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USGv6 Test Methods: General Description and Validation

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USGv6 Test Methods: General Description and Validation

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U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Under Secretary of Commerce for Standards and Technology

Reports on Computer Systems Technology

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Executive Summary

The Office of Management and Budget (OMB) directed [OMB-M21-07, OMB-IPv6, OMB-M05-22] the National Institute of Standards and Technology (NIST) to develop the technical infrastructure (standards and testing) necessary to support wide scale adoption of Internet Protocol version 6 (IPv6) in the US Government (USG). In response, NIST developed the USGv6 Profile to assist agencies in the development of acquisition requirements for IPv6 products and the USGv6 Test Program to provide the means to assess product compliance to such requirements. In subsequent years additional USG policies [OMB-M21-07, OMB-IPv6, FAR-2005-041, OMB-M17-06] referred to these USGv6 programs.

The USGv6 Program is primarily comprised from the USGv6 Profile [SP500-267Br1] and the USGv6 Test Program [SP500-281Ar1]. This document defines the quality management processes for the test program, including the topics of test method validation, laboratory accreditation processes and the role of the laboratory accreditors. In technical terms this document defines the scopes of accreditation for the USGv6 Test Program.

The USGv6 test program requires all testing to be conducted at laboratories that have been formally accredited in the use of its test methods in accordance with [ISO/IEC-17025]. The test program requires that laboratory accreditor organization's qualifications include compliance with [ISO/IEC-17011-2] and being signatory to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Agreement (MRA).

In order to promote comparability of test results across the accredited testing laboratories we encourage qualified accreditors to collaborate in the development of USGv6 testing specific accreditation requirements and publish, or reference, the technical criteria to be applied in addition to the requirements of ISO/IEC 17025 in the accreditation of IPv6 testing laboratories. This document is intended to provide guidance to all accreditors and test laboratories on units of accreditation, standard reference tests, test method validation criteria, and, crucially, feedback mechanisms to foster quality improvement in test suites, in addition to maintaining consistency of test interpretations.

Abstract

This document defines the scope of accreditation for the USGv6 Test Program, including test method validation procedures, laboratory accreditation process and roles of the accreditor.

Key words

Internet Protocol version 6; IPv6; standards profile; conformance testing; interoperability testing; accreditation; USGv6; USGv6 Test Program.

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1. Introduction

This document has been prepared for use in conjunction with USGv6 Profile [SP500-267Br1] and the USGv6 Test Program Guide [SP500-281Ar1]. This document is not subject to copyright and its voluntary reuse by other, nongovernmental user groups, either in its entirety, or in derivative works is encouraged. References to this specification should cite:

- **"*USGv6 Test Methods: General Description and Validation*", NIST Special Publication 500-281B revision 1, National Institute of Standards and Technology, November 2020, https://doi.org/10.6028/NIST.SP.500-281Br1**

1.1. General Discussion of IPv6 Product Testing

The USGv6 Profile provides a means to specify technical requirements for IPv6 capabilities in network products. The variety of product configurations and the range of IPv6 capabilities even within a given product class are vast. Given this diversity, the USGv6 Profile and test program defines sets of named *USGv6 capabilities* as the basic units of IPv6 functionality. It is these named capabilities that should be referenced in requirement specifications and individually tested and reported in product declarations of conformance. Typical commercial products will support several such USGv6 capabilities in each protocol stack that they provide.

The USGv6 Test Program incorporates three distinct forms of testing: conformance, interoperability and functional. These three types of testing are defined in detail in section 3.

The USGv6 program requires testing to be conducted at laboratories accredited in accordance with ISO/IEC 17025. That standard refers to general testing requirements and this document specifies the specific technical test methods involved in IPv6 product testing. That is, it defines the methods to be used by USGv6 accredited test labs and the means of validation of test methods.

The USGv6 test program will develop standardized abstract test specifications for each capability to be tested. For each abstract test specification, and correlated executable test, there must be a validation plan. Abstract test specifications are initially validated against corresponding protocol specifications. This process gives some confidence in the integrity of the abstract test specifications so that executable test methods can be validated by the lab against these abstract test procedures. Conformance, interoperability and functional testing have different traceability chains, and these are further detailed below.

