Network Working Group
Internet-Draft
Obsoletes: 4291 (if approved)
Intended status: Standards Track
Expires: January 4, 2018

R. Hinden
Check Point Software
S. Deering
Retired

July 3, 2017

# IP Version 6 Addressing Architecture
# draft-ietf-6man-rfc4291bis-09

Abstract

This specification defines the addressing architecture of the IP Version 6 (IPv6) protocol. The document includes the IPv6 addressing model, text representations of IPv6 addresses, definition of IPv6 unicast addresses, anycast addresses, and multicast addresses, and an IPv6 node's required addresses.

This document obsoletes RFC 4291, "IP Version 6 Addressing Architecture".

Status of This Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on January 4, 2018.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (http://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect

to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

This document may contain material from IETF Documents or IETF Contributions published or made publicly available before November 10, 2008. The person(s) controlling the copyright in some of this material may not have granted the IETF Trust the right to allow modifications of such material outside the IETF Standards Process. Without obtaining an adequate license from the person(s) controlling the copyright in such materials, this document may not be modified outside the IETF Standards Process, and derivative works of it may not be created outside the IETF Standards Process, except to format it for publication as an RFC or to translate it into languages other than English.

Table of Contents

1. Introduction . . . . . 3
2. IPv6 Addressing . . . . . 3
2.1. Addressing Model . . . . . 4
2.2. Text Representation of IPv6 Addresses . . . . . 4
2.2.1. Text Representation of Addresses . . . . . 4
2.2.2. Text Representation of Address Prefixes . . . . . 6
2.2.3. Recommendation for outputting IPv6 addresses . . . . 7
2.3. Address Type Identification . . . . . 9
2.4. Unicast Addresses . . . . . 10
2.4.1. Interface Identifiers . . . . . 11
2.4.2. The Unspecified Address . . . . . 12
2.4.3. The Loopback Address . . . . . 12
2.4.4. Global Unicast Addresses . . . . . 13
2.4.5. IPv6 Addresses with Embedded IPv4 Addresses . . . . . 13
2.4.5.1. IPv4-Compatible IPv6 Address . . . . . 13
2.4.5.2. IPv4-Mapped IPv6 Address . . . . . 14
2.4.6. Link-Local IPv6 Unicast Addresses . . . . . 14
2.4.7. Other Local Unicast IPv6 Addresses . . . . . 14
2.5. Anycast Addresses . . . . . 15
2.5.1. Required Anycast Address . . . . . 15
2.6. Multicast Addresses . . . . . 16
2.6.1. Pre-Defined Multicast Addresses . . . . . 19
2.7. A Node's Required Addresses . . . . . 20
3. IANA Considerations . . . . . 21
4. Security Considerations . . . . . 22
5. Acknowledgments . . . . . 22
6. References . . . . . 23
6.1. Normative References . . . . . 23
6.2. Informative References . . . . . 23

Appendix A. Modified EUI-64 Format Interface Identifiers . . . . 26
A.1. Creating Modified EUI-64 Format Interface Identifiers . . 27
Appendix B. CHANGES SINCE RFC 4291 . . . . . 29
B.1. Change History Since RFC4291 . . . . . 31
Authors' Addresses . . . . . 35

## 1. Introduction

This specification defines the addressing architecture of the IP Version 6 protocol. It includes the basic formats for the various types of IPv6 addresses (unicast, anycast, and multicast).

## 2. IPv6 Addressing

IPv6 addresses are 128-bit identifiers for interfaces and sets of interfaces (where "interface" is as defined in Section 2 of [I-D.ietf-6man-rfc2460bis]). There are three types of addresses:

Unicast: An identifier for a single interface. A packet sent to a unicast address is delivered to the interface identified by that address.

Anycast: An identifier for a set of interfaces (typically belonging to different nodes). A packet sent to an anycast address is delivered to one of the interfaces identified by that address (the "nearest" one, according to the routing protocols' measure of distance).

Multicast: An identifier for a set of interfaces (typically belonging to different nodes). A packet sent to a multicast address is delivered to all interfaces identified by that address.

There are no broadcast addresses in IPv6, their function being superseded by multicast addresses.

In this document, fields in addresses are given a specific name, for example, "subnet". When this name is used with the term "ID" for identifier after the name (e.g., "subnet ID"), it refers to the contents of the named field. When it is used with the term "prefix" (e.g., "subnet prefix"), it refers to all of the address from the left up to and including this field.

Note: The term "prefix" is used in several different contexts for IPv6: a prefix used by a routing protocol, a prefix used by a node

to determine if another node is connected to the same link, and a prefix used to construct the complete address of a node.

In IPv6, all zeros and all ones are legal values for any field, unless specifically excluded. Specifically, prefixes may contain, or end with, zero-valued fields.

## 2.1. Addressing Model

IPv6 addresses of all types are assigned to interfaces, not nodes. An IPv6 unicast address refers to a single interface. Since each interface belongs to a single node, any of that node's interfaces' unicast addresses may be used as an identifier for the node.

All interfaces are required to have at least one Link-Local unicast address (see Section 2.7 for additional required addresses). A single interface may also have multiple IPv6 addresses of any type (unicast, anycast, and multicast) or scope. Unicast addresses with a scope greater than link-scope are not needed for interfaces that are not used as the origin or destination of any IPv6 packets to or from non-neighbors. This is sometimes convenient for point-to-point interfaces. There is one exception to this addressing model:

A unicast address or a set of unicast addresses may be assigned to multiple physical interfaces if the implementation treats the multiple physical interfaces as one interface when presenting it to the internet layer. This is useful for load-sharing over multiple physical interfaces.

Currently, IPv6 continues the IPv4 model in that a subnet prefix is associated with one link. Multiple subnet prefixes may be assigned to the same link. The relationship between links and IPv6 subnet prefixes differs from the IPv4 model in that all nodes automatically configure an address from the link-local prefix. A host is by definition on-link with it's default router, and that unicast addresses are not automatically associated with an on-link prefix. See [RFC5942] "The IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes" for more details.

## 2.2. Text Representation of IPv6 Addresses

### 2.2.1. Text Representation of Addresses

There are three conventional forms for representing IPv6 addresses as text strings:

1. The preferred form is x:x:x:x:x:x:x:x, where the 'x's are one to four hexadecimal digits of the eight 16-bit pieces of the address. Examples:

   ```
   abcd:ef01:2345:6789:abcd:ef01:2345:6789
   2001:db8:0:0:8:800:200c:417a
   ```

   Note that it is not necessary to write the leading zeros in an individual field, but there must be at least one numeral in every field (except for the case described in 2.).

2. Due to some methods of allocating certain styles of IPv6 addresses, it will be common for addresses to contain long strings of zero bits. In order to make writing addresses containing zero bits easier, a special syntax is available to compress the zeros. The use of "::" indicates one or more groups of 16 bits of zeros. The "::" can only appear once in an address. The "::" can also be used to compress leading or trailing zeros in an address.

