Paper

On Testing IPv6 in Small ISP's Networks

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Abstract—Testing process allows to detect potential faults of implementation of IPv6 in the phase preceding migration, thus minimizing the risk of problems in IPv6 deployment. In general the IPv6 tests should be performed by all network providers, however the test range should fit their needs. It causes that test range for small network operators (offering basic set of services) could be limited in comparison to larger ISPs. In this paper, we propose an approach to IPv6 tests with regard to IPv6 deployment by small operators. We present tools and specifications for IPv6 tests and propose a test platform optimized to small ISP's needs. The test platform is a dedicated LiveCD distribution based on FreeBSD operating system with IPv6 test environment and set of pre-defined tests. An advantage of this solution is the ability to launch the test tool software on any computer equipped with an Ethernet card and CD-ROM/DVD-ROM drive. LiveCD test tool allows users to execute tests and analyze the results in graphical environment.We believe that this approach will help to simplify and shorten the IPv6 testing process in small ISP's networks.

Keywords—conformance testing, interoperability testing, IPv6.

1. Introduction

Many efforts were submitted by the standardization organizations to define tests necessary to validate IPv6 implementations. The most famous standardization organization on IPv6 is the IPv6 Forum[1], which launched the IPv6 Enabled Logo program. The goal of the so-called Logo programs is to accelerate the deployment of IPv6 by specifying the necessary tests and offering the testing tools for conformance tests as well as for interoperability tests. Furthermore, many projects in Europe, US, Japan, China and elsewhere were directed to implement the tools for the defined tests. Enormous amount of tests suggests these don't suit needs of small operators, who need test solutions meeting the following requirements:

- Simplicity: easy to use, limited number of test cases (as needed), based on Unix-like OS.
- Low cost: use of free software and possibility to launch using PC.

Moreover from the point of view of the areas, where IPv6 is implemented and where not, we notice that small ISPs (small operators) have limited human and hardware resources, and possibly lack knowledge about migration to IPv6. On other hand, big network operators as well as service and content providers seem to be able to introduce IPv6 by themselves.

These are reasons why we focus in this paper on needs of small operators with regard to IPv6 testing aspects. We think that offering a selection of tests according to the needs of small providers and preparing a freeware test platform to be published before long may be very useful for deployment of IPv6 in small networks.

In the next section, we present basic tests associated with ISP needs and current IPv6 test tools, distinguishing between commercial and open-source software. Afterwards, we focus on open-source test tools being the best for IPv6 deployment in small domains. Section 4 presents the selection of tests considered strategic for small providers.

2. Principles of Testing

The IT industry performs IPv6 tests to satisfy requirements, which are different in case of equipment suppliers and providers. The equipment suppliers mainly focus on conformity to IPv6 standards whereas the providers rather focus on assurance of efficient interworking with other IPv6 equipment within the network. Generally, tests of network hardware cover three fields: conformance, interoperability and performance. These test types are shortly characterized below. **Conformance tests** are performed to determine whether a particular piece of equipment satisfies the specified criteria of operation. Conformance testing methodology defines the boundaries of the system under test (SUT) as well as the test system responsible for monitoring the SUT behavior. Because the test system controls the sequence and contents of the protocol messages sent to the SUT, it can impose a wide range of both expected and unexpected (invalid) behaviors. Thus, test system can emulate all network nodes which communicate with SUT. To sum up, conformance tests check whether given implementation conforms to protocol specification.

