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R. Hinden
Nokia
S. Deering
Cisco Systems
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IP Version 6 Addressing Architecture

Status of This Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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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 3513, "IP Version 6 Addressing Architecture".

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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 [IPV6]). 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There are no broadcast addresses in IPv6, their function being superseded by multicast addresses.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.

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 2.8 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.

2.2. 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
```

2.3. 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 [CIDR]. 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 number 2001:0DB8:0:CD30::/60

can be abbreviated as 2001:0DB8:0:CD30:123:4567:89AB:CDEF/60
```

2.4. 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	2.5.2
Loopback	00...1 (128 bits)	::1/128	2.5.3
Multicast	11111111	FF00::/8	2.7
Link-Local unicast	1111111010	FE80::/10	2.5.6
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 2.5.4. Some special-purpose subtypes of Global Unicast addresses that contain embedded IPv4 addresses (for the purposes of IPv4-IPv6 interoperation) are described in Section 2.5.5.

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.

2.5. Unicast Addresses

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

There are several types of unicast addresses in IPv6, in particular, Global Unicast, site-local unicast (deprecated, see Section 2.5.7), 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:

```
|                           128 bits                             |
+-----------------------------------------------------------------+
|                          node address                           |
+-----------------------------------------------------------------+
```

A slightly sophisticated host (but still rather simple) 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:

```
|          n bits               |           128-n bits            |
+-------------------------------+---------------------------------+
|       subnet prefix           |           interface ID          |
+-------------------------------+---------------------------------+
```

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.

2.5.1. 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. In some cases, an interface's identifier will be derived directly from that interface's link-layer address. The same interface identifier may be used on multiple interfaces on a single node, as long as they are attached to different subnets.

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 a local scope interface identifier and a Link-Local address may be created with a universal scope interface identifier.

For all unicast addresses, except those that start with the binary value 000, Interface IDs are required to be 64 bits long and to be constructed in Modified EUI-64 format.

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 available (e.g., serial links, tunnel end-points) or where global tokens are undesirable (e.g., temporary tokens for privacy [PRIV]).

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:

```
 0       0 0       1 1       2
|0       7 8       5 6       3|
+----+----+----+----+----+----+
|cccc|ccug|cccc|cccc|cccc|cccc|
+----+----+----+----+----+----+
```

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.

The use of the universal/local bit in the Modified EUI-64 format identifier is to allow development of future technology that can take advantage of interface identifiers with universal scope.

The details of forming interface identifiers are defined in the appropriate "IPv6 over <link>" specification, such as "IPv6 over Ethernet" [ETHER], and "IPv6 over FDDI" [FDDI].

2.5.2. 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.

2.5.3. 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.

2.5.4. Global Unicast Addresses

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

```
|         n bits         |   m bits  |       128-n-m bits         |
+------------------------+-----------+----------------------------+
| global routing prefix  | subnet ID |       interface ID         |
+------------------------+-----------+----------------------------+
```

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 2.5.1.

All Global Unicast addresses other than those that start with binary 000 have a 64-bit interface ID field (i.e., n + m = 64), formatted as described in Section 2.5.1. Global Unicast addresses that start with binary 000 have no such constraint on the size or structure of the interface ID field.

Examples of Global Unicast addresses that start with binary 000 are the IPv6 address with embedded IPv4 addresses described in Section 2.5.5. 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 [GLOBAL].

2.5.5. 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".

2.5.5.1. 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:

```
|                80 bits               | 16 |      32 bits        |
+--------------------------------------+--------------------------+
|0000..............................0000|0000|    IPv4 address     |
+--------------------------------------+----+---------------------+
```

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.

2.5.5.2. 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:

```
|                80 bits               | 16 |      32 bits        |
+--------------------------------------+--------------------------+
|0000..............................0000|FFFF|    IPv4 address     |
+--------------------------------------+----+---------------------+
```

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

2.5.6. Link-Local IPv6 Unicast Addresses

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

```
|   10     |
|  bits    |         54 bits         |          64 bits           |
+----------+-------------------------+----------------------------+
|1111111010|           0             |       interface ID         |
+----------+-------------------------+----------------------------+
```

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.

2.5.7. Site-Local IPv6 Unicast Addresses

Site-Local addresses were originally designed to be used for addressing inside of a site without the need for a global prefix. Site-local addresses are now deprecated as defined in [SLDEP].

