Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 24, 2016

N. Matsuhira
Fujitsu Limited

July 23, 2015

Stateless Automatic IPv4 over IPv6 Encapsulation / Decapsulation Technology: Specification
draft-matsuhira-sa46t-spec-11

Abstract

This document specifies Stateless Automatic IPv4 over IPv6 Encapsulation / Decapsulation Technology (SA46T) base specification. SA46T makes backbone network to IPv6 only. And also, SA46T can stack many IPv4 networks, i.e. the networks using same IPv4 (private) addresses, without interdependence.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

This document provides Stateless Automatic IPv4 over IPv6 Encapsulation / Decapsulation Technology (SA46T) base specification.

The basic strategy for IPv6 deployment is dual stack. Viewing this strategy from operational side, operation cost of dual stack is higher than single stack operation. Viewing from future, IPv6 only operation is more reasonable rather than IPv4 only operation. Therefore IPv6 only operation is desired.

SA46T makes backbone network to IPv6 only. And also, SA46T can stack many IPv4 networks, i.e. the networks using same IPv4 (private) address, without interdependence.

2. Architecture of SA46T

IP address contain two information, one is locator information, and another is identifier information. This is basic architecture of internet protocol, and also the Internet, and no difference between IPv4 and IPv6.

Locater is a information related "Where", and indentifier is a information related "Who". That mean, IP address's semantics is "Where's Who" meaning. Host is identified whole IP address information, that is "Where's Who", however route to the host is identified just locator information in IP address, that is "Where". See Figure 1.

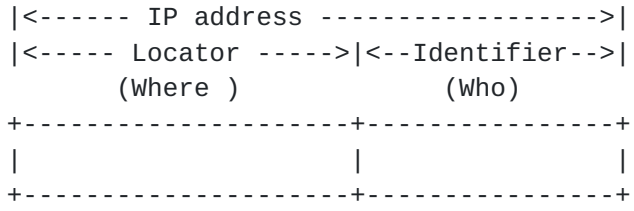


Figure 1

In IPv4 address space, some host has IPv4 address, which consist n bits length identifier and 32 - n bits locator. In Where's Who representation, 32 - n bits "Where" and n bits "Who".

Keeping such "Where's Who" relation, IPv4 address can be represent as IPv6 address by expanding "Where" information from 32 - n bits to 128 - n bits. Expanding " Where" information, IPv4 address can be mapped

to IPv6 address. Figure 2 shows such expanding.

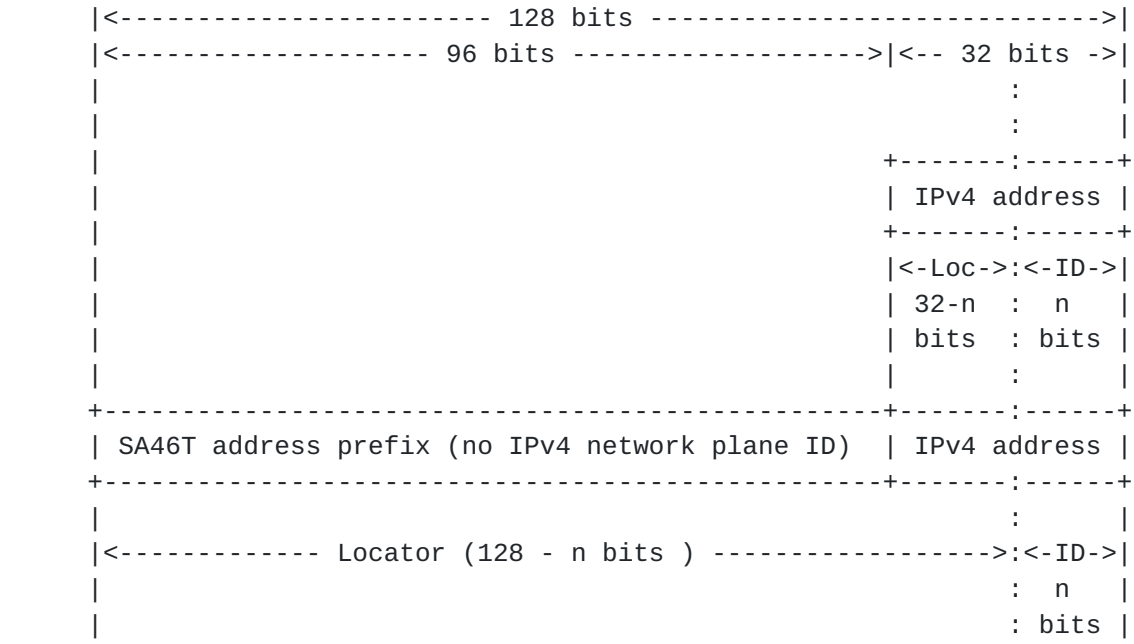


Figure 2

IPv4 address space contain private address, that is non globally unique IP address. If some identifier which distinguish private address can introduce in IPv6 address space, we can treate IPv4 private address as different address in IPv6 address space. This document define such identifier as "IPv4 network plane ID". "IPv6 network plane ID" can provide VPN (Virtual Private Network) like service.

That is SA46T address. In SA46T address, "Where" information's bit length is 128 -n bits, and "Who" information's bit length is n bits. Figure 3 shows summary of IPv4 address and SA46T address relation.

