```
#define AF_GA 134

struct ga_addr
     {
        unsigned char namespacelen;
        unsigned char addrlen;
        char namespace[32];
        char addr[256];
};
```

Figure 6: Address structure for variable-length address

6 Implementation of BGPGA

In this section, we implement BGPGA into GNU Zebra [20], which is one of routing software, based on our design guideline. The GNU Zebra supports many routing protocols including BGP-4 and mpBGP. Furthermore, many organizations of NSPIXP-6 [21] have adopted the Zebra as router software.

6.1 Implementing environment

We prepare two generic PCs to implement our abstraction model, BGPGA, and the PCs are used as BGPGA routers. We installed FreeBSD 7.2-RELEASE and GNU Zebra into the PCs. The PCs are connected directly each other, and also can process IPv4/IPv6 packets.

6.2 Definition of address family

The router that receives a UPDATE message including MP_REACH_NLRI field identifies AFI (Address Family Identifier) field, and decodes NLRI field of the MP_REACH_NLRI attribute depending on the type of the address family. To decode variable-length address with namespace, it is necessary to define a new address family for adopting variable-length address with namespace. We define an address family AF_GA to manage variable-length address with namespace. Figure 6 shows definitions of new address family and the address structure for variable-length address information with namespace in the kernel source of our routers. BGP connects to other BGP speaker by using TCP connection, which is established by UNIX socket. We do not modify the protocol families used by UNIX socket in the implementation of this paper. We use AF_INET and AF_INET6 to establish a TCP connection. Namely, our routers use IPv4/IPv6 address to establish a BGP connection.

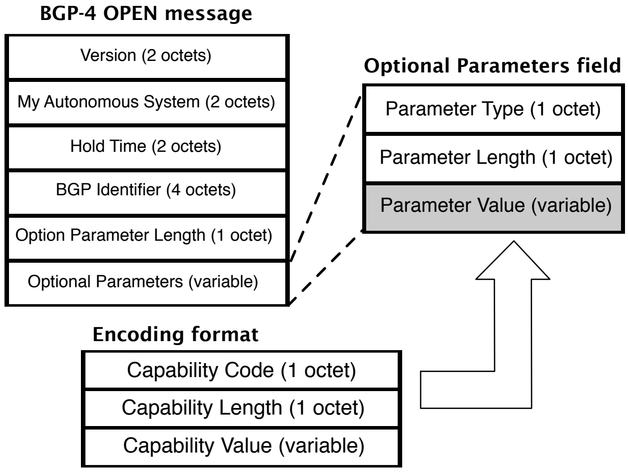


Figure 7: Encoding format of capabilities advertisement message

```
address-family GA            ! Capability advertisement of BGPGA
neighbor fe80::132 active    ! Allow negotiation
neighbor fe80::132 GA:DHT    ! Support for DHT as a BGPGA extension
neighbor fe80::132 GA:phone  ! Support for phone as a BGPGA extension
exit-address-famiry
```

Figure 8: Zebra commands for capabilities advertisement

6.3 Capabilities advertisement

We adopt Capabilities Advertisement [22] to know whether other router can recognize variable-length address information with namespace. BGP OPEN message is sent when a BGP router establishes a BGP peering with another BGP speaker. Figure 7 shows the encoding format of the capabilities advertisement including the BGP OPEN message. The capabilities advertisement message is encoded in the Optional Parameters field in the BGP OPEN message, and the Parameter Type field included in the Optional Parameters field is set to 2.

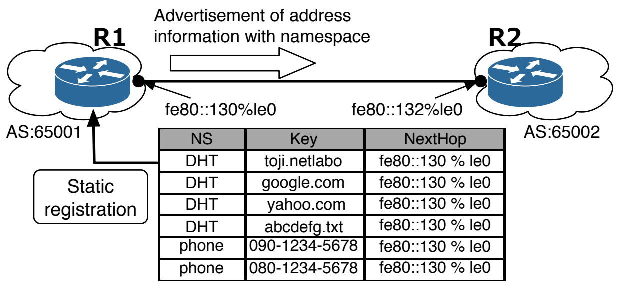
Moreover, BGPGA sets 130 to the Capability Code field of the capabilities advertisement message. The namespace of each protocol implemented as an extension of BGP is stored in the Capability Length field and the Capability Value field.

6.4 Extension and implementation of Zebra command

The capabilities advertisement is implemented as a function of Zebra BGP daemon. We implement some commands that can treat the capabilities advertisement as shown in Fig. 8. Moreover, in order to confirm advertised and received information, we also implement few commands to display this information, which is shown in Fig. 9.

```
! Display advertised address information with namespace
show bgp neighbors fe80::132 advertised-GA-routes
! Display received address information with namespace
show bgp neighbors fe80::132 received-GA-routes
```

Figure 9: Zebra commands to display advertised/received information



NS	Key	NextHop
DHT	toji.netlabo	fe80::130 % le0
DHT	google.com	fe80::130 % le0
DHT	yahoo.com	fe80::130 % le0
DHT	abcdefg.txt	fe80::130 % le0
phone	090-1234-5678	fe80::130 % le0
phone	080-1234-5678	fe80::130 % le0

Figure 10: Network environment for verification of BGPGA

6.5 Verification

We verify that our protocol can exchange variable-length address with namespace of BGPGA on our routers.