The continuous operation and evolution of a test program with potentially multiple accredited laboratories and accreditors will give rise to situations where discrepancies may emerge, or test suites may require further interpretation. To insure to the maximum extent possible that the test results from any accredited laboratory are repeatable, reproducible and consistent with those of other laboratories, it is necessary that tests be synchronized across all participating laboratories, and test interpretations be agreed among laboratories, test method suppliers, producers and specifiers.

1.2. Purpose, Scope and Document Structure

NIST was directed to develop a technical infrastructure of standards and testing to facilitate broad IPv6 acquisition programs in the USG. The USGv6 standards profile [SP500-267Br1] provides guidance for the development of IPv6 technical requirements for product acquisition. By establishing a USGv6 test program for IPv6 products we address the compliance part of the directive.

1.2.1. Test Program Administration

There are two aspects to test program administration and quality control. The first is the development of standardized tests and test methods. The second is ensuring the competence of test laboratories in executing those tests and reporting the results. This document defines the processes and requirements for both aspects of the USGv6 test program. Additional information, such as specific test suites, are documented on the program website [USGv6-Web].

1.2.2. Traceability of Tests

At the root of the testing hierarchy is the set of base technical standards. For IPv6 these include the set of Request for Comments (RFCs) specified in natural language text (as opposed to formal specification methods) by the Internet Engineering Task Force (IETF). Abstract test specifications are derived from these, describing the technical procedures for testing product implementations of RFC functions. Since abstract test specifications are also defined in natural language, the validation method to determine the correctness of these tests is informal expert review, according to systematic procedures published in here. We distinguish between test validation for conformance, interoperability and functional testing, in section 3.

1.2.3. Feedback Mechanisms

It may be that the community of test laboratories discovers the need to alter, add or delete certain tests. In section 4.4 we propose an assessment framework that makes sure test case modifications are communicated among, and agreed between, participating test laboratories.

1.2.4. Test Methods and Scopes of Accreditation

The USGv6 Profile defines a broad range of capabilities that may be found in various classes and configurations of products. All of these capabilities are subject to discrete test methods. An individual test laboratory may choose to test one or more classes of products and provide one or more of these test methods. No test laboratory is obliged to provide all test methods. This document defines specific sets of capabilities and corresponding test methods as individual scopes of accreditation. The list of test methods and scopes of accreditation can be found in further detail in section 5.2.

1.2.5. Test Method Validation

There are different validation requirements for conformance, interoperability and functional test methods. The procedures for validation of conformance, interoperability and functional test methods are described in section 6.1.

1.2.6. Proficiency Testing

The test methods described here must yield results that are comparable across all laboratories engaged in IPv6 testing for this program. The USGv6 test program relies on laboratory proficiency testing to ensure such quality control, see section 7.

1.3. Testing Lifecycles

The provisions of this document will remain in effect through the lifetime of the USGv6 program. Active USG management of the test program will continue at least 24 months beyond the last revision of the profile. As the USGv6 profile and test program evolve, changes to the test specifications and methods and accreditation procedures must be managed in a way that enables graceful evolution for product vendors and test laboratories. This lifecycle model is discussed in the USGv6 Test Program Guide [SP500-281Ar1].

1.4. Audience

The primary audience for this document includes organizations that wish to become an accredited USGv6 test laboratory and the organizations that wish to conduct laboratory proficiency testing and accreditation. This set of stakeholders is depicted in Figure 1 below. Other users of the USGv6 Profile and vendors that are asked to comply with its requirements might also be interested in the underlying details of the test program.

Accreditation organizations assess, audit and accredit test laboratories by scopes of accreditation, which are aligned with test methods. The methods defined in this document are therefore crucial for establishing any accreditation program. The requirements applied by the accreditors are concerned in the traceability of standard reference materials defined here as well as the quality provisions for maintaining and improving test specifications. Testing laboratories seeking accreditation will use the document to acquaint themselves with the test methods, the test method validation mechanisms, and the quality improvement and global coordination aspects of the test program.