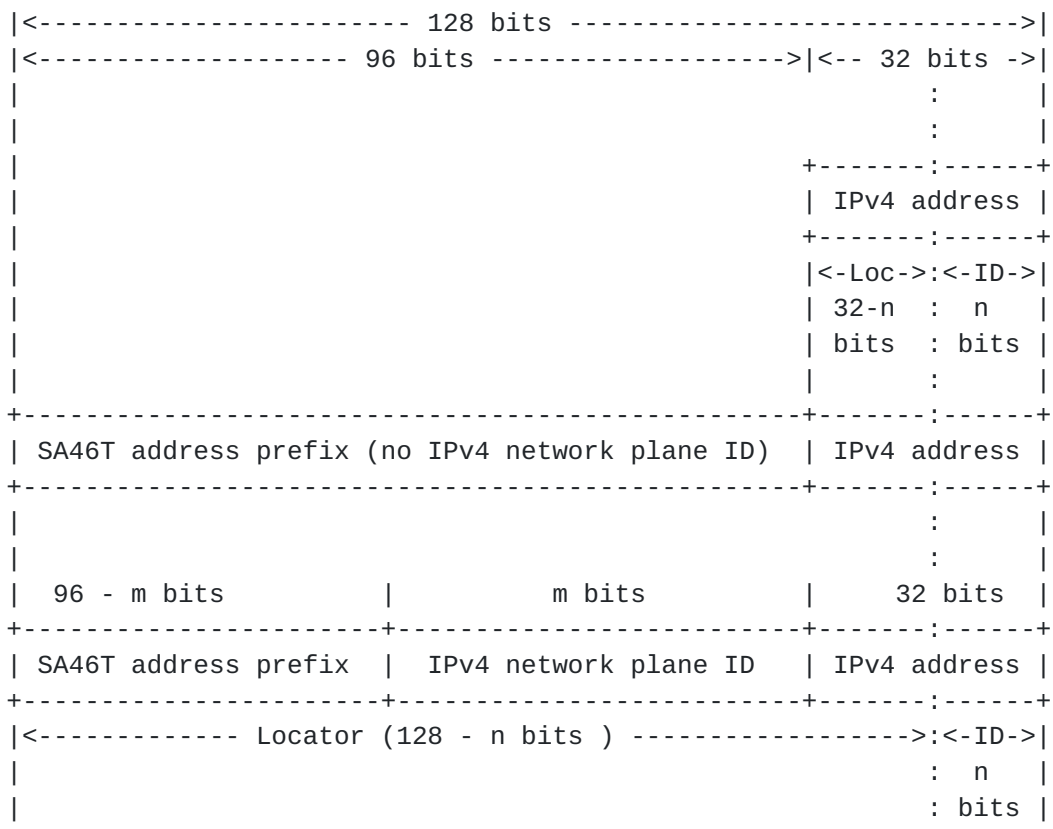


Figure 3

3. Basic Network Configuration

Figure 4 shows network configuration with SA46T. The network consists of three parts. Backbone network, stub network, and SA46T.

Backbone network is operated with IPv6 only. Stub network has three cases. IPv4 only, Dual Stack (both IPv4 and IPv6), and IPv6 only.

SA46T connects backbone network and stub network in case IPv4 still works in that stub network. If stub network is IPv6 only, SA46T is not needed.

Campus network, corporate network, and ISP network are the example for such network.

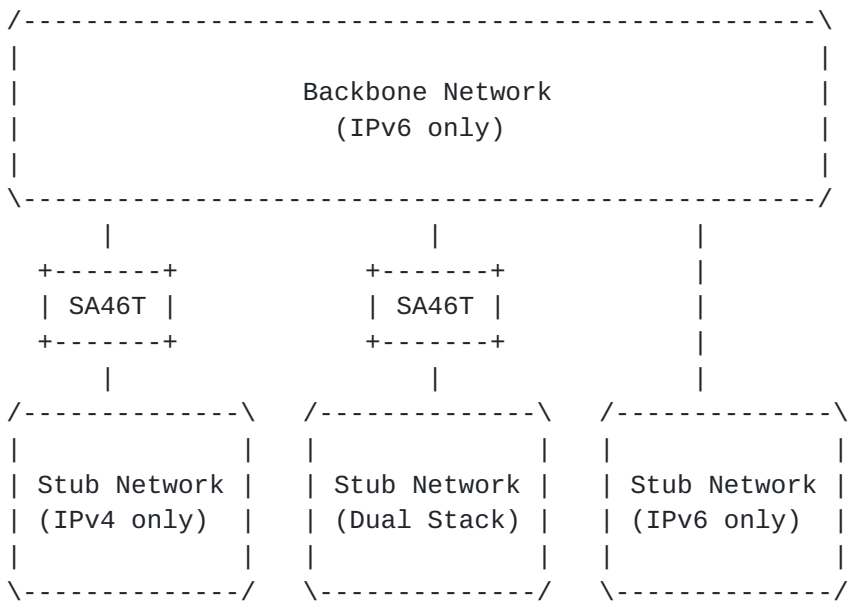


Figure 4

4. Basic Function of SA46T

SA46T has mainly two function. One is IPv4 over IPv6 Encapsulation / Decapsulation, and another is advertise route for stub network.

4.1. IPv4 over IPv6 Encapsulation / Decapsulation

SA46T encapsulates IPv4 packet to IPv6 from stub network to backbone network, and decapsulates IPv6 packet to IPv4 from backbone network to stub network. Figure 5 shows such movement.

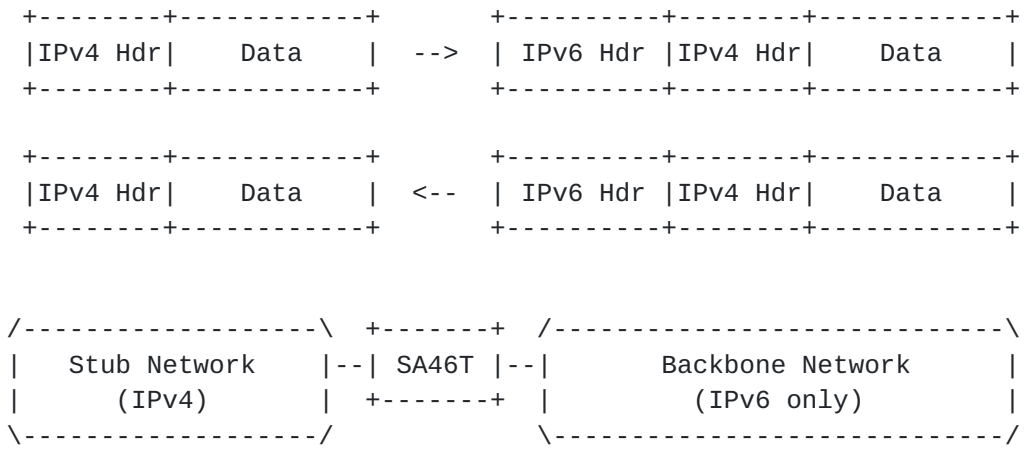


Figure 5

SA46T MUST support tunnel MTU discovery [RFC1853]. When encapsulated IPv6 Packet size exceed path MTU and inner IPv4 packet have the Don't Fragment bit is set, SA46T MUST return ICMP Destination unreachable message with Type3 Code4, fragmentation needed and DS set [RFC0792].

In case IPv6, SA46T just relays IPv6 packet.

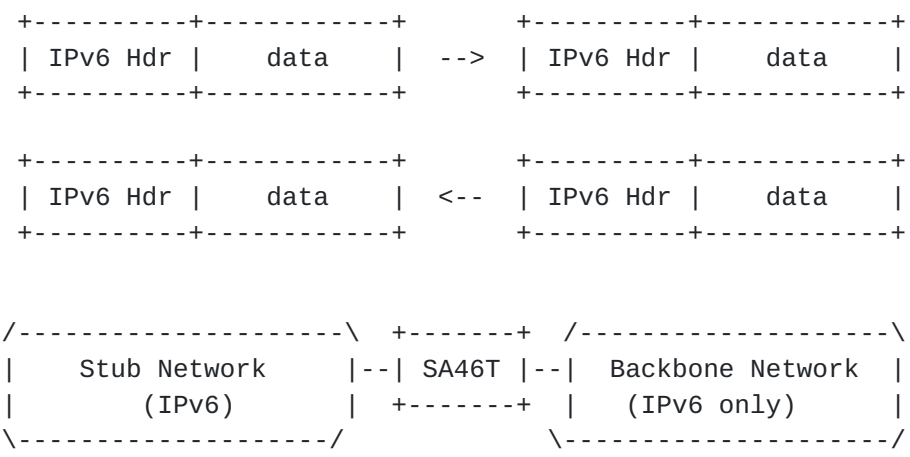


Figure 6

By IPv4 over IPv6 function, SA46T make backbone network to IPv6 only.

