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X. Li
C. Bao
G. Han
CERNET Center/Tsinghua
University
W. Dec
Cisco Systems
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**MAP Interoperability Testing Results
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Abstract

This document presents the testing results of a unified code accommodating encapsulation and translation modes of Mapping of Address and Port (MAP). Experiments show that the unified MAP CE is not only supporting MAP-E and MAP-T modes, but also backward compatible with AFTR of dual-stack lite and stateless/stateful NAT64.

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The address format of Basic Mapping Rule (BMR) and Forwarding Mapping Rule (FMR) are defined in the following figure. Also note that translation mode (MAP-T) and encapsulation mode (MAP-E) have the same

address format of BMR/FMR.

```

<-- n bits -->|<o bits>|<-m bits>|< 8>|<---- L>=32 ----->|<--56-L-->
|0              63|              127|
+-----+-----+-----+-----+-----+-----+-----+
| IPv6 prefix |EA bits |Subnet-id| u | IPv4 address |PSID|  0  |
+-----+-----+-----+-----+-----+-----+
<End-user IPv6 prefix >|

```

Figure 2: BMR/FMR in translation and encapsulation modes

The address format of Default Mapping Rule is different for translation (MAP-T) and encapsulation (MAP-E), as shown in the following figures.

```

|0              63|              127|
+-----+-----+-----+-----+-----+
|          BR prefix          | u | IPv4 address |          0  |
+-----+-----+-----+-----+-----+

```

Figure 3: DMR in translation mode

```

|0              127|
+-----+-----+-----+-----+-----+
|          BR IPv6 address          |
+-----+-----+-----+-----+-----+

```

Figure 4: DMR in encapsulation mode

The testing presented in this document is for the Hubs and Spokes scenario, and therefore, only BMR and DMR are required in each CE.

2.2. Port Mapping Algorithm

The port mapping algorithm is called Generalized Modulus Algorithm (GMA), which contains the sharing ratio ($R=2^k$), the maximum number of contiguous ports ($M=2^m$) and the Port-Set Identifiers (PSID).

2.3. Forwarding Modes

The MAP has two forwarding modes, the translation (MAP-T) and encapsulation (MAP-E). The header processing algorithms of the

translation and the encapsulation modes are defined in [[RFC6145](#)] and [[RFC2473](#)], respectively.

2.4. Implementation

The MAP specification is implemented in Linux environment under GPL [[map-code](#)].

The CE related configuration parameters are:

- i specify the name of the Ethernet device connected to IPv4 world
- I specify the name of the Ethernet device connected to IPv6 world
- H specify in CE mode
- a specify the IPv4 address and mask of the host behind the CE
- P specify the IPv6 rule prefix and prefix length of the host behind the CE
- R specify the associated IPv4 address sharing ratio R of the host behind the CE
- M specify the associated M parameter of the host behind the CE device
- o specify the PSID of the host behind the CE
- N specify in NAT44 mode. The '-A' option is required.
- A specify the public IPv4 address and mask which the host behind the CE device is mapped into. In this case, the '-a' option will specify the private IPv4 network and prefix length
- X specify the IPv6 prefix is not containing EA-bits

3. MAP Testing

The configuration examples and the testing results of the MAP's translation mode (MAP-T), the encapsulation mode (MAP-E), MAP-T/MAP-E 1:1 modes and the mixed MAP-T/MAP-E modes are shown in this section.

The basic testing method is from an IPv4 host connected to CE to ping an IPv4 server (202.112.35.254) connected to BR. The tcpdump records the packet headers of the echo request and echo reply messages.

3.1. MAP-T

The MAP CE in MAP-T mode is configured as:

```
utils/ivictl -r -d -P 2001:da8:b4b6:ffff::/64 -T

utils/ivictl -s -i eth1 -I eth0 -H -N -a 192.168.1.0/24 -A
202.38.117.1/24 -P 2001:da8:b4b6::/48 -R 16 -M 2 -o 0 -c 1440 -T
```

The tcpdump data samples are:

```
09:42:16.526809 IP6 2001:da8:b4b6:100:ca:2675:100:0 > 2001:da8:
b4b6:ffff:ca:7023:fe00:0: ICMP6, echo request, seq 18177, length
40

09:42:16.527448 IP6 2001:da8:b4b6:ffff:ca:7023:fe00:0 > 2001:da8:
b4b6:100:ca:2675:100:0: ICMP6, echo reply, seq 18177, length 40
```

