SRv6创新与标准进展

2019.3

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Zhenbin (Robin) Li

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

- Head of Huawei IP research and standard work.
- Be active in standard activities since IETF75 and proposes 40+ drafts/RFCs in RTG/OPS areas.
- Promote SDN Transition (Netconf/YANG, BGP/PCEP, etc.) innovation and standard work in the past 5 years.
- Focus on the innovation standard work of SRv6, Network Intelligence, Telemetry, etc. since 2016.
- Be elected as the IETF IAB member (No.1 IAB member from Asian Enterprise in the Internet History) to be responsible for Internet architecture work from 2019 to 2021.
Segment Routing简介

首节点指定数据包的端到端转发路径。转发指令被携带在报文头中，用于指导转发节点转发数据包。

2. 头节点将描述转发路径的Segment List插入到报文中

1. 路径信息由控制器下发或其他方式配置

3. 后续节点根据Segment指示的指令转发数据包

- **Segment Routing的优点**
  - 简化控制协议：无需RSVP-TE/LDP
  - 高扩展性：减少网络状态，只在源节点维护逐流的状态
  - 可编程：Segment灵活组合满足不同路径服务需求
  - 更可靠的保护：基于TI-LFA支持100%网络覆盖的FRR

SR-MPLS: TE/FRR/VPN等基础特性已成熟，落地部署中
SRv6: 快速发展中
SRv6 网络编程原理

IPv6 SRH HEADER

<table>
<thead>
<tr>
<th>Version</th>
<th>Traffic Class</th>
<th>Flow Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pload Length</td>
<td>Next=43</td>
<td>Hop Limit</td>
</tr>
</tbody>
</table>

Source Address

Destination Address

<table>
<thead>
<tr>
<th>Next Header</th>
<th>Hdr Ext Len</th>
<th>Routing Type</th>
<th>Segments Left</th>
</tr>
</thead>
</table>

Last Entry

Flags

Tag

Segment List[0]

Segment List[1]

Segment List[2]

Payload

三层编程空间

“Function”字段可以标识L2VPN/L3VPN，以及其他的服务和应用。
L3VPN Over BE Tunnel for SRv6

SA:2.2.2.2  
DA:1.1.1.1
Payload

SA:A1:1::123  
DA:A2:1:B100

SA:2.2.2.2  
DA:1.1.1.1
Payload

SA:A1:1::123  
DA:A2:1:B100

SA:2.2.2.2  
DA:1.1.1.1
Payload

SA:A1:1::123  
DA:A2:1:B100

SA:2.2.2.2  
DA:1.1.1.1
Payload

SA:A1:1::123  
DA:A2:1:B100

For Forwarding

Control

My local sid table:
A2:1::B100 END.DT4
IPv4 L3VPN(VRF 100) END.DX4 – per CE per SID, no FRR for CE/PE

CFG:
1 SR ipv6-srh end-sid A2:1 64
2 ip vpn-instance vpn100 prefix-sid dynamic A2:1 64
3 Interface loopback0 Ipv6 address A2:1::124 64

VPN route:1.1.1.1
NHP:A2:1::124
VPN Sid:A2:1::B100

ISIS Route: A2:1/64
Redistribute to ISIS
BGP Route: A2:1/64
L3VPN Over TE Tunnel for SRv6

SR Policy:{A1:2,A1:3}  
ENDPOINT:A2:1  
explicitly config  
Steering VPN Traffic  
into an SR Policy

Payload
SA:2::2  
DA:1::1

Payload
SA:2::2  
DA:1::1
A2:1::B100  
A1:3  
A1:2  
SA:A1:1::123  
DA:A1:2

Payload
SA:2::2  
DA:1::1
A2:1::B100  
A1:3  
A1:2  
SA:A1:1::123  
DA:A1:3

Payload
SA:2::2  
DA:1::1
A2:1::B100  
A1:3  
A1:2

Payload
SA:2::2  
DA:1::1
A2:1::B100  
A1:3  
A1:2  
SA:A1:1::123  
DA:A2:1::B100

VPN route:1::1  
NHP:A2:1::124  
VPN Sid:A2:1::B100

My local sid table:  
A2:1::B100  
END.DT4  
IPv4 L3VPN(VRF 100)

