NIST Special Publication 500-267Ar1
Revision 1

NIST IPv6 Profile

Doug Montgomery
Mark Carson
Sheila Frankel
Timothy Winters
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National Institute of
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Doug Montgomery
Mark Carson
Sheila Frankel
Information Technology Laboratory
National Institute of Standards and Technology

Timothy Winters
Michayla Newcombe
Timothy Carlin
InterOperability Laboratory
University of New Hampshire

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Reports on Computer Systems Technology

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Executive Summary

This document defines a profile of Internet Protocol version 6 (IPv6) capabilities for the purpose of expressing technical requirements for networked information technology (IT) products and to report the IPv6 capabilities of specific products. The original design of this capability profile was developed collaboratively with, and aligned to, industry led product test programs [IPv6-Ready, NIST-IPv6F] and documented in an acquisition profile for one specific user group [SP500-267].

This new document provides significant updates to the original IPv6 profile, including:

1. Separating the definition of IPv6 Capability Profiles from their use in specific acquisition programs so as to permit other user groups to re-use the capability profiles and their aligned product testing programs.
2. Updating the set of Internet Engineering Task Force (IETF) specifications that form the basis for the profile to their latest published versions.
3. Adding new specifications for important IPv6 capabilities that have been developed since the publication of the first profile.
    a. Highlights of these additions include technologies to support emerging use cases such as Internet of Things, new forms of IPv6 transition technologies necessary to support "IPv6 Only" environments, and better support for specification of IPv6 capable applications.
4. Removing specifications for IPv6 capabilities included in the first version of the profile but that have since failed to achieve significant support in commercial products and network deployments.

An example of one user group's use of this capability profile in an acquisition program and coordinated product testing program can be found in the USGv6 Profile [SP500-267Br1] and USGv6 Test Program [SP500-281Ar1]. While this capability profile has its origins in that specific user group, it has been refactored so as to be independent of any specific acquisition program.

This profile is not subject to copyright and its reuse, either in its entirety, or in derivative works, is encouraged.

Abstract

This profile establishes a basic taxonomy of IPv6 capabilities, defined in terms of IETF specifications, resulting in specific named capability labels for common network functions and usage scenarios. The profile maps each such named capability to one or more specific technical specifications, or parts of specifications. Each named capability adopts by reference the normative requirements of the cited specifications. In rare cases the profile may augment or modify the normative requirements of a base specification. The defined capability labels effectively form a vocabulary for expressing IPv6 requirements for, and documenting the IPv6 capabilities of, specific products. It is expected that, when combined with specific acquisition and product testing programs, this profile can facilitate the efficient adoption of IPv6 technologies in many industry sectors.

Keywords

Internet Protocol version 6; IPv6; standards profile; acquisition; NISTv6; NISTv6-r1.

Table of Contents

1. Introduction

This document establishes a profile of Internet Protocol version 6 (IPv6) capabilities for the purpose of expressing technical requirements for networked information technology (IT) products and to report the IPv6 capabilities of specific products. The original design of this profile was developed collaboratively with, and aligned to, industry led product test programs [IPv6-Ready, NIST-IPv6F] and documented in an acquisition profile for one specific user group [SP500-267].

This new document, provides significant updates to the original profile, including:

1. Separating the definition of IPv6 Capability Profiles from their use in specific acquisition programs so as to permit other user groups to re-use the capability profiles and their aligned product testing programs.
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4. Removing specifications for IPv6 capabilities included in the first version of the profile but that have since failed to achieve significant support in commercial products and network deployments.

An example of one user group's use of this profile in an acquisition program and coordinated product testing program can be found in [SP500-267Br1] and [SP500-281Ar1]. While this capability profile has its origins in a specific user group, it has been refactored so as to be independent of any specific acquisition program.

This profile is not subject to copyright and its reuse, either in its entirety, or in derivative works is encouraged. References to this specification should cite:

- **"NIST IPv6 Profile", NIST Special Publication 500-267A revision 1, National Institute of Standards and Technology, June 2019, https://doi.org/10.6028/NIST.SP.500-267Ar1**
- The abbreviation **"NISTv6-r1"** is used to identify this profile in various usages.

1.1. Audience

This document is intended to assist several communities of interest in the planning and implementation of IPv6 acquisition programs. The range of potential uses of this profile include establishing a technical basis for broad IPv6 acquisition strategies, defining

requirements for individual procurements or documenting the IPv6 capabilities of individual products.

This profile assumes that the readers have some level of familiarity with IPv6 and with its corpus of specifications (i.e. IETF RFCs). Readers are directed to the wealth of books and training materials that provide such introductions to IPv6 technologies.

The main purpose of this document is to identify and organize the vast collection of IPv6 specifications into subsets of named *capabilities* that may be of common utility in planning for and acquiring specific IPv6 products and services. As such, the profile is primarily targeted to users in the following groups:

- **Users and Purchasers** - Those writing procurement and contract language may use this document as a reference to develop product requirement specifications. For their purposes, this document aims to facilitate the development of precise specifications of IPv6 technical requirements that must be met by offered products. It should be noted that this profile only addresses IPv6 requirements, and thus cannot stand in isolation as a complete procurement specification. Many other technical issues (e.g., IPv4 capabilities, hardware, performance, reliability, support) and procurement policies must be typically addressed to fully define a complete procurement requirement. Those developing procurement requirements will be primarily interested in sections 1.4, 2.4 and 3 of this document.
- **Developers** – Developers of network protocols, applications and services may use this document as reference when they describe the IPv6 capabilities of their products. In addition, developers of networked IT should view the defined capabilities in this profile as a potential source of technical requirements for future acquisitions and the anticipate the need to demonstrate and document compliance with such requirements. Developers and vendors will be primarily interested in sections 1.4, 2.4, 2.6 and 4 of this document.
- **Testing and Accreditation Organizations** – Some user groups may request or require independent testing of networked IT products to demonstrate compliance with requirements defined in this profile. Often such testing programs may require accreditation of testing services. Organizations that support formal testing programs associated with this profile will be primarily interested in sections 2.6 and 4 of this document.
- **Other Profile Developers** – User groups may choose to develop derivative works based upon this profile, potentially modifying the recommendations, conformance, testing and/or reporting requirements described herein. While such efforts are encouraged when necessary, it is requested that they avoid duplication and adopt unmodified portions of this profile by reference rather than duplication.

All members of this audience, and others, are encouraged to carefully review this profile and provide comments so that future versions might be improved. Comments should be addressed to: usgv6-program@nist.gov.

1.2. Profiling IPv6 Capabilities

The technical specification of capabilities required by modern networking capabilities is inherently complex. While some use the term "IPv6" as if it were a single, monolithic technology with a simple concise technical definition, the reality is quite different. The complete specification of the range of IPv6 capabilities commonly found in products requires reference to hundreds of individual protocol, architecture, and algorithm specifications. While this profile provides some background and rationale about the choices that are contained within it, it is well beyond the scope of this document to provide a tutorial on these technologies and specifications.

Some of the IPv6 capabilities in this profile are defined in terms of protocol and algorithm specifications that are not specific to IPv6. In fact, many such specifications may not mention IPv6 at all. Examples include various application layer and security services. Although these specifications may have been written with IPv4 in mind, when referenced in this profile, the understanding is that the requirements apply to IPv6 networking. In addition, some specifications for IPv6 capabilities may only define the required changes from the corresponding IPv4 capability. In these cases, the implied requirement is to also support the unchanged functions from the IPv4 specification.

This profile establishes a taxonomy of IPv6 capabilities that are defined primarily in terms of IETF specifications. The result is a collection named IPv6 capability sets for common network functions, applications, services and usage scenarios. The design choices for the granularity and composition of individual named IPv6 capabilities in this profile are guided by several factors including (1) a judgement of the protocol capabilities that are common to all IPv6 products, and the capabilities that differentiate individual IPv6 products, and (2) the granularity and organization of existing industry defined conformance and interoperability tests [IPv6-Ready]. As such, some named capabilities in this profile map one-to-one to specific IETF protocol specifications (or parts of specifications), and some named capabilities map to a set of two or more distinct protocol specifications.

By default, each named capability adopts by reference the normative requirements of the cited specifications. In rare cases the profile may augment or modify the normative requirements of a base specification. These named capability sets effectively form a vocabulary for expressing technical requirements for IPv6 products, and for testing, documenting and reporting IPv6 capabilities of specific products. By using the same vocabulary to express requirements and to report product capabilities, this profile facilities the efficient comparison of user requirements with vendor offerings.

This profile provides the means by which its users can develop requirement specifications for IPv6 capabilities in a wide range of networked IT products and services. Users of this profile can develop IPv6 requirement statements for specific networked IT products and services directly from the NISTv6 Capabilities Profile, or they might develop their own requirements profiles, derived from this specification as a base, but with the additional guidance and requirements suitable for their user group.

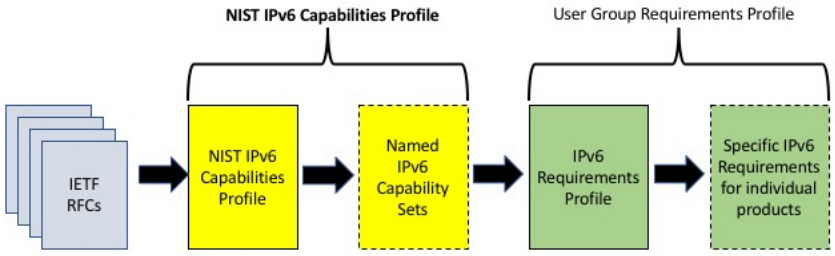

Figure 1 Usage of IPv6 Capabilities Profile

It is expected that, when combined with specific user group requirements profiles and product testing programs, this profile can facilitate the efficient acquisition and adoption of IPv6 technologies in many industry sectors.

1.3. Profile Structure: Functional Roles and Capability Groups

Often IETF specifications are written to describe the normative behavior of multiple parties in a distributed protocol. Often the technical requirements of each party are different based upon the *functional role* they play in the protocol. The most common functional roles distinguished in IETF specifications are those of *Hosts* and *Routers*. Many protocols describe both the required behavior for Hosts and for Routers in a single specification. An individual implementation of such a protocol typically only supports the requirements for either Hosts or Routers depending up the purpose of the product. In order to carefully specify, test and report such differing capabilities, we need to distinguish between a few common functional roles in our profile.

One approach to dealing with this need is to produce separate named capability variants for each functional role. In some cases where the functional role differences are limited to a single protocol, we do this (e.g., "DHCP-Client", "DHCP-Server"). But in case of Hosts and Routers, the differences span many capabilities and specifications. To enable concise specification of these varied requirements we partition our profile to describe Host and Router IPv6 capabilities separately.

This profile defines the following functional roles:

- **Router** – an IPv6 implementation that forwards packets not explicitly addressed to itself. A Router implementation's primary purpose is to support the control protocols necessary to enable interconnection of distinct IP sub-networks by IP layer packet forwarding.
- **Host** – an IPv6 implementation that is not a router. A Host implementation's primary purpose is to support application protocols that are the source and/or destination of IP layer communication.
- **Other** – products that implement IPv6 capabilities that are neither standard Host or Router functions. Currently the profile identifies three additional roles for such products:

- **Network Protection Product (NPP)** – an IPv6 product which provides network protection functions (e.g., firewalls, intrusion detection / prevention). For security reasons, such products often have only partial, or non-standard, Host and/or Router capabilities. For this reason, and because this profile only specifies the protection capabilities required for these products, we call them out using a distinct functional role.
- **Switch** – a product which provides Layer-2 (i.e., sub IP layer) switching, but needs to support IPv6 specific functions for security and performance reasons.
- **Application and Services** – a network enabled application or service that does not directly implement IPv6 protocols (e.g., typically these are implemented by an underlying distinct product such as an operating system) but must operate on IPv6 enabled systems and IPv6 networks.

In the sections that follow, we organize our lists and textural descriptions of capabilities into groups of related functions (e.g. "Security Capabilities", "Routing Capabilities"). These groupings are purely for the convenience of organizing the large range of capabilities described by this profile, and to allow users to easily see related capabilities which may represent alternatives for the same basic functions. Such groupings have no technical impact on the use of this profile and could have been omitted without any normative impact.

1.4. Profiling Products and Implementations.

The purpose of this profile is to support the precise technical specification of IPv6 requirements for networked information technology, and to enable documentation of the IPv6 capabilities of individual products. There is a vast variety of networked IT products and systems in the world today, ranging from supercomputers to systems on a chip and from carrier class routers to home wireless access points. It is impossible to develop a priori a static taxonomy of products that would adequately and flexibly capture such a vast range of offerings. Instead, our approach is to provide a common vocabulary for expressing the requirements and capabilities of individual implementations, thus enabling users to developed unique detailed descriptions of nearly any product.

Even within a single product or system, it is often the case that there are multiple distinct implementations of network protocols and functions. These individual implementations, often called "protocol stacks", may have different capabilities and even different functional roles. For example, an IPv6 Router may well have one or more Host stacks to support network management and configuration functions. It is important to document the requirements and capabilities of all network functions in a given product, not just those associated with its main purpose.[1]

[1] To this day, it is not uncommon to find products that claim to support IPv6 but are not fully functional in IPv6-only environments. Typically, it is the configuration, management and maintenance interfaces / stacks that are lacking full IP6 support.

2. Profile Scope, Applicability and Conventions

The following section provides context information for the general interpretation and use of this profile. Users of this specification that need to alter the information that follows are encouraged to do so explicitly in a separate derivative document. While derivative works are encouraged when necessary, care should be taken to avoid unnecessary duplication of specification and/or potentially conflicting guidance.

2.1. Scope and Applicability

This profile was developed to assist in the acquisition of robust, IPv6 capable networked IT products. The capabilities identified in this profile represent the union of those viewed as being necessary to enable production IPv6 deployment in a wide range of usage scenarios.

