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IPv6 Node Requirements RFC 4294-bis
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Abstract

This document defines requirements for IPv6 nodes. It is expected that IPv6 will be deployed in a wide range of devices and situations. Specifying the requirements for IPv6 nodes allows IPv6 to function well and interoperate in a large number of situations and deployments.

Status of this Memo

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1. Requirements Language

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

2. Introduction

The goal of this document is to define the common functionality required from both IPv6 hosts and routers. Many IPv6 nodes will implement optional or additional features, but this document collects and summarizes requirements from other published Standards Track documents in one place.

This document tries to avoid discussion of protocol details, and references RFCs for this purpose. This document is intended to be an Applicability Statement and provide guidance as to which IPv6 specifications should be implemented in the general case. This document does not update any individual protocol document RFCs.

Although the document points to different specifications, it should be noted that in most cases, the granularity of requirements are smaller than a single specification, as many specifications define multiple, independent pieces, some of which may not be mandatory.

As it is not always possible for an implementer to know the exact usage of IPv6 in a node, an overriding requirement for IPv6 nodes is that they should adhere to Jon Postel's Robustness Principle:

Be conservative in what you do, be liberal in what you accept from others [RFC0793].

2.1. Scope of This Document

IPv6 covers many specifications. It is intended that IPv6 will be deployed in many different situations and environments. Therefore, it is important to develop the requirements for IPv6 nodes to ensure interoperability.

This document assumes that all IPv6 nodes meet the minimum requirements specified here.

2.2. Description of IPv6 Nodes

From the Internet Protocol, Version 6 (IPv6) Specification [RFC2460], we have the following definitions:

Description of an IPv6 Node

- a device that implements IPv6.

Description of an IPv6 router

- a node that forwards IPv6 packets not explicitly addressed to itself.

Description of an IPv6 Host

- any node that is not a router.

3. Abbreviations Used in This Document

ATM Asynchronous Transfer Mode
AH Authentication Header
DAD Duplicate Address Detection
ESP Encapsulating Security Payload
ICMP Internet Control Message Protocol
IKE Internet Key Exchange
MIB Management Information Base
MLD Multicast Listener Discovery
MTU Maximum Transfer Unit
NA Neighbor Advertisement
NBMA Non-Broadcast Multiple Access
ND Neighbor Discovery
NS Neighbor Solicitation
NUD Neighbor Unreachability Detection
PPP Point-to-Point Protocol
PVC Permanent Virtual Circuit
SVC Switched Virtual Circuit

4. Sub-IP Layer

An IPv6 node must include support for one or more IPv6 link-layer specifications. Which link-layer specifications are included will depend upon what link-layers are supported by the hardware available on the system. It is possible for a conformant IPv6 node to support IPv6 on some of its interfaces and not on others.

As IPv6 is run over new layer 2 technologies, it is expected that new specifications will be issued. In the following, we list some of the link-layers for which an IPv6 specification has been developed. It is provided for information purposes only, and may not be complete.

- Transmission of IPv6 Packets over Ethernet Networks [RFC2464]
- IPv6 over ATM Networks [RFC2492]
- Transmission of IPv6 Packets over Frame Relay Networks Specification [RFC2590]
- Transmission of IPv6 Packets over IEEE 1394 Networks [RFC3146]
- Transmission of IPv6, IPv4, and Address Resolution Protocol (ARP) Packets over Fibre Channel [RFC4338]
- Transmission of IPv6 Packets over IEEE 802.15.4 Networks [RFC4944]
- Transmission of IPv6 via the IPv6 Convergence Sublayer over IEEE 802.16 Networks [RFC5121]
- IP version 6 over PPP [RFC5072]

In addition to traditional physical link-layers, it is also possible to tunnel IPv6 over other protocols. Examples include:

- Teredo: Tunneling IPv6 over UDP through Network Address Translations (NATs) [RFC4380]
- Transmission of IPv6 over IPv4 Domains without Explicit Tunnels [RFC2529]

5. IP Layer

5.1. Internet Protocol Version 6 - RFC 2460

The Internet Protocol Version 6 is specified in [RFC2460]. This specification MUST be supported.

Unrecognized options in Hop-by-Hop Options or Destination Options extensions MUST be processed as described in RFC 2460.

The node MUST follow the packet transmission rules in RFC 2460.

Nodes MUST always be able to send, receive, and process fragment headers. All conformant IPv6 implementations MUST be capable of sending and receiving IPv6 packets; the forwarding functionality MAY be supported.

RFC 2460 specifies extension headers and the processing for these headers.