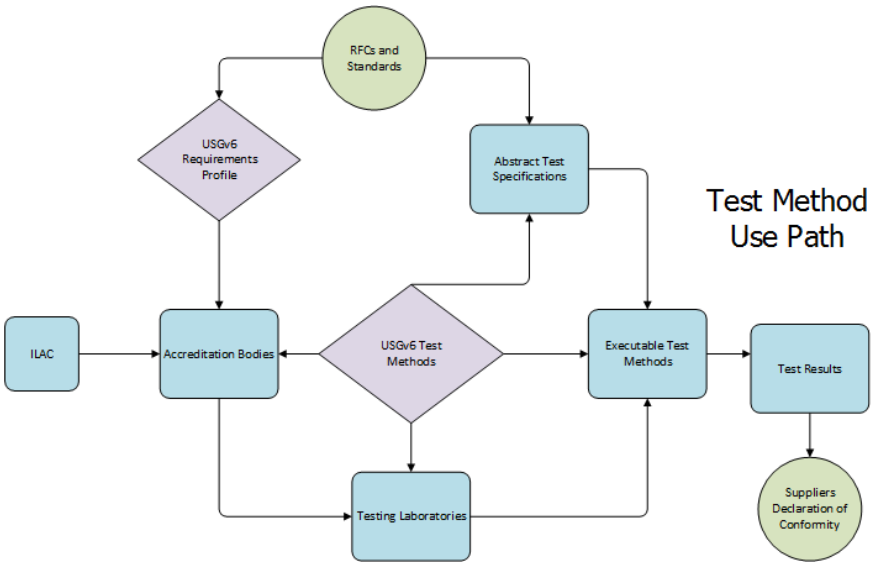

Figure 1: Relationships Between Participants in this Testing Program

The format and standards of coverage of these test specifications provide the basis for confidence in the integrity of the test results. Developers and maintainers of these test specifications should review any constraints these guidelines may place on them. Similarly, developers of executable test methods should review the validation criteria inherent in the traceability hierarchy here.

1.5. Normative Terminology

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

The use of MUST, MAY and SHOULD within this testing document refers to the requirements for testing, as distinct from the requirements for IPv6 products implementation.

2. Linkage to the Accreditation Infrastructure

Large users’ groups and government entities often require compliance to standards as a prerequisite to procure products and services. Test laboratories test products and services for conformance to technical standards. National measurement laboratories such as NIST often develop test methods and standard reference materials for use by test laboratories. Accreditation bodies assess the integrity of test laboratories use of the testing methods and create a community of test laboratories so that the results from every lab are comparable. The International Laboratory Accreditation Cooperation (ILAC) operates a peer assessment system to provide confidence in laboratory accreditation. ILAC MRA signatories operate in accordance with the standard for accreditation systems, ISO/IEC 17011 “*Conformity Assessment – General requirements for accreditation bodies accrediting conformity assessment bodies*”. ILAC is the International Laboratory Accreditation Cooperation both government accreditors and a number of private accreditors has become established as signatories to the ILAC MRA and have demonstrated compliance with ISO/IEC 1701. One or more of these organizations may be interested in establishing programs of accreditation for IPv6 testing laboratories.

2.1. The Role of the Accreditor

Qualified accreditors include those bodies compliant with ISO/IEC 17011 who are also signatory to the ILAC MRA. When an accreditor establishes an accreditation program, there are three components: quality, technical test method, and interlaboratory coordination:

- Assessment of the testing process, laboratory management, and quality control. These are covered by implementing ISO 17025, *General Requirements for the Competence of Calibration and Testing Laboratories*. This is the quality component.

- Assessment of the operation of the test method, and validation of the test method. This is the technical component, and for our purposes the technical content includes

conformance, interoperability and functional testing of IPv6 products. This document describes these technical criteria.

- Oversight of the coordination between test laboratories participating in the IPv6 testing program. This document also describes these coordination criteria. Because of the potential for multiple accreditors, it is particularly important to coordinate comparability of test results from accredited laboratories across test methods, products and test laboratories results.