4.2. SA46T address architecture

SA46T address is a IPv6 address used in outer IPv6 header which encapsulate IPv4 packet by SA46T.

Figure 7 shows SA46T address architecture

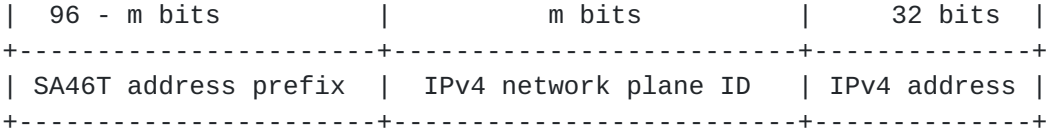


Figure 7

SA46T address consists of three parts as follows.

SA46T address prefix

SA46T address prefix indicates this packet is encapsulated by SA46T and MUST be encapsulated by SA46T. This value is preconfigured to all SA46T in the networks.

IPv4 network plane ID

IPv4 network plane ID is an identifier of IPv4 network stack over IPv6 backbone network. This value is preconfigured depend on the SA46T belong which IPv4 network plane. For more detail see Section 6.

IPv4 address

IPv4 address in inner IPv4 packet.

SA46T address is resolved copying IPv4 address in inner IPv4 packet, and preconfigured values, SA46T prefix and IPv4 network plane ID.

Table 1 shows SA46T IPv4 network plane ID length (m) and number of plane.

m	# of plane
16	65536
32	4294967296
64	18446744073709551616

Table 1

4.3. Route Advertisement

SA46T converts stub network's IPv4 route to SA46T IPv6 route and advertises to backbone network. And reverse direction, SA46T converts SA46T IPv6 route to IPv4 route, that advertises other IPv4 stub networks.

If IPv4 stub network's prefix length is n, the prefix length of SA46T IPv6 route which converts from that IPv4 prefix is 128 - 32 + n. Table 2 shows detail value.

IPv4 prefix length	SA46T IPv6 prefix length
/8	/104
/16	/112
/24	/120

Table 2

The IPv4 route for stub network is map to SA46T IPv6 route one to one, so number of route of IPv4 is same as number of route of SA46T IPv6 route. Total number of route is same as when backbone network operate dual stack, without SA46T.

In stub network, usual dynamic routing protocol for IPv4 and IPv6 can be used such as RIPv2 [RFC2453], RIPng [RFC2080], OSPFv2 [RFC2328], OSPFv3 [RFC2740] and IS-IS [RFC1195][RFC5308]. Similarly, in backbone network, usual dynamic routing protocol for IPv6 can be used such as RIPng [RFC2080], OSPFv3 [RFC2740] and IS-IS [RFC5308] .

If want using default route, default SA46T advertise the route [SA46T address prefix/(96 - m)] as default route. If want using different default route by IPv4 network plane ID, default SA46T in IPv4 network plane #1 advertise the route [SA46T address prefix + IPv4 network plane ID #1 / 96] as default route. Figure 15 in Section 9 show the example using default route.

5. SA46T address format

SA46T can be used closely in the backbone network, so SA46T address does not be advertised outside of the backbone network, and IPv6 packet which contains SA46T address does not be forwarded outside of the backbone network.

So, SA46T address format and SA46T address prefix can be decided each backbone network. But for your information, one example is shown as follows. That is based on IPv6 Global Unicast Address.

Of course, SA46T can be used in the Internet, or between the ASs. This case is discussed shortly in Section 5.2.

5.1. IPv6 Global Unicast Address as SA46T address

This example is based on IPv6 Global Unicast Address Format [RFC3587].

Figure 8 shows IPv6 Global Unicast Address Format.

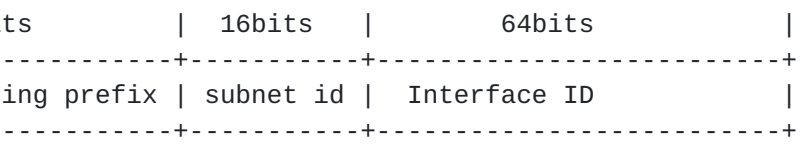
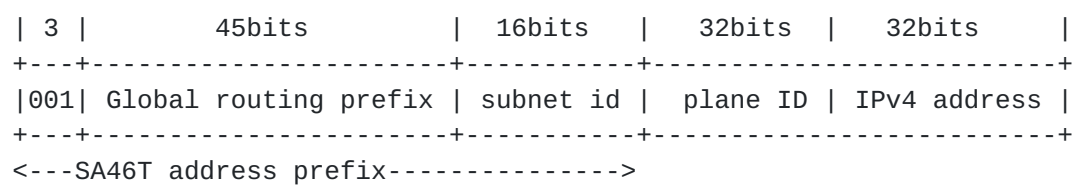


Figure 8

Figure 9 shows SA46T address format using part of IPv6 Global Unicast Address.



Where:

Global routing prefix

global routing prefix

subnet id

indication for SA46T prefix. Example is 0x5A46.

plane id

IPv4 network plane ID. The value 0 should be for the global IPv4 Internet.

IPv4 address

IPv4 address of inner IPv4 packet

5.2. Global SA46T address format

SA46T can be used in The Internet, or between AS. This is achieved by recognizing SA46T address format as common address. Such address should be Global SA46T address.

Global SA46T address format and prefix requires IANA assignment of IPv6 address prefix. Global SA46T address is proposed in [I-D.draft-matsuhira-sa46t-gaddr].

6. Stacking IPv4 Networks

SA46T can provide VPN like service to stub networks by using different IPv4 network plane ID value. Table 3 shows example of IPv4 network plane ID and its usage.

If backbone network operator provide IPv4 privates network service to Organization A, backbone network operator sets IPv4 network plane ID value =1 to the SA46T which connects stub network of organization A. If there are five stub network of organization A, backbone network operator sets same IPv4 network plane ID = 1, to five SA46Ts which connect stub network of organization A. If there are one hundred stub network of organization B, backbone network operator sets same IPv4 network plane ID = 2, to one hundred SA46Ts which connect stub network of organization B. If a new stub network in organization B join, backbone network operator configures same IPv4 network plane ID = 2, to the new stub network only, which connect stub network of organization B, and no configuration is needed to one hundred SA46Ts which are already connected.

Such configuration, that means same stub network group to same IPv4 network plane ID value, is simple and easy to understand, so, it is expected that possibility of misconfiguration is very low. And also, number of configuration is minimum, that mean, number of configuration is same as number of stub networks, and add new stub network, configure to new one only.

Describe above, SA46T can provide VPN like service, for example, Intranet or extranet. And, after IPv4 global address running out, some service provider may want to reuse IPv4 private address. SA46T can provide such IPv4 private address networks over single IPv6 backbone network. By SA46T, some service providers may reuse IPv4 private address.

