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# Semantic IPv6 Prefix
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## Status of this Memo



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Abstract

Some Internet Service Providers and enterprises desire to be aware of more information about each packet, so that packets can be treated differently and efficiently. Packet-level differentiating can also enable flow-level and user-level differentiating.

IPv6, with a large address space, allows semantics to be embedded into addresses. Routers can easily apply relevant operations accordingly. This document provides analysis on how to form semantic prefix and corresponding use cases, and identifies the technical requirements to maximize the benefits of the semantic prefix approach. It is recommended to use 4~12 bits in prefix for embedded semantics.

This informational document only discusses usage of semantics in a semantic prefix domain. It does NOT intent or suggest to standardize any common global semantics.

Table of Contents

1. Introduction ..... 3
2. Why Prefix ..... 4
3. The Semantic Prefix Domain ..... 5
4. The Embedded Semantics ..... 5
5. User Cases of Semantic Prefixes ..... 6
   5.1. ISP semantic bits ..... 6
   5.2. An ISP semantic prefix example ..... 7
   5.3. Enterprise semantic bits ..... 8
   5.4. An enterprise semantic prefix example ..... 8
6. Benefits ..... 9
7. Gaps ..... 9
8. Security Considerations ..... 10
9. IANA Considerations ..... 10
10. Change log ..... 10
11. References ..... 10
   11.1. Normative References ..... 10
   11.2. Informative References ..... 11

## 1. Introduction

While the global Internet increases explosively, more and more differentiated requirements are raised for the packet delivery of networks. Internet Service Providers and enterprises desire to be aware of more information about each packet, such as destination/source location, user types, service types, applications, security requirments, quality requirements, etc. Based on the information, network operators could treat packets differently and efficiently. Packet-level differentiating can also enable flow-level and user-level differentiating.

However, except for destination/source location, almost of abovementioned information is not expressed explicitly. Hence, it is difficult for network operators to identify.

Two passive and indirect technologies are already developed to distinguish the packets. Deep Packet Inspection (DPI) has been used by ISPs to learn the characters of packets. But DPI is expensive for both operational costs and process latency. Its time delay is too much to be able to be used for real time traffic control. Overlay networks are constructed in order to permit routing of packets to destinations not specified by IP addresses. But still, the overlay has no control over how packets are routed in the underlying network between two overlay nodes. Although tunnel or label forwarding may operate the traffic path, they introduce extra overhead while they depend on indirect information sources.

An initiative solution, Quality of Service (QoS) and DiffServ [RFC2474] was also developed. It specifies a simple, scalable and coarse-grained mechanism for classifying and managing network traffic. However, the DiffServ fields set by the packet senders are not trustable by the network operators. In the real user case, ISPs deploy "remarking" points at the edge network, which classify each

received packet and rewrite its DiffServ field according to user information learned from AAA or VLAN.

The abovementioned solutions are mainly developed in IPv4 era, in which IP address is only locator, nothing else, giving the limited space. Although DiffServ was developed identically for IPv4 and IPv6, it inherits the same limitation.

IPv6 has broken such limitation with its very large address space. It allows certain semantics to be embedded into addresses. Applications or ISPs can proactively embed pre-defined information into addresses so that intermediate devices can easily apply relevant operations on packet since addresses are the most explicit element in a packet. It





provides an easy access and trustable fundamental for packet differentiated treatment.

The technical fact that IPv6 allow multiple addresses on a single interface also provides precondition for the approach that user chooses application-associated address differently.

This approach transfers much network complexity to the planning and management of IPv6 address and IP address based policies. It indeed simplifies the management of ISP networks.

This document provides analysis on how to form semantic prefix and its user cases. It is recommended to use 4~12 bits in prefix for embedded semantics. This document also analyzes the technical gaps to maximum the benefits of semantics prefix approach.

Different netowrks may have very different choose for the most important semantics. Therefore, standardizing a general semantic is almost an impossible job.

This informational document only discusses usage of semantics in a semantic prefix domain. It does NOT intent or suggest to standardize any common global semantics.

