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Unique Local IPv6 Unicast Addresses

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Status of this Memo

Abstract

This document defines an unicast address format that is globally unique and is intended for local communications, usually inside of a site. They are not expected to be routable on the global Internet given current routing technology.

1.0 Introduction

This document defines an IPv6 unicast address format that is globally unique and is intended for local communications [IPV6]. These addresses are called Unique Local IPv6 Unicast Addresses and are abbreviated in this document as Local IPv6 addresses. They are not expected to be routable on the global Internet given current routing technology. They are routable inside of a more limited area such as a site. They may also be routed between a limited set of sites.

Local IPv6 unicast addresses have the following characteristics:

- Globally unique prefix.
- Well known prefix to allow for easy filtering at site boundaries.
- Allows sites to be combined or privately interconnected without creating any address conflicts or require renumbering of interfaces using these prefixes.
- Internet Service Provider independent and can be used for communications inside of a site without having any permanent or intermittent Internet connectivity.
- If accidentally leaked outside of a site via routing or DNS, there is no conflict with any other addresses.
- In practice, applications may treat these address like global scoped addresses.

This document defines the format of Local IPv6 addresses, how to allocate them, and usage considerations including routing, site border routers, DNS, application support, VPN usage, and guidelines for how to use for local communication inside a site.

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

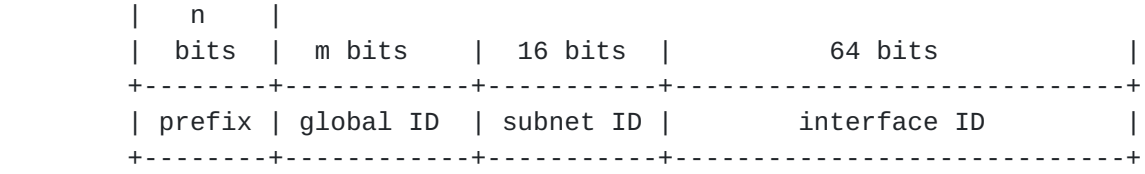
2.0 Acknowledgments

The underlying idea of creating Local IPv6 addresses described in this document been proposed a number of times by a variety of people. The authors of this draft do not claim exclusive credit. Credit goes to Brian Carpenter, Christian Huitema, Aidan Williams, Andrew White, Charlie Perkins, and many others. The authors would also like to thank Brian Carpenter, Charlie Perkins, Harald Alvestrand, Keith Moore, Margaret Wasserman, Shannon Behrens, Alan Beard, Hans Kruse, and Geoff Huston for their comments and suggestions on this document.

3.0 Local IPv6 Unicast Addresses

3.1 Format

The Local IPv6 addresses are created using a centrally allocated global ID. They have the following format:



Where:

prefix	prefix to identify Local IPv6 unicast addresses.
global ID	global identifier used to create a globally unique prefix. See section 3.2 for additional information.
subnet ID	16-bit subnet ID is an identifier of a subnet within the site.
interface ID	64-bit IID as defined in [ADDARCH].

There are a range of choices available when choosing the size of the prefix and Global ID field length. There is a direct tradeoff between having a Global ID field large enough to support foreseeable future growth and not using too much of the IPv6 address space needlessly. A reasonable way of evaluating a specific field length is to compare it to a projected 2050 world population of 9.3 billion [POPUL] to compare the number of resulting /48 prefixes per person. A range of prefix choices is shown in the following table:

Prefix	Global ID Length	Number /48 Prefixes	Prefixes per Person	% of IPv6 Address Space
/11	37	137,438,953,472	15	0.049%
/10	38	274,877,906,944	30	0.098%
/9	39	549,755,813,888	59	0.195%
/8	40	1,099,511,627,776	118	0.391%
/7	41	2,199,023,255,552	236	0.781%
/6	42	4,398,046,511,104	473	1.563%

A very high utilization ratio of these allocations can be assumed because no internal structure is required in the field nor is there any reason to be able to aggregate the prefixes.

The authors believes that a /7 prefix resulting in a 41 bit Global ID is a good choice. It provides for a large number of assignments (i.e., 2.2 trillion) and at the same time uses less than .8% of the total IPv6 address space. It is unlikely that this space will be exhausted. If more than this was needed, then additional IPv6 address space could be allocated for this purpose.