The purpose of **interoperability tests** (also called "Network Integration Testing" according to ETSI TR 101 667 [1]) is to prove the functionality between, at least, two communication systems situated in operating environment. The testing system comprises one or more devices (so called reference hosts or reference routers) from

[1] www.ipv6forum.org/

Table 1
Comparison between conformance testing and network integration testing [1]

	Conformance testing	Network integration testing
Goals	To verify that a protocol implementation conforms to the relevant protocol and profile specifications, ⇒ CONFORMANCE	To verify that a complex network is able to provide user with services in a correct, homogeneous and reliable way, ⇒ SERVICE, FUNCTIONALITY
Object	The implementation of an OSI protocol specification in a network element	A network, or part of it, made up by joining two or more network elements
Process phases	1) specification of an ATS, ICS and IXIT 2) realization of means of testing 3) conformance assessment process (or second party testing)	1) specification of an ATS, ICS and IXIT 2) agreement between different network operators 3) realization of independent means of testing (one for each test laboratory) and of the TCPs 4) result collection
Type of test	Local or dual 1) basic interconnection tests 2) capability tests 3) valid behavior tests 4) inopportune behavior tests 5) invalid behavior tests	Dual only 1) basic interconnection tests 2) valid behavior tests 3) connectivity tests 4) stability and performance tests
Users of the methodology	Manufacturers (to guarantee that their products conform the national and international protocol and profile specification) and network operators (for the same reason)	Network operators (for guarantee their customers that the network is able to provide the subscribed services in a correct and reliable way)

different vendors besides the equipment under test. The equipment under test and the reference equipment together define the boundaries of the interoperability test. In opposite of conformance testing, interoperability tests are performed on interfaces that provide normal user control and observation (no network nodes emulation). Interoperability tests are based on functionality accessed by the user.
These tests are related to normal interworking and do not contain inopportune behavior and invalid behavior tests and therefore, the list of interoperability test cases is shorter than during conformance tests. It could potentially decrease test execution time. On the other hand, interoperability tests should be performed in real environment; they require to more hardware and time compared to conformance testing in order to prepare the test configuration.

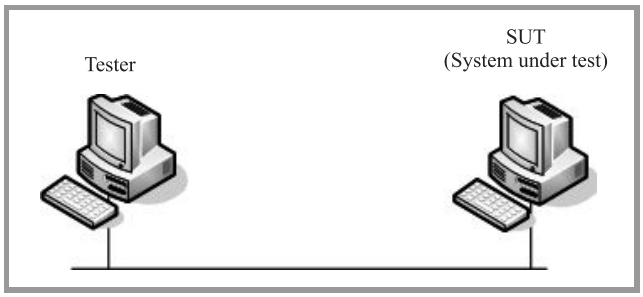

Fig. 1. Sample block diagram for conformance test environment.

Note that devices should be manually configured. Figure 1 presents two exemplary test configurations, one for conformance and the other one for interoperability test, whereas Table 1 presents general differences between both the types of tests.

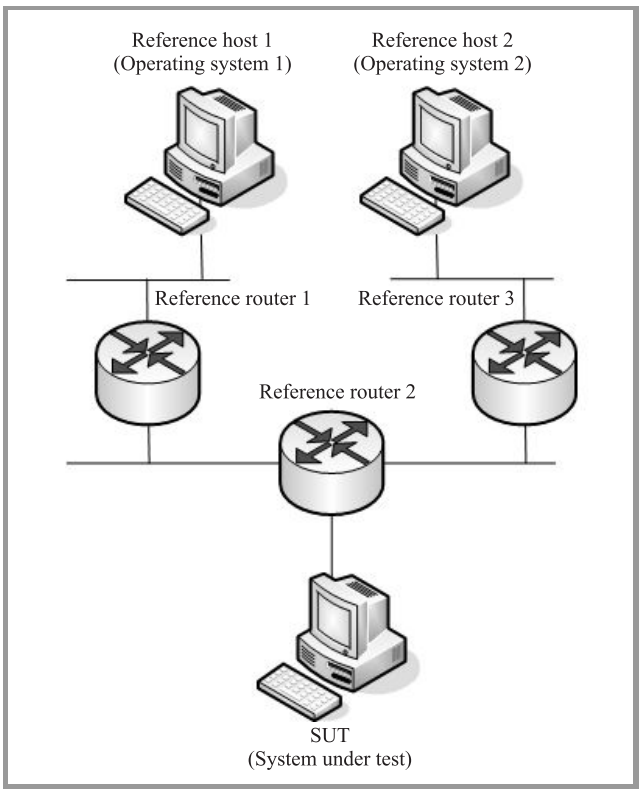

Fig. 2. Sample block diagram for interoperability test environment.