While this profile is designed to allow users to specify what IPv6 capabilities are required in products being purchased for specific deployment scenarios, it is beyond the scope of this profile to address operational concerns such as deployment plans, coexistence and transition schemes to ensure interoperability with legacy IPv4 infrastructure, or specific approaches to securing individual network environments.

Planning for IPv6 deployment in production IT systems is a complex undertaking. There is a large, and ever growing, knowledge base of industry developed specifications and guidance in this area. The IETF IPv6 Operations (v6ops) [IETF-V6OPS] and Operational Security Capabilities for IP Network Infrastructure (opsec) [IETF-OPSEC] Working Group working groups are sources of numerous operational guides addressing deployment plans for numerous environments (e.g., enterprise networks, Internet service providers, cellular networks), security considerations and guidance, and transition and interoperability approaches for deployment in legacy networks.

2.2. Life Cycles and Change Management.

This document is the first major structural and technical revision of an IPv6 profiling effort first published in 2008. While IPv6 technologies and product offerings have matured and stabilized significantly over that period, they continue to evolve. Future revisions of this profile are expected to maintain the structure and format of this document, while only modifying the technical definitions of IPv6 capabilities within.

When a profile revision changes or adds significant new technical capabilities, it is unreasonable to expect the product and testing industry to be able to respond immediately. As a general principle, we recommend waiting at least 24 months between the addition of a significant new capability to the profile and its citation as a procurement requirement. Profile changes that are more incremental (e.g., errata, revisions to existing capabilities) may be operative in less time.

Going forward, we expect to issue updates to this profile every two years. In general, when new revisions of the profile are published, we recommend that users cite the most recent

version of this profile when appropriate and always include a specific indication of the version being referenced.

2.3. Statements of Requirements Levels

In general, the terminology used to describe requirements levels in this specification include: “mandatory”, “optional” (with their common meaning), and "MUST", "MUST NOT", "REQUIRED", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" which are to be interpreted as described in [RFC2119].

2.4. Profile Capabilities Table.

The NISTv6 Capabilities Table (NCT) provides a concise tabular summary of the technical requirements of this profile. For ease of reference, the NCT is maintained as supplemental information to this profile and provided in a separate document. Readers are encouraged to access and review the NCT as an adjunct to this document.

- **NISTv6-r1 Capabilities Table - https://doi.org/10.6028/NIST.SP.500-267Ar1s**

The NCT is interpreted as follows:

- The NCT is organized in rows of references to IPv6 technical specifications, or specific subsections of specifications. The *Reference, Section* and *Title* columns provide the full context for each cited specification. For ease of readability if the Reference column is empty, the last Reference from the rows above is understood.
- The Flag Column indicates changes from previous versions of the profile. N indicates that an RFC wasn’t in a previous revision of the profile. U indicates that the RFC has been updated since the last revision of the profile. If the Flag Column is blank it indicates there is no change from the last revision of the profile.
- The *Capabilities* column defines the capability label (or conjunction or disjunction of multiple capabilities) that indicates support of the referenced technical specification. Capabilities column may be logically joined with “|” and “&”. The “|” stands for “or” indicating that having either capability will satisfy the requirement. The “&” stands for “and” indicating that both capabilities must be meet to satisfy the requirement.
    - Some capability labels contain an “=” symbol. This is just a notational convenience to allow such labels to be easily grouped by name.
- The *Host, Router* and *Other* columns provide profile specific guidance for products in each specific functional role (see section 1.3). The values in each column provide recomendations as to which capabilities should be considered mandatory (M), optional (blank), or not recommended [X]. Entries with the notation “O:1” indicate that at least one of the listed capabilities is recommended to be selected. Entries that are grayed out in any of these columns indicate that the corresponding specification is typically not applicable to products in that functional role.
    - The capability guidance in provided in this profile is derived from the IETF *IPv6 Node Requirements* specification [RFC8504]. That is, the capabilities

marked "M" in the NCT correspond to those specifications that are indicated as MUST in RFC 8504

While the NCT is a complete tabular summary of the normative content of this profile, readers are encouraged to consult section 3 for guidance on how to interpret the NCT for the purpose of developing requirement statements and to consult section 4 for guidance on interpreting the NCT for the expression of product capabilities.

2.5. Capability Summary Strings.

The primary purpose of this profile is to establish a vocabulary for expressing the IPv6 requirements for networked IT and documenting the IPv6 capabilities of specific products. The named IPv6 capability sets defined in the profile form the terms for this vocabulary. We form *Capability Summary Strings (CSS)* from these terms to define a single specific requirement statement or to document the capabilities of a specific product.

Capability Summary Strings have the following syntax:

CSS_Name = Profile: Functional_Role + Capability + Capability + …

The following is an example of a specific CSS:

Example-Desktop-PC = NISTv6-r1:Host + IPv6-ONLY + Core + Addr-Arch + Multicast + [DHCP-Client | SLAAC] + Link=Ethernet

CSS definitions are used to develop both requirement statements and to document product capabilities. Use the following guidance to develop and interpret capability summary strings.

- **CSS_Name –** A short hand name for the part of the CSS to the right of the "=" sign. The CSS_Name has only local significance and should be fully defined in a complete CSS before its use in isolation. If a CSS_Name is defined in a document, then one can refer to a complete specification by referring to both the source document and the CSS. Two strings with the same CSS_Name are understood to be multiple parts of a single requirement or product description.
- **Profile –** The name of the specific profile and version that establishes the technical definitions of the capabilities and roles used in the CSS.
    - **NISTv6-r1** is the profile name associated with this document.
- **Functional_Role –** One of the functional roles identified in the cited profile.
    - **Host, Router, NPP, Switch,** and **App-Serv –** are the functional roles identified in this profile.
- **Capability + Capability + …** - A list of capability labels concatenated with "+" signs enumerating the IPv6 capabilities that comprise the CSS. When used as a requirement statement the capability list should be viewed at the minimal required set

of capabilities necessary. When used to document a specific product, the list should include all the capabilities supported by the product.

- When used as a requirement statement the capability list may indicate that any of a list of capabilities can fulfill the requirement. This is the equivalent of "O:1" notation in the NCT. In the example above, "[DHCP-Client | SLAAC]" indicates that at least one of these capabilities MUST be supported. Note this O:1 notation is not used when documenting the capabilities of specific products. All capabilities supported should just be listed.
- When used to describe the capabilities of a specific products, support for multiple alternatives is expressed by simple concatenation of labels with "+". For example, a product that supported both forms of address configuration mentioned above would simply include the substring "… + DHCP-Client + SLAAC + …".

As previously noted, real networked IT products often contain multiple logically or physically distinct IPv6 protocol stacks that may perform different functional roles as defined in this profile. For example, an IPv6 Router that also includes Host functions to support its configuration and management. It is not uncommon to require multiple CSS to fully describe the IPv6 capabilities of a modern IT product.

The flexibility provided by CSS specifications is capable of representing a vast range of capabilities and features found in modern networked IT products and services. Having this flexibility avoids the artificial constraints of standardizing a priori a small set of product configurations that could not possibly capture the full variety of current or future networked IT products.

2.6. Conformance, Testing and Reporting.

This profile establishes the means to describe the IPv6 capabilities required of and implemented by networked IT products. It is meaningless to require or claim conformance to this profile alone. As noted in the previous section fully instantiated capability summary strings are the only expression of technical capabilities that can be meaningfully cited as a requirement or used to describe the IPv6 capabilities of a product. Users of this profile will rely on CSS to document both requirement statements and product capabilities.

While the ultimate goal of this profile is to enable users and vendors to compare and match stated requirements to the documented capabilities of products, the profile and CSS derived from it are still valuable if only one side of this process is completed. In particular product capability summary strings are useful "full disclosure" statements of the IPv6 features that purchasers can expect, even if a corresponding CSS requirement statement was not provided.

The common assumed usage scenario envisioned for this profile is that purchasers develop requirement CSS and vendors supply the CSS that document their products capabilities. In many situations users may desire additional assurances of the completeness, correctness and interoperability of the IPv6 capabilities provided by vendor products. In these situations,

specific user groups may develop additional guidance on testing and reporting requirements for vendor CSS. Testing guidance might require demonstrated conformance and/or interoperability testing results (potentially from independent testing sources) and/or specific additional means of documenting and reporting the results from such testing.

User groups wishing such levels of additional assurance are encouraged to fully document the details of how such detailed testing and reporting mechanisms are to be conducted and how they will result in the derivation of one or more CSS for individual products.

3. Selection of IPv6 Capabilities

The subsections that follow provide templates to facilitate the selection of capabilities for the purpose of developing requirement statements. The subsections are organized by the functional roles identified in this profile (i.e., Host, Router, NPP, App-Serv). Within each subsection capabilities are arranged in groups of related functions (e.g., Addressing Capabilities, Routing Capabilities).

For each capability a recommended requirement level is indicated. The notations used to indicate the requirement level of each capability include:

- **[M]** – Mandatory, it is recommended that this capability be included in all CSS for this functional role. For example, all Host CSS should include the Core capability.
- **[O:1]=[Capability1 | Capability2]** – Choice, it is recommended that one of the indicated list of capabilities be included in all CSS for this functional role.
- **[O]** – Optional, the profile user can choose to include this capability in CSS as needed. Note, in capability tables, optional is denoted by a blank cell.
- **[X]** – Not recommended for the profile uses described in the scope and applicability section. Such capabilities are included in the profile to maintain alignment with other profiles and/or to document the full range of possibilities.

Users should be conservative in the selection of optional capabilities when developing requirement statements. While there are many optional capabilities defined in this profile, they vary in their common availability in commodity network IT products. Users are recommended to survey the documented IPv6 capabilities of relevant commodity products and/or to interact with potential system developers / integrators as part of the process of developing CSS requirement statements.

To further understand the detailed technical definition of the capabilities below, see the corresponding entries in the NISTv6-r1 Capabilities Table (section 2.4) and section 4 Technical Definition of IPv6 Capabilities. See section 5 for example CSS that incorporate these capabilities.

3.1. IPv6-ONLY Capabilities

There is no standard definition of what it means for products to capable operating in "IPv6-only" networks. This profile defines the IPv6-ONLY capability as requiring a product to support the full lifecycle of operation (i.e., product installation, configuration, operation, management, instrumentation and update) in environments with no IPv4 capabilities (e.g., either IPv4 is not implemented or is administratively disabled).

A product claiming support of the IPv6-ONLY capability must be fully functional when deployed in an IPv6-only network and provide no less functionality than is currently available in IPv4 environments.

The IPv6-ONLY capability applies to a product as a whole and is applicable to each functional role defined in this profile. The technical definition of this capability is provided in section 4.1 of this profile but is the same for all product types. For the sake of clarity, we summarize these capabilities in a single location here.

NISTv6-r1:Host Capabilities: • **IPv6-ONLY Capabilities** – see section 4.1   o [O] – **IPv6-ONLY** - support for full product functionality on an IPv6-only network
NISTv6-r1:Router Capabilities: • **IPv6-ONLY Capabilities** – see section 4.1   o [O] – **IPv6-ONLY** - support for full product functionality on an IPv6-only network
NISTv6-r1:NPP Capabilities: • **IPv6-ONLY Capabilities** – see section 4.1   o [O] – **IPv6-ONLY** - support for full product functionality on an IPv6-only network
NISTv6-r1:Switch Capabilities: • **IPv6-ONLY Capabilities** – see section 4.1   o [O] – **IPv6-ONLY** - support for full product functionality on an IPv6-only network
NISTv6-r1:App-Serv Capabilities: • **IPv6-ONLY Capabilities** – see section 4.1   o [O] – **IPv6-ONLY** - support for full product functionality on an IPv6-only network

3.1.1. Selecting IPv6-ONLY Capabilities

Users of this profile may require any product to be capable of operating in IPv6-only environments.

- Common dual-stack deployments may not require IPv6-ONLY capabilities in the near term, but there are several industry initiatives targeting IPv6-only network infrastructures in the near future.
- Future revisions of the profile will likely recommend IPv6-only as a mandatory requirement for all systems.
- When the IPv6-only capability is indicated, it is implied that all other specified capabilities of a product, must operate in IPv6-only environments.

Note: At the time of publication (2019), few commercial products are fully capable of IPv6-only operation. Users of this profile should carefully consider the state of the market place before selecting this capability.

3.2. Host Capabilities

A template of the various Host capabilities is given below along with references to sections of this profile that provide further discussion and interpretation of the requirements.

NISTv6-r1:Host Capabilities Template:

- **IPv6-ONLY Capabilities** - see section 4.1
  - [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
- **Basic Capabilities** - see section 4.2
  - [M] - **Core** - support for IPv6 core functions.
  - [O] - **Extended-ICMP** - support for ICMPv6 extended messages.
  - [O] - **PLPMTUD** - support for Packetization Layer Path MTU Discovery.
  - [O] - **ND-Ext** - support for Neighbor Discovery features of enhanced DAD and First-Hop Selection.
  - [O] - **ND-WL** - support for packet-loss for router solicitations.
  - [O] - **SEND** - support for neighbor discovery security extensions.
  - [M] - **SLAAC** - support for stateless global address auto-configuration.
  - [O] - **PrivAddr** - support for SLAAC privacy extensions.
  - [O] - **DHCP-Stateless** - support for stateless (DHCP) configuration.
  - [O] - **DHCP-Client** - support for stateful (DHCP) address auto-configuration.
  - [O] - **DHCP-Client-Ext** - support for additional DHCP options including SIP.
  - [O] - **DHCP-Prefix** - support for stateful (DHCP) prefix delegation.
  - [O] - **DHCP-Prefix-Ext** - support for additional DHCP options for prefix exclude using prefix delegation.
  - [O] - **6Lo** - support for IPv6 over low power networks.
  - [O] - **Happy-Eyeballs** - support for Happy Eyeballs algorithm for dual stack environments.
- **Addressing Capabilities** - see section 4.7
  - [M] - **Addr-Arch** - support for address architecture and selection.
  - [O] - **CGA** - support for cryptographically generated addresses.
- **Network Support Capabilities** - see section 4.11
  - [O] - **DNS-Client** - support for DNS client/resolver functions.
  - [O] - **URI** - support for IPv6 uniform resource identifiers.
  - [O] - **NTP-Client** - support for NTP client capabilities.
  - [O] - **NTP-Server** - support for NTP server capabilities.
  - [O] - **DNS-Server** - support for DNS server capabilities.
  - [O] - **DHCP-Server** - support for DHCP server capabilities.
  - [O] - **DHCP-Server-Ext** - support for DHCP server for additional DHCP options and Bulk Leasequery.
  - [O] - **DHCP-Relay** - support for DHCP relay capabilities.
- **Security Capabilities** - see section 4.8
  - [O] - **IPsec** - support for the IP security architecture.
  - [O] - **IPsec-IoT** - support for IoT Cryptographic Algorithms.
  - [O] - **IPsec-CHACHA** - support for ChaCha20 Cryptographic Algorithms.
  - [O] - **IPsec-SHA-512** - support for SHA-512 Cryptographic Algorithms.
  - [O] - **TLS** - support for Transport Layer Security architecture version 1.2.
  - [O] - **TLS-1.3** - support for Transport Layer Security architecture version 1.3.