## 2. Why Prefix

Although interface identifier of IPv6 address has arbitrary bits and extension header can carry much more information, they are not trustable by network operators. Selfish users may easily change the

setting of interface identifier or extension header in order to obtain undeserved priorities/privileges, while servers or enterprise users may be much more self-restricted since they are charged accordingly.

Prefix is almost the only thing a network operator can trust in an IP packet because it is delegated by the network and the network can detect any undesired modifications, then, filter the packet. If one gets the destination address wrong, the packet would not reach; if it gets the source address wrong, the return packet would not arrive. This also would allow enterprise semantics to be able to traverse ISP networks.

The prefix concept here refers the most left bits in IP addresses, that are delegated by the network management plane. It could be longer than 64, if the network operators strictly manage the address assignment by using Dynamic Host Configuration Protocol for IPv6 (DHCPv6) [RFC3315] (but in this case standard Stateless Address Autoconfiguration - SLACC [RFC4862] cannot be used).





Two major arguments against this approach should be considered. One of them is practical: although IPv6 address space is plentiful, it should not be wasted. This argument can be dealt with by ensuring that only a small number of traffic classes are identified within a given user's traffic, so only a few bits in the prefix are needed. The second argument is that addresses should not, as a matter of principle, contain application semantics, because this violates the layering structure of protocols. This argument can be answered by ensuring that the only impact of the approach on the routing and forwarding system is to modestly increase the number of internal routes handled by the ISP concerned; there should be no impact on aggregated routes that the ISP announces to other ISPs.

## 3. The Semantic Prefix Domain

A Semantic Prefix domain, analagous to a Differentiated Services Domain [RFC2474], is a contiguous portion of the Internet over which a consistent set of semantic prefix policies are administered in a coordinated fashion. A Semantic Prefix domain can represent different administrative domains or autonomous systems, different trust regions, different network technologies, hosts and routers, different user groups, different services, different traffic groups, different

applications, etc. An enterprise Semantic Prefix Domain may span several physical networks, traversing ISP networks.

The selections of semantics are various among different Semantic Prefix Domains. Network operators should choose semantics according to their needs for network management and services management. If an ISP has several discontinuous address blocks, it may be organized as a single semantic Prefix domain if the same semantic definition shared among these discontinuous address blocks. If these blocks have different sizes, their semantic prefix domains may be distinguished each other by minimum differences of semantic definition.

A Semantic Prefix domain has a set of pre-defined semantic definitions, which is only meaningful locally. Without an efficient semantics notification or exchanging mechanism or service agreement, the definitions of semantics are only meaningful within local semantic prefix domain. The semantics notification or exchanging does not have to through protocols. Manual interactions between network operators may also work out. However, this may involve trust models among network operators.

Sharing semantic definition among Semantic Prefix domains enables more semantic based network operations.

## 4. The Embedded Semantics

As mentioned in Section 1, much information regarding to packets is useful for network operators, such as destination location, user





types, service types, applications, security requires, quality requirements, etc. But, the prefix bits that can be used for embedded semantics are very limited. Therefore, only the selected, most useful semantics can be embedded in the prefix. Note, however, that DiffServ provides a very rich QoS semantic with only 6 bits. The available bits increase largely in the strictly managed network by DHCPv6.

The following are some semantics may be useful by network operators: user types, service types, security information, traffic identity types, applications or application types, etc. When used, all of them should be restricted in a highly abstracted way.

In a given Semantic Prefix Domain, multiple semantics can be used combinatorially. They may be organized by using semantic type bits in prefix or any pre-defined arbitrary way. However, the former is

preferred.

To use the limited bits efficiently, bits semantics should be pre-defined very carefully. Some formation recommendations are introduced below.

## 5. User Cases of Semantic Prefixes

Depending on the IPv6 address space that network operators received from IANA or upstream network service providers, the number of arbitrary bits in prefix is different. For now, this document only discusses unicast address within IP Version 6 Addressing Architecture [RFC4291].

The first and most important principle is to avoid semantic overlap for packet though semantic overlap for devices/hosts is fine. Any potential scenarios that a given packet may be mapped two or more semantic prefixes are considered harmful.