Network operators often need a close working relationship with vendors to solve unforeseen problems, e.g., interface incompatibilities, which may even imply hardware reconfiguration and software tuning. The result is often a delayed introduction of services, which implies a negative impact on the brand, with increased costs due to necessity to handle customer's complaints. Software upgrades and new version releases also pose notable challenges for operators, who should ensure interoperability within existing networks based on different system vendors and architectures. As a result, interoperability testing of new network technologies with legacy systems became highly costly and time consuming. Moreover, the pressure on operators increased due to shorter and shorter time-to-market of new services required. Consequently, it is particularly important for providers (especially small ISPs) to use a specific, cost-effective, overall testing methodology, assuring an optimal time-to-market for each new service to be deployed; this is specially accentuated when introducing IPv6, because almost all the network hardware must be tested.

Apart from interoperability testing, small ISPs are also interested in **performance tests**, which determine effectiveness of data transmission in their networks. However this group of tests is out of scope of this paper because performance tests depend on the specific services and specific network functionality.

3. Test Specifications and Platforms

This section includes the state of the art of projects focused on IPv6 testing. Especially we describe works on specification of IPv6 tests as well as currently available test platforms delivered by commercial suppliers and non-profit projects.

3.1. Test Specifications

Basically two standardization organizations have the leading position for IPv6 testing; they are IPv6 Forum and ETSI.

The IPv6 Forum is a world-wide consortium focused on providing technical guidance for the deployment of IPv6. To IPv6 Forum belongs the IPv6 Ready Logo Committee, whose mission is to define the test specifications for IPv6 conformance and interoperability testing, to provide access to self-test tools. Devices that passed all the tests can be marked with the IPv6 Ready Logo.

ETSI established the Specialist Task Force 276 (STF276) which worked on IPv6 testing. ETSI STF276 project has provided a publicly available test development framework as well as interoperability test packages for four key areas of IPv6: core protocol, security, mobility and transition from IPv4 to IPv6. The approach is based on flexibility and extensibility to facilitate testing of IPv6 products for interoperability in many contexts including development, procurement and certification schemes. The work were done in a close relationship the IPv6 Ready program of the IPv6 Forum. The project objectives were to:

- produce publicly available (standardized) IPv6 interoperability test specifications,
- reduce the cost of testing and test development through the standardization of an IPv6 test development framework and TTCN-3 library,
- contribute to the implementation of the eEurope 2005 Action Plan,
- strengthen the European influence in the IPv6 Ready certification program,
- actively support and involve stakeholders in the standardization of IPv6 test specifications and the IPv6 certification process,
- contribute to the rollout of reliable and interoperable IPv6 network products.

Besides IPv6 Forum and ETSI specifications, there are test specifications developed by test tool vendors too. These test suites are related to their (commercial) testing solutions.

3.2. Test Platforms

Among the tools used for testing IPv6 commercial tools are available as well as free tools developed under different projects. Examples of commercial tools are:

- Test Center from Spirent,
- IxN2X from Ixia,
- diversifEye from Shenick.

Each of above solutions consists of hardware platform and test suite supplied by the manufacturer. The choice of commercial tools have provide a number of advantages (e.g., like performance, and customer support), but a relatively high price is a disadvantage of these solutions. It should be assumed that for many small operators buying such a tool is unprofitable. Therefore they should focus on available free available test tools which are developed under different projects. Among them we recommend paying attention to TAHI [2] and Go4IT [3] projects, both these projects are popular among researchers, what provesing the correctness of the choice (i.e., [4]–[6]).