- **Transition Mechanism Capabilities** - see section 4.5
  - [O] - **Tunneling-IP** - support for generic packet encapsulation tunnels using IPv6.
  - [O] - **Tunneling-UDP** - support for generic packet encapsulation tunnels using UDP.
  - [O] - **XLAT** - support for transition mechanism 464XLAT.
  - [O] - **NAT64** - support for transition mechanism NAT64.
  - [O] - **DNS64** - support for transition mechanism DNS64.
- **Network Management Capabilities** - see section 4.9
  - [O] - **SNMP** - support for simple network management protocol.
  - [O] - **NETCONF** - support for network configuration functions.
- **Multicast Capabilities** - see section 4.10
  - [O] - **SSM** - require full support for multicast communications.
  - [M] - **Multicast** - support for link-local multicast communication.
- **Quality of Service Capabilities** - see section 4.4
  - [O] - **DiffServ** - support for Differentiated Services capabilities.
  - [O] - **ECN** - support for Explicit Congestion Notification.
- **Link Specific Capabilities** - see section 4.6
  - [O] - **Link=Ethernet** - support for IPv6 over Ethernet.
  - [O] - **Link=PPP** - support for IPv6 over PPP links.
  - [O] - **Link=G.9959** - support for IPv6 over Z-Wave.
  - [O] - **Link=Bluetooth** - support for IPv6 over Bluetooth.
  - [O] - **Link=Bacnet** - support for IPv6 over BACnet.
  - [O] - **Link=6LoWPAN** - support for IPv6 over 802.15.4.

3.2.1. Selecting Host Capabilities

The following guidance is provided for selecting capabilities from this section.

- Core, SLAAC, Multicast, and Addr-Arch capabilities are recommended to be mandatory in all systems.

- For systems that will be deployed on potentially lossy networks with specific features, users will want to consider requiring neighbor discovery and compression extension capabilities of ND-WL and 6Lo.

- IPv6 Neighbor Discovery has several optional updates that provide optimizations in some use case scenarios. Users may want to require ND-EXT for a more robust solution in these deployment scenarios.

- User may want to require additional methods to mitigate packet loss due to fragmentation. An alternative to Path MTU Discovery required in Core is Packetization Layer Path MTU Discovery (PLPMTUD) designed for use over paths where end-to-end delivery of ICMPv6 messages is not assured.

- Capabilities to secure neighbor discovery include ND-SEND and CGA. Note, to date these capabilities are not commonly implemented on commodity systems and should be required only when necessary.

- Privacy addressing features are provided by the PrivAddr capability. Note: Certain deployments, such as Enterprise, may not want this capability enabled as it makes tracking IP addresses difficult.

- Systems that will use stateful address and configuration management (i.e., DHCPv6) should require DHCP-Client. DHCP-Prefix allows for assigning address ranges to a system that will sub-allocate addresses to other nodes and network functions. DHCP-Stateless should be required when SLAAC is the only supported address configuration protocol and additional network configuration information is necessary.

- DHCP-Client-Ext includes support for additional DHCPv6 options including SIP. DHCP-Prefix-Ext adds support for the Prefix Exclude Option.

- Happy-Eyeballs is an algorithm that enhances the robustness and performance of dual-stack systems by trying to contact remote systems with both IPv4 and IPv6 in parallel. Whichever protocol receives the fastest response is used for the remainder of the communication. Users should require this in Dual Stack networks.

- The capability to operate DNS over IPv6 is available for both client and server. The DNS-client and DNS-server capabilities require products to support DNS resolution for IPv6 address records and for DNS queries over native IPv6.

- Users of DHCPv6 for network addressing and information will want to select DHCP-Server for the systems managing network address and configuration information. Additional DHCPv6 Server functions, such as Bulk Leasequery, are included in DHCPv6-Server-Ext that may be required for advanced DHCPv6 deployments.

- Users requiring support for the Network Time Protocol will want to require NTP-server and NTP-client capabilities where appropriate.

- Secure end-to-end communications channels can be required by selecting either TLS or IPSec capabilities. IPsec-IoT, IPsec-CHACHA, IPsec-SHA-512 are additional algorithms and must only be selected when IPsec is selected. The IPSec-VPN capability is for secure data plane channels for routers products. Similarly, IPsec-IOT-VPN, IPsec-IOT-CHACHA-VPN, and IPsec-SHA-512-VPN must only be selected when IPsec-VPN is selected.

- The TLS capability is currently defined in terms of the TLS1.2 specification. The TLS-1.3 capability is available for users that need the enhanced security features of the new specification and understand the operational implications of its use.

- Users have several options for transition mechanisms when deploying IPv6. The capabilities in this profile primarily focus on transition over IPv6-only networks. Host based transition mechanisms include Tunneling-IP, Tunneling-UDP and XLAT. To support XLAT both NAT64 and DNS64 are included as additional functions that are required but often are embedded in different products.

- Systems that require remote management and configuration should elect either NETCONF or SNMP capabilities. Note: commodity Host products do not commonly support either of these remote management capabilities.

- The Multicast capability is specifically defined for link-local multicast necessary to support protocols such as Neighbor Discovery. The SSM capability allows for both a host to support source specific multicast requirements.

- Systems can indicate support for IPv6 Quality of Service using the DiffServ or ECN capabilities. Note that in scenarios where QoS is required, both Hosts and Routers should support the corresponding capabilities.

- The Link Specific Capabilities indicate support for IPv6 mapping to specific layer 2 technologies. Most commodity products support Link=Ethernet (including WiFi), but other link technologies can be indicated. A CSS for a single system may include multiple Link capabilities for distinct physical interfaces.

3.3. Router Capabilities

A template of the various Router capabilities is given below along with references to sections of this profile that provide further discussion and interpretation of the requirements.

NISTv6-r1:Router Capabilities Template:

- **IPv6-ONLY Capabilities** - see section 4.1
  - [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
- **Basic Capabilities** - see section 4.2
  - [M] - **Core** - support for IPv6 core functions.
  - [O] - **Extended-ICMP** - support for ICMPv6 extended messages.
  - [O] - **PLPMTUD** - support for Packetization Layer Path MTU Discovery.
  - [O] - **ND-Ext** - support for Neighbor Discovery features of enhanced DAD and First-Hop Selection.
  - [O] - **ND-WL** - support for packet-loss for router solicitations.
  - [O] - **SEND** - support for neighbor discovery security extensions.
  - [M] - **SLAAC** - support for stateless global address auto-configuration.
  - [O] - **DHCP-Prefix** - support for stateful (DHCP) prefix delegation.
  - [O] - **DHCP-Prefix-Ext** - support for additional DHCP options for prefix exclude using prefix delegation.
  - [O] - **6Lo** - support for IPv6 over low power networks.
- **Addressing Capabilities** - see section 4.7
  - [M] - **Addr-Arch** - support for address architecture and selection.
  - [O] - **CGA** - support for cryptographically generated addresses.
- **Network Support Capabilities** - see section 4.11
  - [O] - **DNS-Client** - support for DNS client/resolver functions.
  - [O] - **URI** - support for IPv6 uniform resource identifiers.
  - [O] - **NTP-Client** - support for NTP client capabilities.
  - [O] - **NTP-Server** - support for NTP server capabilities.
  - [O] - **DNS-Server** - support for DNS server capabilities.
  - [O] - **DHCP-Server** - support for DHCP server capabilities.
  - [O] - **DHCP-Server-Ext** - support for DHCP server for additional DHCP options and Bulk Leasequery.
  - [O] - **DHCP-Relay** - support for DHCP relay capabilities.
- **Routing Capabilities** - see section 4.3
  - [O] - **OSPF** - support for OSPF for intra-domain routing protocol.
  - [O] - **OSPF-IPsec** - support for OSPF Authentication/Confidentiality using IPSec.
  - [O] - **OSPF-Auth** - support for OSPF Authentication Trailer.
  - [O] - **OSPF-Ext** - support for additional OSPF robustness and optimization features.
  - [O] - **OSPF-Trans** - support for OSPF IPv4 over IPv6.
  - [O] - **OSPF-Graceful** - support for OSPF Graceful restart.
  - [O] - **IS-IS** - support for IS-IS for intra-domain routing protocol.
  - [O] - **IS-IS-Auth** - support for IS-IS Authentication support.
  - [O] - **IS-IS-Ext** - support for additional IS-IS robustness and optimization features.
  - [O] - **IS-IS-MT** - support for Multi Topology in IS-IS.
  - [O] - **BGP** - support for BGP for inter-domain routing protocols.
  - [O] - **BGP-FlowSpec** - support for BGP FlowSpec capabilities.
  - [O] - **BGP-OV** - support for BGP Origin Validation capabilities.
  - [O] - **BGP-VPLS** - support for BGP VPLS capabilities.

- [O] - **BGP-EVPN** - support for BGP EVPN capabilities.
- [O] - **BGP-6VPE** - support for BGP 6VPE capabilities.
- [O] - **CE-Router** - support for customer edge router capabilities.
- [O] - **VRRP** - support for VRRP Routing protocols.

- **Security Capabilities** - see section 4.8
  - [O] - **IPsec** - support for the IP security architecture.
  - [O] - **IPsec-VPN** - support for the IP security architecture gateways.
  - [O] - **IPsec-IoT** - support for IoT Cryptographic Algorithms.
  - [O] - **IPsec-IoT-VPN** - support for IoT Cryptographic Algorithms in gateways.
  - [O] - **IPsec-CHACHA** - support for ChaCha20 Cryptographic Algorithms.
  - [O] - **IPsec-CHACHA-VPN** - support for ChaCha20 Cryptographic Algorithms in gateways.
  - [O] - **IPsec-SHA-512** - support for SHA-512 Cryptographic Algorithms.
  - [O] - **IPsec-SHA-512-VPN** - support for SHA-512 Cryptographic Algorithms in gateways.
  - [O] - **TLS** - support for Transport Layer Security architecture version 1.2.
  - [O] - **TLS-1.3** - support for Transport Layer Security architecture version 1.3.
- **Transition Mechanism Capabilities** - see section 4.5
  - [O] - **Tunneling-IP** - support for generic packet encapsulation tunnels using IPv6.
  - [O] - **Tunneling-UDP** - support for generic packet encapsulation tunnels using UDP.
  - [O] - **GRE** - support for generic router encapsulation tunnels.
  - [O] - **DS-Lite** - support for transition mechanism DS-Lite.
  - [O] - **LW4over6** - support for transition mechanism Lightweight 4over6.
  - [O] - **MAP-E** - support for transition mechanism MAP-E.
  - [O] - **MAP-T** - support for transition mechanism MAP-T.
  - [O] - **XLAT** - support for transition mechanism 464XLAT.
  - [O] - **NAT64** - support for transition mechanism NAT64.
  - [O] - **DNS64** - support for transition mechanism DNS64.
  - [O] - **6PE** - support for 6PE.
  - [O] - **LISP** - support for LISP protocol.
- **Network Management Capabilities** - see section 4.9
  - [O] - **SNMP** - support for simple network management protocol.
  - [O] - **NETCONF** - support for network configuration functions.
- **Multicast Capabilities** - see section XXX
  - [O] - **SSM** - require full support for multicast communications.
  - [M] - **Multicast** - support for link-local multicast communication.
  - [O] - **PIM-SM** - support for PIM-SM Routing protocols.
  - [O] - **PIM-SM-RP** - support for PIM-SM RP Discovery mechanisms.
  - [O] - **PIM-SM-IPsec** - support for PIM-SM over IPsec.
  - [O] - **PIM-SM-BiDir** - support for Bidirectional PIM-SM routing protocol.
- **Quality of Service Capabilities** - see section 4.4
  - [O] - **DiffServ** - support for Differentiated Services capabilities.
  - [O] - **ECN** - support for Explicit Congestion Notification.
- **Link Specific Capabilities** - see section 4.6
  - [O] - **Link=Ethernet** - support for IPv6 over Ethernet.
  - [O] - **Link=PPP** - support for IPv6 over PPP links.
  - [O] - **Link=G.9959** - support for IPv6 over Z-Wave.
  - [O] - **Link=Bluetooth** - support for IPv6 over Bluetooth.
  - [O] - **Link=Bacnet** - support for IPv6 over BACnet.
  - [O] - **Link=6LoWPAN** - support for IPv6 over 802.15.4.

3.3.1. Selecting Router Capabilities

The following guidance is provided for selecting capabilities from this section.

- Core, SLAAC, Multicast, and Addr-Arch capabilities are recommended to be mandatory in all systems.

- For systems that will be deployed on potentially lossy networks with specific features, users will want to consider requiring neighbor discovery and compression extension capabilities of ND-WL and 6Lo.

- IPv6 Neighbor Discovery has several optional updates that provide optimizations in some use case scenarios. Users may want to require ND-EXT for a more robust solution in these deployment scenarios.

- Capabilities to secure neighbor discovery include ND-SEND and CGA. Note these capabilities are not commonly implemented on commodity systems and should be required only when necessary.