BGP Route: A2:1/64  
Redistribute to ISIS

ISIS Route: A2:1/64

Control


SRv6愿景: 端到端网络统一转发

- 简化: 基于IPv6可达性即可工作，无需MPLS额外信令。
- 行业接受度: MPLS无法进DC，基于IPv6可达的SRv6称为SR进数据中心的选择。
- 端到端统一: 端到端统一的路由/转发技术；E2E业务和SFC可以轻易增量部署。
- 可延伸性: 按需PNF & VNF连接，无缝实现云网融合联动，从网络扩展到业务/APP。
SRv6标准推动与实现部署双管齐下，支持互联互通

华为与Cisco等合作的草案达到25篇

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Status</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>SRv6 Arch</td>
<td>○</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>SRH</td>
<td>○</td>
<td>H</td>
</tr>
<tr>
<td>VPN</td>
<td>SRv6 VPN</td>
<td>○</td>
<td>H</td>
</tr>
<tr>
<td>IGP</td>
<td>ISIS for SRv6</td>
<td>○</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>OSPFv3 for SRv6</td>
<td>△</td>
<td>M</td>
</tr>
<tr>
<td>SDN Interface</td>
<td>BGP-LS for SRv6</td>
<td>△</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>PCEP for SRv6</td>
<td>△</td>
<td>M</td>
</tr>
</tbody>
</table>

○: Draft, No Risk  △: Draft, With Risk  ×: Incomplete Draft
### SRv6标准进展（1）基础特性

<table>
<thead>
<tr>
<th>Area</th>
<th>Topic</th>
<th>Draft</th>
<th>Vendors</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture/Usecase</td>
<td>SRv6 Network Programming</td>
<td>draft-ietf-spring-srv6-network-programming</td>
<td>Cisco/Huawei</td>
<td>Comcast/Bell Canada/Softbank</td>
</tr>
<tr>
<td>SRH</td>
<td>IPv6 Segment Routing Header (SRH)</td>
<td>draft-ietf-6man-segment-routing-header (LC Request accepted)</td>
<td>Cisco/Huawei</td>
<td>Bell Canada/Softbank</td>
</tr>
<tr>
<td>IGP</td>
<td>ISIS Extensions for SRv6</td>
<td>draft-ietf-isis-srv6-extensions</td>
<td>Cisco/Huawei</td>
<td>Orange</td>
</tr>
<tr>
<td></td>
<td>OSPFv3 Extensions for SRv6</td>
<td>draft-li-ospf-ospfv3-srv6-extensions</td>
<td>Cisco/Huawei</td>
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</tr>
<tr>
<td>VPN</td>
<td>SRv6 VPN</td>
<td>draft-dawra-idr-srv6-vpn/draft-dawra-bess-srv6-services-00 (WG Adoption in process)</td>
<td>Cisco/Huawei</td>
<td>Comcast/Bell Canada/Softbank/Orange</td>
</tr>
<tr>
<td>SDN Interface</td>
<td>BGP-LS for SRv6</td>
<td>draft-ietf-idr-bgppls-srv6-ext</td>
<td>Cisco/Huawei/Ericsson</td>
<td>Bell Canada/Orange/AT&amp;T</td>
</tr>
<tr>
<td></td>
<td>PCEP for SRv6</td>
<td>draft-ietf-pce-segment-routing-ipv6</td>
<td>Cisco/Huawei</td>
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</tr>
</tbody>
</table>

SRv6基础特性标准大都已经成为工作组草案，商用实现和商用部署正在进行。
SRv6标准进展 (2) YANG模型

<table>
<thead>
<tr>
<th>Area</th>
<th>Topic</th>
<th>Draft</th>
<th>Vendors</th>
<th>Operators</th>
<th>Plan</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Yang Models</td>
<td>SRv6 Base Yang</td>
<td>draft-raza-spring-srv6-yang</td>
<td>Cisco/Huawei/Infer/Inera/Infinera/Ciena/Ericsson</td>
<td>Bell Canada/Softbank</td>
<td>IETF101</td>
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<tr>
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<td>SRv6 ISIS Yang</td>
<td>draft-hu-isis-srv6-yang</td>
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<td>IETF 102</td>
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<td>SRv6 BGP Yang</td>
<td>draft-dhjain-spring-bgp-sr-yang</td>
<td>Cisco/Huawei</td>
<td>Orange</td>
<td>IETF 102</td>
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<td></td>
<td>SRv6 TE Yang (SR Policy Yang)</td>
<td>draft-thomas-spring-sr-policy-yang</td>
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<td>Bell Canada/Softbank</td>
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<tr>
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<td>SRv6 OSPF Yang</td>
<td>draft-hu-lsr-ospf-srv6-yang</td>
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<td>IETF 103</td>
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<tr>
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<td>SRv6 PCEP Yang</td>
<td>draft-dhody-pce-pcep-srv6-yang</td>
<td>Cisco/Huawei</td>
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<td>IETF 103</td>
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<tr>
<td></td>
<td>SRv6 EVPN YANG</td>
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<td></td>
<td></td>
<td>IETF 104</td>
<td>In Process</td>
</tr>
<tr>
<td></td>
<td>SRv6 PING YANG</td>
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<td></td>
<td>IETF 104</td>
<td>In Process</td>
</tr>
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</table>