For the rest of this document the FC00::/7 prefix and a 41-bit Global ID is used.

3.2 Global ID

The allocation of global IDs should be pseudo-random [RANDOM]. They should not be assigned sequentially or with well known numbers. This to ensure that there is not any relationship between allocations and to help clarify that these prefixes are not intended to be routed globally. Specifically, these prefixes are designed to not aggregate.

There are two ways to allocate Global IDs. These are centrally by a allocation authority and locally by the site. The Global ID is split into two parts for each type of allocation. The prefixes for each type are:

```
FC00::/8    Centrally assigned
FD00::/8    Locally assigned
```

Each results in a 40-bit space to allocate.

Two assignment methods are included because they have different properties. The centrally assigned global IDs have a much higher probability that they are unique and the assignments can be escrowed to resolve any disputes regarding duplicate assignments. The local assignments are free and do not need any central coordination or assignment, but have a lower (but still adequate) probability of being unique. It is expected that large managed sites will prefer central assignments and small or disconnected sites will prefer local assignments. It is recommended that sites planning to use Local IPv6 addresses for extensive inter-site communication use a centrally assigned prefix as the possibility of any conflicts is lower. Sites are free to choose either approach.

3.2.1 Centrally Assigned Global IDs

Centrally assigned global IDs MUST be generated with a pseudo-random algorithm consistent with [RANDOM]. They should not be assigned

sequentially or by locality. This to ensure that there is not any relationship between allocations and to help clarify that these prefixes are not intended to be routed globally. Specifically, these prefixes are designed to not aggregate.

Global IDs should be assigned centrally by a single allocation authority because they are pseudo-random and without any structure. This is easiest to accomplish if there is a single source of the assignments.

The requirements for centrally assigned global ID allocations are:

- Available to anyone in an unbiased manner.
- Permanent with no periodic fees.
- One time non-refundable allocation fee in the order of 10 Euros (at January 1, 2004 exchange rates) per allocation.
- The ownership of each individual allocation should be private, but should be escrowed.

The allocation authority should permit allocations to be obtained without having any sort of internet connectivity. For example in addition to web based registration they should support some methods like telephone, postal mail, fax, telex, etc. They should also accept a variety of payment methods and currencies.

The reason for the one time 10 Euro charge for each prefix is to provide a barrier to any hoarding of the these allocations but at the same time keep the cost low enough to not create a barrier to anyone needing one. The charge is one time to eliminate the need for an ongoing relationship with the allocation authority. The charge is non-refundable in order to keep overhead low.

The ownership of the allocations is not needed to be public since the resulting addresses are intended to be used for local communication. It is escrowed to insure there are no duplicate allocations and in case it is needed in the future (e.g., to resolve duplicate allocation disputes).

Note, there are many possible ways of of creating an allocation authority. It is important to keep in mind when reviewing alternatives that the goal is to pick one that can do the job. It doesn't have to be perfect, only good enough to do the job at hand.

This document directs the IANA, in section 13.0, to delegate the FC00::/8 prefix to an allocation authority to allocate centrally assigned /48 prefixes consistent with the requirements defined in this section.

3.2.2 Locally Assigned Global IDs

Global IDs can also be generated locally by an individual site. This makes it easy to get a prefix with out the need to contact an assignment authority or internet service provider. There is not as high a degree of assurance that the prefix will not conflict with another locally generated prefix, but the likelihood of conflict is small. Sites that are not comfortable with this degree of uncertainty should use a centrally assigned global ID.

Locally assigned global IDs MUST be generated with a pseudo-random algorithm consistent with [RANDOM]. Section 3.2.3 describes a suggested algorithm. It is important to insure a reasonable likelihood uniqueness that all sites generating a Global IDs use a functionally similar algorithm.

3.2.3 Sample Code for Pseudo-Random Global ID Algorithm

The algorithm described below is intended to be used for centrally and locally assigned Global IDs. In each case the resulting global ID will be used in the appropriate prefix as defined in section 3.2.