- The capability to operate DNS over IPv6 is available for both client and server. The DNS-client and DNS-server capabilities require products to support DNS resolution for IPv6 address records and for DNS queries over native IPv6.

- Users of DHCPv6 for network addressing and information will want to select DHCP-Server for the routers that managing network address and configuration information. Additional DHCPv6 Server functions such as Bulk Leasequery are included in DHCPv6-Server-Ext capability to allow for advanced DHCPv6 deployments.

- DHCP-Prefix allows for routers to delegate address ranges to either host or router. DHCP-Prefix-Ext allows for users that require the PD-Exclude Option for deployments.

- DHCP-Relay will commonly be selected on routers in DHCPv6 networks.

- Users requiring support for the Network Time Protocol will want to require NTP-server and NTP-client capabilities where appropriate.

- The OSPF capability includes the OSPF over IPv6 Routing Protocol functionality. Additional capabilities such as OSPF-IPSec, OSPF-Auth, OSPF-Ext, OSPF-Trans and OSPF-Graceful allow for additional feature parity with existing IPv4 features.

- The IS-IS capability includes IS-IS over IPv6 Routing Protocol functionality. Requirements such as IS-IS-Auth, IS-IS-Ext, and IS-IS-MT allow for additional feature parity with existing IPv4 features.

- The BGP capability includes the collection of RFCs necessary for BGP operation over IPv6. BGP-Flowspec and BGP-OV allow for additional BGP security. BGP capabilities support additional BGP extensions including BGP-VPLS, BGP-EVPN, and BGP-6VPE, which may be required if a user is already deploying these features in IPv4.

- The CE-Router capability is for small routers often provided by a service provider and used for the home or small business networks.

- The VRRP capability allows for support of an IPv6 routing redundancy Protocol.

- Secure end-to-end communications channels can be required by selecting either TLS or IPSec capabilities. IPsec-IoT, IPsec-CHACHA, IPsec-SHA-512 are additional algorithms and must only be selected when IPsec is selected. The IPSec-VPN capability is for secure data plane channels for routers products. Similarly, IPsec-IOT-VPN, IPsec-IOT-CHACHA-VPN, and IPsec-SHA-512-VPN must only be selected when IPsec-VPN is selected.

- The TLS capability is currently defined in terms of the TLS1.2 specification. The TLS-1.3 capability is available for users that need the enhanced security features of the new specification and understand the operational implications of its use.

- Users have several options for transition mechanisms when deploying IPv6. The capabilities in this profile primarily focus on transition over IPv6-only networks. Users will need carefully select from the following Router based transition mechanisms: Tunneling-IP, Tunneling-UDP, GRE, DS-Lite, LW4over6, MAP-E, MAP-T, 6PE, XLAT, DNS64, NAT64 and LISP.

- Systems that require remote management and configuration should select either NETCONF or SNMP capabilities.

- The Multicast capability is specifically defined for link-local multicast necessary to support protocols such as Neighbor Discovery. The SSM capability allows for both a router to support source specific multicast requirements.

- The PIM-SM capability allows for support of routing multicast groups. PIM-SM-IPsec allows for security of PIM-SM. PIM-SM-BiDir allows for a user to require that a router support Bidirectional PIM-SM. PIM-SM-RP allows for RP discovery mechanisms to be selected.

- Systems can indicate support for IPv6 Quality of Service using the DiffServ or ECN capabilities. Note that in scenarios where QoS is required, both Hosts and Routers should support the corresponding capabilities.

- The Link Specific Capabilities indicate support for IPv6 mapping to specific layer 2 technologies. Most commodity products support Link=Ethernet (including WiFi), but other link technologies can be indicated. A CSS for a single system may include multiple Link capabilities for distinct physical interfaces.

3.4. Network Protection Product Capabilities

A template of the various Network Protection Product capabilities is given below along with references to sections of this profile that provide further discussion and interpretation of the requirements.

NISTv6-r1:NPP (Network Protection Product) Capabilities Template:

- **IPv6-ONLY Capabilities** - see section 4.1
  - [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
- **Network Protection Capabilities** - see section 4.14
  - [O] - **FW** - support for basic firewall capabilities.
  - [O] - **IDS** - support for intrusion detection capabilities.
  - [O] - **IPS** - support for intrusion protection capabilities.
  - [O] - **APFW** - support for application firewall capabilities.

3.4.1. Selecting Network Protection Product Capabilities

The following guidance is provided for selecting capabilities from this section.

- For Network Protection Products the profile identifies 4 basic capabilities for common usage scenarios. A CSS for an NPP should include one or more of these capabilities. Note that all NPP capabilities include a common base set of technical requirements (see section 4.12.3).
- Products in this space often have highly specialized, sometimes non-standard (for security purposes) implementations of many other Host and Router IPv6 capabilities. Where these additional required capabilities follow the standards for their use in other functional roles, they can be included as an additional CSS string for that role.
  - For example, a firewall that provides full support of OSPF and operates over Ethernet could add those capabilities.
    - FW = NISTv6-r1:NPP + FW
    - FW-Router = NISTv6-r1:Router + OSPF + Link=Ethernet
  - Care must be taken in selecting standard Host or Router capabilities for NPPs because often such security products have non-standard implementations of core protocols (often in the areas of error reporting, etc).

3.5. Switch Capabilities

A template of the various IPv6 Switch capabilities is given below along with references to sections of this profile that provide further discussion and interpretation of the requirements.

NISTv6-r1:Switch Capabilities Template:

- **IPv6-ONLY Capabilities** - see section 4.1
  - [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
- **Switch Capabilities** - see section 4.13
  - [O] - **DHCPv6-Guard** - support for DHCPv6 Guard at Layer 2.
  - [O] - **RA-Guard** - support for RA Guard at Layer 2.
  - [O] - **MLD-Snooping** - support for MLD Snooping at Layer 2.

3.5.1. Selecting Switch Capabilities

The following guidance is provided for selecting capabilities from this section.

- A user is deploying DHCPv6 should consider requiring switches to support RA-Guard to protect against rogue Router Advertisements which can be a security risk.
- A user is deploying SLAAC for host addressing they should consider requiring switches to support RA-Guard for protecting against rogue Router Advertisements which can be a security risk.
- MLD-Snooping should be required in use cases deploying multicast applications as it allows switches to only forward IPv6 multicast traffic to the listening ports.
- Products in this space often have additional IP stacks that are distinct from the Layer 2 and provide functionality such as managing the switch. Where these additional required capabilities follow common standards, they can be specified as an additional CSS string for that role.
  - For example, a switch that provides full Host support for management purposes.
    - Switch = NISTv6-r1:Switch + DHCPv6-Guard + RA-Guard + MLD-Snooping.
    - Switch-Host = NISTv6-r1:Host + IPv6-ONLY + Core + [SLAAC|DHCP-Client] + Addr-Arch + Multicast + Link=Ethernet.

3.6. Application and Services Capabilities

A template of the various Network Protection Product capabilities is given below along with references to sections of this profile that provide further discussion and interpretation of the requirements.

NISTv6-r1:App-Serv (Application and Services) Capabilities Template:

- **IPv6-ONLY Capabilities** - see section 4.1
  - [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
- **Application and Services Capabilities** - see section 4.12
  - [O] - **App-Serv=[TBD]** - support for application/service specific functions (to be individually specified) over IPv6.

3.6.1. Selecting Application and Services Capabilities

The following guidance is provided for selecting capabilities from this section.

- The number of unique networked applications is vast, making it impossible to develop a priori detailed capabilities for specific products. The general framework above allows users to develop specifications for generic application / service IPv6 requirements and then to enumerate additions requirements specific to the applications. Note when developing such requirements, it is recommended to use one CSS per application. An example of a simple network attached storage might be:
  - NAS-Host = NISTv6-r1:Host + IPv6-ONLY + Core + Multicast + Addr-Arch
  - NAS-Apps = NISTv6-r1:App-Server + IPv6-ONLY + App-Serv=[NFS & SMB & AFS]
- The phrase "over IPv6" is understood to mean that the application or service capability is fully functional, with feature parity to its operation over IPv4, when operating over native IPv6.
- When combined with the IPv6-ONLY capability requirement, the application must be fully functional on a network without IPv4 services.

4. Technical Definition of IPv6 Capabilities

The subsections that follow provide the full technical definition of the IPv6 capabilities defined in this profile. The subsections are organized in groups of related functions (e.g., Addressing Capabilities, Routing Capabilities). Within each subsection by the definitions are further refined by functional roles identified in this profile (i.e., Host, Router, NPP, Switch, App-Serv).

In general, the technical definitions consist of mapping a given profile capability, for a specific functional role, to IETF specifications. A given capability might map to a one or more IETF specifications, or a specific subsection of a specification. In areas in which IETF specifications are lacking (e.g., network protection products), this profile defines the technical requirements associated with the relevant capabilities.

By default, when a profile capability is defined in terms of an IETF specification, it should be understood that means that all of the mandatory (e.g., MUST and MUST NOT) requirements of the specification must be met. In some rare cases this profile might specifically call out an optional feature of an IETF specification as being required for the capability.

Note that some technical specifications are indicated by either the conjunction or disjunction of named capabilities (e.g., SNMP & DiffServ, FW or IDS or IPS or APFW). For those specifications that are indicated by a disjunction of multiple capabilities, we list them under each capability individually. That is, the referenced specification(s) will appear multiple times. When a specification is only required with the conjunction of capabilities (e.g., SNMP & DiffServ), we will list the combination as its own capability definition.

To further understand the detailed technical definition of the capabilities below, see the corresponding entries in the NISTv6-r1 Capabilities Table (section 2.4). See section 5 for example CSS that incorporate these capabilities.

4.1. IPv6-ONLY Capabilities

There is no standard definition of what it means for products to capable operating in "IPv6-only" networks. This profile defines the IPv6-ONLY capability as requiring a product to support the full lifecycle of operation (i.e., product installation, configuration, operation, management, instrumentation and update) in environments with no IPv4 capabilities (e.g., either IPv4 is not implemented in the product or is administratively disabled, or IPv4 is not provided on the network).

A product claiming support of the IPv6-ONLY capability must be fully functional when deployed in an IPv6-only network and provide no less functionality than is currently available in IPv4 environments.

The IPv6-ONLY capability applies to a product as a whole and is applicable to each functional role defined in this profile. The technical definition of this capability is provided in the section below.

4.1.1. Definition of IPv6-only Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host|Router|NPP|Switch|App-Serv Capabilities:

- [O] - **IPv6-ONLY** - support for full product functionality on an IPv6-only network.
  - SP500-267Ar1 Section: 4.1 Install product over IPv6-only network *NIST IPv6 Profile*
  - SP500-267Ar1 Section: 4.1 Product user Interface fully supports IPv6 *NIST IPv6 Profile*
  - SP500-267Ar1 Section: 4.1 Access product over IPv6-only network *NIST IPv6 Profile*
  - SP500-267Ar1 Section: 4.1 Manage product over IPv6-only network *NIST IPv6 Profile*
  - SP500-267Ar1 Section: 4.1 Update product over IPv6-only network *NIST IPv6 Profile*

The detailed implications of the IPv6-ONLY capability will vary with product implementation environments (e.g., operating systems, management and control software, applications, etc) but the functional requirements are the same. The functional requirements of this capability include:

- The product is fully functional in IPv6 network environments in which no IPv4 services are provisioned.
  - A product that conforms to the IPv6-ONLY capability must support operation of all of its other claimed capabilities in IPv6-only networks.
- The product must support full product lifecycle functions (defined below) in an IPv6-only context. Note that often the product support functions below are often provided by additional applications or functions distinct from the main function of the product (e.g., installer applications, update applications, management applications for an OS).

- Installation – the product or service must be able to be instantiated and installed on nodes and in service environments that do not provide IPv4 services. Initial configuration of the product to state where other remote services are operational are part of the installation functions.
- User Interface – all forms of interactive access to the product (e.g., web based interfaces or APIs) must fully support the use of IPv6 and IPv6 addresses of all forms.
  - If the product displays IP addresses, then IPv6 addresses must be displayed according to [RFC5952].
- Management – all forms of remote management and monitoring functions must be fully functional in IPv6-only environments.
- Update – all forms of product update functions (e.g., software, BIOS updates), both automated and user evoked, must be fully functional in IPv6-only environments.

It is expected that the definition of the IPv6-ONLY capability may evolve over time. While IPv6-ONLY is currently defined as an separate optional capability in this version of the profile, over time, this requirement may become an implicit part of all capability definitions. That is, in the future we would expect all products to be fully capable of IPv6-only operation.

4.2. Basic Capabilities

The Basic capabilities group consists of the fundamental protocols necessary for basic IPv6 operations. This includes capabilities for the base IPv6 and ICMPv6 protocols, neighbor discovery protocol (plus numerous ND enhancements), and auto configuration protocols (DHCP and SLAAC). Note that this version of the profiles does require support for non EUI-64 addresses in SLAAC.