SRv6 YANG模型草案与解决方案同步推出，方便第三方对接
### SRv6标准进展（3）OAM/PM

<table>
<thead>
<tr>
<th>Area</th>
<th>Topic</th>
<th>Draft</th>
<th>Vendors</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OAM</strong></td>
<td>SRv6 OAM/IOAM Use cases and Mechanisms</td>
<td>draft-ali-spring-srv6-oam/draft-ali-6man-spring-srv6-oam-01 (WG Adoption in process)</td>
<td>Cisco/Huawei</td>
<td>Comcast/Softbank/ Bell Canada</td>
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<tr>
<td></td>
<td>SR UDP PM</td>
<td>draft-gandhi-spring-udp-pm</td>
<td>Cisco/Huawei</td>
<td>Bell Canada</td>
</tr>
<tr>
<td></td>
<td>SRv6 Light iOAM</td>
<td>draft-li-spring-light-weight-srv6-ioam</td>
<td>Huawei</td>
<td>China Mobile</td>
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<tr>
<td><strong>Path Segment</strong></td>
<td>Use cases and Mechanisms of MPLS</td>
<td>draft-ietf-spring-mpls-path-segment</td>
<td>Huawei/Cisco</td>
<td>China Mobile</td>
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<tr>
<td></td>
<td>SRv6 Path ID</td>
<td>draft-li-spring-srv6-path-segment</td>
<td>Huawei/Cisco</td>
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</tr>
<tr>
<td></td>
<td>Path Segment and Bidir Path in BGP</td>
<td>draft-li-idr-sr-policy-path-segment-distribution</td>
<td>Huawei</td>
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</tr>
<tr>
<td></td>
<td>Path Segment and Bidir Path in BGP-LS</td>
<td>draft-li-idr-bgp-ls-sr-policy-path-segment</td>
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<tr>
<td></td>
<td>Path Segment in PCEP</td>
<td>draft-li-pce-sr-path-segment (WG Adoption in process)</td>
<td>Huawei/Cisco</td>
<td>China Mobile</td>
</tr>
<tr>
<td></td>
<td>Bidir Path in PCEP</td>
<td>draft-li-pce-sr-bidir-path (WG Adoption in process)</td>
<td>Huawei/Cisco</td>
<td>China Mobile</td>
</tr>
<tr>
<td></td>
<td>ID Space Delegation</td>
<td>draft-li-pce-controlled-id-space</td>
<td>Huawei</td>
<td>China Telcom</td>
</tr>
</tbody>
</table>

SRv6 OAM/PM控制面草案已经准备进行工作组接纳，转发面还存在一定的挑战。
### SRv6标准进展（4）5G/云核心网

<table>
<thead>
<tr>
<th>Area</th>
<th>Topic</th>
<th>Drafts</th>
<th>Vendors</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Slicing</td>
<td>VPN+ Architecture</td>
<td>draft-ietf-teas-enhanced-vpn</td>
<td>Huawei</td>
<td>China Mobile</td>
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<tr>
<td></td>
<td>SR for VPN+</td>
<td>draft-dong-spring-sr-for-enhanced-vpn</td>
<td>Huawei</td>
<td>China Mobile</td>
</tr>
<tr>
<td></td>
<td>IGP extensions for SR-based VPN+</td>
<td>draft-dong-lsr-sr-enhanced-vpn</td>
<td>Huawei</td>
<td></td>
</tr>
<tr>
<td>Detnet</td>
<td>SR for bound latency</td>
<td>draft-chen-detnet-sr-based-bounded-latency-00</td>
<td>Huawei</td>
<td>China Mobile</td>
</tr>
<tr>
<td></td>
<td>SRv6 encapsulation for Detnet</td>
<td>draft-geng-detnet-dp-sol-srv6-00</td>
<td>Huawei</td>
<td></td>
</tr>
<tr>
<td>User Plane</td>
<td>SRv6 for mobile User plane</td>
<td>draft-ietf-dmm-srv6-mobile-uplane</td>
<td>Huawei/Cisco</td>
<td>Softbank</td>
</tr>
<tr>
<td></td>
<td>Protocol for Forwarding Policy</td>
<td>draft-ietf-dmm-fpc-cpdp</td>
<td>Huawei/Cisco</td>
<td>Softbank/Bell Canada</td>
</tr>
<tr>
<td></td>
<td>Configuration (FPC) in DMM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