It is recommended network operator only use necessary semantics when they can bring benefits to network operations. The network operators should be very careful to plan and manage the semantic field. The network operators should self-restrict NOT to put too many semantic into prefix. So that they may avoid trap themselves into very complicated management issues.

While assigning all these bits on a separated subfield mechanism is considered inefficient and lack of flexibility, it is recommended to assign in low granularity, such as bit by bit.

### 5.1. ISP semantic bits

Typically, ISPs with millions subscribers would have /16 ~ /24 address space. It allows 40~48 arbitrary bits in prefix to be set by network operators (assuming the network is not strictly managed by





DHCPv6). However, many ISPs plan to assign /56 or even /48 for subscribers, the arbitrary bits are reduced to 22~40.

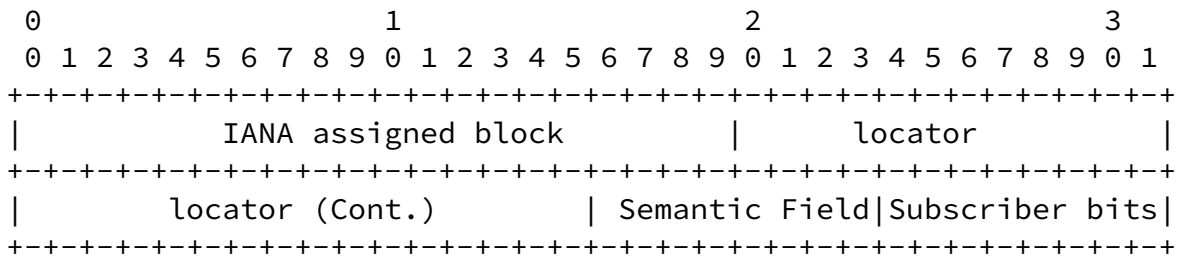
The locator function of IP address should be ensured first. Enough consideration should be given for future expanding. Some address space may be wasted in aggregation. For a Semantic Prefix Domain that organizes several millions subscribers with a continuous IPv6 address block, 24 bits for locator function is a minimum safe allocation.

Several bits may be good for safety margin.

The current network is mainly aggregated according to locator. Hence, it is recommended using the most left bits of prefix for locator function and lower bits for semantics. It is also useful for routing scalability. However, if the network operator would like to organize network aggregation by semantic prior, using higher bits for semantics is also possible. Mixed aggregation model can be reached by put semantics or part of semantics bits in the middle of locator bits.

According to the above analysis, it is recommended to use 4~12 bits in prefix for embedded semantics.

## 5.2. An ISP semantic prefix example




The above figure represents an ISP semantic prefix example.

In this example, the semantic prefix domain have a /20 IPv6 address space. It should serve over one million users. Hence, the 28 most-left (roughly 26 million of /64 prefixes) bits are allocated as locator. It serves network aggregation of topology based. The 8 most-right bits are subscriber bits. It means /56 prefix is assigned to subscribers. 8 bits (from bit 44 to 51) are assigned as semantic field. It may be assigned further for semantic combinations.

A further detailed example, combing user type, service type, VPNs, and application virtual overlay networks, the semantic field can be assigned like blow (presented in octet):

00 Normal individual user with normal internet access services
01 High-end individual user with normal internet access services
02 High-end individual user with secure internet access





services

```
03~07 Reserved
08   Enterprise user with normal internet access services
09   Enterprise user with secure internet access services
0A~0F Reserved
10~3F VPNs (with 48 sub-IDs)
40~7F Application virtual overlay networks (with 64 sub-IDs)
80~FF Reserved
```

