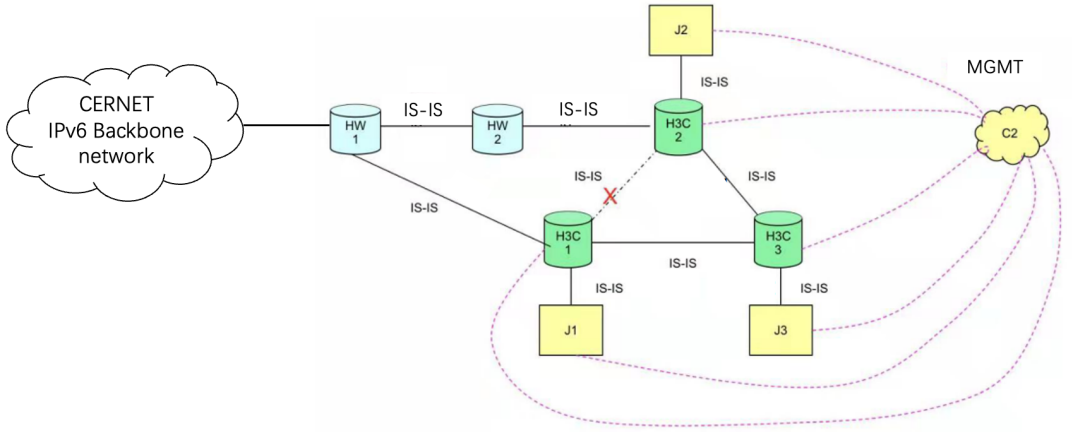
Experimental Result of CRH in CERNET2

1. Introduction

CERNET participated the experiment of CRH in 2019. The deployment was in CERNET2 IPv6-only backbone network, the topology includes three Juniper JOS vms (CRH implementation, J1, J2, J3), three H3C routers (H3C1, H3C2, H3C3) and two Huawei routers (HW1, HW2). H3C routers and Huawei routers are unaware of CRH ' s existence. The experiment result shows that CRH mechanism works well and can interoperate with other routers and therefore be able to deploy incrementally.



2. Experiment Setup and Procedures

Setup

1) Design the topology and make the IPv6 address plan. All IPv6 addresses are assigned from CERNET2 backbone public addresses.

Name on topo	IPv6 Address	Comment
H3C1	2001:da8:2:ff::1	Loopback address
H3C2	2001:da8:2:ff::4	Loopback address
H3C3	2001:da8:2:ff::22	Loopback address
J1	2001:da8:2:ff::1c	Loopback address
J2	2001:da8:2:ff::4c	Loopback address
J3	2001:da8:2:ff::22c	Loopback address
H3C1-H3C2	2001:da8:2:4::/64	H3C1: 2001:da8:2:4::1 H3C1: 2001:da8:2:4::2
H3C1-H3C3	2001:da8:2:3c::/64	H3C1: 2001:da8:2:3c::1 H3C3: 2001:da8:2:3c::2
H3C2-H3C3	2001:da8:2:3d::/64	H3C2: 2001:da8:2:3d::1 H3C3: 2001:da8:2:3d::2
H3C1-J1	2001:da8:2:401::/64	H3C1: 2001:da8:2:401::1 J1: 2001:da8:2:401::2
H3C2-J2	2001:da8:2:404::/64	H3C2: 2001:da8:2:404::1 J2: 2001:da8:2:404::2
H3C3-J3	2001:da8:2:422::/64	H3C3: 2001:da8:2:422::1 J3: 2001:da8:2:422::2
H3C1-HW2	2001:da8:2:43::/64	H3C1: 2001:da8:2:43::1 HW2: 2001:da8:2:43::2
H3C2-HW2	2001:da8:2:44::/64	H3C2: 2001:da8:2:44::1 HW2: 2001:da8:2:44::2
HW2-HW1	2001:da8:2:601::/64	HW2: 2001:da8:2:601::1 HW1: 2001:da8:2:601::2

2) Deploy routers and servers according to the IPv6 address plan.
3) Configure IS-IS on each router and J1/J2/J3. Additionally, on J1/J2/J3, SID<->CRH-FIB mapping is configured by CLI. The mapping are then propagated through IS-IS to other Nodes.