通过SID来指示保证带宽/时延的资源的理念已经被广泛接受。

VPN+框架草案被TEAS工作组接纳是5G网络切片在IETF标准化的一个重要里程碑。

SRv6用于云核心网替代GTP在3GPP受到挑战。
<table>
<thead>
<tr>
<th>Area</th>
<th>Topic</th>
<th>Drafts</th>
<th>Vendors</th>
<th>Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFC</td>
<td>SR for SFC</td>
<td>draft-xuclad-spring-sr-service-programming <em>(WG Adoption in process)</em></td>
<td>Cisco/Huawei/Juniper/Nokia</td>
<td>Bell Canada/Orange/AT&amp;T</td>
</tr>
<tr>
<td></td>
<td>SR + NSH for Stateful SFC</td>
<td>draft-guichard-spring-nsh-sr <em>(WG Adoption in process)</em></td>
<td>Huawei/Ericsson/Nokia/Cisco</td>
<td>Orange</td>
</tr>
<tr>
<td>SD-WAN</td>
<td>SRv6 for SD-WAN</td>
<td>draft-dukes-spring-sr-for-sdwan</td>
<td>Cisco</td>
<td>Bell Canada</td>
</tr>
<tr>
<td>Migration</td>
<td>Interworking Between SRv6 and SR-MPLS</td>
<td>draft-agrawal-spring-srv6-mpls-interworking-00</td>
<td>Huawei/Cisco</td>
<td>Bell Canada</td>
</tr>
<tr>
<td></td>
<td>SRv6 compatibility with legacy devices</td>
<td>draft-peng-spring-srv6-compatibility</td>
<td>Huawei</td>
<td></td>
</tr>
</tbody>
</table>

**SRv6 SFC**相关草案准备发起工作组接纳。
**SRv6**网络演进方案标准化工作正在进行中。
SRv6已经有多家商用和开源实现

### 华为产品支持SRv6
- ATN with VRPV8 – Shipping now
- CX600 with VRPV8 – Shipping now
- NE40E with VRPV8 – Shipping now
- ME60 with VRPV8 – Shipping now
- NE5000E with VRPV8 – Shipping now
- NE9000 with VRPV8 – Shipping now
- NG-OLT MA5800 with VRPV8 – Shipping now

### 开源支持SRv6
- Linux 4.10 Feb 2017
- Linux srext April 2017
  - [https://github.com/netgroup/SRv6-net-prog](https://github.com/netgroup/SRv6-net-prog)
- FD.io VPP 17.04: April

### Cisco产品支持SRv6
- First support April 2017
- Cisco ASR 9000 – Shipping now
- Cisco NCS 5500 – Shipping now
- Cisco NCS 540 – Shipping now
- Cisco ASR 1000 – engineering code

### NPU和测试仪厂商支持SRv6
- Barefoot - Tofino NPU Shipping Now (since May 2017)
- Spirent - Hardware implementation in Spirent TestCenter.
- Ixia - Hardware implementation in Ixia IxNetwork.

EANTC 2019: 成功完成多厂家SRv6互通测试

**SRv6 VPN测试例**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PE1</th>
<th>P</th>
<th>PE2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPv4 L3VPN over SRv6</td>
<td>HUAWEI NE9000-8</td>
<td>Cisco NCS 540, HUAWEI NE40E-X8A</td>
<td>Cisco NCS 5500</td>
</tr>
<tr>
<td></td>
<td>HUAWEI NE9000-8</td>
<td>Cisco NCS 540, HUAWEI NE40E-X8A</td>
<td>Keysight (Ixia) %Network</td>
</tr>
<tr>
<td></td>
<td>HUAWEI NE9000-8</td>
<td>HUAWEI NE9000-8, HUAWEI NE40E-X8A</td>
<td>Keysight (Ixia) %Network</td>
</tr>
<tr>
<td>IPv4 EVPN L3VPN over SRv6</td>
<td>HUAWEI NE9000-8</td>
<td>Cisco NCS 540, HUAWEI NE40E-X8A</td>
<td>Keysight (Ixia) %Network</td>
</tr>
<tr>
<td></td>
<td>Cisco NCS 5500</td>
<td>HUAWEI NE9000-8, HUAWEI NE40E-X8A</td>
<td>Keysight (Ixia) %Network</td>
</tr>
</tbody>
</table>