   For example, the following addresses

   ```
   2001:db8:0:0:8:800:200c:417a  a unicast address
   ff01:0:0:0:0:0:0:101          a multicast address
   0:0:0:0:0:0:0:1               the loopback address
   0:0:0:0:0:0:0:0               the unspecified address
   ```

   may be represented as

   ```
   2001:db8::8:800:200c:417a     a unicast address
   ff01::101                     a multicast address
   ::1                           the loopback address
   ::                            the unspecified address
   ```

3. An alternative form that is sometimes more convenient when dealing with a mixed environment of IPv4 and IPv6 nodes is x:x:x:x:x:x:d.d.d.d, where the 'x's are the hexadecimal values of the six high-order 16-bit pieces of the address, and the 'd's are the decimal values of the four low-order 8-bit pieces of the address (standard IPv4 representation). Examples:

```
0:0:0:0:0:0:13.1.68.3
0:0:0:0:0:ffff:129.144.52.38
```

or in compressed form:

```
::13.1.68.3
::ffff:129.144.52.38
```

### 2.2.2. Text Representation of Address Prefixes

The text representation of IPv6 address prefixes is similar to the way IPv4 address prefixes are written in Classless Inter-Domain Routing (CIDR) notation [RFC4632]. An IPv6 address prefix is represented by the notation:

```
ipv6-address/prefix-length
```

where

ipv6-address is an IPv6 address in any of the notations listed in Section 2.2.

prefix-length is a decimal value specifying how many of the leftmost contiguous bits of the address comprise the prefix.

For example, the following are legal representations of the 60-bit prefix 20010db80000cd3 (hexadecimal):

```
2001:0db8:0000:cd30:0000:0000:0000:0000/60

2001:0db8::cd30:0:0:0:0/60

2001:0db8:0:cd30::/60
```

The following are NOT legal representations of the above prefix:

| | |
|---|---|
| 2001:0db8:0:cd3/60 | may drop leading zeros, but not trailing zeros, within any 16-bit chunk of the address |
| 2001:0db8::cd30/60 | address to left of "/" expands to 2001:0db8:0000:0000:0000:0000:0000:cd30 |
| 2001:0db8::cd3/60 | address to left of "/" expands to 2001:0db8:0000:0000:0000:0000:0000:0cd3 |

When writing both a node address and a prefix of that node address (e.g., the node's subnet prefix), the two can be combined as follows:

| | |
|---|---|
| the node address | 2001:0db8:0:cd30:123:4567:89ab:cdef |
| and its subnet prefix | 2001:0db8:0:cd30::/60 |

| | |
|---|---|
| can be abbreviated as | 2001:0db8:0:cd30:123:4567:89ab:cdef/60 |

### 2.2.3. Recommendation for outputting IPv6 addresses

This section provides a recommendation for systems generating and outputting IPv6 addresses as text. Note, all implementations must accept and process all addresses in the formats defined in the previous two sections of this document. Background on this recommendation can be found in [RFC5952].

The recommendations are as follows:

1. The hexadecimal digits "a", "b", "c", "d", "e", and "f" in an IPv6 address must be represented in lowercase.

2. Leading zeros in a 16-Bit Field must be suppressed. For example,

   2001:0db8::0001

   is not correct and must be represented as

   2001:db8::1

3. A single 16-bit 0000 field must be represented as 0.

   The use of the symbol "::" must be used to its maximum capability. For example:

   2001:db8:0:0:0:0:2:1

   must be shortened to

```
2001:db8::2:1
```

Likewise,

```
2001:db8::0:1
```

is not correct, because the symbol "::" could have been used to produce a shorter representation

```
2001:db8::1.
```

4. When there is an alternative choice in the placement of a "::", the longest run of consecutive 16-bit 0 fields must be shortened, that is, in

```
2001:0:0:1:0:0:0:1
```

the sequence with three consecutive zero fields is shortened to

```
2001:0:0:1::1
```

5. When the length of the consecutive 16-bit 0 fields are equal, for example

```
2001:db8:0:0:1:0:0:1
```

the first sequence of zero bits must be shortened. For example

```
2001:db8::1:0:0:1
```

is the correct representation.

6. The symbol "::" must not be used to shorten just one 16-bit 0 field. For example, the representation

2001:db8:0:1:1:1:1:1

is correct, but

2001:db8::1:1:1:1:1

is not correct.

7. The text representation method describe in this section should also be use for text Representation of IPv6 Address Prefixes. For example

2001:0db8:0000:cd30:0000:0000:0000:0000/60

should be shown as

2001:0db8:0:cd30::/60

8. The text representation method describe in this section should be applied for IPv6 addresses with embedded IPv4 address. For example

0:0:0:0:0:ffff:192.0.2.1

should be shown as

::ffff:192.0.2.1

## 2.3. Address Type Identification

The type of an IPv6 address is identified by the high-order bits of the address, as follows:

| Address type | Binary prefix | IPv6 notation | Section |
|---|---|---|---|
| Unspecified | 00...0 (128 bits) | ::/128 | 2.4.2 |
| Loopback | 00...1 (128 bits) | ::1/128 | 2.4.3 |
| Multicast | 11111111 | ff00::/8 | 2.6 |
| Link-Local unicast | 1111111010 | fe80::/10 | 2.4.6 |
| Global Unicast | (everything else) | | |

Anycast addresses are taken from the unicast address spaces (of any scope) and are not syntactically distinguishable from unicast addresses.

The general format of Global Unicast addresses is described in Section 2.4.4. Some special-purpose subtypes of Global Unicast addresses that contain embedded IPv4 addresses (for the purposes of IPv4-IPv6 interoperation) are described in Section 2.4.5.

Future specifications may redefine one or more sub-ranges of the Global Unicast space for other purposes, but unless and until that happens, implementations must treat all addresses that do not start with any of the above-listed prefixes as Global Unicast addresses.

The current assigned IPv6 prefixes and references to their usage can be found in the IANA Internet Protocol Version 6 Address Space registry [IANA-AD] and the IANA IPv6 Special-Purpose Address Registry [IANA-SP].

## 2.4. Unicast Addresses

IPv6 unicast addresses are aggregatable with prefixes of arbitrary bit-length, similar to IPv4 addresses under Classless Inter-Domain Routing.

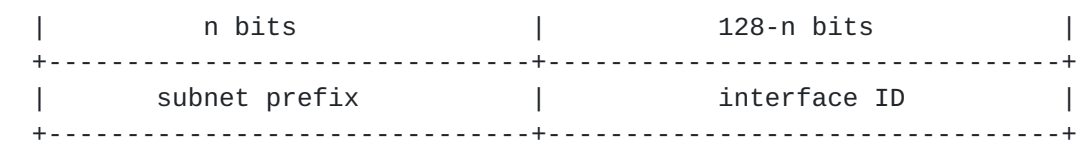
IPv6 unicast routing is based on prefixes of any valid length up to 128 [BCP198].

There are several types of unicast addresses in IPv6, in particular, Global Unicast, Local unicast, and Link-Local unicast. There are also some special-purpose subtypes of Global Unicast, such as IPv6 addresses with embedded IPv4 addresses. Additional address types or subtypes can be defined in the future.