J1:

```
set routing-options router-id 1.1.1.1
set protocols isis interface ens10
set protocols isis interface lo.0l
set protocols isis srv6-plus
set protocols isis interface ens10 level 2 metric 10
set protocols isis srv6-plus sid 1
set protocols isis srv6-plus sid address 2001:da8:2:ff::1c
```

J2:

```
set routing-options router-id 2.2.2.2
set protocols isis interface ens10
set protocols isis interface lo.0l
set protocols isis srv6-plus
set protocols isis interface ens10 level 2 metric 10
set protocols isis srv6-plus sid 2
set protocols isis srv6-plus sid address 2001:da8:2:ff::4c
```

J3:

```
set routing-options router-id 3.3.3.3
set protocols isis interface ens10
set protocols isis interface lo.0l
set protocols isis srv6-plus
set protocols isis interface ens10 level 2 metric 10
set protocols isis srv6-plus sid 3
set protocols isis srv6-plus sid address 2001:da8:2:ff::22c
```

Procedures:

1) Keep the link between H3C1 and H3C3 up, and test
   - Whether J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, check the path
2) Keep the link between H3C1 and H3C3 up, and configure SRv6 path through J2 on J1/J3, and test
   - Whether J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, check the path

SRv6 configuration on J1:

```
ip -f inet6 route add 2001:da8:2:422::2 encap seg6plus mode encap com 1 segs
2 dev enp3s0 metric 800 pref medium
ip sr tunsrc set 2001:da8:2:ff::1c
```

SRv6 configuration on J3:

```
ip -f inet6 route add 2001:da8:2:401::2 encap seg6plus mode encap com 1 segs
2 dev enp3s0 metric 800 pref medium
```

3) Disconnect the link between H3C1 and H3C2, and configure SRv6 path through J2 on J1/J3, and test
   - Whether J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - Whether J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, check the path

3. Experiment Results

1) Keep the link between H3C1 and H3C3 up, test result:
   - J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, path is J1-H3C1-H3C2-J3
2) Keep the link between H3C1 and H3C3 up, and configure SRv6 path through J2 on J1/J3, test result:
   - J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, path is J1-J2-H3C2-H3C3-J3
3) Disconnect the link between H3C1 and H3C2, and configure SRv6 path through J2 on J1/J3, and test
   - J1 can ping J2/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J2 can ping J1/J3/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J3 can ping J1/J2/HW1/HW2/H3C1/H3C2/H3C3 successfully
   - J1 traceroute J3, path is J1-J2-H3C2-H3C3-J3

Some screenshots:

1) Keep the link between H3C1 and H3C3 up

```
root@r1:/# ping6 2001:da8:2:ff::4c
PING 2001:da8:2:ff::4c(2001:da8:2:ff::4c) 56 data bytes
64 bytes from 2001:da8:2:ff::4c: icmp_seq=2 ttl=62 time=0.492 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=3 ttl=62 time=0.511 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=4 ttl=62 time=0.472 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=5 ttl=62 time=0.530 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=6 ttl=62 time=0.466 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=7 ttl=62 time=0.520 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=8 ttl=62 time=0.467 ms
64 bytes from 2001:da8:2:ff::4c: icmp_seq=9 ttl=62 time=0.500 ms
^C
--- 2001:da8:2:ff::4c ping statistics ---
9 packets transmitted, 8 received, 11% packet loss, time 8180ms
rtt min/avg/max/mdev = 0.466/0.494/0.530/0.035 ms
root@r1:/# ^C
root@r1:/# traceroute 2001:da8:2:ff::4c
traceroute to 2001:da8:2:ff::4c (2001:da8:2:ff::4c), 30 hops max, 80 byte packets
 1  2001:da8:2:401::1 (2001:da8:2:401::1)  0.474 ms  0.443 ms  0.442 ms
 2  2001:da8:2:4::2 (2001:da8:2:4::2)  0.425 ms  0.418 ms  0.435 ms
 3  2001:da8:2:ff::4c (2001:da8:2:ff::4c)  0.387 ms  0.374 ms  0.351 ms
root@r1:/# _
```

J1->J2

```
root@r1:/# ping6 2001:da8:2:ff::22C
connect: Network is unreachable
root@r1:/# ping6 2001:da8:2:ff::22c
PING 2001:da8:2:ff::22c(2001:da8:2:ff::22c) 56 data bytes
64 bytes from 2001:da8:2:ff::22c: icmp_seq=1 ttl=62 time=0.413 ms
64 bytes from 2001:da8:2:ff::22c: icmp_seq=2 ttl=62 time=0.496 ms
64 bytes from 2001:da8:2:ff::22c: icmp_seq=3 ttl=62 time=0.393 ms
64 bytes from 2001:da8:2:ff::22c: icmp_seq=4 ttl=62 time=0.495 ms
64 bytes from 2001:da8:2:ff::22c: icmp_seq=5 ttl=62 time=0.458 ms
^C
--- 2001:da8:2:ff::22c ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4080ms
rtt min/avg/max/mdev = 0.393/0.451/0.496/0.042 ms
root@r1:/# traceroute 2001:da8:2:ff::22c
traceroute to 2001:da8:2:ff::22c (2001:da8:2:ff::22c), 30 hops max, 80 byte packets
 1  2001:da8:2:401::1 (2001:da8:2:401::1)  0.469 ms  0.440 ms  0.424 ms
 2  2001:da8:2:3c::2 (2001:da8:2:3c::2)  0.411 ms  0.406 ms  0.399 ms
 3  2001:da8:2:ff::22c (2001:da8:2:ff::22c)  0.394 ms  0.374 ms  0.359 ms
root@r1:/# _
```

