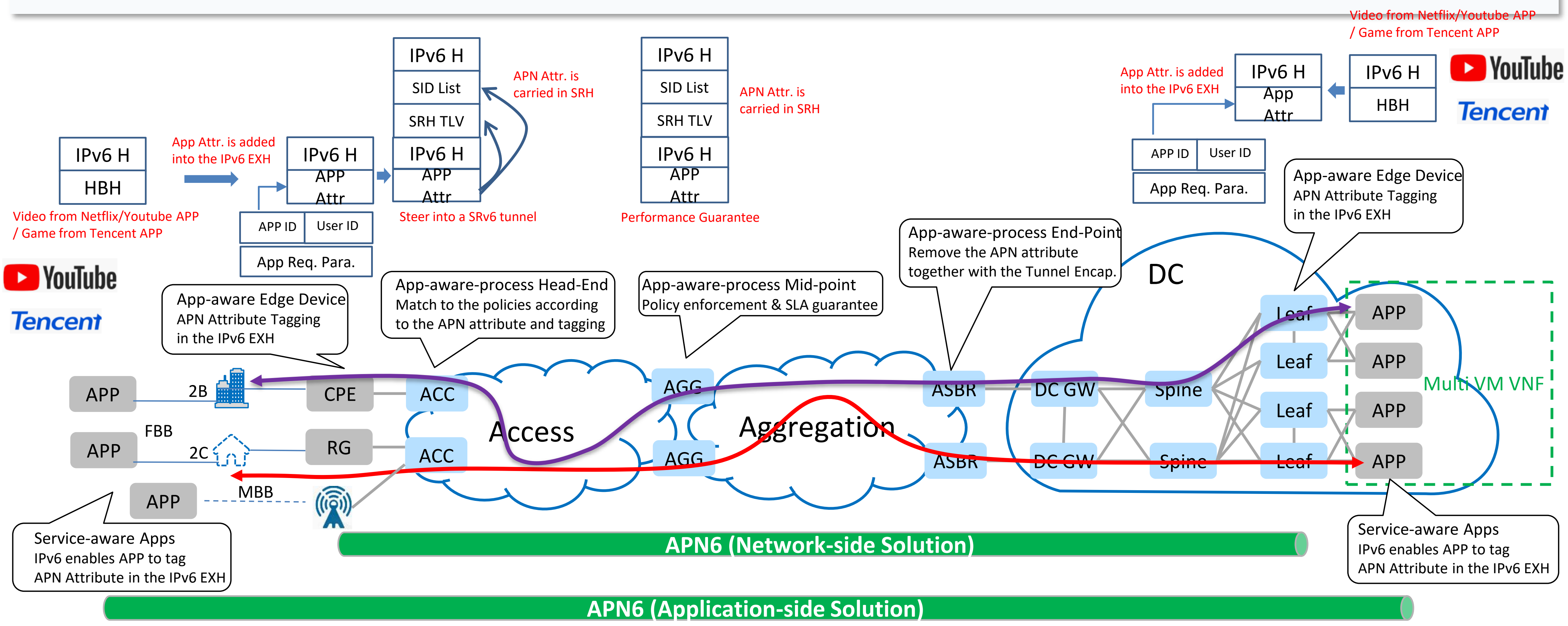
- Network does not know about the accurate service requirement from applications, so SLA is actually guaranteed by low bandwidth utilization.
- Network capabilities are improved greatly and there is Lack of flexible fine-grained mapping between applications and network services

TO BE: Convergence of application and network to provide fine-grained services

- Use Identifiers for mapping of applications' requirements and parameters to network service functions， to further release network capabilities
- The application-aware ID and parameters need to solve the challenges in existing methods and reduce CAPEX and OPEX
- IPv6 can act as an important medium in application and network convergence