3.2. MAP-E

The MAP CE in MAP-E mode is configured as:

```
utils/ivictl -r -d -P 2001:da8:b4b6:ffff:1234::5678/128 -E

utils/ivictl -s -i eth1 -I eth0 -H -N -a 192.168.1.0/24 -A
202.38.117.1/24 -P 2001:da8:b4b6::/48 -R 16 -M 2 -o 8 -c 1400 -E
```

The tcpdump data samples are:

```
09:38:43.326429 IP6 2001:da8:b4b6:180:ca:2675:180:0 > 2001:da8:
b4b6:ffff:1234::5678: IP 202.38.117.1 > 202.112.35.254: ICMP echo
request, id 1040, seq 32512, length 40

09:38:43.327786 IP6 2001:da8:b4b6:ffff:1234::5678 > 2001:da8:b4b6:
180:ca:2675:180:0: IP 202.112.35.254 > 202.38.117.1: ICMP echo
reply, id 1040, seq 32512, length 40
```

3.3. 1:1 mode MAP-T/MAP-E

The 1:1 mode MAP-T/MAP-E means that each CE has its own mapping rule with or without the IPv4 address sharing.

The MAP CE in MAP-T 1:1 mode is configured as:

```
utils/ivictl -r -d -P 2001:da8:b4b6:ffff::/64 -T

utils/ivictl -s -i eth1 -I eth0 -H -X -N -a 192.168.1.0/24 -A
202.38.117.1/24 -P 2001:da8:b4b6:2700::/64 -R 16 -M 2 -o 8 -c 1440
```


-T

The tcpdump data samples are:

```
22:53:30.977999 IP6 2001:da8:b4b6:2700:ca:2675:100:0 > 2001:da8:
b4b6:ffff:ca:7023:fe00:0: ICMP6, echo request, seq 7113, length 40
```

```
22:53:30.978876 IP6 2001:da8:b4b6:ffff:ca:7023:fe00:0 > 2001:da8:
b4b6:2700:ca:2675:100:0: ICMP6, echo reply, seq 7113, length 40
```

The MAP CE in MAP-E 1:1 mode is configured as:

```
utils/ivictl -r -d -P 2001:da8:b4b6:ffff:1234::5678/128 -E

utils/ivictl -s -i eth1 -I eth0 -H -X -N -a 192.168.1.0/24 -A
202.38.117.1/24 -P 2001:da8:b4b6:2700::/64 -R 16 -M 2 -o 8 -c 1400
-E
```

The tcpdump data samples are:

```
22:56:29.661058 IP6 2001:da8:b4b6:2700:ca:2675:180:0 > 2001:da8:
b4b6:ffff:1234::5678: IP 202.38.117.1 > 202.112.35.254: ICMP echo
request, id 4113, seq 7276, length 40
```

```
22:56:29.661751 IP6 2001:da8:b4b6:ffff:1234::5678 > 2001:da8:b4b6:
2700:ca:2675:180:0: IP 202.112.35.254 > 202.38.117.1: ICMP echo
reply, id 4113, seq 7276, length 40
```

3.4. Mixed MAP-T/MAP-E

The CE and BR can be configured in different modes, for example CE can be configured in translation mode and BR can be configured in encapsulation mode. The reason is that the forwarding mode is only required in the IPv4 to IPv6 direction, while it can be automatically identified by checking the value of the next header in the IPv6 packets in the IPv6 to IPv4 direction. This feature provides great flexibility to the users and operators to select desired forwarding mode without dropping a single packet in different forwarding mode. The following are two examples of BR and CE in different forwarding modes with the configurations shown in MAP-T and MAP-E sections.

When BR is in T mode and CE is in E mode, the tcpdump data samples are:

```
09:39:48.829067 IP6 2001:da8:b4b6:180:ca:2675:180:0 > 2001:da8:
b4b6:ffff:1234::5678: IP 202.38.117.1 > 202.112.35.254: ICMP echo
request, id 1040, seq 47104, length 40
```



```
09:39:48.833054 IP6 2001:da8:b4b6:ffff:ca:7023:fe00:0 > 2001:da8:
b4b6:180:ca:2675:180:0: ICMP6, echo reply, seq 47104, length 40
```

When BR is in E mode and CE is in T mode, the tcpdump data samples are:

```
09:44:11.692130 IP6 2001:da8:b4b6:100:ca:2675:100:0 > 2001:da8:
b4b6:ffff:ca:7023:fe00:0: ICMP6, echo request, seq 41473, length
40
```

```
09:44:11.693044 IP6 2001:da8:b4b6:ffff:1234::5678 > 2001:da8:b4b6:
100:ca:2675:100:0: IP 202.112.35.254 > 202.38.117.1: ICMP echo
reply, id 1024, seq 41473, length 40
```

4. Backward Compatibility Testing

The MAP CE is backward compatible to dual-stack lite in the E mode and to NAT64 in the T mode.