6.5.1 Verification environment

Figure 10 shows our network environment that has two routers peering with each other directly. Router R1 has an interface `le0` where the IPv6 address is `fe80::130` in IPv6. Router R2 has an interface `le0` where the IPv6 address is `fe80::132`. We configure some variable-length information addresses to R1 as static addresses described in Fig. 10.

When R1 or R2 tries to peer with the other router, peering router sends BGPGA capabilities advertisement message including namespaces of protocols implemented at the router. After establishing a BGP peering, R1 sends the address information with namespace. R2 receives the advertised information, and then constructs the FIB table by using the received information.

6.5.2 Verification results

We verify whether our router can recognize the capabilities advertisement message by using BGP OPEN message, and identify namespaces in the capabilities advertisement message. Moreover, we verify whether a router can advertise and receive variable-length information with namespace.

We implement the commands shown in Fig. 8 at both R1 and R2. These commands enable the routers to treat variable-length address information

```
bgpd> show bpg neighbors fe80::132 advertised-GA-routes
BGP table version is 0, local router ID is 172.16.55.130
   Network             Next Hop            Metric LocPrf Weight Path
*> DHT:toji.netlabo    fe80::130                0         32768 ?
*> DHT:google.com      fe80::130                0         32768 ?
*> DHT:yahoo.com       fe80::130                0         32768 ?
*> DHT:abcdefg.txt     fe80::130                0         32768 ?
*> phone:090-1234-5678 fe80::130                0         32768 ?
*> phone:080-1234-5678 fe80::130                0         32768 ?
Total number of prefixes 6
```

Figure 11: Advertised information from R1 to R2 supporting “DHT” and “phone”

```
bgpd> show bpg neighbors fe80::130 received-GA-routes
BGP table version is 0, local router ID is 172.16.55.132
   Network             Next Hop            Metric LocPrf Weight Path
*> DHT:toji.netlabo    fe80::130                0             0 65001 ?
*> DHT:google.com      fe80::130                0             0 65001 ?
*> DHT:yahoo.com       fe80::130                0             0 65001 ?
*> DHT:abcdefg.txt     fe80::130                0             0 65001 ?
*> phone:090-1234-5678 fe80::130                0             0 65001 ?
*> phone:080-1234-5678 fe80::130                0             0 65001 ?
Total number of prefixes 6
```

Figure 12: Received information at R2 supporting “DHT” and “phone”

with namespace, which are “DHT” and “phone”. Then, we confirm advertised information at R1, and received information at R2. Figure 11 shows the routing information advertised by R1, and Fig. 12 shows the received information at R2. As seen in these figures, R1 advertises all of the address information with namespace, and R2 received the routing information about “DHT” and “phone” because R1 and R2 can recognize the namespaces “DHT” and “phone” by using the commands shown in Fig. 8.

We next consider that R2 can recognize a part of the namespaces that R1 can treat. We configure so that R1 recognizes “DHT” and “phone”, and R2 recognizes “phone” only. R1 recognizes namespaces that R2 can treat by using the capabilities advertisement message, and sends advertised information including only namespaces that R2 can treat. Figures 13 and 14 show the confirmation result when R2 supports “phone” only. Although R1 can recognize “DHT” and “phone”, R1 sends the information that R2 can recognize, because R2 advertise the supporting namespaces by using the capabilities advertisement message.

Based on the results of our verification, BGPGA does not advertise variable-length address information with namespace to the traditional BGP speakers by using the capabilities advertisement message. Moreover, variable-length address information with namespace is advertised and received between BGP speakers that BGPBA is implemented.

7 Concluding remarks

In this paper, we have considered the fundamental routing functions from existing protocols imple-

```
bgpd> show bpg neighbors fe80::132 advertised-GA-routes
BGP table version is 0, local router ID is 172.16.55.130
   Network              Next Hop            Metric LocPrf Weight Path
*> phone:090-1234-5678 fe80::130                0         32768 ?
*> phone:080-1234-5678 fe80::130                0         32768 ?
Total number of prefixes 2
```

Figure 13: Advertized information from R1 to R2 supporting "phone" only

```
bgpd> show bpg neighbors fe80::130 received-GA-routes
BGP table version is 0, local router ID is 172.16.55.132
   Network              Next Hop            Metric LocPrf Weight Path
*> phone:090-1234-5678 fe80::130                0              0 65001 ?
*> phone:080-1234-5678 fe80::130                0              0 65001 ?
Total number of prefixes 2
```

Figure 14: Received information at R2 supporting "phone" only

mented in layer-3 or overlay networks. Moreover, we have designed the abstraction model of main routing functions as BGPGA. Finally, we have implemented and verified behaviors of BGPGA in a simple network environment. As a result, we have shown that BGPGA can treat variable-length address information with namespace, and BGPGA routers can exchange routing information including variable-length address. For future topics, we need to implement various routing protocols as extensions of BGPGA. Although we have implemented our routing protocol as an extension of BGP, we next plan to implement the protocol into layer-3 without using BGP-4.

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