IPv4 network plane ID value	usage
0	IPv4 Internet (Global)
1	IPv4 Private network for Organization A (Intranet)
2	IPv4 Private network for Organization B (Intranet)
3	IPv4 Private network for Group A (Extranet)
4	IPv4 Private network for Group B (Extranet)
5	Net10 reuse network for consumer group A (Private address access)
6	Net10 reuse network for consumer group B (Private address access)
7	Net10 reuse network for consumer group C (Private address access)
....	....

Table 3

7. Redundancy of SA46T

SA46T brings no limit for redundancy. Figure 10 shows such example in case two connection between backbone network and stub network. Number of link between backbone network and stub network is not limited, and different type of link can be used, for example, for wire and wireless.

Configuration of SA46Ts, which connect same stub network, is same. That mean same SA46T prefix and same IPv4 network plane ID value.

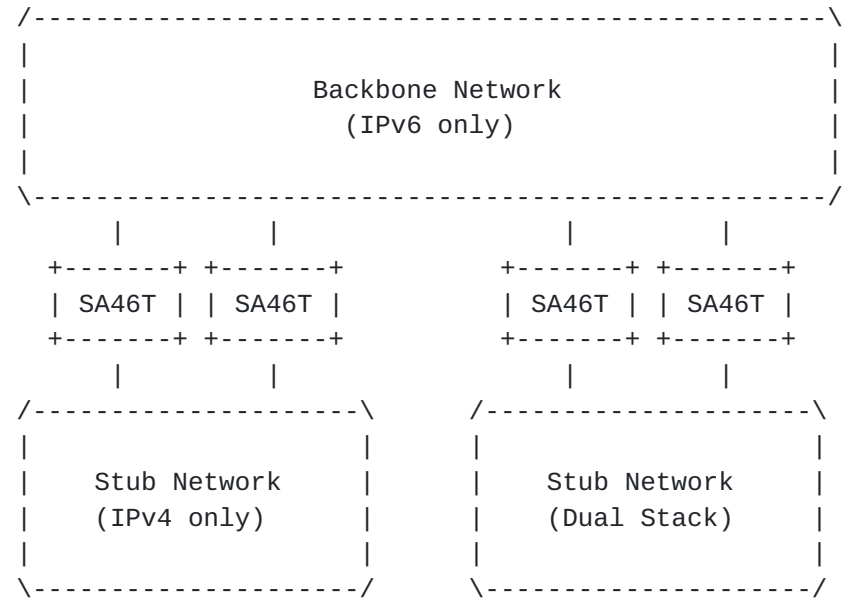


Figure 10

8. Configuration of SA46T and address allocation

Configuration of SA46T require just three information, SA46T address prefix, IPv4 Network plane ID, and prefix length of SA46T route. These information could explain just only one line, "<SA46T address prefix><IPv4 network plane ID>/ prefix length of SA46T route".

When there are N numbers SA46Ts in a certain backbone network, configure one line per SA46T to the N numbers SA46Ts are needed. Total line is just N. If adding new SA46T to the backbone network, configure one line to the new SA46T only is needed, and addition or change does not needed to existing N numbers SA46Ts. Now new 1 line

and total numbers of line is N+1.

Static configured tunnel require N(N-1) configurations. So, SA46T needs less configuration than static configured tunnel, especially when value of N is large number.

SA46T require few configuration, so when numbers of SA46T is small, manual configuration may be enough. However, when large number of SA46T needed in big network, configuration via server may useful. For automatic configuration of SA46T, IPv4 address allocation in stub network should consider, both static address allocation and automatic address allocation. In the latter case, using DHCP should be reasonable.

Figure 11 shows example of configuration database for SA46T. As identifier of SA46T, MAC address is used, however, other information may be used.

When stub network connected SA46T is configured with dynamic address, allocate IPv4 address in allocatable IPv4 address block to the stub network side interface of SA46T at startup phase. That is default router address in the stub network. When SA46T receive DHCP request from a host in stub network, DHCP server allocate IP address from allocatable IPv4 address block, and notify IP address of DNS server and IP address of default router.

When stub network connected SA46T is configuraed with static address, a value of allocatable IPv4 address block should be 0.0.0.0/0 and a value of DNS Server should be 0.0.0.0..

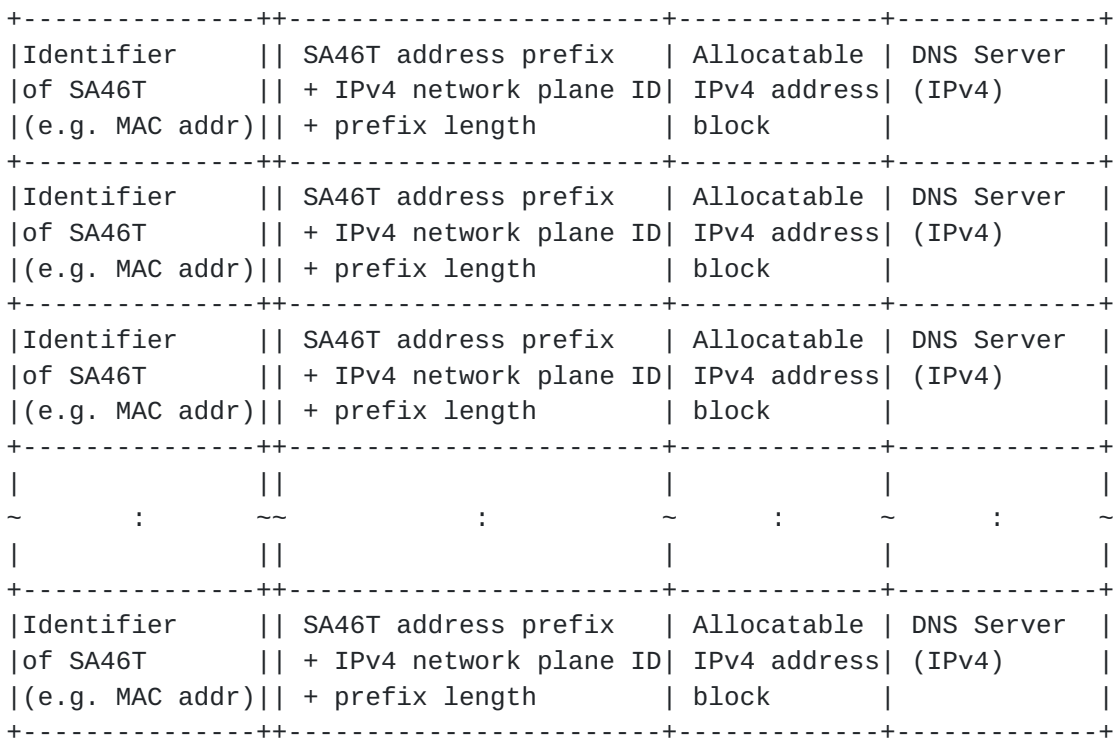


Figure 11

Figure 12 shows timeline diagram of message exchange between SA46T and host in stub network and SA46T configuration server when stub network is configured with dynamic address. Protocol between SA46T and SA46T configuration server including SA46T server discovery may be defined in future.