1) Obtain the current time of day in 64-bit NTP format [NTP].
2) Obtain an EUI-64 identifier from the system running this algorithm. If an EUI-64 does not exist, one can be created from a 48-bit MAC address as specified in [ADDARCH]. If an EUI-64 cannot be obtained or created, a suitably unique identifier, local to the node, should be used (e.g. system serial number).
3) Concatenate the time of day with the system-specific identifier creating a key.
4) Compute an MD5 digest on the key as specified in [MD5DIG].
5) Use the least significant 40 bits as the Global ID.

This algorithm will result in a global ID that is reasonably unique and can be used as a Global ID.

3.2.4 Analysis of the Uniqueness of Global IDs

The selection of a pseudo random global ID is similar to the selection of an SSRC identifier in RTP/RTCP defined in section 8.1 of [RTP]. This analysis is adapted from that document.

Since the global ID is chosen randomly, it is possible that two or more networks that have an inter-network connection using globally-unique local addresses will chose the same global ID. The probability of collision can be approximated based on the number of

inter-connections using globally-unique local addresses and the length of the ID (40 bits). The formula

```
P = 1 - exp(-N**2 / 2**(L+1))
```

approximates the probability of collision (where N is the number inter-connections and L is the length of the global ID).

The following table shows the probability of a collision for a range of inter-connections using a 40 bit global ID field.

Inter-connections	Probability of Collision
2	1.81**-12
10	4.54**-11
100	4.54**-09
1000	4.54**-07
10000	4.54**-05

Based on this analysis the uniqueness of locally generated global IDs is adequate for sites planning a small to moderate amount inter-site communication using locally generated global IDs. Sites planning more extensive inter-site communication should consider using the centrally assigned global ID.

3.3 Scope Definition

By default, the scope of these addresses is global. That is, they are not limited by ambiguity like the site-local addresses defined in [ADDARCH]. Rather, these prefixes are globally unique, and as such, their applicability exceeds the current site-local addresses. Their limitation is in the routability of the prefixes, which is limited to a site and any explicit routing agreements with other sites to propagate them. Also, unlike site-locals, these prefixes can overlap each other.

4.0 Routing

Local IPv6 addresses are designed to be routed inside of a site in the same manner as other types of unicast addresses. They can be carried in any IPv6 routing protocol without any change.

It is expected that they would share the same subnet IDs with provider based global unicast addresses if they were being used concurrently [GLOBAL].

Any routing protocol that is used between sites MUST filter out any incoming or outgoing Local IPv6 unicast routes. The exception to this is if specific /48 IPv6 local unicast routes have been configured to allow for inter-site communication.

If BGP is being used at the site border with an ISP, filters MUST be installed by default in the BGP configuration to keep any Local IPv6 address prefixes from being advertised outside of the site or for these prefixes to be learned from another site. The exception to this is if there are specific /48 routes created for one or more Local IPv6 prefixes.

5.0 Renumbering and Site Merging

The use of Local IPv6 addresses in a site results in making communication using these addresses independent of renumbering a site's provider based global addresses.

When merging multiple sites none of the addresses created with these prefixes need to be renumbered because all of the addresses are unique. Routes for each specific prefix would have to be configured to allow routing to work correctly between the formerly separate sites.

6.0 Site Border Router and Firewall Packet Filtering

While no serious harm will be done if packets with these addresses are sent outside of a site via a default route, it is recommended that they be filtered to keep any packets with Local IPv6 destination addresses from leaking outside of the site and to keep any site prefixes from being advertised outside of their site.

Site border routers SHOULD install a black hole route for the Local IPv6 prefix FC00::/7. This will insure that packets with Local IPv6 destination addresses will not be forwarded outside of the site via a default route.

Site border routers and firewalls SHOULD NOT forward any packets with Local IPv6 source or destination addresses outside of the site unless they have been explicitly configured with routing information about other Local IPv6 prefixes. The default behavior of these devices SHOULD be to filter them.

Additionally, domain border routers connecting autonomous systems throughout the Internet SHOULD obey these recommendations for site border routers.

7.0 DNS Issues

AAAA records for Local IPv6 addresses SHOULD NOT be installed in the global DNS. They may be installed in a naming system local to the site or kept separate from the global DNS using techniques such as "two-faced" DNS.

If Local IPv6 address are configured in the global DNS, no harm is done because they are unique and will not create any confusion. They may not be reachable, but this is a property that is common to all types of global IPv6 unicast addresses.