4.2.1. Definition of Basic Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Basic Capabilities:

- [M] - **Core** - support for IPv6 core functions.
  - RFC8200 *Internet Protocol, Version 6 (IPv6) Specification*
  - RFC4443 *Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification*
  - RFC8201 *Path MTU Discovery for IP version 6*
  - RFC4861 *Neighbor Discovery for IP version 6 (IPv6)*
  - RFC4861 Section: 8 Redirect *Neighbor Discovery for IP version 6 (IPv6)*
  - RFC6437 *IPv6 Flow Label Specification*
  - RFC5942 *IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes*
  - RFC6980 *Security Implications of IPv6 Fragmentation with IPv6 Neighbor Discovery*
  - RFC4191 *Default Router Preferences and More-Specific Routes*
  - RFC4862 Section: 5.3 Creation of Link Local Addresses *IPv6 Stateless Address Autoconfiguration*
  - RFC4862 Section: 5.4 Duplicate Address Detection *IPv6 Stateless Address Autoconfiguration*
- [O] - **Extended-ICMP** - support for ICMPv6 extended messages.
  - RFC4884 *Extended ICMP to Support Multi-Part Messages*
- [O] - **PLPMTUD** - support for Packetization Layer Path MTU Discovery.
  - RFC4821 *Packetization Layer Path MTU Discovery*
- [O] - **ND-Ext** - support for Neighbor Discovery features of enhanced DAD and First-Hop Selection.
  - RFC4429 *Optimistic Duplicate Address Detection (DAD) for IPv6*
  - RFC7527 *Enhanced Duplicate Address Detection*
  - RFC8028 *First-Hop Router Selection by Hosts in a Multi-Prefix Network*
- [O] - **ND-WL** - support for packet-loss for router solicitations.
  - RFC7048 *Neighbor Unreachability Detection Is Too Impatient*
  - RFC7559 *Packet-Loss Resiliency for Router Solicitations*
  - RFC8319 *Support for Adjustable Maximum Router Lifetimes per Link*
- [O] - **SEND** - support for neighbor discovery security extensions.
  - RFC3971 *SEcure Neighbor Discovery (SEND)*
  - RFC6494 *Certificate Profile and Certificate Management for SEcure Neighbor Discovery (SEND)*
  - RFC6495 *Subject Key Identifier (SKI) SEcure Neighbor Discovery (SEND) Name Type Fields*
- [M] - **SLAAC** - support for stateless global address auto-configuration.
  - RFC4862 *IPv6 Stateless Address Autoconfiguration*
  - RFC4862 Section: 5.5 Creation of Global Addresses *IPv6 Stateless Address Autoconfiguration*
  - RFC8106 *IPv6 Router Advertisement Options for DNS Configuration*

- RFC7217 *A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)*

- [O] - **PrivAddr** - support for SLAAC privacy extensions.
  - RFC4941 *Privacy Extensions for Stateless Address Autoconfiguration in IPv6*
- [O] - **DHCP-Stateless** - support for stateless (DHCP) configuration.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Client** - support for stateful (DHCP) address auto-configuration.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
  - RFC3646 *DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Client-Ext** - support for additional DHCP options including SIP.
  - RFC3319 *Dynamic Host Configuration Protocol (DHCPv6) Options for Session Initiation Protocol (SIP) Servers*
- [O] - **DHCP-Prefix** - support for stateful (DHCP) prefix delegation.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Prefix-Ext** - support for additional DHCP options for prefix exclude using prefix delegation.
  - RFC6603 *Prefix Exclude Option for DHCPv6-based Prefix Delegation*
- [O] - **6Lo** - support for IPv6 over low power networks.
  - RFC6282 *Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks*
  - RFC6775 *Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)*
- [O] - **Happy-Eyeballs** - support for Happy Eyeballs algorithm for dual stack environments.
  - RFC8305 *Happy Eyeballs Version 2: Better Connectivity Using Concurrency*

NISTv6-r1:Router Basic Capabilities:

- [M] - **Core** - support for IPv6 core functions.
  - RFC8200 *Internet Protocol, Version 6 (IPv6) Specification*
  - RFC4443 *Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification*
  - RFC8201 *Path MTU Discovery for IP version 6*
  - RFC4861 *Neighbor Discovery for IP version 6 (IPv6)*
  - RFC4861 Section: 8 Redirect *Neighbor Discovery for IP version 6 (IPv6)*
  - RFC6437 *IPv6 Flow Label Specification*
  - RFC5942 *IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes*
  - RFC6980 *Security Implications of IPv6 Fragmentation with IPv6 Neighbor Discovery*
  - RFC7608 *IPv6 Prefix Length Recommendation for Forwarding*
  - RFC4191 *Default Router Preferences and More-Specific Routes*
  - RFC4862 Section: 5.3 Creation of Link Local Addresses *IPv6 Stateless Address Autoconfiguration*
  - RFC4862 Section: 5.4 Duplicate Address Detection *IPv6 Stateless Address Autoconfiguration*
- [O] - **Extended-ICMP** - support for ICMPv6 extended messages.
  - RFC4884 *Extended ICMP to Support Multi-Part Messages*
- [O] - **PLPMTUD** - support for Packetization Layer Path MTU Discovery.
  - RFC4821 *Packetization Layer Path MTU Discovery*
- [O] - **ND-Ext** - support for Neighbor Discovery features of enhanced DAD and First-Hop Selection.
  - RFC4429 *Optimistic Duplicate Address Detection (DAD) for IPv6*
  - RFC7527 *Enhanced Duplicate Address Detection*
  - RFC8028 *First-Hop Router Selection by Hosts in a Multi-Prefix Network*
- [O] - **ND-WL** - support for packet-loss for router solicitations.
  - RFC7048 *Neighbor Unreachability Detection Is Too Impatient*

- RFC7559 *Packet-Loss Resiliency for Router Solicitations*
- RFC8319 *Support for Adjustable Maximum Router Lifetimes per Link*

- [O] - **SEND** - support for neighbor discovery security extensions.
  - RFC3971 *SEcure Neighbor Discovery (SEND)*
  - RFC6494 *Certificate Profile and Certificate Management for SEcure Neighbor Discovery (SEND)*
  - RFC6495 *Subject Key Identifier (SKI) SEcure Neighbor Discovery (SEND) Name Type Fields*
- [M] - **SLAAC** - support for stateless global address auto-configuration.
  - RFC4862 *IPv6 Stateless Address Autoconfiguration*
  - RFC4862 Section: 5.5 Creation of Global Addresses *IPv6 Stateless Address Autoconfiguration*
  - RFC8106 *IPv6 Router Advertisement Options for DNS Configuration*
- [O] - **DHCP-Prefix** - support for stateful (DHCP) prefix delegation.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Prefix-Ext** - support for additional DHCP options for prefix exclude using prefix delegation.
  - RFC6603 *Prefix Exclude Option for DHCPv6-based Prefix Delegation*
- [O] - **6Lo** - support for IPv6 over low power networks.
  - RFC6282 *Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks*
  - RFC6775 *Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)*

4.3. Routing Capabilities

The Routing capabilities group consists of capabilities for IPv6 routing protocols for enterprise and wide-area network usage scenarios and the CE-Router capability for typical home or small office routers. Both OSPFv3 and IS-IS contain routing mechanisms that are unchanged when using IPv4 or IPv6. As stated in OSPFv3 RFC these mechanisms are documented RFC 2328. IS-IS also these mechanisms are documented in RFC 1195.

This revision of the profile contains more OSPF, IS-IS and BGP extensions with the intention of keeping parity between IPv4 and IPv6.

4.3.1. Definition of Routing Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Router Routing Capabilities:

- [O] - **OSPF** - support for OSPF for intra-domain routing protocol.
  - RFC5340 *OSPF for IPv6*
  - RFC5613 *OSPF Link-Local Signaling*
- [O] - **OSPF-IPsec** - support for OSPF Authentication/Confidentiality using IPSec.
  - RFC4552 *Authentication/Confidentiality for OSPFv3*
- [O] - **OSPF-Auth** - support for OSPF Authentication Trailer.
  - RFC7166 *Supporting Authentication Trailer for OSPFv3*
- [O] - **OSPF-Ext** - support for additional OSPF robustness and optimization features.
  - RFC5838 *Support of Address Families in OSPFv3*
  - RFC6845 *OSPF Hybrid Broadcast and Point-to-Multipoint Interface Type*
  - RFC6860 *Hiding Transit-Only Networks in OSPF*
  - RFC8362 *OSPFv3 Link State Advertisement (LSA) Extensibility*
  - RFC5185 *OSPF Multi-Area Adjacency*
- [O] - **OSPF-Trans** - support for OSPF IPv4 over IPv6.
  - RFC7949 *OSPFv3 over IPv4 for IPv6 Transition*
- [O] - **OSPF-Graceful** - support for OSPF Graceful restart.
  - RFC5187 *OSPFv3 Graceful Restart*
  - RFC8379 *OSPF Graceful Link Shutdown*
- [O] - **IS-IS** - support for IS-IS for intra-domain routing protocol.
  - RFC5308 *Routing IPv6 with IS-IS*
- [O] - **IS-IS-Auth** - support for IS-IS Authentication support.
  - RFC5304 *IS-IS Cryptographic Authentication*
  - RFC5310 *IS-IS Generic Cryptographic Authentication*
- [O] - **IS-IS-Ext** - support for additional IS-IS robustness and optimization features.
  - RFC7775 *IS-IS Route Preference for Extended IP and IPv6 Reachability*
  - RFC6232 *Purge Originator Identification TLV for IS-IS*
  - RFC6233 *IS-IS Registry Extension for Purges*
  - RFC5301 *Dynamic Hostname Exchange Mechanism for IS-IS*
- [O] - **IS-IS-MT** - support for Multi Topology in IS-IS.
  - RFC5120 *M-ISIS: Multi Topology (MT) Routing in Intermediate System to Intermediate Systems (IS-ISs)*

- [O] - **BGP** - support for BGP for inter-domain routing protocols.
  - RFC4271 *A Border Gateway Protocol 4 (BGP-4)*
  - RFC4760 *Multiprotocol Extensions for BGP-4*
  - RFC2545 *Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing*
  - RFC6286 *Autonomous-System-Wide Unique BGP Identifier for BGP-4*
  - RFC6608 *Subcodes for BGP Finite State Machine Error*
  - RFC6793 *BGP Support for Four-Octet Autonomous System (AS) Number Space*
  - RFC7606 *Revised Error Handling for BGP UPDATE Messages*
  - RFC7607 *Codification of AS 0 Processing*
  - RFC7705 *Autonomous System Migration Mechanisms and Their Effects on the BGP AS_PATH Attribute*
  - RFC8212 *Default External BGP (EBGP) Route Propagation Behavior without Policies*
- [O] - **BGP-FlowSpec** - support for BGP FlowSpec capabilities.
  - RFC5575 *Dissemination of Flow Specification Rules*
  - RFC7674 *Clarification of the Flowspec Redirect Extended Community*
- [O] - **BGP-OV** - support for BGP Origin Validation capabilities.
  - RFC6811 *BGP Prefix Origin Validation*
  - RFC8481 *Clarifications to BGP Origin Validation Based on Resource Public Key Infrastructure (RPKI)*
  - RFC8097 *BGP Prefix Origin Validation State Extended Community*
  - RFC8210 *The Resource Public Key Infrastructure (RPKI) to Router Protocol, Version 1*
- [O] - **BGP-VPLS** - support for BGP VPLS capabilities.
  - RFC4761 *Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling*
- [O] - **BGP-EVPN** - support for BGP EVPN capabilities.
  - RFC7432 *BGP MPLS-Based Ethernet VPN*
- [O] - **BGP-6VPE** - support for BGP 6VPE capabilities.
  - RFC4659 *BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN*
  - RFC6565 *OSPFv3 as a Provider Edge to Customer Edge (PE-CE) Routing Protocol*
- [O] - **CE-Router** - support for customer edge router capabilities.
  - RFC7084 *Basic Requirements for IPv6 Customer Edge Routers*
  - RFC7084 Section: 4.5 Ingress Filtering (BCP38) *Basic Requirements for IPv6 Customer Edge Routers*
  - RFC6092 *Recommended Simple Security Capabilities in Customer Premises Equipment (CPE) for Providing Residential IPv6 Internet Service*
- [O] - **VRRP** - support for VRRP Routing protocols.
  - RFC5798 *Virtual Router Redundancy Protocol (VRRP) Version 3 for IPv4 and IPv6*

4.4. Quality of Service Capabilities

The Quality of Service capabilities group consists of the support for Differentiated Services QoS signaling and forwarding and support for Explicit Congestion Notification capabilities for congestion avoidance.

4.4.1. Definition of Quality of Service Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Quality of Service Capabilities:

- [O] - **DiffServ** - support for Differentiated Services capabilities.
  - RFC2474 *Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers*
  - RFC3140 *Per Hop Behavior Identification Codes*
  - RFC2597 *Assured Forwarding PHB Group*
  - RFC3246 *An Expedited Forwarding PHB (Per-Hop Behavior)*
  - RFC3247 *Supplemental Information for the New Definition of the EF PHB (Expedited Forwarding Per-Hop Behavior)*
- [O] - **ECN** - support for Explicit Congestion Notification.
  - RFC3168 *The Addition of Explicit Congestion Notification (ECN) to IP*

NISTv6-r1:Router Quality of Service Capabilities:

- [O] - **DiffServ** - support for Differentiated Services capabilities.
  - RFC2474 *Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers*
  - RFC3140 *Per Hop Behavior Identification Codes*
  - RFC2597 *Assured Forwarding PHB Group*
  - RFC3246 *An Expedited Forwarding PHB (Per-Hop Behavior)*
  - RFC3247 *Supplemental Information for the New Definition of the EF PHB (Expedited Forwarding Per-Hop Behavior)*
- [O] - **ECN** - support for Explicit Congestion Notification.
  - RFC3168 *The Addition of Explicit Congestion Notification (ECN) to IP*

4.5. Transition Mechanism Capabilities

The Transition Mechanisms capabilities group consists of multiple approaches to tunneling and interworking between IPv6 and IPv4 networks and Hosts. While the first technologies in this area focused on supporting tunneling IPv6 over IPv4, recent trends are for the reverse. It should be noted that IPv6 GRE (RFC 7676) requires support for RFC 2784 to make GRE functional.