J1->J3

2) Keep the link between H3C1 and H3C3 up, and configure SRv6 path through J2 on J1/J3,

```
64 bytes from 2001:da8:2:422::2: icmp_seq=520 ttl=61 time=0.999 ms
64 bytes from 2001:da8:2:422::2: icmp_seq=521 ttl=61 time=0.976 ms
64 bytes from 2001:da8:2:422::2: icmp_seq=522 ttl=61 time=0.952 ms
64 bytes from 2001:da8:2:422::2: icmp_seq=523 ttl=61 time=0.955 ms
^C
--- 2001:da8:2:422::2 ping statistics ---
523 packets transmitted, 491 received, 6% packet loss, time 529235ms
rtt min/avg/max/mdev = 0.478/0.903/1.305/0.143 ms
root@r1:/# traceroute 2001:da8:2:422::2
traceroute to 2001:da8:2:422::2 (2001:da8:2:422::2), 30 hops max, 80 byte packets
 1  * * *
 2  * * *
 3  2001:da8:2:3c::2 (2001:da8:2:3c::2)  0.548 ms  0.565 ms  0.574 ms
 4  2001:da8:2:422::2 (2001:da8:2:422::2)  0.845 ms  0.826 ms  0.844 ms
```

J1->J3

J2

H3C2

H3C3

J3

TCPDUMP result on J2

```
03:19:23.375919 IP6 (flowlabel 0x8d921, hlim 63, next-header ICMPv6 (58) payload length: 64) 2001:da8:2:401::2 > 2001:da8:2:422:
:2: [icmp6 sum ok] ICMP6, echo request, seq 273
03:19:23.376291 IP6 (flowlabel 0x5b693, hlim 62, next-header Routing (43) payload length: 120) 2001:da8:2:ff::22c > 2001:da8:2:f
f::4c: srcrt (len=1, type=5, segleft=0[1srcrt]
03:19:23.376295 IP6 (flowlabel 0x5b693, hlim 62, next-header Routing (43) payload length: 120) 2001:da8:2:ff::22c > 2001:da8:2:f
f::4c: srcrt (len=1, type=5, segleft=0[1srcrt]
03:19:23.376300 IP6 (flowlabel 0x5b693, hlim 63, next-header ICMPv6 (58) payload length: 64) 2001:da8:2:422::2 > 2001:da8:2:401:
:2: [icmp6 sum ok] ICMP6, echo reply, seq 273
```

4. Experiment Results

The experiment result shows that CRH mechanism works well and can interoperate with other routers and therefore be able to deploy incrementally.

5. Additional information and remarks.

- Effort required to deploy
  - Was deployment incremental or network-wide?

  A: it was deployed in CERNET2 IPv6-only backbone, participate in the backbone wide IS-IS IGP routing, in Pops in Beijing.
  - Was there a need to synchronize configurations at each node, or could nodes be configured independently?

  A: nodes can configure sid<->CRH-FIB mappings independently, and can be synchronized through IS-IS.
  - Did the deployment require a hardware upgrade?

  A: intermediate routers are unaware of CRH, no need to upgrade hardware.
  - Did the CRH SIDs have domain-wide or node-local significance?

  A: node-local.
- Effort required to secure

A; The router between the experiment topology and backbone is configured with ACLs, such that the routes of the experiment are not leaked to CERNET backbone network. J1/J2/J3 did not configure ACLs to discard untrusted packets.

- Performance impact

A: CRH implementation does not involve much overhead, and the overall latency was always less than 1ms.

- Effectiveness of risk mitigation with ACLs

A: did not test

- Cost of risk mitigation with ACLs

A: did not test

- Mechanism used to populate the CRH-FIB

A: CLI configuration and use IS-IS to populate

- Scale of deployment

A: 3 CRH nodes and 5 routers

- Interoperability
  - Did you deploy two interoperable implementations?

  A: Yes.
  - Did you experience interoperability problems?

  A: No
  - Did implementations generally implement the same topological functions with identical arguments?

  A: Yes
  - Were topological function semantics identical on each implementation?

  A: Yes
- Effectiveness and sufficiency of Operations, Administration, and Maintenance (OAM) mechanisms
  - Did PING work?

  A: yes
  - Did Traceroute work?

  A: partially yes, when configured with srv6-plus, the first hop and the second hop

seems to be always“*”

- Did Wireshark work?

A: yes

- Did TCPDUMP work?

A: yes