For future study names with Local IPv6 addresses may be resolved inside of the site using dynamic naming systems such as Multicast DNS.

8.0 Application and Higher Level Protocol Issues

Application and other higher level protocols can treat Local IPv6 addresses in the same manner as other types of global unicast addresses. No special handling is required. This type of addresses may not be reachable, but that is no different from other types of IPv6 global unicast addresses. Applications need to be able to handle multiple addresses that may or may not be reachable any point in time. In most cases this complexity should be hidden in APIs.

From a host's perspective this difference shows up as different reachability than global unicast and could be handled by default that way. In some cases it is better for nodes and applications to treat them differently from global unicast addresses. A starting point might be to give them preference over global unicast, but fall back to global unicast if a particular destination is found to be unreachable. Much of this behavior can be controlled by how they are allocated to nodes and put into the DNS. However it is useful if a host can have both types of addresses and use them appropriately.

Note that the address selection mechanisms of [ADDSEL], and in particular the policy override mechanism replacing default address selection, are expected to be used on a site where Local IPv6 addresses are configured.

9.0 Use of Local IPv6 Addresses for Local Communications

Local IPv6 addresses, like global scope unicast addresses, are only assigned to nodes if their use has been enabled (via IPv6 address autoconfiguration [ADDAUTO], DHCPv6 [DHCP6], or manually) and

configured in the DNS. They are not created automatically the way that IPv6 link-local addresses are and will not appear or be used unless they are purposely configured.

In order for hosts to autoconfigure Local IPv6 addresses, routers have to be configured to advertise Local IPv6 /64 prefixes in router advertisements. Likewise, a DHCPv6 server must have been configured to assign them. In order for a node to learn the Local IPv6 address of another node, the Local IPv6 address must have been installed in the DNS. For these reasons, it is straight forward to control their usage in a site.

To limit the use of Local IPv6 addresses the following guidelines apply:

- Nodes that are to only be reachable inside of a site: The local DNS should be configured to only include the Local IPv6 addresses of these nodes. Nodes with only Local IPv6 addresses must not be installed in the global DNS.

- Nodes that are to be limited to only communicate with other nodes in the site: These nodes should be set to only autoconfigure Local IPv6 addresses via [ADDAUTO] or to only receive Local IPv6 addresses via [DHCP6]. Note: For the case where both global and Local IPv6 prefixes are being advertised on a subnet, this will require a switch in the devices to only autoconfigure Local IPv6 addresses.

- Nodes that are to be reachable from inside of the site and from outside of the site: The DNS should be configured to include the global addresses of these nodes. The local DNS may be configured to also include the Local IPv6 addresses of these nodes.

- Nodes that can communicate with other nodes inside of the site and outside of the site: These nodes should autoconfigure global addresses via [ADDAUTO] or receive global address via [DHCP6]. They may also obtain Local IPv6 addresses via the same mechanisms.

10.0 Use of Local IPv6 Addresses with VPNs

Local IPv6 addresses can be used for inter-site Virtual Private Networks (VPN) if appropriate routes are set up. Because the addresses are unique these VPNs will work reliably and without the need for translation. They have the additional property that they will continue to work if the individual sites are renumbered or

merged.

11.0 Advantages and Disadvantages

11.1 Advantages

This approach has the following advantages:

- Provides Local IPv6 prefixes that can be used independently of any provider based IPv6 unicast address allocations. This is useful for sites not always connected to the Internet or sites that wish to have a distinct prefix that can be used to localize traffic inside of the site.
- Applications can treat these addresses in an identical manner as any other type of global IPv6 unicast addresses.
- Sites can be merged without any renumbering of the Local IPv6 addresses.
- Sites can change their provider based IPv6 unicast address without disrupting any communication using Local IPv6 addresses.
- Well known prefix that allows for easy filtering at site boundary.
- Can be used for inter-site VPNs.
- If accidently leaked outside of a site via routing or DNS, there is no conflict with any other addresses.

11.2 Disadvantages

This approach has the following disadvantages:

- Not possible to route Local IPv6 prefixes on the global Internet with current routing technology. Consequentially, it is necessary to have the default behavior of site border routers to filter these addresses.
- There is a very low probability of non-unique locally assigned global IDs being generated by the algorithm in section 3.2.3. This risk can be ignored for all practical purposes, but it leads to a theoretical risk of clashing address prefixes.