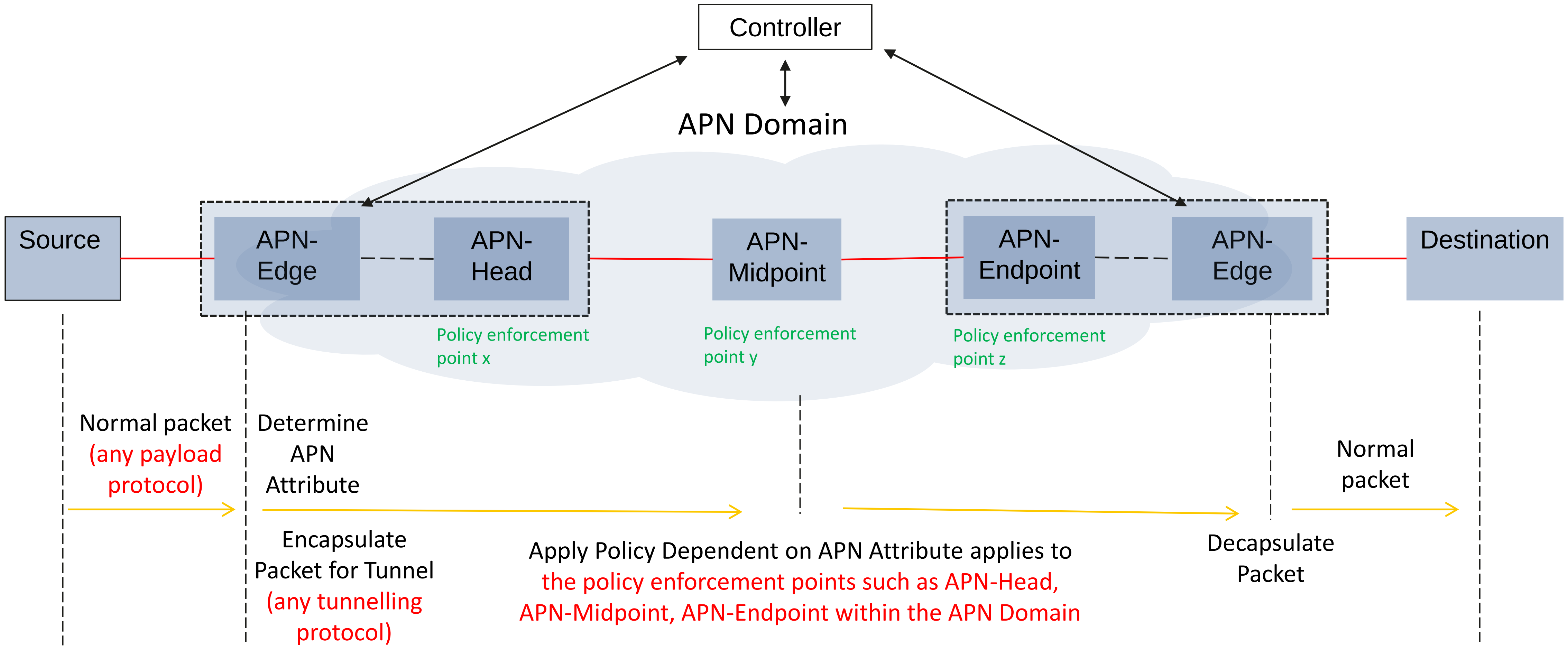
APN6: Application-aware IPv6 Networking

- 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

Reference Diagram of APN Network-side Solution

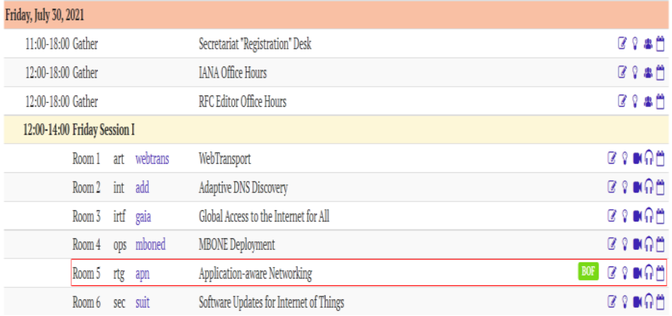


An APN Domain may span multiple network domains controlled by the same operator

Approved IETF APN BOF based on APN Application-side Solution

- **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)