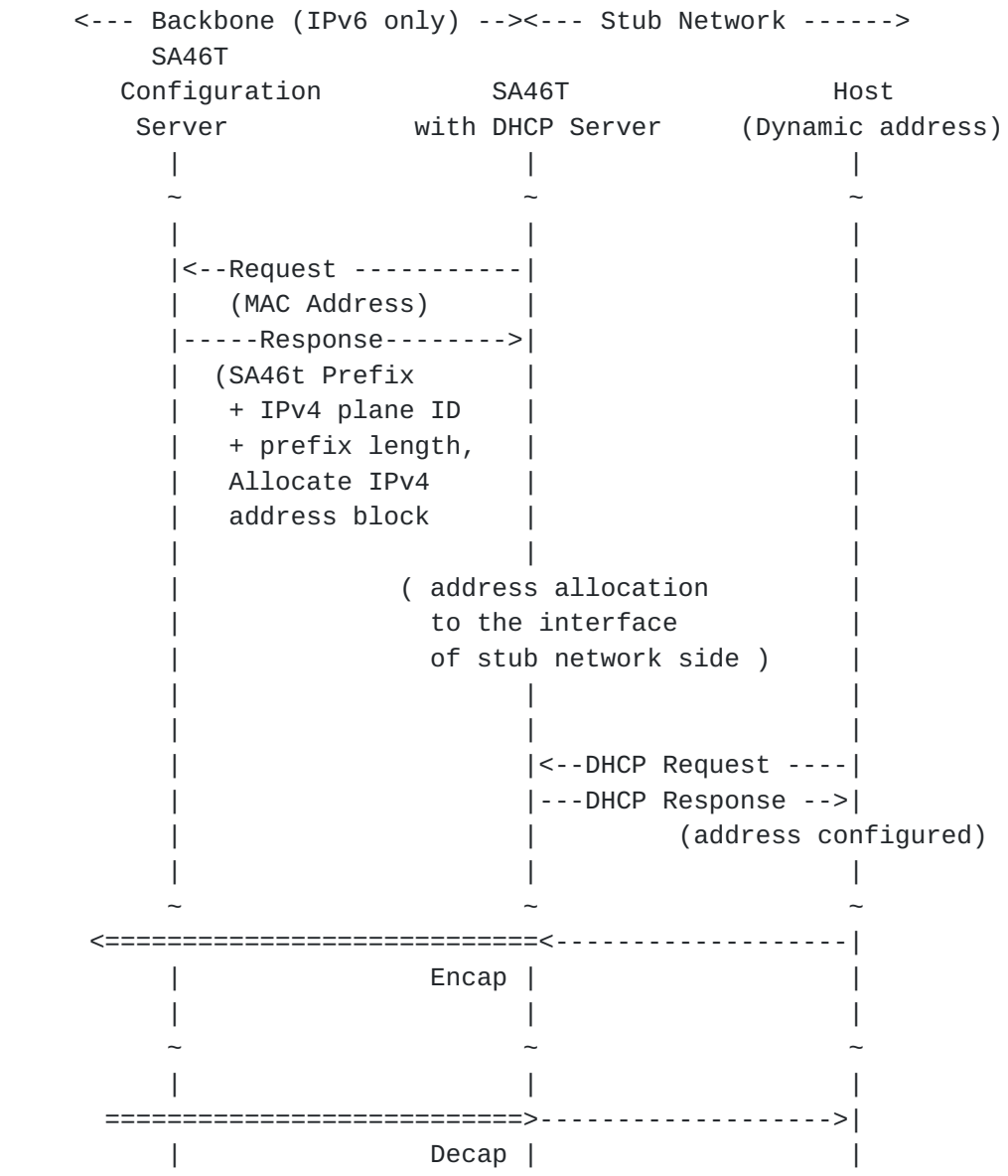


Figure 12

Figure 13 shows timeline diagram of message exchange between SA46T and host in stub network and SA46T configuration server when stub network is configured with static address. Such static address configuration may be used mainly at server zone, so such stub network may be well managed, so SA46T may also configured manually.

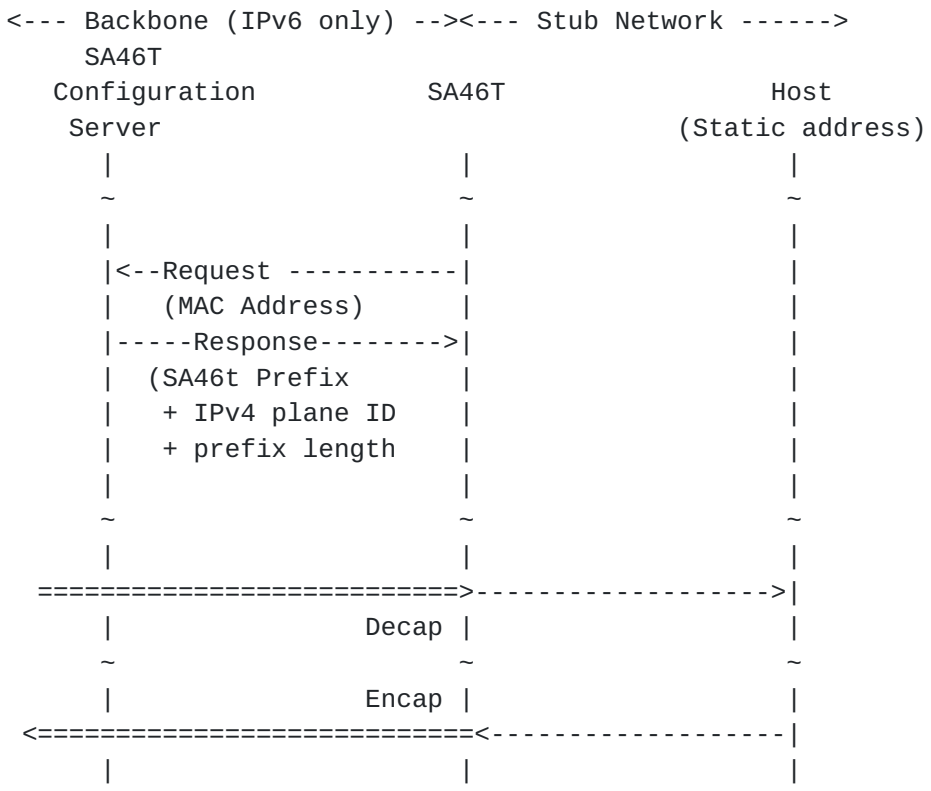


Figure 13

9. Example of SA46T Operation

9.1. Basic SA46T Operation

Figure 14 shows SA46T operation which does not use IPv4 network plane ID. In this example, two stub network is connected to backbone network via SA46T. One stub network is 10.1.1.0/24 sub network, and the other is 10.1.2.0/24 sub network.