12.0 Security Considerations

Local IPv6 addresses do not provide any inherent security to the nodes that use them. They may be used with filters at site boundaries to keep Local IPv6 traffic inside of the site, but this is no more or less secure than filtering any other type of global IPv6 unicast addresses.

Local IPv6 addresses do allow for address-based security mechanisms, including IPSEC, across end to end VPN connections.

13.0 IANA Considerations

The IANA is instructed to allocate the FC00::/7 prefix for Unique Local IPv6 unicast addresses.

The IANA is instructed to delegate, within a reasonable time, the prefix FC00::/8 to an allocation authority for Unique Local IPv6 Unicast prefixes of length /48. This allocation authority shall comply with the requirements described in section 3.2 of this document, including in particular the charging of a modest one-time fee, with any profit being used for the public good in connection with the Internet.

14.0 References

14.1 Normative References

[ADDARCH] Hinden, R., S. Deering, S., "IP Version 6 Addressing Architecture", RFC 3515, April 2003.

[GLOBAL] Hinden, R., S. Deering, E. Nordmark, "IPv6 Global Unicast Address Format", RFC 3587, August 2003.

[IPV6] Deering, S., R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, December 1998.

[MD5DIG] Rivest, R., "The MD5 Message-Digest Algorithm", RFC 1321, April 1992.

[NTP] Mills, David L., "Network Time Protocol (Version 3) Specification, Implementation and Analysis", RFC 1305, March 1992.

[POPUL] Population Reference Bureau, "World Population Data Sheet of the Population Reference Bureau 2002", August 2002.

[RANDOM] Eastlake, D. 3rd, S. Crocker, J. Schiller, "Randomness Recommendations for Security", RFC 1750, December 1994.

[RFC2026] Bradner, S., "The Internet Standards Process -- Revision 3", RFC 2026, BCP00009, October 1996.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", RFC 2119, BCP14, March 1997.

14.2 Informative References

[ADDAUTO] Thomson, S., T. Narten, "IPv6 Stateless Address Autoconfiguration", RFC 2462, December 1998.

[ADDSEL] Draves, R., "Default Address Selection for Internet Protocol version 6 (IPv6)", RFC 3484, February 2003.

[DHCP6] Droms, R., et. al., "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)", RFC3315, July 2003.

[RTP] Schulzrinne, H., S. Casner, R. Frederick, V. Jacobson, "RTP: A Transport Protocol for Real-Time Applications" RFC1889, January 1996.

15.0 Authors' Addresses

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16.0 Change Log

Draft <draft-ietf-ipv6-unique-local-addr-01.txt>

- Removed example of PIR as an example of an allocation authority and clarified the text that the IANA should delegate the centrally assigned prefix to an allocation authority.
- Changed sample code for generating pseudo random Global IDs to not require any human input. Changes from using birthday to unique token (e.g., EUI-64, serial number, etc.) available on machine running the algorithm.
- Added a new section analyzing the uniqueness properties of the pseudo random number algorithm.
- Added text to recommend that centrally assigned local addresses be used for site planning extensive inter-site communication.
- Clarified that domain border routers should follow site border router recommendations.
- Clarified that AAAA DNS records should not be installed in the global DNS.
- Several editorial changes.

Draft <draft-ietf-ipv6-unique-local-addr-00.txt>

- Changed file name to become an IPv6 w.g. group document.
- Clarified language in Routing and Firewall sections.
- Several editorial changes.

Draft <draft-hinden-ipv6-global-local-addr-02.txt>

- Changed title and name of addresses defined in this document to "Unique Local IPv6 Unicast Addresses" with abbreviation of "Local IPv6 addresses".
- Several editorial changes.

Draft <draft-hinden-ipv6-global-local-addr-01.txt>

- Added section on scope definition and updated application requirement section.
- Clarified that, by default, the scope of these addresses is global.
- Renumbered sections and general text improvements
- Removed reserved global ID values
- Added pseudo code for local allocation submitted by Brian Haberman and added him as an author.
- Split Global ID values into centrally assigned and local assignments and added text to describe local assignments

Draft <draft-hinden-ipv6-global-local-addr-00.txt>

- Initial Draft