IPv6 nodes may have considerable or little knowledge of the internal structure of the IPv6 address, depending on the role the node plays (for instance, host versus router). At a minimum, a node may consider that unicast addresses (including its own) have no internal structure:




A slightly more complex node may additionally be aware of subnet prefix(es) for the link(s) it is attached to, where different addresses may have different values for n:




Though a very simple router may have no knowledge of the internal structure of IPv6 unicast addresses, routers will more generally have knowledge of one or more of the hierarchical boundaries for the operation of routing protocols. The known boundaries will differ from router to router, depending on what positions the router holds in the routing hierarchy.

Except for the knowledge of the subnet boundary discussed in the previous paragraphs, nodes should not make any assumptions about the structure of an IPv6 address.

### 2.4.1. Interface Identifiers

Interface identifiers in IPv6 unicast addresses are used to identify interfaces on a link. They are required to be unique within a subnet prefix. It is recommended that the same interface identifier not be assigned to different nodes on a link. They may also be unique over a broader scope. The same interface identifier may be used on multiple interfaces on a single node, as long as they are attached to different subnets.

Interface IDs must be viewed outside of the node that created Interface ID as an opaque bit string without any internal structure.

Note that the uniqueness of interface identifiers is independent of the uniqueness of IPv6 addresses. For example, a Global Unicast address may be created with an interface identifier that is only unique on a single subnet, and a Link-Local address may be created with interface identifier that is unique over multiple subnets.

Interface Identifiers are 64 bit long except if the first three bits of the address are 000, or when the addresses are manually configured, or by exceptions defined in standards track documents. The rationale for using 64 bit Interface Identifiers can be found in

[RFC7421]. An example of a standards track exception is [RFC6164] that standardises 127 bit prefixes on inter-router point-to-point links.

The details of forming interface identifiers are defined in other specifications, such as "Privacy Extensions for Stateless Address Autoconfiguration in IPv6" [RFC4941] or "A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)"[RFC7217]. Specific cases are described in appropriate "IPv6 over <link>" specifications, such as "IPv6 over Ethernet" [RFC2464] and "Transmission of IPv6 Packets over ITU-T G.9959 Networks" [RFC7428]. The security and privacy considerations for IPv6 address generation is described in [RFC7721].

Earlier versions of this document described a method of forming interface identifiers derived from IEEE MAC-layer addresses call Modified EUI-64 format. These are described in Appendix A and are no longer recommended.

### 2.4.2. The Unspecified Address

The address 0:0:0:0:0:0:0:0 is called the unspecified address. It must never be assigned to any node. It indicates the absence of an address. One example of its use is in the Source Address field of any IPv6 packets sent by an initializing host before it has learned its own address.

The unspecified address must not be used as the destination address of IPv6 packets or in IPv6 Routing headers. An IPv6 packet with a source address of unspecified must never be forwarded by an IPv6 router.

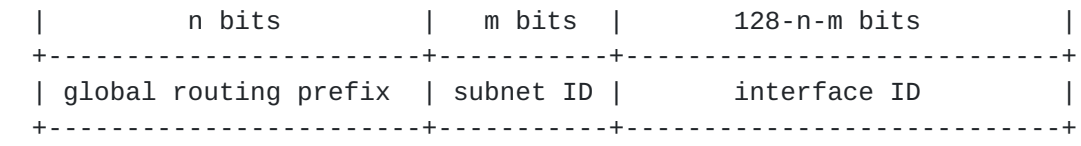
### 2.4.3. The Loopback Address

The unicast address 0:0:0:0:0:0:0:1 is called the loopback address. It may be used by a node to send an IPv6 packet to itself. It must not be assigned to any physical interface. It is treated as having Link-Local scope, and may be thought of as the Link-Local unicast address of a virtual interface (typically called the "loopback interface") to an imaginary link that goes nowhere.

The loopback address must not be used as the source address in IPv6 packets that are sent outside of a single node. An IPv6 packet with a destination address of loopback must never be sent outside of a single node and must never be forwarded by an IPv6 router. A packet received on an interface with a destination address of loopback must be dropped.

### 2.4.4. Global Unicast Addresses

The general format for IPv6 Global Unicast addresses is as follows:




where the global routing prefix is a (typically hierarchically-structured) value assigned to a site (a cluster of subnets/links), the subnet ID is an identifier of a link within the site, and the interface ID is as defined in Section 2.4.1.

Examples of Global Unicast addresses that start with binary 000 are the IPv6 address with embedded IPv4 addresses described in Section 2.4.5. An example of global addresses starting with a binary value other than 000 (and therefore having a 64-bit interface ID field) can be found in [RFC3587].

### 2.4.5. IPv6 Addresses with Embedded IPv4 Addresses

Two types of IPv6 addresses are defined that carry an IPv4 address in the low-order 32 bits of the address. These are the "IPv4-Compatible IPv6 address" and the "IPv4-mapped IPv6 address".

#### 2.4.5.1. IPv4-Compatible IPv6 Address

The "IPv4-Compatible IPv6 address" was defined to assist in the IPv6 transition. The format of the "IPv4-Compatible IPv6 address" is as follows:




Note: The IPv4 address used in the "IPv4-Compatible IPv6 address" must be a globally-unique IPv4 unicast address.

The "IPv4-Compatible IPv6 address" is now deprecated because the current IPv6 transition mechanisms no longer use these addresses. New or updated implementations are not required to support this address type.

#### 2.4.5.2. IPv4-Mapped IPv6 Address

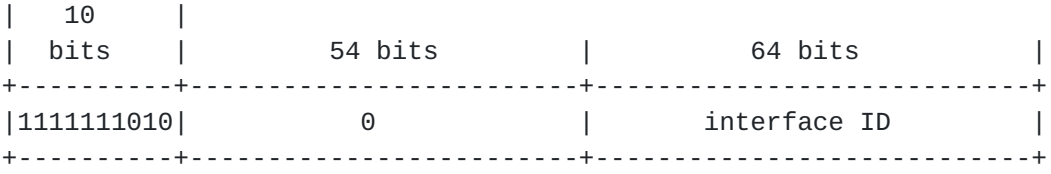
A second type of IPv6 address that holds an embedded IPv4 address is defined. This address type is used to represent the addresses of IPv4 nodes as IPv6 addresses. The format of the "IPv4-mapped IPv6 address" is as follows:




See [RFC4038] for background on the usage of the "IPv4-mapped IPv6 address".

### 2.4.6. Link-Local IPv6 Unicast Addresses

Link-Local addresses are for use on a single link. Link-Local addresses have the following format:




Link-Local addresses are designed to be used for addressing on a single link for purposes such as automatic address configuration, neighbor discovery, or when no routers are present.

Routers must not forward any packets with Link-Local source or destination addresses to other links.

### 2.4.7. Other Local Unicast IPv6 Addresses

Unique Local Addresses (ULA) [RFC4193], the current form of Local IPv6 Addresses, are intended to be used for local communications, have global unicast scope, and are not expected to be routable on the global Internet.

Site-Local addresses, deprecated by [RFC3879], the previous form of Local IPv6 Addresses, were originally designed to be used for addressing inside of a site without the need for a global prefix.

The special behavior of Site-Local defined in [RFC3513] must no longer be supported in new implementations (i.e., new implementations must treat this prefix as Global Unicast). Existing implementations and deployments may continue to use this prefix.

## 2.5. Anycast Addresses

An IPv6 anycast address is an address that is assigned to more than one interface (typically belonging to different nodes), with the property that a packet sent to an anycast address is routed to the "nearest" interface having that address, according to the routing protocols' measure of distance.