A full implementation of IPv6 includes implementation of the following extension headers: Hop-by-Hop Options, Routing (Type 0), Fragment, Destination Options, Authentication and Encapsulating Security Payload [RFC2460].

An IPv6 node MUST be able to process these headers. An exception is Routing Header type 0 (RH0) which was deprecated by [RFC5095] due to

security concerns, and which MUST be treated as an unrecognized routing type.

5.2. Neighbor Discovery for IPv6 - RFC 4861

Neighbor Discovery SHOULD be supported. [RFC4861] states:

> Unless specified otherwise (in a document that covers operating IP over a particular link type) this document applies to all link types. However, because ND uses link-layer multicast for some of its services, it is possible that on some link types (e.g., NBMA links) alternative protocols or mechanisms to implement those services will be specified (in the appropriate document covering the operation of IP over a particular link type). The services described in this document that are not directly dependent on multicast, such as Redirects, Next-hop determination, Neighbor Unreachability Detection, etc., are expected to be provided as specified in this document. The details of how one uses ND on NBMA links is an area for further study.

Some detailed analysis of Neighbor Discovery follows:

Router Discovery is how hosts locate routers that reside on an attached link. Router Discovery MUST be supported for implementations.

Prefix Discovery is how hosts discover the set of address prefixes that define which destinations are on-link for an attached link. Prefix discovery MUST be supported for implementations. Neighbor Unreachability Detection (NUD) MUST be supported for all paths between hosts and neighboring nodes. It is not required for paths between routers. However, when a node receives a unicast Neighbor Solicitation (NS) message (that may be a NUD's NS), the node MUST respond to it (i.e., send a unicast Neighbor Advertisement).

Duplicate Address Detection MUST be supported on all links supporting link-layer multicast (RFC 4862, Section 5.4, specifies DAD MUST take place on all unicast addresses).

A host implementation MUST support sending Router Solicitations.

Receiving and processing Router Advertisements MUST be supported for host implementations. The ability to understand specific Router Advertisement options is dependent on supporting the specification where the RA is specified.

Sending and Receiving Neighbor Solicitation (NS) and Neighbor Advertisement (NA) MUST be supported. NS and NA messages are

required for Duplicate Address Detection (DAD).

Redirect functionality SHOULD be supported. If the node is a router, Redirect functionality MUST be supported.

5.3. SEcure Neighbor Discovery (SEND) - RFC 3971

SEND [RFC3971] and Cryptographically Generated Address (CGA) [RFC3972] provide a way to secure the message exchanges of Neighbor Discovery. SEND is a new technology, in that it has no IPv4 counterpart but it has significant potential to address certain classes of spoofing attacks. While there have been some implementations of SEND, there has been only limited deployment experience to date in using the technology. In addition, the IETF working group Cga & Send maIntenance (csi) is currently working on additional extensions intended to make SEND more attractive for deployment.

At this time, SEND is considered optional and IPv6 nodes MAY provide SEND functionality.

5.4. IPv6 Router Advertisement Flags Option - RFC 5175

Router Advertisements include an 8-bit field of single-bit Router Advertisement flags. The Router Advertisement Flags Option extends the number of available flag bits by 48 bits. At the time of this writing, 6 of the original 8 bit flags have been assigned, while 2 remain available for future assignment. No flags have been defined that make use of the new option, and thus strictly speaking, there is no requirement to implement the option today. However, implementations that are able to pass unrecognized options to a higher level entity that may be able to understand them (e.g., a user-level process using a "raw socket" facility), MAY take steps to handle the option in anticipation of a future usage.

5.5. Path MTU Discovery and Packet Size

5.5.1. Path MTU Discovery - RFC 1981

From [RFC2460]:

> It is strongly recommended that IPv6 nodes implement Path MTU Discovery [RFC1981], in order to discover and take advantage of path MTUs greater than 1280 octets. However, a minimal IPv6 implementation (e.g., in a boot ROM) may simply restrict itself to sending packets no larger than 1280 octets, and omit implementation of Path MTU Discovery.

The rules in RFC 2460 MUST be followed for packet fragmentation and reassembly.

5.6. IPv6 Jumbograms - RFC 2675

IPv6 Jumbograms [RFC2675] MAY be supported.

5.7. ICMP for the Internet Protocol Version 6 (IPv6) - RFC 4443

ICMPv6 [RFC4443] MUST be supported.

5.8. Addressing

5.8.1. IP Version 6 Addressing Architecture - RFC 4291

The IPv6 Addressing Architecture [RFC4291] MUST be supported.

5.8.2. IPv6 Stateless Address Autoconfiguration - RFC 4862

IPv6 Stateless Address Autoconfiguration is defined in [RFC4862]. This specification MUST be supported for nodes that are hosts. Static address can be supported as well.