2.2. The Role of the Program Sponsor

Accreditors generally establish programs based on an expressed stakeholder need. The USGv6 Profile was published by NIST in support of broad USG IPv6 adoption programs. The associated testing program is sponsored by NIST. The sponsor's role includes identifying the standard reference materials, test methods, and methods of validating operational tools against the reference standards. The content of this document is the expression of responsibility for establishing test methods for IPv6 products under the USGv6 Profile.

Ongoing coordination between profile requirements and testing infrastructure is also provided by NIST, through the testing website at and the Testing mailing list at usgv6-testing@list.nist.gov .

3. Testing Frameworks

The Internet has a complex architecture with a wide selection of subnetworks for which RFCs are identified in the USGv6 Profile. There are ways to test this nexus of protocols by isolating protocols in individual products, or by assessing the aggregate behavior of the network.

For conformance testing, [ISO/IEC-9646-2] describes a rich set of methods including single and multi-layer methods, point-to-point or transverse methods, and methods involving explicit test protocol coordination, or by human coordination between the application end-points. Most current executable methods seem to be multi-layer, loosely coordinated types. Any methods from the full ISO/IEC 9646 range are permissible.

Interoperability testing is control points for introducing traffic and observing and analyzing results. This requires several different components working together for a successful user experience.

Functional testing is behavioral testing when no formal technical specification exists to allow for conformance and interoperability testing. Its purpose is to verify that a single component is functional in a specific operational environment.

Separate testing frameworks are required for the conduct of conformance, interoperability and functional testing. A framework includes the test methods and the procedures required to validate and maintain them, and the broad constraints for the conduct of each of these types of testing. The constraints on testing conduct are given here.

3.1. Performing Interoperability Testing

- Any product with a host, router, or switch capability acquired by the US Government MUST demonstrate evidence of Interoperability with three or more independent implementations of IPv6, to include at least one each of a functional role, where appropriate.
- Interoperability Testing MUST be done in a facility accredited to ISO 17025 by an organization controlled by the US Government (2nd party) or an independent, fee-for-service organization (3rd Party).
- The technical test method(s) for Interoperability MUST follow and reference these guidelines.
- Multiple product configurations for interoperability testing SHOULD allow for the possibility of testing to a client's specific network configuration, where practical, as well as plug-and-play in a general configuration.
- For each capability, testing MUST be according to the interoperability abstract test specifications published at the NIST website.
- For any product, testing can be conducted in a single laboratory, or split among multiple laboratories. This especially applies where particular test laboratories specialize in particular test methods and capabilities.

3.2. Performing Conformance Testing

- Any product with a host, router, network protection or switch capability acquired by the US Government MUST demonstrate evidence of conformance to the USGv6 IPv6 abstract test specifications.
- Conformance testing MUST be done in a facility accredited to ISO 17025 by an organization which may be controlled by the product supplier (1st party), by the US Government (2nd party) or by an independent, fee-for-service organization (3rd Party).
- The technical test methods for conformance MUST follow and reference these guidelines.
- Network protection products (NPP) (e.g., intrusion detection system [IDS], intrusion detection and prevention [IDP], firewall or application firewall) acquired by the US Government MUST demonstrate evidence of functionality as specified in the USGv6 Profile.
- NPP testing MUST be done in a facility accredited to ISO 17025 by an organization controlled by the US Government (2nd party) or an independent, fee-for-service organization (3rd Party).

3.3. Functional Testing

- Any product with host, router, switch, network protection product, and application or service capability acquired by the US Government can demonstrate evidence of functioning with IPv6-only networks.
- Functional testing MUST be done in a facility accredited to ISO 17025 by an organization controlled by the US Government (2nd party) or an independent, fee-for-service organization (3rd Party).
- The technical test methods for functional testing MUST follow and reference these guidelines.

4. Traceability of Tests

The objective of testing is to determine whether a product complies with a given specification. In physical artifact testing a comparison is usually made of test results to the product against the requirements of the specification, accurate to a stated uncertainty. For the purpose of assessing IPv6 products, the specification is USGv6 Profile and the compendium of RFCs it references. Tests are derived from the protocol specifications and verified in a peer evaluation process, by test laboratories and test tool developers. These then serve as the traceability root against which executable tests are validated. This section establishes the traceability chains for conformance, interoperability and functional testing. Validation procedures for each test specification are stated in section 4.2.