Anycast addresses are allocated from the unicast address space, using any of the defined unicast address formats. Thus, anycast addresses are syntactically indistinguishable from unicast addresses. When a unicast address is assigned to more than one interface, thus turning it into an anycast address, the nodes to which the address is assigned must be explicitly configured to know that it is an anycast address.

For any assigned anycast address, there is a longest prefix P of that address that identifies the topological region in which all interfaces belonging to that anycast address reside. Within the region identified by P, the anycast address must be maintained as a separate entry in the routing system (commonly referred to as a "host route"); outside the region identified by P, the anycast address may be aggregated into the routing entry for prefix P.

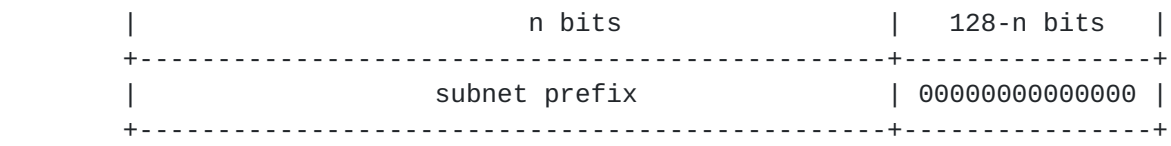
Note that in the worst case, the prefix P of an anycast set may be the null prefix, i.e., the members of the set may have no topological locality. In that case, the anycast address must be maintained as a separate routing entry throughout the entire Internet, which presents a severe scaling limit on how many such "global" anycast sets may be supported. Therefore, it is expected that support for global anycast sets may be unavailable or very restricted.

One expected use of anycast addresses is to identify the set of routers belonging to an organization providing Internet service. Such addresses could be used as intermediate addresses in an IPv6 Routing header, to cause a packet to be delivered via a particular service provider or sequence of service providers.

Some other possible uses are to identify the set of routers attached to a particular subnet, or the set of routers providing entry into a particular routing domain.

### 2.5.1. Required Anycast Address

The Subnet-Router anycast address is predefined. Its format is as follows:



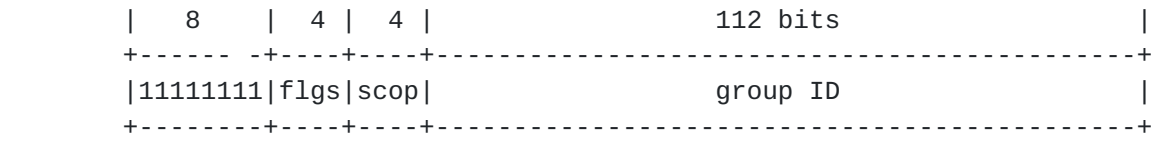

The "subnet prefix" in an anycast address is the prefix that identifies a specific link. This anycast address is syntactically the same as a unicast address for an interface on the link with the interface identifier set to zero.

Packets sent to the Subnet-Router anycast address will be delivered to one router on the subnet. All routers are required to support the Subnet-Router anycast addresses for the subnets to which they have interfaces.

The Subnet-Router anycast address is intended to be used for applications where a node needs to communicate with any one of the set of routers.

## 2.6. Multicast Addresses

An IPv6 multicast address is an identifier for a group of interfaces (typically on different nodes). An interface may belong to any number of multicast groups. Multicast addresses have the following format:




binary 11111111 at the start of the address identifies the address as being a multicast address.




The high-order flag is reserved, and must be initialized to 0.

T = 0 indicates a permanently-assigned ("well-known") multicast address, assigned by the Internet Assigned Numbers Authority (IANA).

T = 1 indicates a non-permanently-assigned ("transient" or "dynamically" assigned) multicast address.

The P flag's definition and usage can be found in [RFC3306].

The R flag's definition and usage can be found in [RFC3956].

scop is a 4-bit multicast scope value used to limit the scope of the multicast group. The values are as follows:

0 reserved
1 Interface-Local scope
2 Link-Local scope
3 Realm-Local scope
4 Admin-Local scope
5 Site-Local scope
6 (unassigned)
7 (unassigned)
8 Organization-Local scope
9 (unassigned)
A (unassigned)
B (unassigned)
C (unassigned)
D (unassigned)
E Global scope
F reserved

Interface-Local scope spans only a single interface on a node and is useful only for loopback transmission of multicast. Packets with interface-local scope received from another node must be discarded.

Link-Local multicast scope spans the same topological region as the corresponding unicast scope.

Interface-Local, Link-Local, and Realm-Local scope boundaries are automatically derived from physical connectivity or other non-multicast-related configurations. Global scope has no boundary. The boundaries of all other non-reserved scopes of Admin-Local or larger are administratively configured. For reserved scopes, the way of configuring their boundaries will be defined when the semantics of the scope are defined.

According to [RFC4007], the zone of a Realm-Local scope must fall within zones of larger scope. Because the zone of a Realm-Local scope is configured automatically while the zones of larger scopes are configured manually, care must be taken in the definition of those larger scopes to ensure that the inclusion constraint is met.

Realm-Local scopes created by different network technologies are considered to be independent and will have different zone indices (see Section 6 of [RFC4007]). A router with interfaces on links using different network technologies does not forward traffic between the Realm-Local multicast scopes defined by those technologies.

Site-Local scope is intended to span a single site.

Organization-Local scope is intended to span multiple sites belonging to a single organization.

scopes labeled "(unassigned)" are available for administrators to define additional multicast regions.

group ID identifies the multicast group, either permanent or transient, within the given scope. Additional definitions of the multicast group ID field structure are provided in [RFC3306].

The "meaning" of a permanently-assigned multicast address is independent of the scope value. For example, if the "NTP servers group" is assigned a permanent multicast address with a group ID of 101 (hex), then

ff01:0:0:0:0:0:0:101 means all NTP servers on the same interface (i.e., the same node) as the sender.

ff02:0:0:0:0:0:0:101 means all NTP servers on the same link as the sender.

ff05:0:0:0:0:0:0:101 means all NTP servers in the same site as the sender.

ff0e:0:0:0:0:0:0:101 means all NTP servers in the Internet.

Non-permanently-assigned multicast addresses are meaningful only within a given scope. For example, a group identified by the non-permanent, site-local multicast address ff15:0:0:0:0:0:0:101 at one site bears no relationship to a group using the same address at a different site, nor to a non-permanent group using the same group ID with a different scope, nor to a permanent group with the same group ID.

Multicast addresses must not be used as source addresses in IPv6 packets or appear in any Routing header.

Routers must not forward any multicast packets beyond the scope indicated by the scop field in the destination multicast address.

Nodes must not originate a packet to a multicast address whose scop field contains the reserved value 0; if such a packet is received, it must be silently dropped. Nodes should not originate a packet to a multicast address whose scop field contains the reserved value F; if such a packet is sent or received, it must be treated the same as packets destined to a global (scop E) multicast address.

### 2.6.1. Pre-Defined Multicast Addresses

The following well-known multicast addresses are pre-defined. The group IDs defined in this section are defined for explicit scope values.