Nodes that are routers MUST be able to generate link local addresses as described in RFC 4862 [RFC4862].

From 4862:

> The autoconfiguration process specified in this document applies only to hosts and not routers. Since host autoconfiguration uses information advertised by routers, routers will need to be configured by some other means. However, it is expected that routers will generate link-local addresses using the mechanism described in this document. In addition, routers are expected to successfully pass the Duplicate Address Detection procedure described in this document on all addresses prior to assigning them to an interface.

Duplicate Address Detection (DAD) MUST be supported.

5.8.3. Privacy Extensions for Address Configuration in IPv6 - RFC 4941

Privacy Extensions for Stateless Address Autoconfiguration [RFC4941] addresses a specific problem involving a client device whose user is concerned about its activity or location being tracked. The problem arises both for a static client and for one that regularly changes its point of attachment to the Internet. When using Stateless Address Autoconfiguration [RFC4862], the Interface Identifier portion

of formed addresses stays constant and is globally unique. Thus, although a node's global IPv6 address will change if it changes its point of attachment, the Interface Identifier portion of those addresses remain the same, making it possible for servers to track the location of an individual device as it moves around, or its pattern of activity if it remains in one place. This may raise privacy concerns as described in [RFC4862].

In such situations, RFC4941 SHOULD be implemented. In other cases, such as with dedicated servers in a data center, RFC4941 provides limited or no benefit.

5.8.4. Default Address Selection for IPv6 - RFC 3484

The rules specified in the Default Address Selection for IPv6 [RFC3484] document MUST be implemented. It is expected that IPv6 nodes will need to deal with multiple addresses.

5.8.5. Stateful Address Autoconfiguration

Stateful Address Autoconfiguration MAY be supported. DHCPv6 [RFC3315] is the standard stateful address configuration protocol; see Section 6.2 for DHCPv6 support.

Nodes which do not support Stateful Address Autoconfiguration may be unable to obtain any IPv6 addresses, aside from link-local addresses, when it receives a router advertisement with the 'M' flag (Managed address configuration) set and that contains no prefixes advertised for Stateless Address Autoconfiguration (see Section 4.5.2). Additionally, such nodes will be unable to obtain other configuration information, such as the addresses of DNS servers when it is connected to a link over which the node receives a router advertisement in which the 'O' flag (Other stateful configuration) is set.

5.9. Multicast Listener Discovery (MLD) for IPv6 - RFC 2710

Nodes that need to join multicast groups MUST support MLDv1 [RFC3590]. MLDv1 is needed by any node that is expected to receive and process multicast traffic. Note that Neighbor Discovery (as used on most link types -- see Section 5.2) depends on multicast and requires that nodes join Solicited Node multicast addresses.

Nodes that need to join multicast groups SHOULD implement MLDv2 [RFC3810]. However, if the node has applications that only need support for Any-Source Multicast [RFC3569], the node MAY implement MLDv1 [RFC2710] instead. If the node has applications that need support for Source-Specific Multicast [RFC3569], [RFC4607], the node

MUST support MLDv2 [RFC3810]. In all cases, nodes are strongly encouraged to implement MLDv2 rather than MLDv1, as the presence of a single MLDv1 participant on a link requires that all other nodes on the link operate in version 1 compatibility mode.

When MLDv1 is used, the rules in the Source Address Selection for the Multicast Listener Discovery (MLD) Protocol [RFC3590] MUST be followed.

6. DHCP vs. Router Advertisement Options for Host Configuration

In IPv6, there are two main protocol mechanisms for propagating configuration information to hosts: Router Advertisements and DHCP. Historically, RA options have been restricted to those deemed essential for basic network functioning and for which all nodes are configured with exactly the same information. Examples include the Prefix Information Options, the MTU option, etc. On the other hand, DHCP has generally been preferred for configuration of more general parameters and for parameters that may be client-specific. That said, identifying the exact line on when whether a particular option should be configured via DHCP vs an RA option has not always been easy. Generally speaking, however, there has been a desire to define only one mechanism for configuring a given option, rather than defining multiple (different) ways of configurating the same information.

One issue with having multiple ways of configuring the same information is that if a host choses one mechanism, but the network operator chooses a different mechanism, interoperability suffers. For "closed" environments, where the network operator has significant influence over what devices connect to the network and thus what configuration mechanisms they support, the operator may be able to ensure that a particular mechanism is supported by all connected hosts. In more open environments, however, where arbitrary devices may connect (e.g., a WIFI hotspot), problems can arise. To maximize interoperability in such environments hosts may need to implement multiple configuration mechanisms to ensure interoperability.