4.5.1. Definition of Transition Mechanism Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Transition Mechanism Capabilities:

- [O] - **Tunneling-IP** - support for generic packet encapsulation tunnels using IPv6.
  - RFC2473 *Generic Packet Tunneling in IPv6 Specification*
- [O] - **Tunneling-UDP** - support for generic packet encapsulation tunnels using UDP.
  - RFC6936 *Applicability Statement for the Use of IPv6 UDP Datagrams with Zero Checksums*
- [O] - **XLAT** - support for transition mechanism 464XLAT.
  - RFC6877 *464XLAT: Combination of Stateful and Stateless Translation*
  - RFC7915 *IP/ICMP Translation Algorithm*
- [O] - **NAT64** - support for transition mechanism NAT64.
  - RFC6146 *Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers*
- [O] - **DNS64** - support for transition mechanism DNS64.
  - RFC6147 *DNS64: DNS Extensions for Network Address Translation from IPv6 Clients to IPv4 Servers*

NISTv6-r1:Router Transition Mechanism Capabilities:

- [O] - **Tunneling-IP** - support for generic packet encapsulation tunnels using IPv6.
  - RFC2473 *Generic Packet Tunneling in IPv6 Specification*
- [O] - **Tunneling-UDP** - support for generic packet encapsulation tunnels using UDP.
  - RFC6936 *Applicability Statement for the Use of IPv6 UDP Datagrams with Zero Checksums*
- [O] - **GRE** - support for generic router encapsulation tunnels.
  - RFC7676 *IPv6 Support for Generic Routing Encapsulation (GRE)*
- [O] - **DS-Lite** - support for transition mechanism DS-Lite.
  - RFC6333 *Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion*
- [O] - **LW4over6** - support for transition mechanism Lightweight 4over6.
  - RFC7596 *Lightweight 4over6: An Extension to the Dual-Stack Lite Architecture*
- [O] - **MAP-E** - support for transition mechanism MAP-E.
  - RFC7597 *Mapping of Address and Port with Encapsulation (MAP-E)*
- [O] - **MAP-T** - support for transition mechanism MAP-T.
  - RFC7599 *Mapping of Address and Port using Translation (MAP-T)*
- [O] - **XLAT** - support for transition mechanism 464XLAT.
  - RFC6877 *464XLAT: Combination of Stateful and Stateless Translation*
  - RFC7915 *IP/ICMP Translation Algorithm*
- [O] - **NAT64** - support for transition mechanism NAT64.

- RFC6146 *Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers*

- [O] - **DNS64** - support for transition mechanism DNS64.
  - RFC6147 *DNS64: DNS Extensions for Network Address Translation from IPv6 Clients to IPv4 Servers*
- [O] - **6PE** - support for 6PE.
  - RFC4798 *Connecting IPv6 Islands over IPv4 MPLS Using IPv6 Provider Edge Routers (6PE)*
- [O] - **LISP** - support for LISP protocol.
  - RFC6830 *The Locator/ID Separation Protocol (LISP)*

4.6. Link Specific Capabilities

The Link Specific capabilities group consists of the specifications for mapping and encapsulating IPv6 over various layer 2 technologies. Systems with a diversity of interface types will have multiple Link capability specifications.

4.6.1. Definition of Link Specific Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Link Specific Capabilities:

- [O] - **Link=Ethernet** - support for IPv6 over Ethernet.
  - RFC2464 *Transmission of IPv6 Packets over Ethernet Networks*
- [O] - **Link=PPP** - support for IPv6 over PPP links.
  - RFC5072 *IP Version 6 over PPP*
- [O] - **Link=G.9959** - support for IPv6 over Z-Wave.
  - RFC7428 *Transmission of IPv6 Packets over ITU-T G.9959 Networks*
- [O] - **Link=Bluetooth** - support for IPv6 over Bluetooth.
  - RFC7668 *IPv6 over BLUETOOTH(R) Low Energy*
- [O] - **Link=Bacnet** - support for IPv6 over BACnet.
  - RFC8163 *Transmission of IPv6 over Master-Slave/Token-Passing (MS/TP) Networks*
- [O] - **Link=6LoWPAN** - support for IPv6 over 802.15.4.
  - RFC4944 *Transmission of IPv6 Packets over IEEE 802.15.4 Networks*

NISTv6-r1:Router Link Specific Capabilities:

- [O] - **Link=Ethernet** - support for IPv6 over Ethernet.
  - RFC2464 *Transmission of IPv6 Packets over Ethernet Networks*
- [O] - **Link=PPP** - support for IPv6 over PPP links.
  - RFC5072 *IP Version 6 over PPP*
- [O] - **Link=G.9959** - support for IPv6 over Z-Wave.
  - RFC7428 *Transmission of IPv6 Packets over ITU-T G.9959 Networks*
- [O] - **Link=Bluetooth** - support for IPv6 over Bluetooth.
  - RFC7668 *IPv6 over BLUETOOTH(R) Low Energy*
- [O] - **Link=Bacnet** - support for IPv6 over BACnet.
  - RFC8163 *Transmission of IPv6 over Master-Slave/Token-Passing (MS/TP) Networks*
- [O] - **Link=6LoWPAN** - support for IPv6 over 802.15.4.
  - RFC4944 *Transmission of IPv6 Packets over IEEE 802.15.4 Networks*

4.7. Addressing Capabilities

The Addressing capabilities group consists of the requirements for supporting the common IPv6 addressing architecture and some enhancements for cryptographically generated addresses. Note, the capabilities associated with Privacy Addressing are in the Basic Capabilities section along with other extensions that effect Neighbor Discovery protocol.

4.7.1. Definition of Addressing Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Addressing Capabilities:

- [M] - **Addr-Arch** - support for address architecture and selection.
  - RFC4291 *IP Version 6 Addressing Architecture*
  - RFC4007 *IPv6 Scoped Address Architecture*
  - RFC4193 *Unique Local IPv6 Unicast Addresses*
  - RFC3879 *Deprecating Site Local Addresses*
  - RFC2526 *Reserved IPv6 Subnet Anycast Addresses*
  - RFC6724 *Default Address Selection for Internet Protocol Version 6 (IPv6)*
  - RFC5952 *A Recommendation for IPv6 Address Text Representation*
  - RFC7136 *Significance of IPv6 Interface Identifiers*
  - RFC7346 *IPv6 Multicast Address Scopes*
- [O] - **Addr-Arch & DHCP-Client** - applicable when both capabilities are selected.
  - RFC7078 *Distributing Address Selection Policy Using DHCPv6*
- [O] - **CGA** - support for cryptographically generated addresses.
  - RFC3972 *Cryptographically Generated Addresses (CGA)*
  - RFC4581 *Cryptographically Generated Addresses (CGA) Extension Field Format*
  - RFC4982 *Support for Multiple Hash Algorithms in Cryptographically Generated Addresses (CGAs)*

NISTv6-r1:Router Addressing Capabilities:

- [M] - **Addr-Arch** - support for address architecture and selection.
  - RFC4291 *IP Version 6 Addressing Architecture*
  - RFC4007 *IPv6 Scoped Address Architecture*
  - RFC4193 *Unique Local IPv6 Unicast Addresses*
  - RFC3879 *Deprecating Site Local Addresses*
  - RFC2526 *Reserved IPv6 Subnet Anycast Addresses*
  - RFC6724 *Default Address Selection for Internet Protocol Version 6 (IPv6)*
  - RFC5952 *A Recommendation for IPv6 Address Text Representation*
  - RFC7136 *Significance of IPv6 Interface Identifiers*
  - RFC6164 *Using 127-Bit IPv6 Prefixes on Inter-Router Links*
  - RFC7346 *IPv6 Multicast Address Scopes*
- [O] - **Addr-Arch & DHCP-Client** - applicable when both capabilities are selected.
  - RFC7078 *Distributing Address Selection Policy Using DHCPv6*
- [O] - **CGA** - support for cryptographically generated addresses.
  - RFC3972 *Cryptographically Generated Addresses (CGA)*
  - RFC4581 *Cryptographically Generated Addresses (CGA) Extension Field Format*

- RFC4982 *Support for Multiple Hash Algorithms in Cryptographically Generated Addresses (CGAs)*

4.8. Security Capabilities

The security capabilities group consists of the specifications related to both IP (IPsec) and Transport (TLS) secure channels. This includes capabilities for key management and underlying cryptographic algorithms.

4.8.1. Definition of Security Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Security Capabilities:

- [O] - **IPsec** - support for the IP security architecture.
  - RFC4301 *Security Architecture for the Internet Protocol*
  - RFC4303 *IP Encapsulating Security Payload (ESP)*
  - RFC7296 *Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8221 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-IoT** - support for IoT Cryptographic Algorithms.
  - RFC8221 Section: 5 AES-CCM with a 8 octet ICV *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.1 AES-CCM with a 8 octet ICV *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.2 PRF_AES128_XCBC *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_AES_XCBC_96 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-CHACHA** - support for ChaCha20 Cryptographic Algorithms.
  - RFC8221 Section: 5 CHACHA20_POLY1305 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.1 CHACHA20_POLY1305 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-SHA-512** - support for SHA-512 Cryptographic Algorithms.
  - RFC8221 Section: 6 AUTH_HMAC_SHA2_512_256 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.2 PRF_HMAC_SHA2_512 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_HMAC_SHA2_512_256 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **TLS** - support for Transport Layer Security architecture version 1.2.
  - RFC5246 *The Transport Layer Security (TLS) Protocol Version 1.2*
  - RFC6176 *Prohibiting Secure Sockets Layer (SSL) Version 2.0*
  - RFC7465 *Prohibiting RC4 Cipher Suites*

- RFC7568 *Deprecating Secure Sockets Layer Version 3.0*
- RFC5746 *Transport Layer Security (TLS) Renegotiation Indication Extension*

- [O] - **TLS-1.3** - support for Transport Layer Security architecture version 1.3.
  - RFC8446 *The Transport Layer Security (TLS) Protocol Version 1.3*

NISTv6-r1:Router Security Capabilities:

- [O] - **IPsec** - support for the IP security architecture.
  - RFC4301 *Security Architecture for the Internet Protocol*
  - RFC4303 *IP Encapsulating Security Payload (ESP)*
  - RFC7296 *Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8221 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-VPN** - support for the IP security architecture gateways.
  - RFC4301 *Security Architecture for the Internet Protocol*
  - RFC4303 *IP Encapsulating Security Payload (ESP)*
  - RFC7296 *Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8221 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-IoT** - support for IoT Cryptographic Algorithms.
  - RFC8221 Section: 5 AES-CCM with a 8 octet ICV *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.1 AES-CCM with a 8 octet ICV *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.2 PRF_AES128_XCBC *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_AES_XCBC_96 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-IoT-VPN** - support for IoT Cryptographic Algorithms in gateways.
  - RFC8221 Section: 5 AES-CCM with a 8 octet ICV *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.1 AES-CCM with a 8 octet ICV *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.2 PRF_AES128_XCBC *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_AES_XCBC_96 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-CHACHA** - support for ChaCha20 Cryptographic Algorithms.
  - RFC8221 Section: 5 CHACHA20_POLY1305 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.1 CHACHA20_POLY1305 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-CHACHA-VPN** - support for ChaCha20 Cryptographic Algorithms in gateways.

- RFC8221 Section: 5 CHACHA20_POLY1305 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
- RFC8247 Section: 2.1 CHACHA20_POLY1305 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*

- [O] - **IPsec-SHA-512** - support for SHA-512 Cryptographic Algorithms.
  - RFC8221 Section: 6 AUTH_HMAC_SHA2_512_256 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.2 PRF_HMAC_SHA2_512 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_HMAC_SHA2_512_256 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **IPsec-SHA-512-VPN** - support for SHA-512 Cryptographic Algorithms in gateways.
  - RFC8221 Section: 6 AUTH_HMAC_SHA2_512_256 *Cryptographic Algorithm Implementation Requirements and Usage Guidance for Encapsulating Security Payload (ESP) and Authentication Header (AH)*
  - RFC8247 Section: 2.2 PRF_HMAC_SHA2_512 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
  - RFC8247 Section: 2.3 AUTH_HMAC_SHA2_512_256 *Algorithm Implementation Requirements and Usage Guidance for the Internet Key Exchange Protocol Version 2 (IKEv2)*
- [O] - **TLS** - support for Transport Layer Security architecture version 1.2.
  - RFC5246 *The Transport Layer Security (TLS) Protocol Version 1.2*
  - RFC6176 *Prohibiting Secure Sockets Layer (SSL) Version 2.0*
  - RFC7465 *Prohibiting RC4 Cipher Suites*
  - RFC7568 *Deprecating Secure Sockets Layer Version 3.0*
  - RFC5746 *Transport Layer Security (TLS) Renegotiation Indication Extension*
- [O] - **TLS-1.3** - support for Transport Layer Security architecture version 1.3.
  - RFC8446 *The Transport Layer Security (TLS) Protocol Version 1.3*

4.9. Network Management Capabilities

The Network Management capabilities group consists of the specifications related to management of networked devices. This includes capabilities for both SNMP and NETCONF based configuration, monitoring and management.