A measurement result is complete only when accompanied by a quantitative statement of its uncertainty. NIST policy, as expressed in NIST Technical Note 1297, 1994 [Note-1297] is that measurement results be accompanied by such statements, and that a uniform approach to measurement uncertainty be followed. This is developed in section 4.3. Because of the communal nature of test development and review, and the uncertainty in the correctness of test specifications test-by-test, procedures for feedback and continuous improvement are necessary. These are given in section 4.4.

4.1. Traceability Chains

Conformance and interoperability tests are derived from the specifications in the same way, and interoperability tests are analogous to multi-protocol, loosely coordinated conformance test methods. They differ principally in their purposes, and the fact that in interoperability, multiple products are tested simultaneously, rather than in isolation. It follows that their validation and traceability can be the same, and this is detailed in section 4.1.1. For network protection products, USGv6 Profile is the specification. Validation and traceability methods for these are discussed in section 4.1.2 and 4.1.3.

4.1.1. Traceability Chain for Conformance and Interoperability Tests

- **Base specifications:** The RFCs and other specifications selected by USGv6 Profile [SP500-267Br1].
- **Reference tests:** Abstract test specifications for each named IPv6 capability and functional role. The abstract test suites are documented on the USGv6 Program website.

- **Executable test methods**: For each reference test specification listed, above, the executable test method comprises tests and test execution software and hardware. An executable test method may combine the tests of one or more abstract test specifications. The validation of these executable methods is described in Section 6, below. Validation MUST be conducted in an appropriately accredited test laboratory accredited with respect to the USGv6 Test program.

4.1.2. Traceability Chain for Functional Tests

- **Base specification**: The functional requirements specified in the USGv6 Profile [SP500-267Br1].

- **Reference tests:** For each IPv6 capability tests MUST be derived from the functions given in the base specification. Abstract test specifications for these are listed at the website.

- **Executable test methods**: The test methods include written procedures. The reference tests establish the minimum set. Since the actual set of tests is constructed at the time of testing, the laboratory MUST apply and document a procedure for validating each deviant test after live testing and before issuing the test report.

4.2. Reference Test Validation

Conformance and interoperability testing of products is based on RFCs and other natural language specifications. Apart from differences in the scope of test purposes and testing configurations, the tests are broadly similar in construction. We should expect their validation also to be similar. These are laid out in sections 4.2.2 and 4.2.3 below.

4.2.1. General

- The USGv6 Profile lists RFCs and other standards, which are the base specifications that abstract test specifications for conformance and interoperability are derived from.
- RFCs are written in natural language text and therefore they are informal. Any tests derived from these are also informal.
- The impetus of validation comes from the uncertainty of the method of deriving test specifications from RFCs. Since protocol specifications are written in natural language, the general answer to this is that there is no formal proof, therefore we must use heuristic, “trial and error” methods to increase our confidence in the test.
- For each abstract test specification, the set of RFCs contained shall be analyzed for testable functionality, including not only MUST and SHOULD designated functions, but also functions specified by imperatives and declarative statements in the running text.

4.2.2. Conformance Tests

- Conformance test topologies include a target product under test, and one or more pieces of test equipment connected over an IPv6 network.
- Conformance abstract test specifications include a test purpose, reference to RFCs or standards, setup information, a procedure describing packet flows and packet field values, and an observable result. For convenience of reference they also include a systematic test identifier and/or title.
- The objective of a conformance test is to determine whether a product under test can realize the isolated behaviors specified in a set of RFCs or standards.
- For conformance testing, the coverage criteria recommended are those given in ISO/IEC 9646-2, sections 10.1 to 10.4. Validation of abstract test specifications for conformance mirrors these procedures.
- Validation is the procedure that resolves the abstract tests against the RFC functional analysis.
- Testing, traceability and validation differ for network protection functionality assessment. The profile for network protection products calls for general, configurable, extensible capabilities rather than specific settings or protocols. Validation MUST take account of the following tenets:
    - The requirements that various capabilities be administratively configurable imply that a sizeable proportion of the tests will involve demonstration of administrative interfaces and hence less amenable to automation or scripting.
    - For NPP, some level of penetration testing is needed to demonstrate the assurance aspects of some of the requirements, such as security of administrative controls.
    - For NPP, testing the performance under load/fail safe requirements will require sufficient test traffic generation capacity to reach the design limits of the product being tested.