The TAHI project was launched in 1998, its main goals are support of IPv6 deployment by providing test tool and developing test suite consisting of conformance and interoperability tests. The TAHI Conformance Test Suite is a bundle of software based on FreeBSD, consisting of a conformance test tool and a conformance tests packages dedicated to different functionalities of IPv6. Conformance test tool consists of two parts: V6eval and KOI. V6eval is designed to develop tests for IP layer protocol test and KOI is designed to develop tests for application layer protocol test, using sockets API of operating system it works on. V6eval

presumes a test environment with a tester node (TN) directly connected to the system under test (SUT) via one or multiple Ethernet interfaces, depending on SUT type. This environment is shown in Figs. 3 and 4.

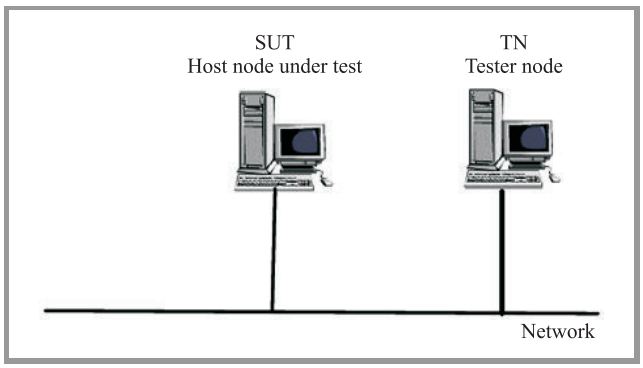

Fig. 3. TAHI test environment for host.

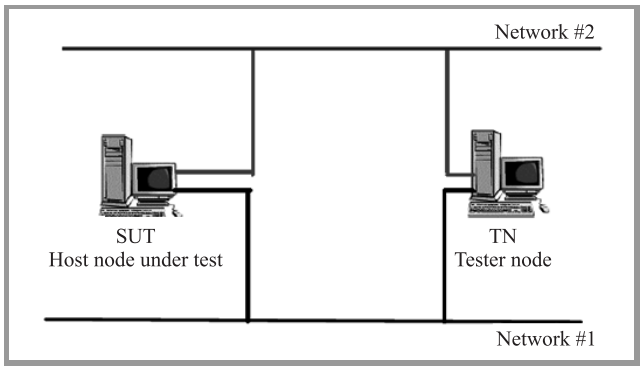

Fig. 4. TAHI test environment for router.

In order to fully automate the testing process, an RS-232 connection should be arranged between the TN and the SUT, over which commands can be sent from the TN interactively. V6eval supports remote control scripts for more than 30 different IPv6 implementations in order to automate the testing process. Currently, TAHI test suites cover the following areas:

- IPv6 Core Protocols including
  - IPv6 Specification (RFC2460),
  - ICMPv6 for IPv6 Specification,
  - Neighbor Discovery for IP Version 6 (IPv6),
  - IPv6 Stateless Address Autoconfiguration,
  - Path MTU Discovery for IP version 6,
  - Transition mechanisms for IPv6 hosts and routers (IPv6 over IPv4 tunnel),
  - Default address selection for IPv6,
  - NAT-PT,
- IPSec (v6 and v4),
- Mobility Support in IPv6,
- DNS Discovery,
- Multicast Listener Discovery for IPv6,
- SIP (IPv6).

The Go4IT project was launched in November 2005 and aimed to provide a TTCN-3-based test environment for IPv6 protocol testing including related test tools, test suites and associated testing services. The motivation for the development of this test tool has been the lack of freely available test execution environment for IPv6 testing based on TTCN-3. The TTCN-3 testcases are defined in ETSI STF 276. The Go4IT project has gone in two directions, leading to development of package 1 and package 2. Package 1 is focused on creation of downloadable, easy and ready to use executable TTCN-3 test suites for IPv6 protocols. Package 2 is focused on the development of an open TTCN-3 test development environment that allows users to develop and execute their own test cases. To fulfill the objectives defined for Package 1, a test tool, named "Go4IT IPv6 executable test suites" (GIPETS) including ready to use executable IPv6 test cases, has been developed.
Release 2.0.0 of GIPETS includes 497 IPv6 ready to execute test cases for IPv6 Core protocol, IPsec and IPv6 Mobility.