When SA46T receives IPv4 route advertisement, then SA46T convert this IPv4 route to IPv6 route by address resolution to SA46T address, and advertise this IPv6 route to backbone network. When SA46T receives IPv6 route advertisements, then SA46T converts this IPv6 route to IPv4 route if this IPv6 route is match SA46T address (same prefix with SA46T), and advertise this IPv4 route to stub network.

In this example. IPv4 route, 10.1.1.0/24 is converted to IPv6 route, <SA46Tprefix>:10.1.1.0/120,and IPv4 route, 10.1.2.0/24 is converted to IPv6 route, <SA46Tprefix>:10.1.2.0/120 at SA46T from stub network to backbone network. And, from backbone network to stub network, IPv6 route, <SA46Tprefix>:10.1.1.0/120 is converted to IPv4 route,

10.1.1.0/24, and IPv6 route, <SA46Tprefix>:10.1.2.0/120 is converted to IPv4 route, 10.1.2.0/24.

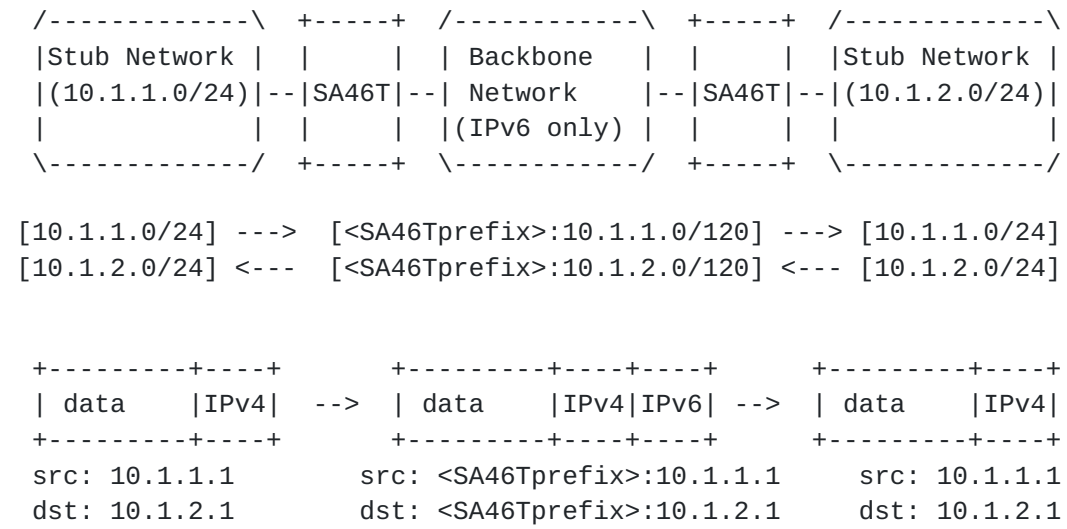


Figure 14

Figure 15 shows the example using default route. Default route is useful in case most packets are routed same path. Typically, access network is one of the example. Although using default route, communication between stub networks can be done. Communication between host 10.1.1.1 and host 10.1.2.1 can be done inside in access network, and does not pass over default SA46T.

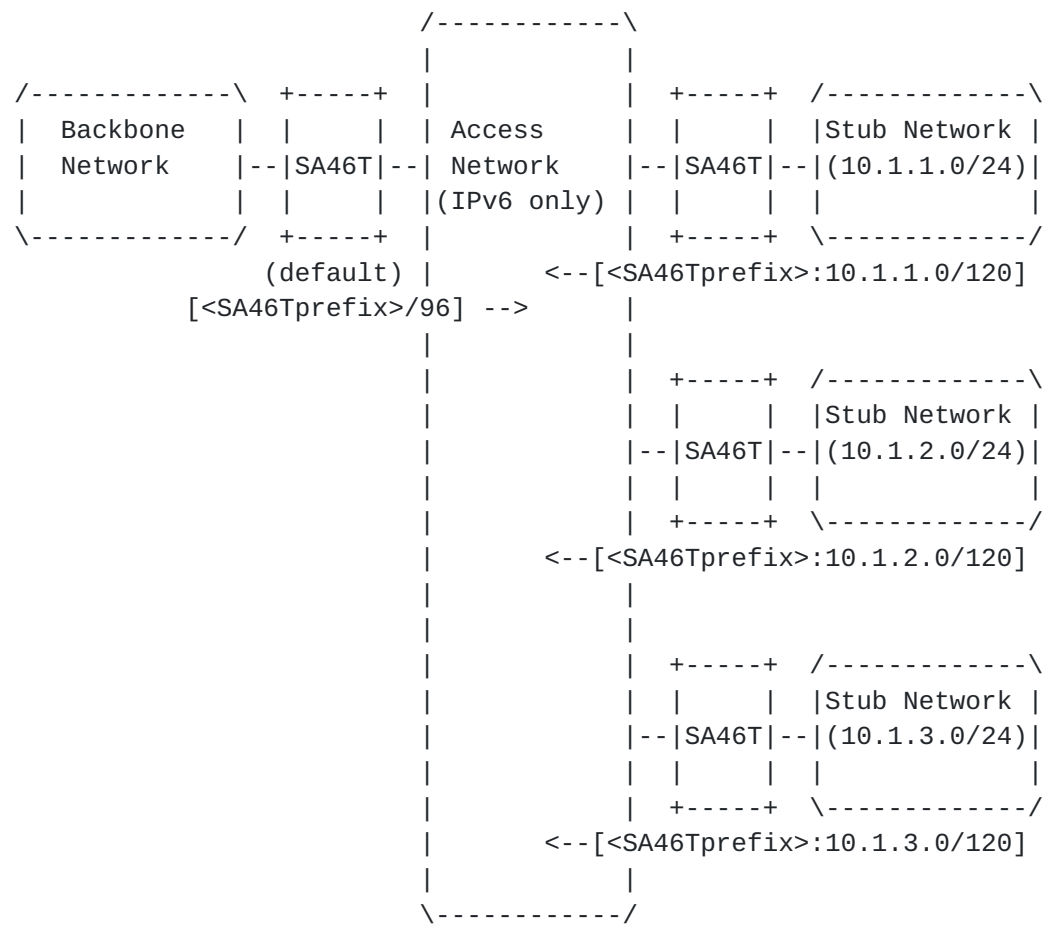


Figure 15

9.2. SA46T Operation with plane ID

Figure 16 shows SA46T operation which uses IPv4 network plane ID. In this example, there are two planes, and two stub network in each plane is connected to backbone network via SA46T. In each plane, one stub network is 10.1.1.0/24 sub network, and the other is 10.1.2.0/24 sub network, that means same IPv4 address is used in different plane.

