



OPEN NETWORKING
FOUNDATION

OpenFlow Conformance Test Program

ONF White Paper

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Executive Overview

This paper describes the Open Networking Foundation (ONF) OpenFlow™ Conformance Testing Program, including its benefits, processes, and approved devices.

The ONF Testing and Interoperability Working Group seeks to accelerate the development and adoption of the OpenFlow Standard. The group works toward this goal by ensuring standardization development through testing and certification, fostering interoperability among vendor implementations, and providing an industry-recognized certification for OpenFlow compliance.

In general, a test program is used to validate devices against a defined specification and provides a base level of assurance that can save both time and money from development (for manufacturers) to deployment (for end-user customers). The OpenFlow Conformance Testing Program provides a way for networking vendors to demonstrate compliance with the OpenFlow specification. An OpenFlow Conformance certificate is the highest level of assurance to validate product conformance with a specific version of the OpenFlow specification. Networking vendors can earn this certificate for hardware or software devices that support the OpenFlow protocol.

The key objective of the ONF Conformance Testing Program is to be flexible and open while maximizing the practical utility of testing and reducing the need for redundant or excessive burden on vendors and laboratories. As such, the program accommodates product families, requiring only one device within an established product family to be tested.

This paper provides information for service providers and enterprises to learn the latest status of approved OpenFlow-enabled equipment and level of profile support. Network equipment manufacturers will get a “walk through” of the testing process, including ONF approved labs, test specifications, profiles, and future development and program roadmaps.

CERTIFICATION BENEFITS TO SERVICE PROVIDERS AND ENTERPRISES

The ONF Certificate of Conformance provides a trusted and independent level of confidence. It ensures that purchases are more deployment-ready, because they conform to a particular version of OpenFlow, which is the only globally acknowledged specification for Software-Defined Networking (SDN). Other benefits of certification include:

- Increase in quality of deployed products
- Cost reduction as product issues are found prior to field deployment
- Collaboration with vendors that are ONF members and at the forefront of SDN development and solutions

CERTIFICATION BENEFITS TO NETWORK EQUIPMENT MANUFACTURERS

Participating in the ONF OpenFlow Conformance Testing Program provides ONF members with both technical and marketing benefits. Once a product passes the OpenFlow Conformance test, a company can use the trademarked OpenFlow Conformant logo on software and hardware packaging, printed and web collateral, and other materials vital to getting customers to notice (and purchase) the product.

The benefits of conformance include:

- Reduced time to market due to a third-party inspection that can find conformance issues that were not discovered during the internal development and QA processes
- Increased engineering expertise and talent as personnel gain familiarity with additional open-source tools and tests that can improve all of their SDN products
- Increased sales opportunities through marketing that leverages the proven, globally trusted OpenFlow Conformant™ logo
- Global recognition as a thought leader in SDN solutions
- Reduced costs for in-house test plan development, implementation, and execution

IT thought leaders and customers who know SDN know and trust ONF and OpenFlow.

Conformant Profiles and Test Specification v1.0.1

The [OpenFlow Switch Test Specification v1.0.1](#)¹ defines the requirements and corresponding test procedures that determine the conformance of an OpenFlow v1.0.1–enabled switch. As the foundation of the OpenFlow Conformance Testing Program, this specification was developed and reviewed by test experts from ONF member institutions. The test cases are derived from the OpenFlow Switch Specification 1.0.0 and the subsequent Errata v1.0.1².

In order to guarantee that the test specification is fully conformant, test cases were carefully designed for every single point in the OpenFlow Switch Specification 1.0.0. Every test case in the test specification has a Specification Reference field that references the relevant document, section, and page in the switch specification. The test case then verifies that the requirements of the document are correctly implemented.

There are three designated profiles available for the program to accommodate specialized devices that may not require the use of all 12-match fields outlined in the OpenFlow Switch Test Specification v1.0.1:

- Full Conformance
- Layer 3 Conformance
- Layer 2 Conformance

Please refer to Section 3.0 of the test specification for a complete description of profile requirements.

MANDATORY VS. OPTIONAL TEST CASES

In each profile there are mandatory and optional test cases. Per profile requirements are outlined in each test section of the OpenFlow Switch Test Specification v1.0.1. Vendors may request an approved lab to perform additional testing and reporting for any available optional test cases. This will allow vendors to indicate conformance for additional optional feature support. Mandatory vs. optional test case requirements were based on the OpenFlow Switch Specification 1.0.0, but real-world hardware limitations and industry demand were also taken

into account. These requirements were carefully crafted based on vendor and user feedback during the pilot testing phase.

OpenFlow Conformant Approved Devices List

The [OpenFlow Conformant Product Registry](#)³ contains devices that have met all the requirements for the ONF Certificate of Conformance as per the test profile. The list includes each product's name, firmware version, a simple description, product family and optional support, as well as links to more detailed notes based on testing.