Use of these group IDs for any other scope values, with the T flag equal to 0, is not allowed.

| | |
|---|---|
| Reserved Multicast Addresses: | ff00:0:0:0:0:0:0:0 |
| | ff01:0:0:0:0:0:0:0 |
| | ff02:0:0:0:0:0:0:0 |
| | ff03:0:0:0:0:0:0:0 |
| | ff04:0:0:0:0:0:0:0 |
| | ff05:0:0:0:0:0:0:0 |
| | ff06:0:0:0:0:0:0:0 |
| | ff07:0:0:0:0:0:0:0 |
| | ff08:0:0:0:0:0:0:0 |
| | ff09:0:0:0:0:0:0:0 |
| | ff0a:0:0:0:0:0:0:0 |
| | ff0b:0:0:0:0:0:0:0 |
| | ff0c:0:0:0:0:0:0:0 |
| | ff0d:0:0:0:0:0:0:0 |
| | ff0e:0:0:0:0:0:0:0 |
| | ff0f:0:0:0:0:0:0:0 |

The above multicast addresses are reserved and shall never be assigned to any multicast group.

| | |
|---|---|
| All Nodes Addresses: | ff01:0:0:0:0:0:0:1 |
| | ff02:0:0:0:0:0:0:1 |

The above multicast addresses identify the group of all IPv6 nodes, within scope 1 (interface-local) or 2 (link-local).

All Routers Addresses: ff01:0:0:0:0:0:0:2
ff02:0:0:0:0:0:0:2
ff05:0:0:0:0:0:0:2

The above multicast addresses identify the group of all IPv6 routers, within scope 1 (interface-local), 2 (link-local), or 5 (site-local).

Solicited-Node Address: ff02:0:0:0:0:1:ffxx:xxxx

Solicited-Node multicast address are computed as a function of a node's unicast and anycast addresses. A Solicited-Node multicast address is formed by taking the low-order 24 bits of an address (unicast or anycast) and appending those bits to the prefix FF02:0:0:0:0:1:FF00::/104 resulting in a multicast address in the range

ff02:0:0:0:0:1:ff00:0000

to

ff02:0:0:0:0:1:ffff:ffff

For example, the Solicited-Node multicast address corresponding to the IPv6 address 4037::01:800:200e:8c6c is ff02::1:ff0e:8c6c. IPv6 addresses that differ only in the high-order bits (e.g., due to multiple high-order prefixes associated with different aggregations) will map to the same Solicited-Node address, thereby reducing the number of multicast addresses a node must join.

A node is required to compute and join (on the appropriate interface) the associated Solicited-Node multicast addresses for all unicast and anycast addresses that have been configured for the node's interfaces (manually or automatically).

Additional defined multicast address can be found in the IANA IPv6 Multicast Address Allocation registry [IANA-MC]

## 2.7. A Node's Required Addresses

A host is required to recognize the following addresses as identifying itself:

- Its required Link-Local address for each interface.

- Any additional Unicast and Anycast addresses that have been configured for the node's interfaces (manually or automatically).
- The loopback address.
- The All-Nodes multicast addresses defined in Section 2.6.1.
- The Solicited-Node multicast address for each of its unicast and anycast addresses.
- Multicast addresses of all other groups to which the node belongs.

A router is required to recognize all addresses that a host is required to recognize, plus the following addresses as identifying itself:

- The Subnet-Router Anycast addresses for all interfaces for which it is configured to act as a router.
- All other Anycast addresses with which the router has been configured.
- The All-Routers multicast addresses defined in Section 2.6.1.

## 3. IANA Considerations

RFC4291 is referenced in a number of IANA registries. These include:

- Internet Protocol Version 6 Address Space [IANA-AD]
- IPv6 Global Unicast Address Assignments [IANA-GU]
- IPv6 Multicast Address Space Registry [IANA-MC]
- Application for an IPv6 Multicast Address [IANA-MA]
- Internet Protocol Version 6 (IPv6) Anycast Addresses [IANA-AC]
- IANA IPv6 Special-Purpose Address Registry [IANA-SP]
- Reserved IPv6 Interface Identifiers [IANA-ID]

- Number Resources [IANA-NR]
- Protocol Registries [IANA-PR]
- Technical requirements for authoritative name servers [IANA-NS]
- IP Flow Information Export (IPFIX) Entities [IANA-FE]

The IANA should update these references to point to this document.

There are also other references in IANA procedures documents that the IANA should investigate to see if they should be updated.

## 4. Security Considerations

IPv6 addressing documents do not have any direct impact on Internet infrastructure security. Authentication of IPv6 packets is defined in [RFC4302].

One area relavant to IPv6 addressing is privacy. IPv6 addresses can be created using interface identifiers constructed with unique stable tokens. The addresses created in this manner can be used to track the movement of devices across the Internet. Since earlier versions of this document were published, several approaches have been developed that mitigate these problems. These are described in "Security and Privacy Considerations for IPv6 Address Generation Mechanisms" [RFC7721], "Privacy Extensions for Stateless Address Autoconfiguration in IPv6" [RFC4941], and "A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)" [RFC7217].

## 5. Acknowledgments

The authors would like to acknowledge the contributions of Bill Simpson, Bob Fink, Bob Gilligan, Brian Carpenter, Christian Huitema, Deborah Estrin, Dimitry Haskin, Erik Nordmark, Greg Minshall, James Woodyatt. Jim Bound, Jun-ichiro Itojun Hagino, Larry Masinter, Mahmood Ali, Markku Savela, Matt Crawford, Paul Francis, Peter Ford, Roger Fajman, Scott Bradner, Sue Thomson, Suresh Krishnan, Tatuya Jinmei, Thomas Narten, Tom Harsch, Tony Li, and Yakov Rekhter.

The authors would also like to acknowledge the authors of the updating RFCs that were incorporated in this version of the document to move IPv6 to Internet Standard. This includes Marcelo Bagnulo, Congxiao Bao, Mohamed Boucadair, Brian Carpenter, Ralph Droms, Christian Huitema, Sheng Jiang, Seiichi Kawamura, Masanobu Kawashima, Xing Li, and Stig Venaas.

# 6. References

## 6.1. Normative References

[I-D.ietf-6man-rfc2460bis]
Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", draft-ietf-6man-rfc2460bis-13 (work in progress), May 2017.

## 6.2. Informative References

[BCP198] Boucadair, M., Petrescu, A., and F. Baker, "IPv6 Prefix Length Recommendation for Forwarding", BCP 198, RFC 7608, DOI 10.17487/RFC7608, July 2015, <http://www.rfc-editor.org/info/rfc7608>.

[EUI64] "IEEE, "Guidelines for 64-bit Global Identifier (EUI-64) Registration Authority"", March 1997, <http://standards.ieee.org/regauth/oui/tutorials/EUI64.html>.

[IANA-AC] "Internet Protocol Version 6 (IPv6) Anycast Addresses", <http://www.iana.org/assignments/ipv6-anycast-addresses/ipv6-anycast-addresses.xhtml>.

[IANA-AD] "Internet Protocol Version 6 Address Space", <https://www.iana.org/assignments/ipv6-address-space/ipv6-address-space.xhtml>.

[IANA-FE] "IP Flow Information Export (IPFIX) Entities", <http://www.iana.org/assignments/ipfix/ipfix.xhtml>.