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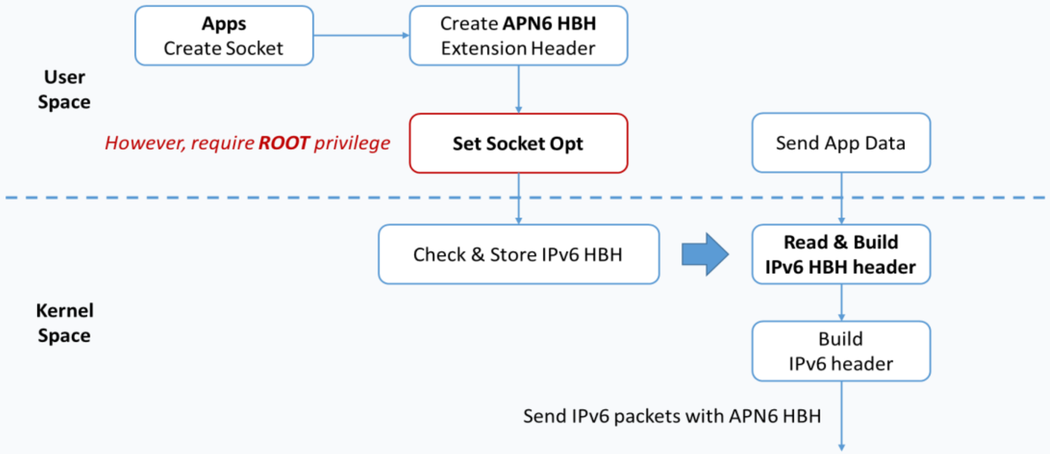
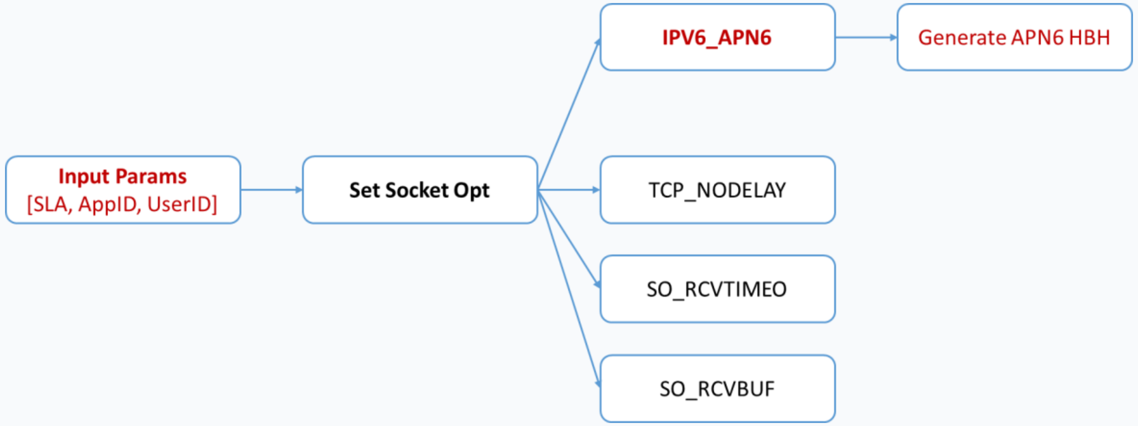
Exploring APN Application-side Solution: Open Source Implementation with Linux

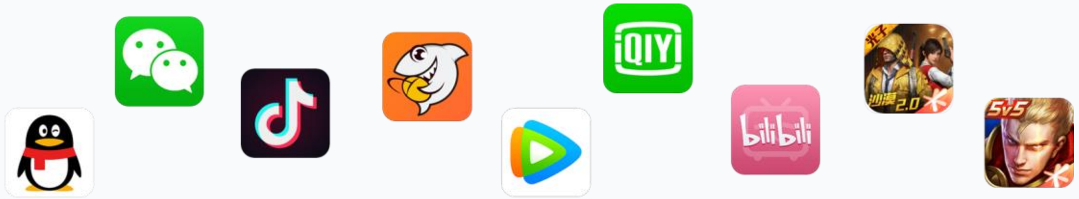
① Latest kernel supports to bind an arbitrary HBH extension header with a socket, but that **requires the ROOT privilege**. That is unacceptable.



② So, we need to **extend the socket API**, to allow Apps passing in APN attributes, and to generate HBH extension header securely in the kernel.



③ Then, Apps need to be upgraded to take advantage of the extended API, **binding the socket with APN attributes.**



Demo_TCP_Client.c

```
unsigned int apn6_id[] = {0x20150810, 0xAABBCCDD, 0x00522703};
int ret = setsockopt(connectSocket, IPPROTO_IPV6, IPV6_APN6, apn6_id, sizeof(unsigned int)*3);
```