4.2.3. Interoperability Tests

- Interoperability test topologies include one or more target products under test, one or more reference products, or test equipment including traffic generators and logging/analysis tools.
- Interoperability abstract test specifications include a test purpose, reference to RFCs or standards, setup information, a procedure describing packet flows and packet field values, and an observable result. For convenience of reference they also include a systematic test identifier and/or title.
- The objective of an interoperability test is to determine whether a product under test can realize the aggregate behaviors specified in a set of RFCs or standards.

- In all types of Interoperability testing, actual IPv6 product communicates with each other. Traffic is driven through applications at one or more product. The construction, purposing and analysis of tests are not otherwise different than conformance. The validation methodology is the same, allowing for these architectural differences.

4.2.4. Functional Tests

- Testing, traceability and validation differ for functional assessment. The profile for calls for general, configurable, extensible capabilities rather than specific settings or protocols. Validation MUST take account must employ sampling methods to provide evidence that the required capability exists and functions properly in an IPv6 environment.
    - IPv6-only functionality can be tested over any of the products types (Host, Router, NPP, Switch, or Application).
    - Given that testing of products applications or services involves exploratory testing over and above execution of the written tests, the reference test specification may be shown to be correct but not complete.

4.3. A Statement of Measurement Uncertainty

The base specifications referenced by USGv6 Profile are informally written to include assertions of functionality using imperative statements and modal verbs MUST, SHOULD, MAY, and NOT. Tests are informally constructed procedures that mimic the behavior prescribed by the specifications. This is not inherently a quantitative activity. Exhaustive testing is not possible, and uncertainty exists according to the shortfall in ideal coverage. Given that ISO/IEC 9646-2 10.4 specifies ideal coverage of a test specification, the test laboratory MUST quantify this shortfall and use this as the measure of uncertainty for a test method.

4.4. Test Feedback Mechanisms

The abstract test specifications initially approved as the reference tests may still have errors and omissions. These will be uncovered in the course of testing experience. There may also be differences of interpretation. It is important that test methods be improved in a timely fashion. It is also important that corrupted tests not affect the overall integrity of results. Corrupted tests will be addressed by community and stakeholder agreement. Subject to agreement, they may be withheld from the test base until the next revision or retained for continuous use. While the test base is volatile, IPv6 product developers should be prepared to revise their products to meet current test requirements and enhance interoperability going forward.

The community and stakeholders in this context include representatives of IPv6 product suppliers, users and the testing industry. Consistency of interpretation is essential to the quality of the aggregate testing and the stakeholder's confidence that compliant products will meet user's needs.

The mechanism for achieving feedback includes discussion and agreement on test interpretations and test specifications, through a mail group: usgv6-testing@list.nist.gov . All test developers and test laboratories engaged in testing with respect to the USGv6 testing program MUST actively participate in this mailing list.

5. Test Methods and Scopes of Accreditation

The term test method refers to the executable realization of an abstract test specification and may be associated with one or more RFCs and other standards referred to as base specifications. These may differ for the testing modes of conformance, interoperability and functional. A laboratory's scope of accreditation is the discrete technical method identified by an accreditor as the method that will be assessed and audited during the accreditation process. At a minimum, one scope of accreditation is required for a laboratory to be eligible for participation under this program. The IPv6 functional roles identified in the USGv6 Profile are reiterated here, in section 5.1. The scopes of accreditation are described here in terms of their test methods in section 5.2. The permissible combinations, and their restrictions, follow in section 5.3.

5.1. Summarization of Product Functional Roles

The USGv6 Profile identifies several functional roles that define broad classes of products or capabilities.

- **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 basic Host nor Router functions. Currently the profile identifies three classes of such capabilities:
    - **Network Protection Capabilities** – 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.
    - **Application/Services Capabilities** – 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 networks.
    - **Switch Capabilities** – a product that does not directly implement IPv6 protocols but makes decisions about layer 2 forwarding based IPv6 packets.