[IANA-GU] "IPv6 Global Unicast Address Assignments", <http://www.iana.org/assignments/ipv6-unicast-address-assignments/ipv6-unicast-address-assignments.xhtml>.

[IANA-ID] "IANA IPv6 Special-Purpose Address Registry", <http://www.iana.org/assignments/ipv6-interface-ids/ipv6-interface-ids.xhtml>.

[IANA-MA] "Application for an IPv6 Multicast Address", <https://www.iana.org/form/multicast-ipv6>.

[IANA-MC] "IPv6 Multicast Address Space Registry", <http://www.iana.org/assignments/ipv6-multicast-addresses/ipv6-multicast-addresses.xhtml>.

[IANA-NR] "Number Resources", <http://https://www.iana.org/numbers>.

[IANA-NS] "Technical requirements for authoritative name servers", <https://www.iana.org/help/nameserver-requirements>.

[IANA-PR] "Protocol Registries", <https://www.iana.org/protocols>.

[IANA-SP] "IANA IPv6 Special-Purpose Address Registry", <https://www.iana.org/assignments/iana-ipv6-special-registry/iana-ipv6-special-registry.xhtml>.

[RFC2464] Crawford, M., "Transmission of IPv6 Packets over Ethernet Networks", RFC 2464, DOI 10.17487/RFC2464, December 1998, <http://www.rfc-editor.org/info/rfc2464>.

[RFC3306] Haberman, B. and D. Thaler, "Unicast-Prefix-based IPv6 Multicast Addresses", RFC 3306, DOI 10.17487/RFC3306, August 2002, <http://www.rfc-editor.org/info/rfc3306>.

[RFC3513] Hinden, R. and S. Deering, "Internet Protocol Version 6 (IPv6) Addressing Architecture", RFC 3513, DOI 10.17487/RFC3513, April 2003, <http://www.rfc-editor.org/info/rfc3513>.

[RFC3587] Hinden, R., Deering, S., and E. Nordmark, "IPv6 Global Unicast Address Format", RFC 3587, DOI 10.17487/RFC3587, August 2003, <http://www.rfc-editor.org/info/rfc3587>.

[RFC3879] Huitema, C. and B. Carpenter, "Deprecating Site Local Addresses", RFC 3879, DOI 10.17487/RFC3879, September 2004, <http://www.rfc-editor.org/info/rfc3879>.

[RFC3956] Savola, P. and B. Haberman, "Embedding the Rendezvous Point (RP) Address in an IPv6 Multicast Address", RFC 3956, DOI 10.17487/RFC3956, November 2004, <http://www.rfc-editor.org/info/rfc3956>.

[RFC4007] Deering, S., Haberman, B., Jinmei, T., Nordmark, E., and B. Zill, "IPv6 Scoped Address Architecture", RFC 4007, DOI 10.17487/RFC4007, March 2005, <http://www.rfc-editor.org/info/rfc4007>.

[RFC4038] Shin, M-K., Ed., Hong, Y-G., Hagino, J., Savola, P., and E. Castro, "Application Aspects of IPv6 Transition", RFC 4038, DOI 10.17487/RFC4038, March 2005, <http://www.rfc-editor.org/info/rfc4038>.

[RFC4193] Hinden, R. and B. Haberman, "Unique Local IPv6 Unicast Addresses", RFC 4193, DOI 10.17487/RFC4193, October 2005, <http://www.rfc-editor.org/info/rfc4193>.

[RFC4302] Kent, S., "IP Authentication Header", RFC 4302, DOI 10.17487/RFC4302, December 2005, <http://www.rfc-editor.org/info/rfc4302>.

[RFC4632] Fuller, V. and T. Li, "Classless Inter-domain Routing (CIDR): The Internet Address Assignment and Aggregation Plan", BCP 122, RFC 4632, DOI 10.17487/RFC4632, August 2006, <http://www.rfc-editor.org/info/rfc4632>.

[RFC4941] Narten, T., Draves, R., and S. Krishnan, "Privacy Extensions for Stateless Address Autoconfiguration in IPv6", RFC 4941, DOI 10.17487/RFC4941, September 2007, <http://www.rfc-editor.org/info/rfc4941>.

[RFC5942] Singh, H., Beebee, W., and E. Nordmark, "IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes", RFC 5942, DOI 10.17487/RFC5942, July 2010, <http://www.rfc-editor.org/info/rfc5942>.

[RFC5952] Kawamura, S. and M. Kawashima, "A Recommendation for IPv6 Address Text Representation", RFC 5952, DOI 10.17487/RFC5952, August 2010, <http://www.rfc-editor.org/info/rfc5952>.

[RFC6164] Kohno, M., Nitzan, B., Bush, R., Matsuzaki, Y., Colitti, L., and T. Narten, "Using 127-Bit IPv6 Prefixes on Inter-Router Links", RFC 6164, DOI 10.17487/RFC6164, April 2011, <http://www.rfc-editor.org/info/rfc6164>.

[RFC7217] Gont, F., "A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)", RFC 7217, DOI 10.17487/RFC7217, April 2014, <http://www.rfc-editor.org/info/rfc7217>.

[RFC7421] Carpenter, B., Ed., Chown, T., Gont, F., Jiang, S., Petrescu, A., and A. Yourtchenko, "Analysis of the 64-bit Boundary in IPv6 Addressing", RFC 7421, DOI 10.17487/RFC7421, January 2015, <http://www.rfc-editor.org/info/rfc7421>.

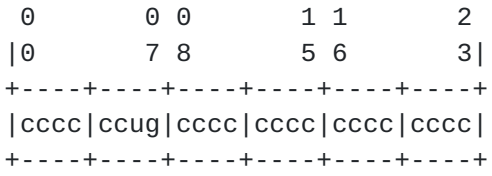
[RFC7428] Brandt, A. and J. Buron, "Transmission of IPv6 Packets over ITU-T G.9959 Networks", RFC 7428, DOI 10.17487/RFC7428, February 2015, <http://www.rfc-editor.org/info/rfc7428>.

[RFC7721] Cooper, A., Gont, F., and D. Thaler, "Security and Privacy Considerations for IPv6 Address Generation Mechanisms", RFC 7721, DOI 10.17487/RFC7721, March 2016, <http://www.rfc-editor.org/info/rfc7721>.

## Appendix A. Modified EUI-64 Format Interface Identifiers

Modified EUI-64 format-based interface identifiers may have universal scope when derived from a universal token (e.g., IEEE 802 48-bit MAC or IEEE EUI-64 identifiers [EUI64]) or may have local scope where a global token is not being used (e.g., serial links, tunnel end-points) or where global tokens are undesirable (e.g., temporary tokens for privacy [RFC4941].

Modified EUI-64 format interface identifiers are formed by inverting the "u" bit (universal/local bit in IEEE EUI-64 terminology) when forming the interface identifier from IEEE EUI-64 identifiers. In the resulting Modified EUI-64 format, the "u" bit is set to one (1) to indicate universal scope, and it is set to zero (0) to indicate local scope. The first three octets in binary of an IEEE EUI-64 identifier are as follows:




written in Internet standard bit-order, where "u" is the universal/local bit, "g" is the individual/group bit, and "c" is the bits of the company_id. Appendix A, "Creating Modified EUI-64 Format Interface Identifiers", provides examples on the creation of Modified EUI-64 format-based interface identifiers.