4.9.1. Definition of Network Management Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Network Management Capabilities:

- [O] - **SNMP** - support for simple network management protocol.
  - RFC3411 *An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks*
  - RFC3412 *Message Processing and Dispatching for the Simple Network Management Protocol (SNMP)*
  - RFC3413 *Simple Network Management Protocol (SNMP) Applications*
  - RFC3414 *User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3)*
  - RFC4293 *Management Information Base for the Internet Protocol (IP)*
  - RFC4292 *IP Forwarding Table MIB*
  - RFC4022 *Management Information Base for the Transmission Control Protocol (TCP)*
  - RFC4113 *Management Information Base for the User Datagram Protocol (UDP)*
- [O] - **SNMP & Tunneling** - applicable when both capabilities are selected.
  - RFC4087 *IP Tunnel MIB*
- [O] - **SNMP & IPsec** - applicable when both capabilities are selected.
  - RFC4807 *IPsec Security Policy Database Configuration MIB*
- [O] - **SNMP & DiffServ** - applicable when both capabilities are selected.
  - RFC3289 *Management Information Base for the Differentiated Services Architecture*
- [O] - **NETCONF** - support for network configuration functions.
  - RFC6241 *Network Configuration Protocol (NETCONF)*
  - RFC8344 *A YANG Data Model for IP Management*
  - RFC8343 *A YANG Data Model for Interface Management*
  - RFC8348 *A YANG Data Model for Hardware Management*
  - RFC8349 *A YANG Data Model for Routing Management (NMDA Version)*

NISTv6-r1:Router Network Management Capabilities:

- [O] - **SNMP** - support for simple network management protocol.
  - RFC3411 *An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks*
  - RFC3412 *Message Processing and Dispatching for the Simple Network Management Protocol (SNMP)*
  - RFC3413 *Simple Network Management Protocol (SNMP) Applications*
  - RFC3414 *User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3)*
  - RFC4293 *Management Information Base for the Internet Protocol (IP)*
  - RFC4292 *IP Forwarding Table MIB*

- RFC4022 *Management Information Base for the Transmission Control Protocol (TCP)*
- RFC4113 *Management Information Base for the User Datagram Protocol (UDP)*

- [O] - **SNMP & Tunneling** - applicable when both capabilities are selected.
  - RFC4087 *IP Tunnel MIB*
- [O] - **SNMP & IPsec** - applicable when both capabilities are selected.
  - RFC4807 *IPsec Security Policy Database Configuration MIB*
- [O] - **SNMP & DiffServ** - applicable when both capabilities are selected.
  - RFC3289 *Management Information Base for the Differentiated Services Architecture*
- [O] - **NETCONF** - support for network configuration functions.
  - RFC6241 *Network Configuration Protocol (NETCONF)*
  - RFC8344 *A YANG Data Model for IP Management*
  - RFC8343 *A YANG Data Model for Interface Management*
  - RFC8348 *A YANG Data Model for Hardware Management*
  - RFC8349 *A YANG Data Model for Routing Management (NMDA Version)*

4.10. Multicast Capabilities

The Multicast capabilities group consists of the specifications for both link local and routed multicast communications. Since MLDv2 requires the Router Alert Option (RFC 2711) as specified in RFC 3810 it's support is included in the Multicast and SSM Capabilities. PIM-SM and its extended features provides multicast routing.

4.10.1. Definition of Multicast Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Multicast Capabilities:

- [O] - **SSM** - require full support for multicast communications.
  - RFC3810 *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*
  - RFC4607 *Source-Specific Multicast for IP*
  - RFC4604 *Using Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast*
- [M] - **Multicast** - support for link-local multicast communication.
  - RFC3810 *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*
  - RFC3306 *Unicast-Prefix-based IPv6 Multicast Addresses*
  - RFC3307 *Allocation Guidelines for IPv6 Multicast Addresses*
  - RFC7371 *Updates to the IPv6 Multicast Addressing Architecture*

NISTv6-r1:Router Multicast Capabilities:

- [O] - **SSM** - require full support for multicast communications.
  - RFC3810 *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*
  - RFC4607 *Source-Specific Multicast for IP*
  - RFC4604 *Using Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Discovery Protocol Version 2 (MLDv2) for Source-Specific Multicast*
- [M] - **Multicast** - support for link-local multicast communication.
  - RFC3810 *Multicast Listener Discovery Version 2 (MLDv2) for IPv6*
  - RFC3306 *Unicast-Prefix-based IPv6 Multicast Addresses*
  - RFC3307 *Allocation Guidelines for IPv6 Multicast Addresses*
  - RFC7371 *Updates to the IPv6 Multicast Addressing Architecture*
- [O] - **PIM-SM** - support for PIM-SM Routing protocols.
  - RFC7761 *Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)*
- [O] - **PIM-SM-RP** - support for PIM-SM RP Discovery mechanisms.
  - RFC4610 *Anycast-RP Using Protocol Independent Multicast (PIM)*
  - RFC5059 *Bootstrap Router (BSR) Mechanism for Protocol Independent Multicast (PIM)*
  - RFC3956 *Embedding the Rendezvous Point (RP) Address in an IPv6 Multicast Address*
- [O] - **PIM-SM-IPsec** - support for PIM-SM over IPsec.
  - RFC5796 *Authentication and Confidentiality in Protocol Independent Multicast Sparse Mode (PIM-SM) Link-Local Messages*
- [O] - **PIM-SM-BiDir** - support for Bidirectional PIM-SM routing protocol.
  - RFC5015 *Bidirectional Protocol Independent Multicast (BIDIR-PIM)*

4.11. Network Support Capabilities

The Network Support capabilities group consists of the specifications for protocols for DHCPv6 Server, DNS resolution of IPv6 names and the use of IPv6 addresses in URIs.

4.11.1. Definition of Network Support Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Host Network Support Capabilities:

- [O] - **DNS-Client** - support for DNS client/resolver functions.
  - RFC3596 *DNS Extensions to Support IP Version 6*
  - RFC2671 *Extension Mechanisms for DNS (EDNS0)*
  - RFC3226 *DNSSEC and IPv6 A6 aware server/resolver message size requirements*
- [O] - **URI** - support for IPv6 uniform resource identifiers.
  - RFC3986 *Uniform Resource Identifier (URI): Generic Syntax*
  - RFC6874 *Representing IPv6 Zone Identifiers in Address Literals and Uniform Resource Identifiers*
- [O] - **NTP-Client** - support for NTP client capabilities.
  - RFC5905 *Network Time Protocol Version 4: Protocol and Algorithms Specification*
- [O] - **NTP-Server** - support for NTP server capabilities.
  - RFC5905 *Network Time Protocol Version 4: Protocol and Algorithms Specification*
- [O] - **DNS-Server** - support for DNS server capabilities.
  - RFC3596 *DNS Extensions to Support IP Version 6*
- [O] - **DHCP-Server** - support for DHCP server capabilities.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
  - RFC3646 *DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Server-Ext** - support for DHCP server for additional DHCP options and Bulk Leasequery.
  - RFC5460 *DHCPv6 Bulk Leasequery*
  - RFC3319 *Dynamic Host Configuration Protocol (DHCPv6) Options for Session Initiation Protocol (SIP) Servers*
- [O] - **DHCP-Relay** - support for DHCP relay capabilities.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*

NISTv6-r1:Router Network Support Capabilities:

- [O] - **DNS-Client** - support for DNS client/resolver functions.
  - RFC3596 *DNS Extensions to Support IP Version 6*
  - RFC2671 *Extension Mechanisms for DNS (EDNS0)*
  - RFC3226 *DNSSEC and IPv6 A6 aware server/resolver message size requirements*
- [O] - **URI** - support for IPv6 uniform resource identifiers.
  - RFC3986 *Uniform Resource Identifier (URI): Generic Syntax*
  - RFC6874 *Representing IPv6 Zone Identifiers in Address Literals and Uniform Resource Identifiers*
- [O] - **NTP-Client** - support for NTP client capabilities.
  - RFC5905 *Network Time Protocol Version 4: Protocol and Algorithms Specification*

- [O] - **NTP-Server** - support for NTP server capabilities.
  - RFC5905 *Network Time Protocol Version 4: Protocol and Algorithms Specification*
- [O] - **DNS-Server** - support for DNS server capabilities.
  - RFC3596 *DNS Extensions to Support IP Version 6*
- [O] - **DHCP-Server** - support for DHCP server capabilities.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
  - RFC3646 *DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*
- [O] - **DHCP-Server-Ext** - support for DHCP server for additional DHCP options and Bulk Leasequery.
  - RFC5460 *DHCPv6 Bulk Leasequery*
  - RFC3319 *Dynamic Host Configuration Protocol (DHCPv6) Options for Session Initiation Protocol (SIP) Servers*
- [O] - **DHCP-Relay** - support for DHCP relay capabilities.
  - RFC8415 *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*

4.12. Application and Service Capabilities

The Application and Service capabilities group consists of a framework to define the IPv6 capabilities of a broad range of general applications. User defined capabilities allow the specification of application specific functions and protocols that may not have consensus standard specifications.

4.12.1. Definition of Application and Service Capability Requirements

The technical requirements of the capabilities in this group are defined by the users based on the application types:

NISTv6-r1:App-Serv Capabilities:

- [O] - **App-Serv=[TBD]** - support for application/service specific functions over IPv6.
  - SP500-267Ar1 Section: 4.12 Application and Service Capabilities. *NIST IPv6 Profile*

Beyond the application environment requirements explained above, users of this profile should require any application to demonstrate working in an IPv6-only environment as documented in Section 4.1. The following general guidance may be useful in the formulation of such additional validation of application requirements.

The practical implications of the above guidance will vary with applications and specific implementation. The following lists some of the common issues that will require code modifications to support IPv6 at the application level.

- If the application parses text that may contain an IP address (e.g., as part of URI processing), such code must also support IPv6 addresses.
- If the application stores any information in files (e.g., in a cache), and that information can include IP addresses, it must be possible to store IPv6 addresses as well.
- If the application stores IP addresses in binary format, then it should make use of protocol agnostic structures (e.g., sockaddrs), rather than, say 4-byte integers, so that it will automatically be able to handle IPv6's longer addresses.
- If the application uses DNS names that application support use IPv6 AAAA resource records and the operation of DNS natively over IPv6. It should also support receiving A resource records in conjunction with AAAA and be able to connect over IPv6.
- When storing information using a network protocol (Cloud Service, FTP, Sharing Service) ensure it can work over IPv6.

- The product must be fully functional in IPv6 only network contexts.
    - If the product runs a private protocol with a peer, and the message flows include IP-address specific information (e.g., a specific IP address), the protocol needs to be updated to support the transport of IPv6 information as well.

Users of this profile may supply any additional requirements that must be met by specific applications.

4.13. Switch Capabilities

The Switch capabilities group consists of capabilities for Layer 2 switches improve network performance and security of IPv6.

4.13.1. Definition of Switch Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:Switch Capabilities:

- [O] - **DHCPv6-Guard** - support for DHCPv6 Guard at Layer 2.
  - RFC7610 *DHCPv6-Shield: Protecting against Rogue DHCPv6 Servers*
- [O] - **RA-Guard** - support for RA Guard at Layer 2.
  - RFC6105 *IPv6 Router Advertisement Guard*
  - RFC7113 *Implementation Advice for IPv6 Router Advertisement Guard (RA-Guard)*
- [O] - **MLD-Snooping** - support for MLD Snooping at Layer 2.
  - RFC4541 *Considerations for Internet Group Management Protocol (IGMP) and Multicast Listener Discovery (MLD) Snooping Switches*

4.14. Network Protection Product Capabilities

The Network Protection Product capabilities group consists of the requirements defined in this document to specify the requirements of common network security devices. This includes capabilities for firewalls, intrusions detection and protection applications, as well as application specific firewalls.

4.14.1. Definition of Network Protection Product Capability Requirements

The technical requirements of the capabilities in this group are defined by the following mappings:

NISTv6-r1:NPP Capabilities:

- [O] - **FW** - support for basic firewall capabilities.
  - SP500-267Ar1 Section: 4.14.3 Common Requirements for Network Protection Devices *NIST IPv6 Capabilities Profile*
  - SP500-267Ar1 Section: 4.14.4 Firewall Requirements *NIST IPv6 Capabilities Profile*
- [O] - **IDS** - support for intrusion detection capabilities.
  - SP500-267Ar1 Section: 4.14.3 Common Requirements for Network Protection Devices *NIST IPv6 Capabilities Profile*
  - SP500-267Ar1 Section: 4.14.5.1 Intrusion Detection System *NIST IPv6 Capabilities Profile*
- [O] - **IPS** - support for intrusion protection capabilities.
  - SP500-267Ar1 Section: 4.14.3 Common Requirements for Network Protection Devices *NIST IPv6 Capabilities Profile*
  - SP500-267Ar1 Section: 4.14.5.2 Intrusion Prevention *NIST IPv6 Capabilities Profile*
- [O] - **APFW** - support for application firewall capabilities.
  - SP500-267Ar1 Section: 4.14.3 Common Requirements for Network Protection Devices *NIST IPv6 Capabilities Profile*
  - SP500-267Ar1 Section: 4.14.4.2 Application Firewall *NIST IPv6 Capabilities Profile*

Given the lack of public consensus standards in this area, this section serves as the primary source of Network Protection Product (NPP) requirements. Thus, this section provides both the definition of the capabilities in this area and the definition of their technical requirements.

Network protection products (firewalls, intrusion detection systems (IDS), intrusion prevention systems (IPS) and the like) are currently essential for securing external network connections in the Internet. As IPv6 is deployed in production networks, it is essential that IPv6 network protection products be just as capable as their IPv4 counterparts. Ensuring this capability exists is the goal of these requirements.

The requirements listed here concentrate on the IPv6-specific features required for network protection products. Any other features an agency requires for its network function (e.g., support for a particular administrative model or a special authentication method) are to be addressed through the user's usual specification and validation methods.

In particular, IPv4-only features are not addressed here. While it is to be expected that IPv4 traffic will continue for the foreseeable future, and hence IPv4 network protection products will be required, a user can choose to use separate network protection products for IPv4 and IPv6 traffic. Hence, even for network functions which offer both IPv4 and IPv6 network protection features, this profile only addresses their IPv6 functionality.

In general, these requirements seek merely to establish the minimal threshold of functionality required for IPv6 network protection products. For firewalls, this means basic port-blocking and (for application firewalls) application data filtering, while for intrusion detection and prevention systems, this means the ability to detect (and, in the case of IPSs, to prevent or disrupt) known attack patterns, including IPv6 version of known IPv4 attacks. In both cases, network protection products will typically offer other more sophisticated features, such as statistical anomaly detection, but given the minimal nature of these requirements, they will not be addressed here.

4.14.2. Source of requirements

The sort of functionality provided by network protection products is not well-covered by protocol or interoperability specifications such as Internet RFCs. Hence, we cannot create the same sort of profiles as for Host systems or Routers, where we can specify desired functionality by listing relevant RFCs and options. Instead, we must list all requirements explicitly.

4.14.3. Common requirements for network protection products

4.14.3.1. Basic host or router IPv6 connectivity requirements

While network protection products are technically, in terms of their connection characteristics, either hosts or routers, they are not typically expected to provide the same level of functionality, unless they are part of some combined capabilities (such as a firewall-router).

More commonly, network protection products only implement basic protocol capabilities to the extent necessary to perform their security functions while not interfering with the interoperability of desirable traffic passing through them. This typically includes basic protocol parsing, address recognition, link encapsulation, etc. Often many other basic protocol functions (e.g., error reporting, auto configuration) are implemented in non-standard ways on such functions or omitted.