**SRv6 FRR（TI-LFA）测试例**

<table>
<thead>
<tr>
<th>Test Setup</th>
<th>PLR (PE) (Network Node 1)</th>
<th>P Node (Network Node 2)</th>
<th>PQ Node (Network Node 3)</th>
<th>Egress PE (Network Node 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cisco NCS 5500</td>
<td>Cisco NCS 540</td>
<td>HUAWEI NE40E-X8A</td>
<td>HUAWEI NE9000-8</td>
</tr>
<tr>
<td>2</td>
<td>HUAWEI NE40E-X8A</td>
<td>HUAWEI NE9000-8</td>
<td>Cisco NCS 540</td>
<td>Cisco NCS 5500</td>
</tr>
</tbody>
</table>
四川电信SRv6现网试验：魔镜业务

- 四川电信和华为联合部署SRv6，用于支持魔镜业务。
- 第一阶段跨域163骨干网部署SRv6 VPN开通业务，第二阶段考虑引入SRv6 TE用于路径调优。

![ SRv6 TE Diagram ]

**Video Monitoring Platform**

**PE1**

**CR1**

**CN2**

**ASBR1**

**ASBR2**

**PE2**

**IDC (City)**

**IDC (Province)**

**NCE Controller**
易于增量部署是SRv6网络演进的重要优势

- 两种网络演进思路:
  - Option 1: IP/MPLS -> IPv6->SRv6 （优先推荐）
  - Option 2: IP/MPLS -> SR-MPLS -> IPv6 - > SRv6

步骤1：网络升级支持IPv6可达性（IPv6部署是SRv6的基础）
步骤2：网络边缘节点升级支持部署SRv6 VPN，通过BE隧道承载业务。
步骤3：升级部分或全部网络内节点支持快速重路由（TI-LFA），TE，SFC等。
步骤4：升级业务网络设备支持端到端SRv6。
国际首次SRv6产业圆桌会议

MPLS + NFV + SDN World Congress 2019
@Paris, 2019.4.10

业界专家认为SRv6是继MPLS之后下一代IP承载网络的核心协议

**Topic 1: SRv6价值**

IHS: Network Evolution and SRV6
Clarence: SRV6 NP Architecture and Usecases
Zhenbin Li: SRV6 for 5G and Cloud

讨论:
1. SRv6价值：简单性以及支持新业务的可扩展性
2. 可能的杀手级应用: SRV6 VPN, 网络融合, VPN+切片, SRV6 IFIT/IOAM

**Topic 2: 如何促进SRv6发展**

EANTC: SRV6 Inter-op Test for MPLS Congress 2019
Spirent: SRV6 Test Capability and Inter-op Test
Huawei: SRV6 Deployment in China

讨论:
1. 先行者应当提供更多相关培训和指导
2. 运营商应当承担一定的风险，快速试错，分享经验。
Internet发展历史反思

- IPv4的教训：可扩展性（Scalability）
- IPv6的教训：兼容性（Compatibility）
  - SRv6兼容IPv6转发
  - SRv6兼容MPLS转发
- All IP 1.0的成功
  - MPLS承担了重要角色
  - SRv6必须首先继承MPLS三个成功之处：VPN/FRR/TE
- All IP1.0的挑战
  1. IP承载网络孤岛问题突出，基于MPLS的网络融合复杂度高
  2. IPv4和MPLS封装的可编程空间有限，无法支持新业务
     - IPv4: IPv4报头选项几乎没有实现
     - MPLS: 固定长度/固定封装域字段
  3. 应用与网络承载解耦导致网络自身优化难以提升价值
     - ATM到桌面: 失败
     - MPLS到云：失败
SRv6开启IP新时代

- IPv6重思考：地址空间不足未能强烈驱动IPv6部署
- SRv6的使命：
  - 基于对IP可达性的亲和性，使得不同网络域间连接更容易
  - 基于IPv6扩展头/SRH等可扩展性支持更多种类的封装，满足新业务的需求。
  - 基于对IP亲和性和网络编程能力，实现IP承载网络与应用的融合，提升网络价值。
  - 结合对更多地址空间的需求，进一步推广IPv6
THANK YOU

www.huawei.com