By providing general definitions of IPv6 capabilities and identifying these functional roles, the USGv6 profile establishes a vocabulary capable to describing the requirements of almost any class or instance of an individual product.

5.2. Scopes of Accreditation

While the USGv6 Profile product requirements subdivide into configuration options, the individual test methods for IPv6 protocol groups are sufficiently discrete that these should be used as the indivisible units of test. A laboratory's scope of accreditation comprise the set of test methods claimed among its competence. The test methods for conformance, interoperability, and functional are listed below.

5.2.1. Conformance Test Methods

The scopes of accreditation for conformance tests are defined in the table below.

Method	Title	Capability
F1	Core Capabilities	Core, ND-Ext, ND-WL, Extended-ICMP, PLPMTUD, Happy-Eyeballs
F2	Stateless Address Auto-configuration	SLAAC, PrivAddr
F3	IPv6 Neighbor Discovery over Low Power	6Lo
F4	DHCPv6	DHCP-Client, DHCP-Stateless, DHCP-Prefix, DHCP-Server, DHCP-Relay, DHCP-Client-Ext, DHCP-Prefix-Ext, DHCP-Server-Ext
F5	Addressing Capabilities	Addr-Arch
F6	Cryptographically Generated Address, Secure Neighbor Discovery	CGA, SEND
F7	DNS	DNS-Client, DNS-Server, DNS-Server-Ext
F8	Network Support	URI, NTP-Client, NTP-Server
F9	Routing Protocol	OSPF,OSPF-IPsec, OSPF-Auth, OSPF-Ext, OSPF-Graceful, OSPF-Trans, IS-IS,IS-IS-Auth, IS-IS-Ext, IS-IS-MT, BGP, BGP-Reflect, BGP-Graceful, BGP-FlowSpec, BGP-OV, BGP-VPLS, BGP-EVPN, BGP-6VPE, BGP-MVPN, VRRP, MPLS
F10	Routing Protocol – Customer Edge	CE-Router
F11	Security	IPsec, IPsec-VPN, IPsec-SHA-512, IPsec-SHA-512-VPN, TLS, TLS-1.3, SSHv2
F12	Transition Mechanism Capabilities	Tunneling-IP, Tunneling-UDP, GRE, DS-Lite, LW4over6, MAP-E, MAP-T, XLAT, NAT64, DNS64, 6PE, LISP
F13	Network Management Capabilities	SNMP, NETCONF

F14	Multicast Capabilities	SSM, Multicast, PIM-SM, PIM-SM-IPsec, PIM-SM-BiDir
F15	Quality of Service Capabilities	DiffServ, ECN
F16	Link Specific Capabilities	Link=Ethernet, Link=PPP, Link=G.9959, Link=Bluetooth, Link=BACnet, Link=6LoWPAN
F17	Switch Capabilities	DHCPv6-Guard, RA-Guard, MLD-Snooping
F18	Network Protection Capabilities	FW, IDS, IPS, APFW

5.2.2. Interoperability Test Methods

Interoperability test methods and scopes of accreditation are organized in the identical manner as conformance test methods and denoted with an "I". The actual tests applicable are different. Note, network protection does not have an interoperability capability.

5.2.3. Functional Test Methods

The scopes of accreditation for functional tests are defined in the table below.

Method	Title	Capability
A1	Application and Service	App-Serv=TBD.
A2	IPv6 only	IPv6-Only

5.3. Combinations and Restrictions

There are distinct test methods and scopes of accreditation for conformance, interoperability and functional tests.

- Test laboratories may be 1st, 2nd or 3rd party. A 1st party laboratory is associated with the product vendor. A 2nd party laboratory is associated with an acquisition authority. A 3rd party laboratory is independent.
- 1st, 2nd and 3rd party laboratories may perform one or more conformance testing methods. A 1st party laboratory may offer 3rd party services for conformance testing.
- 2nd and 3rd party laboratories may perform one or more interoperability test methods, functional test methods or one or more network protection test methods. A 1st party laboratory MUST NOT offer services for interoperability or functional testing.
- A single IPv6 product may complete the USGv6 testing requirements in multiple test laboratories, considering their accreditation scopes for different functional categories.