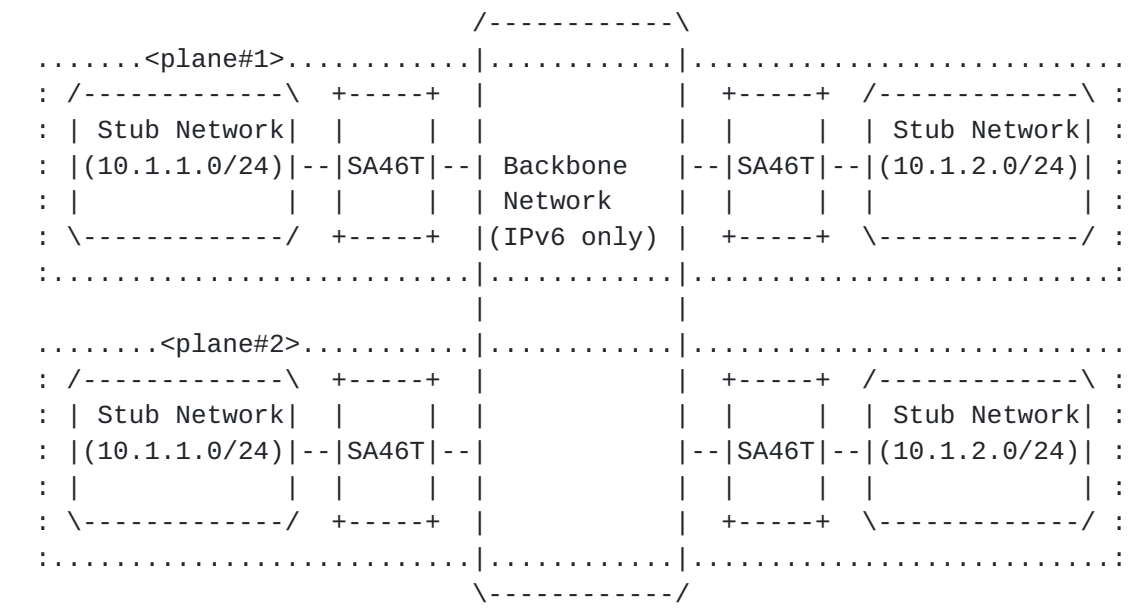
When SA46T receives IPv4 route advertisements, then SA46T converts this IPv4 route to IPv6 route by address resolution to SA46T address, and advertise this IPv6 route to backbone network. When SA46T receives IPv6 route advertisements, then SA46T converts this IPv6 route to IPv4 route if this IPv6 route is match SA46T address (same prefix with SA46T), and advertises this IPv4 route to stub network.

In this example in plane #1. IPv4 route, 10.1.1.0/24 is converted to IPv6 route, <SA46Tprefix><#1>:10.1.1.0/120,and IPv4 route, 10.1.2.0/24 is converted to IPv6 route, <SA46Tprefix><#1>:10.1.2.0/

120 at SA46T from stub network to backbone network. And, from backbone network to stub network, IPv6 route, <SA46Tprefix><#1>:10.1.1.0/120 is converted to IPv4 route, 10.1.1.0/24, and IPv6 route, <SA46Tprefix><#1>:10.1.2.0/120 is converted to IPv4 route, 10.1.2.0/24.

And also, In this example in plane #2. IPv4 route, 10.1.1.0/24 is converted to IPv6 route, <SA46Tprefix><#2>:10.1.1.0/120,and IPv4 route, 10.1.2.0/24 is converted to IPv6 route, <SA46Tprefix><#2>:10.1.2.0/120 at SA46T from stub network to backbone network. And, from backbone network to stub network, IPv6 route, <SA46Tprefix><#2>:10.1.1.0/120 is converted to IPv4 route, 10.1.1.0/24, and IPv6 route, <SA46Tprefix><#2>:10.1.2.0/120 is converted to IPv4 route, 10.1.2.0/24.

In IPv6 space, address <SA46Tprefix><#1>:10.1.1.1 and address <SA46Tprefix><#2>:10.1.1.1 are different address, route <SA46Tprefix><#1>:10.1.1.0/120 and route <SA46Tprefix><#2>:10.1.1.0/120 are different route, although in IPv4 space, address 10.1.1.1 in plane #1 and 10.1.1.1 in plane#2 are same address, route 10.1.1.0/24 in plane#1 and route 10.1.1.0/24 in plane#2 are same route.



<<plane #1>>

[10.1.1.0/24] --->[<SA46Tprefix><#1>:10.1.1.0/120] ---> [10.1.1.0/24]
[10.1.2.0/24] <---[<SA46Tprefix><#1>:10.1.2.0/120] <--- [10.1.2.0/24]

data	IPv4	-->	data	IPv4	IPv6	-->	data	IPv4
src: 10.1.1.1			src: <SA46Tprefix><#1>:10.1.1.1				src: 10.1.1.1	
dst: 10.1.2.1			dst: <SA46Tprefix><#1>:10.1.2.1				dst: 10.1.2.1	

<<plane#2>>

[10.1.1.0/24] --->[<SA46Tprefix><#2>:10.1.1.0/120] ---> [10.1.1.0/24]
[10.1.2.0/24] <---[<SA46Tprefix><#2>:10.1.2.0/120] <--- [10.1.2.0/24]

data	IPv4	-->	data	IPv4	IPv6	-->	data	IPv4
src: 10.1.1.1			src: <SA46Tprefix><#2>:10.1.1.1				src: 10.1.1.1	
dst: 10.1.2.1			dst: <SA46Tprefix><#2>:10.1.2.1				dst: 10.1.2.1	

Figure 16

Figure 17shows the example using default route with IPv4 network plane. In this case, default SA46T may configure different by each IPv4 network plane.