④ **Demo:** with TCP Echo application, the packets of sent messages carry the specified HBH extension header **with APN attributes** successfully.

```
0000  e2 4c 96 0e b1 94 fe 7a  f5 48 09 16 86 dd 60 05   ·L·····z ·H····`·
0010  b5 df 00 63 00 40 20 01  0d a8 02 15 00 0a 00 00   ···c·@ · ········
0020  00 00 00 00 aa aa 20 01  0d a8 02 15 00 0a 00 00   ······ · ········
0030  00 00 00 00 bb bb 06 01  03 0c aa aa 08 10 00 00   ······ ··········
0040  aa aa 00 52 27 03 e0 68  15 87 07 ea 1d 62 6d b9   ···R'··h ·····bm·
0050  79 6e 80 18 01 fb d6 4f  00 00 01 01 08 0a 85 27   yn·····O ·······'
0060  28 ac 15 b4 b4 07 2e 2e  2e 2e 2e 2e 2e 2e 2e 2e   (·····.. ........
0070  63 6f 6e 74 61 63 74 20  42 65 69 6a 69 6e 67 20   contact  Beijing
0080  54 6f 77 65 72 20 6f 6e  20 31 31 38 2e 35 2c 20   Tower on  118.5,
0090  67 6f 6f 64 20 64 61 79  21                        good day !
```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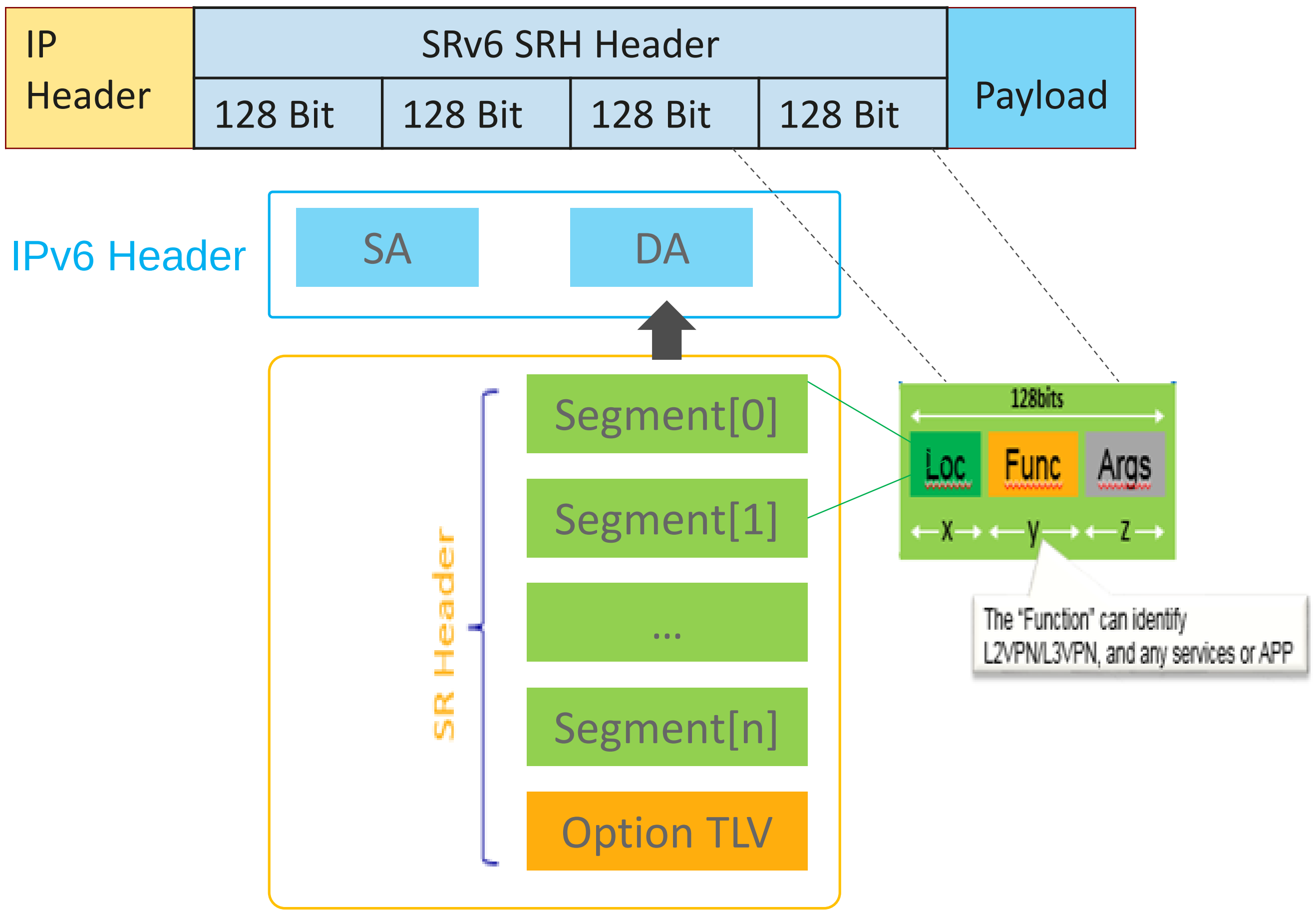
IPv6 Extension Headers and SRv6: Release Network Programming Capabilities