The motivation for inverting the "u" bit when forming an interface identifier is to make it easy for system administrators to hand configure non-global identifiers when hardware tokens are not available. This is expected to be the case for serial links and tunnel end-points, for example. The alternative would have been for these to be of the form 0200:0:0:1, 0200:0:0:2, etc., instead of the much simpler 0:0:0:1, 0:0:0:2, etc.

IPv6 nodes are not required to validate that interface identifiers created with modified EUI-64 tokens with the "u" bit set to universal are unique.

## A.1. Creating Modified EUI-64 Format Interface Identifiers

Depending on the characteristics of a specific link or node, there are a number of approaches for creating Modified EUI-64 format interface identifiers. This appendix describes some of these approaches.

Links or Nodes with IEEE EUI-64 Identifiers

The only change needed to transform an IEEE EUI-64 identifier to an interface identifier is to invert the "u" (universal/local) bit. An example is a globally unique IEEE EUI-64 identifier of the form:

```
|0              1|1              3|3              4|4              6|
|0              5|6              1|2              7|8              3|
+----------------+----------------+----------------+----------------+
|cccccc0gccccccccc|ccccccccmmmmmmmm|mmmmmmmmmmmmmmmm|mmmmmmmmmmmmmmmm|
+----------------+----------------+----------------+----------------+
```

where "c" is the bits of the assigned company_id, "0" is the value of the universal/local bit to indicate universal scope, "g" is individual/group bit, and "m" is the bits of the manufacturer-selected extension identifier. The IPv6 interface identifier would be of the form:

```
|0              1|1              3|3              4|4              6|
|0              5|6              1|2              7|8              3|
+----------------+----------------+----------------+----------------+
|cccccc1gccccccccc|ccccccccmmmmmmmm|mmmmmmmmmmmmmmmm|mmmmmmmmmmmmmmmm|
+----------------+----------------+----------------+----------------+
```

The only change is inverting the value of the universal/local bit.

Links or Nodes with IEEE 802 48-bit MACs

[EUI64] defines a method to create an IEEE EUI-64 identifier from an IEEE 48-bit MAC identifier. This is to insert two octets, with hexadecimal values of 0xFF and 0xFE (see the Note at the end of appendix), in the middle of the 48-bit MAC (between the company_id and vendor-supplied id). An example is the 48-bit IEEE MAC with Global scope:

```
|0              1|1              3|3              4|
|0              5|6              1|2              7|
+----------------+----------------+----------------+
|cccccc0gccccccccc|ccccccccmmmmmmmm|mmmmmmmmmmmmmmmm|
+----------------+----------------+----------------+
```

where "c" is the bits of the assigned company_id, "0" is the value of the universal/local bit to indicate Global scope, "g" is individual/ group bit, and "m" is the bits of the manufacturer- selected extension identifier. The interface identifier would be of the form:

```
|0              1|1              3|3              4|4              6|
|0              5|6              1|2              7|8              3|
+----------------+----------------+----------------+----------------+
|cccccc1gcccccccc|cccccccc11111111|11111110mmmmmmmm|mmmmmmmmmmmmmmmm|
+----------------+----------------+----------------+----------------+
```

When IEEE 802 48-bit MAC addresses are available (on an interface or a node), an implementation may use them to create interface identifiers due to their availability and uniqueness properties.

Links with Other Kinds of Identifiers

There are a number of types of links that have link-layer interface identifiers other than IEEE EUI-64 or IEEE 802 48-bit MACs. Examples include LocalTalk and Arcnet. The method to create a Modified EUI-64 format identifier is to take the link identifier (e.g., the LocalTalk 8-bit node identifier) and zero fill it to the left. For example, a LocalTalk 8-bit node identifier of hexadecimal value 0x4F results in the following interface identifier:

```
|0              1|1              3|3              4|4              6|
|0              5|6              1|2              7|8              3|
+----------------+----------------+----------------+----------------+
|0000000000000000|0000000000000000|0000000000000000|0000000001001111|
+----------------+----------------+----------------+----------------+
```

Note that this results in the universal/local bit set to "0" to indicate local scope.

Links without Identifiers

There are a number of links that do not have any type of built-in identifier. The most common of these are serial links and configured tunnels. Interface identifiers that are unique within a subnet prefix must be chosen.

When no built-in identifier is available on a link, the preferred approach is to use a universal interface identifier from another interface or one that is assigned to the node itself. When using this approach, no other interface connecting the same node to the same subnet prefix may use the same identifier.

If there is no universal interface identifier available for use on the link, the implementation needs to create a local-scope interface identifier. The only requirement is that it be unique within a subnet prefix. There are many possible approaches to select a subnet-prefix-unique interface identifier. These include the following:

Manual Configuration
Node Serial Number
Other Node-Specific Token

The subnet-prefix-unique interface identifier should be generated in a manner such that it does not change after a reboot of a node or if interfaces are added or deleted from the node.

The selection of the appropriate algorithm is link and implementation dependent. The details on forming interface identifiers are defined in the appropriate "IPv6 over <link>" specification. It is strongly recommended that a collision detection algorithm be implemented as part of any automatic algorithm.

Note: [EUI64] actually defines 0xFF and 0xFF as the bits to be inserted to create an IEEE EUI-64 identifier from an IEEE MAC-48 identifier. The 0xFF and 0xFE values are used when starting with an IEEE EUI-48 identifier. The incorrect value was used in earlier versions of the specification due to a misunderstanding about the differences between IEEE MAC-48 and EUI-48 identifiers.

This document purposely continues the use of 0xFF and 0xFE because it meets the requirements for IPv6 interface identifiers (i.e., that they must be unique on the link), IEEE EUI-48 and MAC-48 identifiers are syntactically equivalent, and that it doesn't cause any problems in practice.

## Appendix B. CHANGES SINCE RFC 4291

This document has the following changes from RFC4291, "IP Version 6 Addressing Architecture":

- Added Note: to Section 2 that the term "prefix" is used in different contexts in IPv6: a prefix used by a routing protocol, a prefix used by a node to determine if another node is connected to the same link, and a prefix used to construct the complete address of a node.

- Added text to the last paragraph in Section 2.1 to clarify the differences on how subnets are hangled in IPv4 and IPv6, includes

a reference to RFC5942 "The IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes".

- Incorporate the updates made by RFC5952 in Section 2.2.3 regarding the text format when outputting IPv6 addresses. A new section was added for this and addresses shown in this document were changed to lower case. This includes a reference to RFC5952.

- Incorporate the updates made by RFC6052. The change was to add a text in Section 2.3 that points to the IANA registries that records the prefix defined in RFC6052 and a number of other special use prefixes.

- Clarified text that 64 bit Interface IDs are used except when the first three bits of the address are 000, or addresses are manually configured, or when defined by a standard track document. Added text that Modified EUI-64 identifiers not recommended and moved the text describing the format to Appendix A. This text was moved from Section 2.4 and is now consolidated in Section 2.4.1. Also removed text in Section 2.4.4 relating to 64 bit Interface IDs.