6. Test Method Validation

As a step in the traceability of tests described in section 4, the results of using executable test methods MUST be traceable to the reference test specifications. This requires validating the results to ensure that they match the expected outcomes. The test laboratory is responsible to ensure validation is done, but this may be performed in an external, accredited laboratory or by a consortium of accredited test laboratories and test method developers. Validation of conformance and interoperability test systems is functionally equivalent and procedures for these are given in Section 6.1. Validation procedures for network protection are discussed in Section 6.2.

6.1. Conformance and Interoperability Tests

Validation Method: Conformance and interoperability executable test methods must conform to the latest released abstract test specifications or reference tests. These test methods may be validated using the procedures below.

Executable test methods per each abstract test specification may be cross-examined by an accredited laboratory, a consortium of accredited laboratories, or a consortium of test method developers with applicable technical knowledge to ensure comparable testing results.

Cross-examination Procedure: The laboratory may use the "golden node" method in order to obtain the set of results. Refer to the test capture file and report structure requirements below. This is defined as follows:

A designated IPv6 product subject to the same testing procedures using different test tools shall produce comparable results. This method is ideal for when two or more test tools exist for a given abstract test specification.

This testing is typically against an open source or freely available implementation. The implementation may not pass 100% however the test procedures and observable results MUST be comparable to the abstract test specification.

- If one executable test method exists, a single technical expert may examine the test results.

- If multiple executable test methods exist, all test results should be comparable and consistent.

The cross-examiner shall send comments to the laboratory if deviation from the abstract test specification was observed. The laboratory will have ability to comment and action must be taken to resolve the comments before test method acceptance. Action may result in a change to the abstract test specification, change in executable test tool or no change necessary. The resolution SHOULD be a consensus between the cross-examiner and laboratory(s). Alternative technical experts may be requested if consensus cannot be achieved.

- Each test method per abstract test specification may be validated against an approved test tool designed to examine the executable results. This test tool must be developed by an alternative laboratory or facility.

- All accredited test laboratories MUST participate in interlaboratory comparisons. Refer to section 7.

Test Capture File Structure: Each test procedure that produces a capture result must be saved as a capture dump file in packet capture (pcap) format. The test capture result files must be named using the test number and extension. For example, test 1.1 should have a corresponding test capture result 1.1.cap file.

Report Structure: Each test method must produce a reporting capability that illustrates the test number and title along with result, typically indicated by a pass or fail notation.

Objective: To ensure that the procedures and observable results as listed in the reference tests are packet-for-packet and test-for-test comparable between executable test methods under validation.

6.2. Functional Tests

Validation Method: Functional testing is conducted as functionality testing as per the specific functions of the product in an IPv6 environment.

- The test procedures are developed in collaboration with the application developer and the accredited test laboratory to verify that the product works as defined.

- The test specifications are then published on the USGv6 Tested Registry [USGv6-Tested] website.

- Validation of this set occurs by execution against one or more sample implementations and reconciliation of the results by two or more independent domain experts.

Objective: To ensure that the results of executing every test in the functional test set are procedurally and syntactically compatible among all laboratories accredited for this method.

7. Proficiency Testing

Assessment for accreditation involves two kinds of proficiency testing. During the on-site assessment conducted by the accreditation body, the laboratory's staff proficiency with the domain area, test methods, test tools and associated quality procedures is assessed.

It is a requirement of the USGv6 testing program that the results of testing in any and every accredited laboratory be field-for-field, packet-for-packet and test-for-test comparable. This is established via a system of interlaboratory comparisons. This is accomplished by NIST

choosing test samples (i.e., an open source operating system) and having accredited laboratories test the given test sample. The results are independently assessed, and the results from each participating laboratory MUST be agreed upon. If test results are discrepant, a systematic resolution process is taken:

- A pure laboratory proficiency problem will trigger accreditor action, up to and including a spot-check on-site assessment.
- Ambiguities in test interpretation will trigger the USG IPv6 community resolution process.

NIST will instruct labs to conduct interlaboratory comparisons. NIST will post feedback and the results from each laboratory on the USGv6 project website.

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