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



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IPv6 Enhanced Innovations

- SRv6: [RFC8704] defines IPv6 encapsulation for SRv6 network programming.
- Alternate Marking: [I-D.ietf-6man-ipv6-alt-mark] defines IPv6 encapsulation for Alternate Marking.
- IOAM: [I-D.ietf-ippm-ioam-ipv6-options] defines IPv6 encapsulation for IOAM.
- Network Slicing: [I-D.ietf-6man-enhanced-vpn-vtn-id] defines the IPv6 encapsulation used to determine resource isolation.
- DetNet: [I-D.yzz-detnet-enhanced-data-plane]defines the IPv6 encapsulation for implementing bounded latency.
- APN: [I-D.li-apn-ipv6-encap] defines the IPv6 encapsulation of an APN.

Why Need GIP6

- Currently there are many types of IP tunnels, such as VXLAN and GRE. On IPv6 networks, it is hard to define extensions for all these tunnels to support new features. On the other hand it is not recommended to extend new features based on the IPv4 data plane for these tunnels

There have been many types of IP tunnels

- GRE Tunnels: defined in [RFC2784].
- IP in IP Tunnels: defined in [RFC1853].
- L2TPv3 Tunnels: defined in [RFC3931].
- ISATAP Tunnels: defined in [RFC4214].
- IPv4/IPv6 over IPv6 (4over6) Tunnels: defined in [RFC2473].
- VXLAN Tunnels: defined in [RFC7348].
- NVGRE Tunnels: defined in [RFC7637].
- MPLS over UDP: defined in [RFC7510].
- VXLAN-GPE (Generic Protocol Extension for VXLAN) Tunnels: defined in [I-D.ietf-nvo3-vxlan-gpe].

GIP6 Technical Description

- The Generalized IPv6 (GIP6) tunnel is defined to use the IPv6 header and IPv6 extension header to support both existing IP tunnels functions and new features.
- A GIP6 encapsulated packet has the following format:

Option 1 (Recommended)

```
+-------------------------------------+
|           IPv6 Header               |
+-------------------------------------+
|           IPv6 Extension Header     |
|     (Encapsulations of new features +           |
| Encapsulations of functions of existing IP tunnels) |
+-------------------------------------+
|           Payload packet            |
+-------------------------------------+
```

GIP6 Encapsulation

Option 2

```
+-------------------------------------+
|           IPv6 Header               |
+-------------------------------------+
|           IPv6 Extension Header     |
|     (Encapsulations of new features)        |
|                                     |
+-------------------------------------+
|           Existing IP Tunnel Headers |
+-------------------------------------+
|           Payload packet            |
+-------------------------------------+
```

GIP6 Encapsulation

GIP6 for QUIC: Transport Control in IP Layer

- 1. The function of the UDP is replaced by the flow label of the IPv6 header in the GIP6 tunnel. To ensure compatibility, the value of the flow label calculated for the purpose of ECMP SHOULD be the same as that of the source port of the UDP.
- 2. Definition of the QUIC Option

A new option called QUIC Option is defined to carry the VXLAN header information. The QUIC Option MUST only be encapsulated in the Destination Options Header (DOH).

QUIC Option

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                |  Option Type  |  Opt Data Len |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                 QUIC Header (Variable Bytes)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Combine E2E Transport Control with Transport Control in IP Layers

GIP6 Related Drafts

Draft

Draft topic	Draft name
Generalized IPv6 Tunnel (GIP6)	draft-li-rtgwg-generalized-ipv6-tunnel
Generalized IPv6 Tunnel (GIP6) for QUIC	draft-li-rtgwg-gip6-for-quic
Genralized IPv6 Tunnel for MPLS	draft-li-mpls-gip6-mpls
Protocol Extension Requirements of Generalized IPv6 Tunnel	draft-li-rtgwg-gip6-protocol-ext-requirements

Summary

- Integration of network and applications to cope with the challenges of transporting metaverse traffic and guarantee QoE (Quality of Experience).
  - ➢ Computing-aware Networking (CAN)
  - ➢ Host-initiated MSR6
  - ➢ Application-aware Networking
- IPv6 will play a import role in the network layer.
  - ➢ User side: Carry application-aware information depending on IPv6 extensions
  - ➢ Network side: Enhance network capabilities based on IPv6 extensions

Thank you.

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每个组织，构建万物互联的智能世界。

Bring digital to every person, home and organization for a fully connected, intelligent world.