- Added text to Section 2.4 summarizing IPv6 unicast routing and referencing BCP198, citing RFC6164 as an example of longer prefixes, and that IIDs are required to be 64 bits long as described in RFC7421.

- Incorporate the updates made by RFC7136 to deprecate the U and G bits in Modified EUI-64 format Internet IDs.

- Rename Section 2.4.7 to "Other Local Unicast Addresses" and rewrote the text to point to ULAs and say that Site-Local addresses were deprecated by RFC3879. The format of Site-Local was removed.

- Incorporate the updates made by RFC7346. The change was to add Realm-Local scope to the multicast scope table in Section 2.6, and add the updating text to the same section.

- Added a reference to the IANA Multicast address registry in Section 2.6.1.

- Added instructions in IANA Considerations to update references in the IANA registries that currently point to RFC4291 to point to this document.

- Expanded Security Considerations Section to discuss privacy issues related to using stable interface identifiers to create IPv6

addresses, and reference solutions that mitigate these issues such as RFC7721, RFC4941, RFC7271.

- Add note to Section 5 section acknowledging the authors of the updating documents.

- Updates to resolve the open Errata on RFC4291. These are:

  Errata ID: 3480: Corrects the definition of Interface-Local multicast scope to also state that packets with interface-local scope received from another node must be discarded.

  Errata ID: 1627: Remove extraneous "of" in Section 2.7.

  Errata ID: 2702: This errata is marked rejected. No change is required.

  Errata ID: 2735: This errata is marked rejected. No change is required.

  Errata ID: 4406: This errata is marked rejected. No change is required.

  Errata ID: 2406: This errata is marked rejected. No change is required.

  Errata ID: 863: This errata is marked rejected. No change is required.

  Errata ID: 864: This errata is marked rejected. No change is required.

  Errata ID: 866: This errata is marked rejected. No change is required.

- Editorial changes.

### B.1. Change History Since RFC4291

NOTE TO RFC EDITOR: Please remove this subsection prior to RFC Publication

This section describes change history made in each Internet Draft that went into producing this version. The numbers identify the Internet-Draft version in which the change was made.

Working Group Internet Drafts

09) Added text to the last paragraph in Section 2.1 to clarify the differences on how subnets are hangled in IPv4 and IPv6, includes a reference to RFC5942 "The IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes".

09) Removed short paragraph about manual configuration in Section 2.4.1 that was added in the -08 version.

09) Revised "Changes since RFC4291" Section to have a summary of changes since RFC4291 and a separate subsection with a change history of each Internet Draft. This subsection will be removed when the RFC is published.

09) Editorial changes.

08) Added Note: to Section 2 that the term "prefix" is used in different contexts in IPv6: a prefix used by a routing protocol, a prefix used by a node to determine if another node is connected to the same link, and a prefix used to construct the complete address of a node.

08) Based on results of IETF last call and extensive w.g. list discussion, revised text to clarify that 64 bit Interface IDs are used except when the first three bits of the address are 000, or addresses are manually configured, or when defined by a standard track document. This text was moved from Section 2.4 and is now consolidated in Section 2.4.1 Also removed text in Section 2.4.4 relating to 64 bit Interface IDs.

08) Removed instruction to IANA fix error in Port Number assignment. IANA fixed the error on 4 March 2017.

08) Editorial changes.

07) Added text to Section 2.4 summarizing IPv6 unicast routing and referencing BCP198, citing RFC6164 as an example of longer prefixes, and that IIDs are required to be 64 bits long as described in RFC7421.

07) Based on review by Brian Haberman added reference to RFC5952 in Section 2.2.3, corrected case errors in Section 2.6.1, and added a reference to the IANA Multicast address registry in Section 2.6.1.

07) Corrected errors in Section 2.2.3 where the examples in 7. and 8. were reversed.

07) Editorial changes.

06) Editorial changes.

05) Expanded Security Considerations Section to discuss privacy issues related to using stable interface identifiers to create IPv6 addresses, and reference solutions that mitigate these issues such as RFC7721, RFC4941, RFC7271.

05) Added instructions in IANA Considerations to update references in the IANA registries that currently point to RFC4291 to point to this document.

05) Rename Section 2.4.7 to "Other Local Unicast Addresses" and rewrote the text to point to ULAs and say that Site-Local addresses were deprecated by RFC3879. The format of Site-Local was removed.

05) Added to Section 2.4.1 a reference to RFC7421 regarding the background on the 64 bit boundary in Interface Identifiers.

05) Editorial changes.

04) Added text and a pointer to the ULA specification in Section 2.4.7

04) Removed old IANA Considerations text, this was left from the baseline text from RFC4291 and should have been removed earlier.

04) Editorial changes.

03) Changes references in Section 2.4.1 that describes the details of forming IIDs to RFC7271 and RFC7721.

02) Remove changes made by RFC7371 because there isn't any known implementation experience.

01) Revised Section 2.4.1 on Interface Identifiers to reflect current approach, this included saying Modified EUI-64 identifiers not recommended and moved the text describing the format to Appendix A.

01) Editorial changes.

00) Working Group Draft.

00) Editorial changes.

Individual Internet Drafts

06) Incorporate the updates made by RFC7371. The changes were to the flag bits and their definitions in Section 2.6.

05) Incorporate the updates made by RFC7346. The change was to add Realm-Local scope to the multicast scope table in Section 2.6, and add the updating text to the same section.

04) Incorporate the updates made by RFC6052. The change was to add a text in Section 2.3 that points to the IANA registries that records the prefix defined in RFC6052 and a number of other special use prefixes.

03) Incorporate the updates made by RFC7136 to deprecate the U and G bits in Modified EUI-64 format Internet IDs.

03) Add note to the reference section acknowledging the authors of the updating documents.

03) Editorial changes.

02) Updates to resolve the open Errata on RFC4291. These are:

Errata ID: 3480: Corrects the definition of Interface-Local multicast scope to also state that packets with interface-local scope received from another node must be discarded.

Errata ID: 1627: Remove extraneous "of" in Section 2.7.

Errata ID: 2702: This errata is marked rejected. No change is required.

Errata ID: 2735: This errata is marked rejected. No change is required.

Errata ID: 4406: This errata is marked rejected. No change is required.

Errata ID: 2406: This errata is marked rejected. No change is required.

Errata ID: 863: This errata is marked rejected. No change is required.

Errata ID: 864: This errata is marked rejected. No change is required.

Errata ID: 866: This errata is marked rejected. No change is required.

02) Update references to current versions.

02) Editorial changes.

01) Incorporate the updates made by RFC5952 regarding the text format when outputting IPv6 addresses. A new section was added for this and addresses shown in this document were changed to lower case.

01) Revise this Section to document to show the changes from RFC4291.

01) Editorial changes.

00) Establish a baseline from RFC4291. The only intended changes are formatting (XML is slightly different from .nroff), differences between an RFC and Internet Draft, fixing a few ID Nits, and updates to the authors information. There should not be any content changes to the specification.

## Authors' Addresses

Robert M. Hinden
Check Point Software
959 Skyway Road
San Carlos, CA 94070
USA

Email: bob.hinden@gmail.com

Stephen E. Deering
Retired
Vancouver, British Columbia
Canada