Given the variance of capability and behavior of these basic IPv6 connectivity requirements in NPPs, we do not attempt to specify them in detail here. Instead we focus on the specification of their network security capabilities. Certainly, for combined capabilities, users of this profile can specify that a network protection device comply with the requirements of both a Router and a firewall (for example).

4.14.3.2. Dual stack

While it is expected that most network protection products will provide protection functionality for both IPv4 and IPv6 traffic, only IPv6 protection functionality is addressed here.

4.14.3.3. Administrative functionality

A network protection device must offer sufficient administrative controls to allow effective use of the facilities it offers. This includes controls over the configuration of its protective functionality, its logging and alert facilities, and access to the administrative facilities themselves. Such administrative functionality MUST be available either directly on the network protection device console or equivalent, or through remote communications using openly-defined means.

4.14.3.4. Authentication and authorization

All administrative access to a network protection device MUST be controlled through appropriate authentication mechanisms and restricted to appropriately authorized users. In the case of network protection products which do not separate administrative roles, authentication as an administrator can be viewed as sufficient authorization.

4.14.3.5. Security of control and communications

All administrative controls MUST be secure from non-authorized access, and all administrative communications with a network protection device must be secure from outside observation. This can be done through local console-type access; through FIPS-approved encrypted network communication; or through network communications which are secured through other means from outside access (such as VLAN separation or firewall blocking).

4.14.3.6. Persistence

All network protection products settings MUST persist through loss and restoration of electrical power.

4.14.3.7. Logging and alerts

Network protection products MUST provide sufficient administrative capability to allow inspection of all administratively-controlled settings and give assurance of their proper functioning. Such capability MUST be controllable by, and accessible to, properly authorized administrators.

Intrusion detection systems have additional logging requirements, as described below.

4.14.3.8. Fragmented packet handling

Network protection products MUST be able to handle fragmented packets, whether by provisionally reassembling and applying appropriate controls based on the reassembled packet.

4.14.3.9. Tunneled traffic handling

Network protection products MUST be able to handle all v4/v6 tunneling schemes, no matter how embedded, either by analyzing and applying the appropriate controls based on the encapsulated packet header, or (in the case of firewalls) by simply blocking all unanalyzed tunneled packets.

4.14.4. Firewall requirements (Common Requirements)

4.14.4.1. Port/protocol/address blocking

Firewalls MUST allow selective blocking/admission of traffic by protocol, and, for IPv6 packets, by source and/or destination subnet and/or address, by extension header type and, for higher-level protocols, by the appropriate per-protocol subfields - ports for UDP and TCP, and type and code for ICMP. Such blocking/admission MUST be equally effective for both normal and IPsec traffic; the latter to the extent such fields are visible in the packet.

Port blocking/admission functionality MUST be sufficiently rich to allow discrete controls in both directions down to the individual port level, for any desired ports. While it is desirable to be able to block/admit any possible combination of ports, at a minimum the port-blocking functionality MUST have sufficient capacity to selectively include or exclude all commonly used services.

Address blocking functionality MUST be sufficiently rich to allow blocking of all traffic with source or destination addresses which ought not to be present in traffic sent between external and internal networks, such as local addresses (including loopback, link local, site local, and RFC4193-style unique local addresses), or source multicast addresses.

Firewalls MUST allow blocking of all traffic which has not been explicitly authorized.

4.14.4.2. Asymmetrical blocking

Firewalls MUST, either through software or hardware configuration, distinguish between external and internal connected networks, and allow imposing asymmetrical controls on traffic between these networks. In particular, for connection-oriented protocols such as TCP, firewalls MUST have the ability to allow bidirectional traffic flow over connections initiated from hosts on the internal network to hosts on the external network, while blocking connection initiation from the external network.

For request/response protocols without explicit connection setup (e.g., ICMP echo request and reply), firewalls MUST be able to selectively block unsolicited (vs. solicited) replies coming from the external network.

4.14.4.3. IPv6 Traffic Filtering

Firewalls MUST discard all traffic from and to reserved IPv6 address space. Firewalls should also filter packets with illegal IPv6 Header chains.

4.14.4.4. IPsec traffic handling

Firewalls MUST either be capable of terminating IPsec connections (security gateways) or be capable of selectively blocking IPsec traffic.

4.14.4.5. Performance under load, fail-safe

When firewalls suffer operational degradation or failure due to high network loads or other factors, they MUST fail in such a manner as not to allow unauthorized access.

4.14.5. Application firewall requirements

4.14.5.1. No violation of trust barriers

Application firewall mediation of data transversal (session, file, etc.) through the firewall MUST NOT violate trust barriers, either by improperly rewriting incoming untrusted data to appear trusted, or by improperly exposing information (such as internal network structures) to external untrusted networks.

4.14.5.2. Session traffic authorization

Application firewalls MUST have means of controlled authorization for the establishment of sessions initiated from the external network to internal hosts.

4.14.5.3. Email, file filtering

Application firewalls MUST have configurable means for examining files (such as email attachments) that are transferred from the external network to internal hosts for the presence of undesired elements, and, when such elements are found, selectively blocking or stripping them. The means of detection used varies with the firewall, ranging from pattern (signature)-matching or other heuristics for virus detection, to the simple blocking of, for example, all executable file content. In any case, the means MUST be sufficient to block typical threat traffic.

4.14.6. Intrusion detection and prevention system requirements

4.14.6.1. Known attack detection

Intrusion detection systems MUST provide a configurable capability to detect suspicious traffic based on known attack patterns, including those embedded in HTTP and SMTP traffic.

4.14.6.2. Port-scanning detection

Intrusion detection systems MUST detect typical port scanning (multiple ports of a single host) and host scanning (single port across multiple hosts) techniques, including "stealth" scans. (Note that while "blind" host scanning across a subnet is not considered feasible for IPv6, other techniques such as scanning based on DNS data are still a concern.)

4.14.6.3. Tunneled traffic detection

Intrusion detection systems MUST be able to detect threat patterns even for tunneled traffic, when packet data contents may be embedded with multiple IP (v6/v4) headers. For tunneling methods for which content examination is not supported, it is sufficient merely to block all such tunneled packets.

4.14.6.4. Logging and alerts

Intrusion detection systems MUST provide means to log all suspicious traffic and send notification to the appropriate administrators.

4.14.6.5. Performance under load, fail-safe

When intrusion detection systems suffer operational degradation or failure due to high network loads or other factors, they MUST provide notification of such failure. In cases of overload, intrusion detection systems SHOULD prioritize their processing to preferentially examine the highest-risk traffic.

4.14.7. Intrusion prevention requirements

4.14.7.1. Intrusion prevention

Intrusion prevention products MUST implement the intrusion detection capabilities listed in the previous section. In addition, intrusion prevention products MUST provide means to stop or attenuate detected attacks, either (when inline) directly or through manipulation of other network functions (e.g., updating a router ACL or firewall rule set). Such prevention means include dropping or rejecting suspect packets, throttling bandwidth usage from suspect sources, or rewriting or removing malicious content.

5. Profile Usage Guidance and Examples

This appendix provides guidance and examples to illustrate the expected usage of this profile. This profile is intended to be a strategic document for IT planning and acquisition officials that provides a technical basis for conveying technical requirements to IPv6 product vendors. Likewise, vendors can use the profile to unambiguously convey detailed information about the IPv6 capabilities of their product offerings.

The primary means to facilitate this exchange of information between users and vendors is through Capability Summary Strings (CSS) (see section 2.5). As noted CSS can be used both as statements of IPv6 requirements from purchasers and statements of product IPv6 capabilities from vendors.

Some example capability summary definitions are given below. These CSS strings could be either requirements statements or product capability reports depending upon the usage scenario. These examples are provided both to illustrate the use of the profile and to provide templates that can be modified and used by others.

- **Minimal-Host = NISTv6-r1:Host + Core + SLAAC + Addr-Arch + Multicast**
    - This CSS describes the minimal mandatory Host requirements from the IETF Node Requirements specification [RFC8504]. Note this example can be used as a stub from which to build other, more complete CSS.
- **Minimal-Router = NISTv6-r1:Router + Core + SLAAC + Addr-Arch + Multicast**
    - This CSS describes the minimal mandatory Host requirements from the IETF Node Requirements specification [RFC8504]. Note this example can be used as a stub from which to build other, more complete CSS.
- **IPv6-only-Laptop = NISTv6-r1:Host + IPv6-ONLY + Core + SLAAC + Addr-Arch + Multicast + DNS-Client + TLS + Link=Ethernet.**
    - This CSS describes a typical configuration for a laptop to be used on an IPv6-only Wireless link. When using the IPv6-ONLY capability it indicates that all the capabilities work in an IPv6-only environment.
- **Default-Desktop = NISTv6-r1:Host + Core + SLAAC + Addr-Arch + Multicast + DHCP-client + DNS-Client + TLS + URI + Link=Ethernet.**
    - This CSS describes a typical configuration for a desktop PC that relies DHCP for network configuration and a dual stack transition mechanism.
- **Default-App-Server = NISTv6-r1:Host + Core + Addr-Arch + Multicast + [IPSec|TLS] + URI + DNS-Client + Link=Ethernet.**
    - This CSS describes a requirement statement for a typical application server that uses manually configured addresses, dual stack transition mechanisms,

and a choice of IPsec or TLS for secure communication. If there is a specific application being supported it would be an additional capability string for that function.

- **Default-IOT = NISTv6-r1:Host + IPv6-ONLY + 6Lo + Link=6LoWPAN**
    - This CSS describes a requirement statement for a typical IoT device operating on a low powered wireless network with only support for IPv6. Notice the lack of support for many of the recommended mandatory capabilities. IoT devices sometimes have very minimal, or non-standard implementations of core protocols. Note this example can be used as a stub from which to build other, more complete CSS.
- **Default-DC-Router = NISTv6-r1:Router + Core + Addr-Arch + Multicast + BGP + BGP-EVPN + BGP-VPLS + [SNMP|NETCONF] + IPv6-ONLY + Link=Ethernet**
    - This CSS describes a requirement statement for a typical data center router supporting BGP as the IPv6 routing protocol and either NETCONF or SNMP for configuration and management. IPv6-only requires that this DataCenter router works properly in an IPv6-only Datacenter.
- **Example.com-DC-Router = NISTv6-r1:Router + Core + Addr-Arch + Multicast + OSPF + ISIS + NETCONF + IPv6-ONLY + GRE + Link=Ethernet**
    - This CSS describes a product capability statement for Example.com's data center router that meets the requirement statement above. This product supports both OSPF and ISIS as the IPv6 routing protocol but only NETCONF for configuration and management. Note that the product documents some additional capabilities (GRE) not mentioned in the requirements statement above. A requirements state is understood to document the minimal required set of IPv6 capabilities.
- **Default-Enterprise-Router = NISTv6-r1:Router + Core + Addr-Arch + Multicast + [OSPF|ISIS] + [SNMP|NETCONF] + [IPsec|TLS] + [Tunneling-IP|Tunneling-UDP] + PIM-SM + Link=Ethernet**
    - This CSS describes a requirement statement for a typical enterprise router, that expands on the previous data center definition to add capabilities for secure channels and simple transition mechanisms.
- **Advanced-Enterprise-OSPF-Router = NISTv6-r1:Router + Core + Addr-Arch + Multicast + OSPF + OSPF-Auth + OSPF-Ext + OSPF-Graceful + [SNMP|NETCONF] + [IPsec|TLS] + [Tunneling-IP|Tunneling-UDP] + PIM-SM + Link=Ethernet**
    - This CSS describes a requirement statement for a typical enterprise router, that expands on the previous data center definition to add capabilities for secure channels and simple transition mechanisms.

- **Default-Border-Router = NISTv6-r1:Router + Core + Addr-Arch + Multicast + BGP + BGP-OV + BGP-Flowspec + TLS + [OSPF|ISIS] + [SNMP|NETCONF] + Tunneling-IP + Link=Ethernet**
    - This CSS describes a requirement statement for a typical border router supporting either OSPF or ISIS as the IPv6 routing protocol and either NETCONF or SNMP for configuration and management. An IP Tunneling transition mechanisms is required. BGP security specifications are also included for protecting the router. Note that the choice of IPv6 routing protocols would have to be coordinated with enterprise router specifications.
- **Default-SGW = NISTv6-r1:Router + Core + OSPF + TLS + IPsec-VPN + Link=Ethernet**
    - This CSS describes a requirement statement for a Security Gateway running OSPF.
- **Default-CE-Router = NISTv6-r1:Router + CE-Router + Link=Ethernet**
    - This CSS describes a requirement statement for a typical SOHO router.
- **Default-MAP-E = NISTv6-r1:Router + CE-Router + MAP-E + Link=Ethernet**
    - This CSS describes a requirement statement for a typical SOHO router that provides the MAP-E transition mechanisms for IPv6-only wide area networking.
- **Default-Firewall = NISTv6-r1:NPP + Firewall**
    - This CSS describes a requirement statement for a typical simple firewall.
- **Default-IDS-IPS = NISTv6-r1:NPP + IPS + IDS**
    - This CSS describes a requirement statement for a typical intrusion detection / prevention system.
- **Default-Switch = NISTv6-r1:Switch + IPv6-ONLY + DHCPv6-Guard + RA-Guard + MLD-Snooping**
    - This CSS describes a requirement statement for a Layer 2 switch that functions on IPv6-only network supporting all the necessary functions for deploying IPv6 network. In many cases switches will also have a capability string for host for management purposes.

By providing a convenient way to select and articulate sets of requirements, the profile facilitates the description of a vast array of distinct product requirements and configurations. While we suspect that there will be a few bundled sets of requirements that will be used quite commonly, we also believe that there is tremendous variance in the packaging of feature sets

in commercial products and attempts to overly "standardize" such configurations may not afford the flexibility needed.

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Appendix A: Change Log

Future revisions of this document will list major changes in this appendix.