4. Test Platform Recommended for Small ISP

To meet the expectations of small operators we propose new approach in IPv6 area. Currently we are working on deployment of a dedicated test tool for IPv6 testing in their networks. This tool is based on the TAHI platform. An advantage of this solution is the ability to launch the test tool software on any computer equipped with an Ethernet card and CD-ROM/DVD-ROM drive. Using this test tool does not require FreeBSD and the TAHI environment installation, which greatly accelerates and simplifies the preparation for the tests. This is achieved through the preparation of a dedicated distribution LiveCD based on FreeBSD operating system including TAHI environment and selected test suite. A Live CD distribution is an entire operating system that is contained on a removable medium such as a CD or DVD. Because the entire operating system is on the CD or DVD, and uses PC RAM to hold temporary data, the user can run the test tool without touching the contents of hard disk. It's important that all software packages included in LiveCD do not require installation.
Another distinguishing feature of this distribution is test suite, tailored to small operator needs. The main purpose of these tests is to check functionality usually verified within interoperability tests These are tests executed in a simply configuration used for conformance testing. Mentioned above FreeBSD distribution with test environment and set of pre-selected tests is currently under work. At the moment we have already developed pre-release version of LiveCD tool which allows users to execute tests and an-

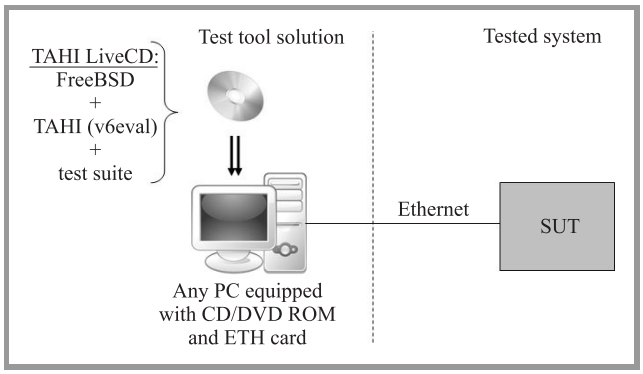

Fig. 5. Proposed solution based on TAHI LiveCD distribution and selected test suite.

alyze the results in graphical environment. The LiveCD tool includes following main software packages:

- FreeBSD 8.0,
- V6eval v3.0.1,
- Wireshark v1.2.2,
- Perl 5.8,
- XFCE4 windows manager,
- Lighttpd server,
- Opera web browser.

LiveCD tool contains two sets of IPv6 testcases. One of these sets is a replication of TAHI testcases. The other one is the set of selected tests optimized to small ISP needs. The set of selected tests comprise a subset of conformance tests available in TAHI project for base IPv6 functionality which is mandatory from small operator point of view. The following assumptions have been made to choose tests:

- Tests should cover functionalities commonly used by small ISPs.
- Tests should focus on mandatory IPv6 protocol features.
- Tests should cover functionality usually verified during interoperability tests.
- Chosen tests does not include tests related to handling of unexpected events which occur rarely during messages exchange.

Taking into account the above assumptions we are working on preparing a adequate testcases in following areas:

1. IPv6 Base Specification

   Tests selected in this group will address and verify that:

   – a node properly processes and generates the following fields in the IPv6 header: version, traffic class, flow label, payload length, next header, and hop limit;

   – a node properly processes and generates the following fields in the IPv6 header: the header extension length field in extension headers, and the option type and option data length;

   – a node properly times out fragment reassembly, abandons reassembly on packets that exceed a maximum size, processes stub fragments, and reassembles overlapping fragments.