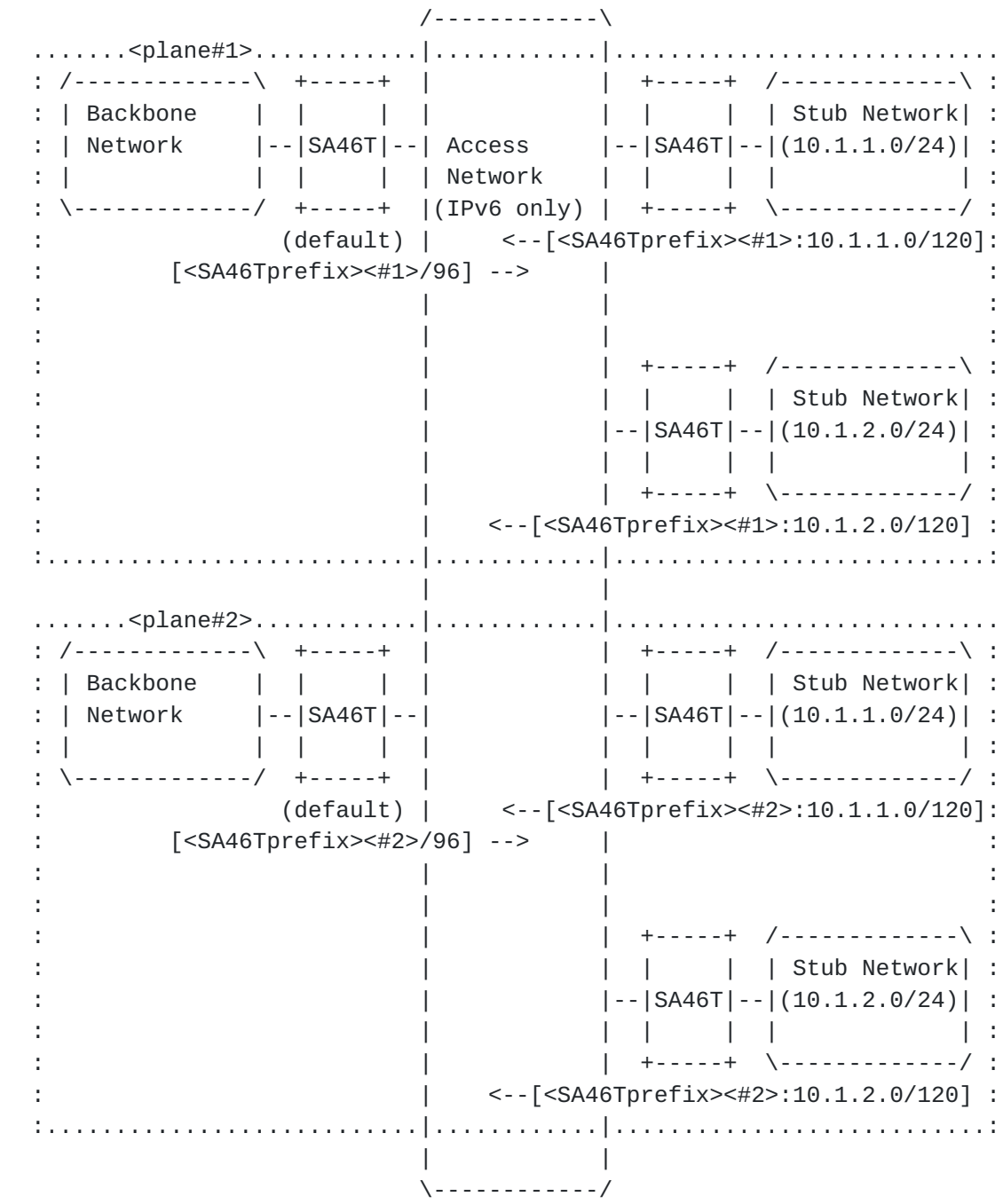


Figure 17

10. Characteristic

SA46T has following useful characteristics.

- Reduce backbone network operation cost with IPv6 single stack (at least less than Dual Stack)
- Can allocate IPv4 address to stub networks, which used in backbone network before installing SA46T
- Less configuration
- No need for special protocol
- No dependent Layer 2 network
- Can Stack IPv4 Private networks
- Easy stop IPv4 operation in stub network for future (just remove SA46T)
- Provide redundancy

11. IANA Considerations

This document makes no request of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

12. Security Considerations

SA46T use automatic Encapsulation / Decapsulation technologies. Security consideration related tunneling technologies are discussed in RFC2893[RFC2893], RFC2267[RFC2267], etc.

13. Acknowledgements

This document is based on Naoki Matsuhira's original ideas and an individual effort of the author.

Review and encouragement have been provided by many peoples. Particulary Akira Kato at WIDE Project / Keio University and Masanobu Katoh at Fujitsu in initial stage. And many discussions and assists are provided from Toshiya Asaba, Osamu Nakamura, Yoshiki Ishida, Ichiro Mizukoshi, Noriyuki Shigechika, Miya Kohno, Yoshinobu Matsuzaki, Akira Nakagawa. And comments and discussions are provided in IETF meeting from Fred Baker, Brian Carpenter, Randy Bush, Dave Thaler and Alain Duland. If there is a comment not refrected, it is

surely because of my English language capability, and the author still want reflect it include missing.

The author would like to thank all above people, and others discussed with in WIDE project meeting and inside Fujitsu.

Originally, SA46T is an abbreviation for "Stateless Automatic IPv4 over IPv6 Tunneling". Now, SA46T is an abbreviation for "Stateless Automatic IPv4 over IPv6 Encapsulation / Decapsulation Technology". This change was made in response to the indication from the softwire WG chair at 4th softwire interim meeting in September 2011.

14. References

14.1. Normative References

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Appendix A. Test implementation of SA46T

Test implementation of SA46T is developed for evaluation the SA46T technology. This implementation is developed as module in kernel space of CentOS. The amount of development is about 300 step with C language.

Appendix B. SA46T experiments

B.1. WIDE camp at Sept 2010

SA46T implementation is tested at WIDE camp in 4.5 days at Semtemper 2010. Attendees of WIDE camp served SA46T service via WIreless LAN. SA46T provide both IPv4 and IPv6. IPv4 packets are encapsulated and decapsulated in camp net, that mean this test is in LAN environments. This time single IPv4 plane was used.

About 200 peoples joins this experiments and 275 clients are used, inculude Windows, MacOS, Linux, FreeBSD, iPhone and iPod Touch, etc. IPv4 address is allocated via DHCP. There are no change in clients, servers, and network equipment, just add SA46T. Total, four SA46T boxes were used in this experiments.

SA46T work fine and very stable.

B.2. NICT JGN2Plus Testbed at Feb 2011

SA46T implementation is tested at NICT JGN2Plus testbed at February 2011. This test is held at WAN environments. SA46T is setted up at Sapporo, Osaka, Okayama and Okinawa in Japan and Thai, and carry HDTV Live Stream and 3D HDTV Live stream. Experimental period is about an one month. Total, five SA46T boxes were used in this experiments.

In JGN2Plus, OSPFv3 was used, and BGP4+ is used for peering with Thai.

This time, single IPv4 plane was used too.

SA46T work fine and very stable, too.

B.3. Some corporate network

SA46Ts are installed some corporate network. This installation is done with secrets basically, that mean, nobody know SA46T was installed, and if there are some trouble, someone craim or report the problem.

After few month trial, there was no problem.

B.4. Interop 2011 Tokyo at Jun 2011

SA46T is demonstrated at Interop 2011 Tokyo at June 2011.

At this time, three planes were used. Plane #0 is used for Internet access, using IPv4 Global address. Visitor can have a experiments with SA46T from the cables wich connected to SA46T in access corner. Plane #1 is used for closed network, such like between Data Center network and enterprise network. In this plane, private addresses are used. Plane #2 is used for video streaming. In this plane, same private addresses which used in Plane#1 are used by intention. And this plane in Interop ShowNet and NICT and Thai were connected.

Total, nine SA46T boxes are used in this demonstration.

About 128,000 peoples visit in this event, and see many demonstration include SA46T.

SA46T work fine and very stable, too.

Author's Address

Naoki Matsuhira
Fujitsu Limited
1-1, Kamikodanaka 4-chome, Nakahara-ku
Kawasaki, 211-8588
Japan

Phone: +81-44-754-3466
Fax:
Email: matsuhira@jp.fujitsu.com