Site-Local addresses have the following format:

```
|   10     |
|  bits    |         54 bits         |         64 bits            |
+----------+-------------------------+----------------------------+
|1111111011|        subnet ID        |       interface ID         |
+----------+-------------------------+----------------------------+
```

The special behavior of this prefix 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.

2.6. 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.

2.6.1. Required Anycast Address

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

```
|                         n bits                 |   128-n bits   |
+------------------------------------------------+----------------+
|                   subnet prefix                | 00000000000000 |
+------------------------------------------------+----------------+
```

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.

2.7. 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:

```
|   8    |  4 |  4 |                  112 bits                   |
+------ -+----+----+---------------------------------------------+
|11111111|flgs|scop|                  group ID                   |
+--------+----+----+---------------------------------------------+
```

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

```
                                 +-+-+-+-+
flgs is a set of 4 flags:        |0|R|P|T|
                                 +-+-+-+-+
```

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  reserved
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.

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

Admin-Local scope is the smallest scope that must be administratively configured, i.e., not automatically derived from physical connectivity or other, non-multicast-related configuration.

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 of 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.

2.7.1. 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).

2.8. A Node's Required Addresses

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

- o Its required Link-Local address for each interface.
- o Any additional Unicast and Anycast addresses that have been configured for the node's interfaces (manually or automatically).
- o The loopback address.
- o The All-Nodes multicast addresses defined in Section 2.7.1.
- o The Solicited-Node multicast address for each of its unicast and anycast addresses.
- o 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:

- o The Subnet-Router Anycast addresses for all interfaces for which it is configured to act as a router.
- o All other Anycast addresses with which the router has been configured.
- o The All-Routers multicast addresses defined in Section 2.7.1.

3. Security Considerations

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

4. IANA Considerations

The "IPv4-Compatible IPv6 address" is deprecated by this document. The IANA should continue to list the address block containing these addresses at http://www.iana.org/assignments/ipv6-address-space as "Reserved by IETF" and not reassign it for any other purpose. For example:

```
0000::/8        Reserved by IETF        [RFC3513]      [1]
```

The IANA has added the following note and link to this address block.

[5] 0000::/96 was previously defined as the "IPv4-Compatible IPv6 address" prefix. This definition has been deprecated by RFC 4291.

The IANA has updated the references for the IPv6 Address Architecture in the IANA registries accordingly.

5. Acknowledgements

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6. References

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Appendix A: 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|
+----------------+----------------+----------------+----------------+
|cccccc0gcccccccc|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|
+----------------+----------------+----------------+----------------+
|cccccc1gcccccccc|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|
+----------------+----------------+----------------+
|cccccc0gcccccccc|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: [EUI-64] 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 from RFC 3513

The following changes were made from RFC 3513, "IP Version 6 Addressing Architecture":

o The restrictions on using IPv6 anycast addresses were removed because there is now sufficient experience with the use of anycast addresses, the issues are not specific to IPv6, and the GROW working group is working in this area.

o Deprecated the Site-Local unicast prefix. Changes include the following:

   - Removed Site-Local from special list of prefixes in Section 2.4.

   - Split section titled "Local-use IPv6 Unicast Addresses" into two sections, "Link-Local IPv6 Unicast Addresses" and "Site-Local IPv6 Unicast Addresses".

   - Added text to new section describing Site-Local deprecation.

- o Changes to resolve issues raised in IAB response to Robert Elz appeal. Changes include the following:

   - Added clarification to Section 2.5 that nodes should make no assumptions about the structure of an IPv6 address.

   - Changed the text in Section 2.5.1 and Appendix A to refer to the Modified EUI-64 format interface identifiers with the "u" bit set to one (1) as universal.

   - Added clarification to Section 2.5.1 that IPv6 nodes are not required to validate that interface identifiers created in Modified EUI-64 format with the "u" bit set to one are unique.

- o Changed the reference indicated in Section 2.5.4 "Global Unicast Addresses" to RFC 3587.

- o Removed mention of NSAP addresses in examples.

- o Clarified that the "x" in the textual representation can be one to four digits.

- o Deprecated the "IPv6 Compatible Address" because it is not being used in the IPv6 transition mechanisms.

- o Added the "R" and "P" flags to Section 2.7 on multicast addresses, and pointers to the documents that define them.

- o Editorial changes.

Authors' Addresses

Robert M. Hinden
Nokia
313 Fairchild Drive
Mountain View, CA 94043
USA

Phone: +1 650 625-2004
EMail: bob.hinden@nokia.com

Stephen E. Deering
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA

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