Originally in IPv6, configuring information about DNS servers was performed exclusively via DHCP. In 2007, an RA option was defined, but was published as Experimental [RFC5006]. In 2010, "IPv6 Router Advertisement Options for DNS Configuration" was placed on the Standards Track. Consequently, DNS configuration information can now be learned either through DHCP or through RAs. Hosts will need to decide which mechanism (or whether both) should be implemented.

7. DNS and DHCP

7.1. DNS

DNS is described in [RFC1034], [RFC1035], [RFC3363], and [RFC3596]. Not all nodes will need to resolve names; those that will never need to resolve DNS names do not need to implement resolver functionality. However, the ability to resolve names is a basic infrastructure capability that applications rely on and generally needs to be supported. All nodes that need to resolve names SHOULD implement stub-resolver [RFC1034] functionality, as in RFC 1034, Section 5.3.1, with support for:

- AAAA type Resource Records [RFC3596];
- reverse addressing in ip6.arpa using PTR records [RFC3596];
- EDNS0 [RFC2671] to allow for DNS packet sizes larger than 512 octets.

Those nodes are RECOMMENDED to support DNS security extensions [RFC4033], [RFC4034], and [RFC4035].

Those nodes are NOT RECOMMENDED to support the experimental A6 Resource Records [RFC3363].

7.2. Dynamic Host Configuration Protocol for IPv6 (DHCPv6) - RFC 3315

7.2.1. Managed Address Configuration

DHCP can be used to obtain and configure addresses. In general, a network may provide for the configuration of addresses through RAs, DHCP or both. At the present time, the configuration of stateless address autoconfiguraiton is more widely implemented in hosts than address configuration through DHCP. However, some environments may require the use of DHCP and may not support the configuration of addresses via RAs. Implementations should be aware of what operating environment their devices will be deployed. Hosts MAY implement address configuration via DHCP.

In the absence of a router, IPv6 nodes using DHCP for address assignment MAY initiate DHCP to obtain IPv6 addresses and other configuration information, as described in Section 5.5.2 of [RFC4862].

7.2.2. Other Configuration Information

IPv6 nodes use DHCP to obtain additional (non-address) configuration. If a host implementation will support applications or other protocols that require configuration that is only available via DHCP, hosts

SHOULD implement DHCP. For specialized devices on which no such configuration need is present, DHCP is not necessary.

An IPv6 node can use the subset of DHCP (described in [RFC3736]) to obtain other configuration information.

7.2.3. Use of Router Advertisements in Managed Environments

Nodes using the Dynamic Host Configuration Protocol for IPv6 (DHCPv6) are expected to determine their default router information and on-link prefix information from received Router Advertisements.

7.3. IPv6 Router Advertisement Options for DNS Configuration - RFC XXXX

Router Advertisements have historically limited options to those that are critical to basic IPv6 functioning. Originally, DNS configuration was not included as an RA option and DHCP was the recommended way to obtain DNS configuration information. Over time, the thinking surrounding such an option has evolved. It is now generally recognized that few nodes can function adequately without having access to a working DNS resolver. RFC 5006 was published as an experimental document in 2007, and recently, a revised version was placed on the Standards Track [I-D.I-D.ietf-6man-dns-options-bis].

Implementations SHOULD implement the DNS RA option.

8. IPv4 Support and Transition

IPv6 nodes MAY support IPv4.

8.1. Transition Mechanisms

8.1.1. Basic Transition Mechanisms for IPv6 Hosts and Routers - RFC 4213

If an IPv6 node implements dual stack and tunneling, then [RFC4213] MUST be supported.

9. Mobility

Mobile IPv6 [RFC3775] and associated specifications [RFC3776] [RFC4877] allow a node to change its point of attachment within the Internet, while maintaining (and using) a permanent address. All communication using the permanent address continues to proceed as expected even as the node moves around. The definition of Mobile IP includes requirements for the following types of nodes:

- mobile nodes
- correspondent nodes with support for route optimization
- home agents
- all IPv6 routers

At the present time, Mobile IP has seen only limited implementation and no significant deployment, partly because it originally assumed an IPv6-only environment, rather than a mixed IPv4/IPv6 Internet. Recently, additional work has been done to support mobility in mixed-mode IPv4 and IPv6 networks[RFC5555].

More usage and deployment experience is needed with mobility before any one can be recommended for broad implementation in all hosts and routers. Consequently, [RFC3775], [RFC5555], and associated standards such as [RFC4877] are considered a MAY at this time.

10. Security

This section describes the specification of IPsec for the IPv6 node.