2. ICMPv6 tests included in this group will verify conformance of the Internet control message protocol to IPv6 specification.
3. IPv6 Neighbor Discovery

   Tests in this group verify:

   – conformance of the address resolution and neighbor unreachability detection functions with the neighbor discovery specification,

   – that host properly performs router and prefix discover.

4. IPv6 Stateless Address Autoconfiguration

   Selected tests in this group will verify:

   – conformance of the address autoconfiguration and duplicate address detection to IPv6 Stateless Address Autoconfiguration Specification,

   – conformance of creating global addresses, processing Router Advertisements and expiring an address to IPv6 Stateless Address Autoconfiguration Specification.

5. DHCPv6 basic tests

   Tests in this group will verify correctness of server and user side implementation.

Test cases are divided in subsets by the functionality tested. Unlike TAHI environment (command-line based), LiveCD

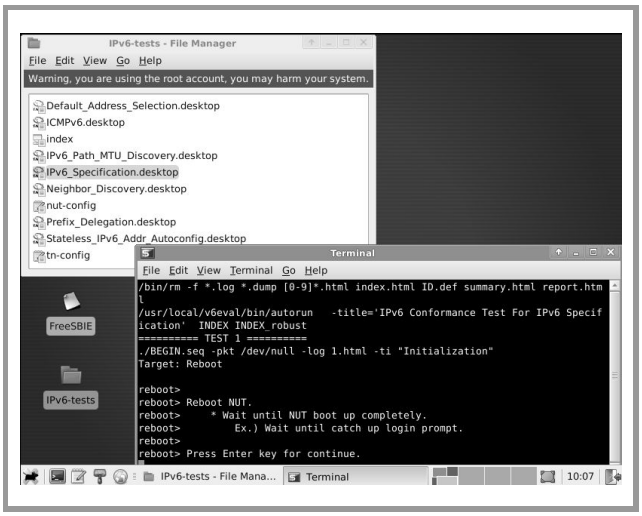

Fig. 6. LiveCD test tool – users view at the stage of selection and execution of IPv6 test.

test tool uses window-based interface (XFCE4). We believe that is a more user-friendly solution. In particular, the user not familiar with FreeBSD OS is able to configure test environment and execute the tests. To run the tests user operates on two windows. The first one is directory window where he can configure interfaces and execute subsets of tests as well as open test results in web browser. Moreover, test execution is observed in terminal window. This allows to trace test progress and respond to commands appearing during the test execution. Figure 4 shows screen during selection and execution of IPv6 test.
User can view test report in a web browser window. It contains test results as well as links to: test description, sent/expected packet description and saved packet flow as pcap file. Saved packet flow can be analyzed using Wireshark, protocol sniffer included in LiveCD tool.

5. Summary

In this paper we have briefly described the IPv6 testing process in small ISP networks and proposed an approach to IPv6 testing using a platform in a LiveCD form, which allows users to execute tests and analyze results in graphical environment. In our opinion, this approach to testing IPv6 technology in a small operator network brings several benefits. Among them, the most important are: ease of test execution - only one PC involved in testing process, reduced number of tests, test automation and finally shorter testing time. Moreover, we expect that approach based on LiveCD could be applicable to other areas. For example, we are going to use this test method in our current research project, because we want to achieve repeatability and comparability of tests performed by different teams.
As mentioned, we already have developed pre-release version of LiveCD test tool. Current work focuses on developing complete sets of tests. Final distribution will be available after completion of work from the website of Future Internet project (www.iip.net.pl).

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Konrad Sienkiewicz – for biography, see this issue, p. 14.

Mariusz Gajewski – for biography, see this issue, p. 12.

Jordi Mongay Batalla – for biography, see this issue, p. 11.