4.1. AFTR of dual-stack lite

Dual-stack lite is a stateful encapsulation technology defined in [\[RFC6333\]](#). For the testing, the MAP BR is replaced by dual-stack lite AFTR [\[dual-stack-lite-code\]](#).

The MAP CE is configured as:

```
utils/ivictl -r -d -P 2001::1/128

utils/ivictl -s -i eth1 -I eth0 -H -N -X -a 192.168.1.0/24 -A
10.255.255.1/24 -P 2001:da8:b001:1009::/64 -R 16 -M 2 -o 0 -c 1400
-E
```

The tcpdump data samples are:

```
22:48:42.536559 IP6 2001:da8:b001:1009:a:ffff:100:0 > 2001::1: IP
10.255.255.1 > 202.112.35.254: ICMP echo request, id 1024, seq
41473, length 40
```

```
22:48:42.539352 IP6 2001::1 > 2001:da8:b001:1009:a:ffff:100:0: IP
202.112.35.254 > 10.255.255.1: ICMP echo reply, id 1024, seq
41473, length 40
```


4.2. NAT64 with double translation

NAT64 is a stateful translation technology defined in [[RFC6146](#)] and [[RFC6145](#)]. For the testing, the MAP BR is replaced by NAT64 [[nat64-code](#)].

The MAP CE is configured as:

```
utils/ivictl -r -d -P 2001:da8:b4b6:1000::/64 -T

utils/ivictl -s -i eth1 -I eth0 -H -N -X -a 192.168.1.0/24 -A
2.2.2.2/32 -P 2001:da8:b001:fff9::/64 -R 16 -M 2 -o 0 -c 1440 -T
```

The tcpdump data samples are:

```
09:24:16.478385 IP6 2001:da8:b001:fff9:2:202:200:0 > 2001:da8:
b4b6:1000:ca:7023:fe00:0: ICMP6, echo request, seq 25600, length
40

09:24:16.479638 IP6 2001:da8:b4b6:1000:ca:7023:fe00:0 > 2001:da8:
b001:fff9:2:202:200:0: ICMP6, echo reply, seq 25600, length 40
```

Note that for this scenario, the CE defined in [[RFC6877](#)] can also achieve this goal.

5. Conclusions

Although only the echo request/echo reply testing results with the corresponding MAP CE configuration examples are presented in this document, the TCP/UDP applications are also tested in CERNET/CERNET2 successfully. The concluding remarks are:

- o A unified MAP can support MAP-T, MAP-E, 1:1 mode MAP-T/MAP-E and even the mixed modes without introducing additional complexity.
- o A unified MAP CE can be configured to support MAP-T, MAP-E, 1:1 mode MAP-T/MAP-E, mixed MAP-T/MAP-E, and backward compatible with stateless NAT64, stateful NAT64 and dual-stack lite.

6. Security Considerations

This document does not introduce any new security considerations.

7. IANA Considerations

None.

8. Acknowledgments

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Authors' Addresses

Xing Li

CERNET Center/Tsinghua University

Room 225, Main Building, Tsinghua University

Beijing 100084

CN

Phone: +86 10-62785983

Email: xing@cernet.edu.cn

Congxiao Bao

CERNET Center/Tsinghua University

Room 225, Main Building, Tsinghua University

Beijing 100084

CN

Phone: +86 10-62785983

Email: congxiao@cernet.edu.cn

Guoliang Han

CERNET Center/Tsinghua University

Room 225, Main Building, Tsinghua University

Beijing 100084

CN

Phone: +86 10-62785983

Email: bupthgl@gmail.com

Wojciech Dec
Cisco Systems
Haarlerbergpark Haarlerbergweg 13-19
Amsterdam, NOORD-HOLLAND 1101 CH
Netherlands

Phone:

Email: wdec@cisco.com