## 5.3. Enterprise semantic bits

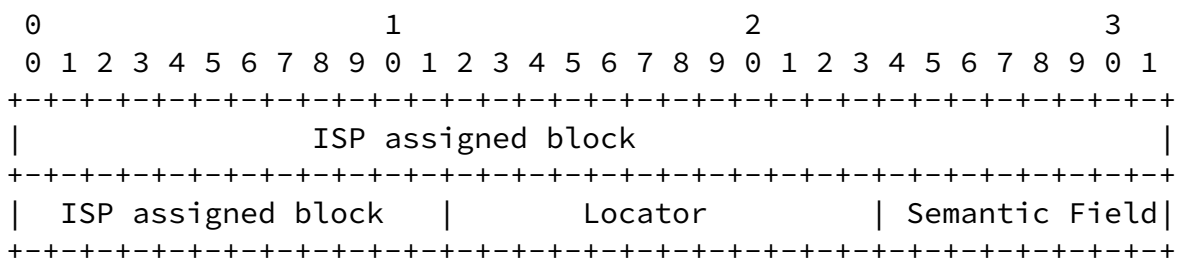
Typically, enterprises with thousands users would have /32 ~ /48 address space from upstream network provider or address allocation organization directly. It allows 16~32 arbitrary bits in prefix to be set by enterprise network operators (assuming the network is not strictly managed by DHCPv6).

The locator function of IP address should also be considered though it is not as important as ISP networks. The enterprise network operator may prefer to organize network by semantic prior.

A multiple-site enterprise may receive several prefixes that have different lengths. The semantic bits should be based on the longest prefix. The shorter prefix can use available bits for locators. It is compatible that shorter prefix serves bigger network with more users.

According to the above analysis, it is recommended to use 4~12 bits in prefix for embedded semantics.

## 5.4. An enterprise semantic prefix example




The above figure represents an enterprise semantic prefix example.

In this example, an enterprise have received a 38/ address block for one site (A) and a /44 for another site (B). They can be organized in a same semantic prefix domain. The most-left 18 (site A) / 12 (site B) bits are allocated as locator. It serves network aggregation of topology based. The most-right 8 bits (from bit 56 to 63) are assigned as semantic field.

## 6. Benefits

This section presents some, definitely not all, benefits. Depending on embedded semantics, various beneficial scenarios can be expected.

- Easy measurement and statistic

The semantic prefix provides explicit identifiers for measurement and statistic. They are as simple as checking certain bits of address in each packets.

- Easy flow control

By applying policies according to certain bit value, it is easy to control packets that have the same semantics.

- Policy aggregation

Semantic prefix allows many policies to be aggregated according to the same semantics in the policy based routing system [RFC1104].

- Application-aware routing

Embedding application information into IP addresses is the simplest way to realize application aware routing.

## 7. Gaps

The simplest model of semantic prefix is only embedded abstracted user type semantic into the prefix. It can be supported with the current network architecture because each subscribe still assigned one prefix, while they are not notified the semantic within it.

The more semantics embedded into prefix, the more complicated functions are needed for prefix delegation, host notification and address selections.

- Associate semantics with prefix delegation

When DHCPv6-PD [RFC3633] delegates a prefix, the associated semantics should be bounded.

- Notify prefix semantics to hosts

When a host connects to network, it should be assign a short prefix locator with some enabled semantics rules.

- Address selection according to semantics on hosts





In practice, a host may belong to several semantics. It means several IPv6 addresses are available on a single physical interface. A certain packet would only serve a certain semantic. The IPv6 stack on that host must know and understand these semantics and its correspondent bits in order to choose right source address when forming a packet. If the embedded semantic is application relevant, applications should also be involved in the address choosing process. The host IPv6 stack reports multiple available addresses to application through socket API (one example is "IPv6 Socket API for Source Address Selection" [RFC5014]. But more complicated functions are needed). Then application responses the one it attached.

In this architecture, hosts have to be intelligent enough to choose its source address according to its given information. It may also receive address select information from the applications. In some complicated scenarios, choosing destination address may also need further supporting functions.

The current address selection algorithms and address selection API [RFC5014] are too simple to support this architecture.

## 8. Security Considerations

This document provides no new security features.

## 9. IANA Considerations

This document has no IANA considerations.

## 10. Change log

draft-jiang-semantic-prefix-01: added enterprise considerations and scenarios, emphasizing semantics only for local meaning and no intend to standardize any common global semantics, 2012-07-16

draft-jiang-semantic-prefix-00: original version, 2012-07-09

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