Note: This section needs a rethink. According to RFC4301, IKEv2 MUST be supported. This section cites RFC 4301 as a MUST, yet the remainder of this section only makes IKEv2 a SHOULD. The IPv6 WG has discussed the topic of mandating key management in the past, but has not been willing to make IKE (v1 or v2) a MUST. Is it time to revisit this recommendation? Does it make sense to leave key management as a SHOULD? And what about how that contradicts RFC 4301?

10.1. Basic Architecture

Security Architecture for the Internet Protocol [RFC4301] MUST be supported.

10.2. Security Protocols

ESP [RFC4303] MUST be supported. AH [RFC4302] MAY be supported.

10.3. Transforms and Algorithms

The current set of mandatory-to-implement algorithms for ESP and AH are defined in 'Cryptographic Algorithm Implementation Requirements For ESP and AH' [RFC4835]. IPv6 nodes SHOULD conform to the requirements in [RFC4835].

10.4. Key Management Methods

An implementation MUST support the manual configuration of the security key and SPI. The SPI configuration is needed in order to delineate between multiple keys.

Key management SHOULD be supported. Examples of key management systems include IKEv2 [RFC4306] and Kerberos; S/MIME and TLS include key management functions.

Where key refresh, anti-replay features of AH and ESP, or on-demand creation of Security Associations (SAs) is required, automated keying MUST be supported.

Key management methods for multicast traffic are also being worked on by the MSEC WG.

11. Router-Specific Functionality

This section defines general host considerations for IPv6 nodes that act as routers. Currently, this section does not discuss routing-specific requirements.

11.1. General

11.1.1. IPv6 Router Alert Option - RFC 2711

The IPv6 Router Alert Option [RFC2711] is an optional IPv6 Hop-by-Hop Header that is used in conjunction with some protocols (e.g., RSVP [RFC2205] or MLD [RFC2710]). The Router Alert option will need to be implemented whenever protocols that mandate its usage are implemented. See Section 4.6.

11.1.2. Neighbor Discovery for IPv6 - RFC 4861

Sending Router Advertisements and processing Router Solicitation MUST be supported.

12. Network Management

Network Management MAY be supported by IPv6 nodes. However, for IPv6 nodes that are embedded devices, network management may be the only possible way of controlling these nodes.

12.1. Management Information Base Modules (MIBs)

The following two MIBs SHOULD be supported by nodes that support an SNMP agent.

12.1.1. IP Forwarding Table MIB

IP Forwarding Table MIB [RFC4292] SHOULD be supported by nodes that support an SNMP agent.

12.1.2. Management Information Base for the Internet Protocol (IP)

IP MIB [RFC4293] SHOULD be supported by nodes that support an SNMP agent.

13. Open Issues

1. The recommendations regarding when to invoke DHCP are problematical with out being able to reference the M&O bits.
2. Security Recommendations needs updating. See note in that Section.

14. Security Considerations

This document does not directly affect the security of the Internet, but implementations of IPv6 are expected to support a minimum set of security features to ensure security on the Internet.

Security is also discussed in Section XXX above.

15. Authors and Acknowledgments

15.1. Authors and Acknowledgments (Current Document)

15.2. Authors and Acknowledgments From RFC 4279

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16. Appendix: Changes from -04 to -05

1. Cleaned up IPsec section, but key questions (MUST vs. SHOULD) still open.

2. Added background section on DHCP vs. RA options.

3. Added SHOULD recomendation for DNS configuration vi RAs (RFC5006bis).

4. Cleaned up DHCP section, as it was referring to the M&O bits.

5. Cleaned up the Security Considerations Section.

17. Appendix: Changes from -03 to -04

1. Updated the Introduction to indicate document is an applicabity statement

2. Updated the section on Mobility protocols

3. Changed Sub-IP Layer Section to just list relevant RFCs, and added some more RFCs.

4. Added Section on SEND (make it a MAY)

5. Redid Section on Privacy Extensions (RFC4941) to add more nuance to recommendation

6. Redid section on Mobility, and added additional RFCs [

18. Appendix: Changes from RFC 4294

This appendix keeps track of the chances from RFC 4294

1. Section 5.1, removed "and DNAME" from the discussion about RFC-3363.

2. RFC 2463 references updated to RFC 4443.

3. RFC 3513 references updated to RFC 4291.

4. RFC 3152 references updated to RFC 3596.

5. RFC 2893 references updated to RFC 4213.

6. AH [RFC4302] support chanced from MUST to MAY.

7. The reference for RFC 3152 has been deleted, as the RFC has been obsoleted, and has been incorporated into RFC 3596.

8. The reference for RFC 3879 has been removed as the material from RFC 3879 has been incorporated into RFC 4291.

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