Approved devices are eligible to use the OpenFlow Conformant logo. All usage of the logo must abide by the ONF [trademark](#)⁴ and [logo](#)⁵ policies.



ONF Approved SDN Testing Laboratories

The following laboratories are authorized OpenFlow conformance testing labs that are ISO 17025-compliant or have formally applied for ISO 17025 accreditation as well as have followed the Lab Validation and Proficiency requirements as defined by the ONF.

 <p>Bii 天地互连</p>	<p>Bii – Beijing Internet Institute, China www.biigroup.com Contact: Li Zhen, zli@biigroup.com</p>
 <p>CNLABS</p>	<p>CNLabs – Criterion Networks, Bangalore, India www.criterionnetworks.com Contact: Kumar Jayaprakash, jp@criterionnetworks.com</p>
 <p>InCNTRE</p>	<p>InCNTRE – Indiana Center for Network Translational Research and Education, Indiana, USA www.incntre.iu.edu Contact: Ron Milford, rmilford@incntre.iu.edu</p>

	<p>NBL – Network Benchmarking Lab at National Chiao Tung University, Taiwan</p> <p>www.nbl.org.tw</p> <p>Contact: Ying-Dar Lin, ydlin@cs.nctu.edu.tw</p>
	<p>CATR – Telecommunication Technology Labs (CTTL) hosted by China Academy of Telecommunication Research of MIIT, Beijing, China</p> <p>english.catr.cn</p> <p>Contact: Chen Lei, chenlei@catr.cn</p>
	<p>UNH-IOL – University of New Hampshire InterOperability Laboratory, New Hampshire, USA</p> <p>www.iol.unh.edu</p> <p>Contact: Erica Johnson, Erica.johnson@iol.unh.edu</p>

Approved laboratories must have policies and procedures in place to perform OpenFlow testing per the defined test specifications. All of the laboratories are third party and independent. Each lab may offer testing services for a fee and should be contacted for more details.

VALIDATED TEST TOOLS

The OFTest tool⁶ has been validated as the first test tool to perform the ONF Conformance Test Specification for OpenFlow Switch Specification 1.0.1. OFTest can be used to pre-test and gain confidence prior to contracting with an approved test lab. Commercial test tools will be available as the program grows and will be validated to the test specifications by an ONF-approved process.

Product Testing Workflow

Network equipment manufacturers must follow the steps depicted in Figure 1 to gain OpenFlow-conformant status. It should be noted that as of November 2014, ONF extended conformance testing to non-members. Thus, companies interested in receiving an OpenFlow Certificate of Conformance, regardless of ONF membership, are entitled to use the OpenFlow-conformant logo with the respective version of the OpenFlow specification upon successful completion of the testing as described below.

Once the device supports OpenFlow, the approved lab will test to an agreed-upon profile and work with the vendor to get 100% pass results for mandatory test cases in the designated profile. The lab will then issue a validation of conformance with a recommendation of certification, and will work with the vendor to complete an application form with detailed information to serve as a record of completion. Testing may apply to product families as long as the internals (firmware, chipsets, and software) are identical.

The application will be approved by ONF and then added to the OpenFlow Conformance Product Registry.



Figure 1: Certificate of conformance workflow

Interoperability Test Events

ONF conducts interoperability test events twice a year to provide vendors the opportunity to test their products with other ONF members' equipment. These events are consistently described as one of the most valuable benefits of an ONF membership. The equivalent of months of QA testing can be accomplished in a week's time.

While conformance has not been a requirement for participation in these events, it is highly recommended that vendors self-test or contract with one of the approved labs to test their product with an approved testing tool prior to participation in these interoperability events. Pre-testing helps companies identify and fix common issues that otherwise cause significant delays during interoperability testing, preventing participants from getting the most value out of such events.

These events also serve as a testing ground to validate the tools used for test conformance and provide a forum for feedback to the ONF specification writers.

See the Testing and Interoperability Working Group page at <https://www.opennetworking.org/working-groups/testing-interoperability> for more information on these events, and white papers outlining commonly reported interoperability issues.

Development Process Roadmap and Milestones

In 2011, the ONF Testing and Interoperability Working Group (TIWG) was created, with a charter to develop an equally open and comprehensive testing and validation program. A small number of companies and a few volunteer members designed a process whereby vendors could independently validate OpenFlow conformance, formulate benchmarks for system and component performance, and create resources to develop an effective interoperability matrix.

ONF began sponsoring PlugFests and other technical gatherings so that companies could discover how their OpenFlow devices (both hardware and software) behaved in more complex

environments. Six such weeklong events have already taken place. The TIWG created the following roadmap for its first 5 years (see Figure 2).

ONF Testing Development Roadmap

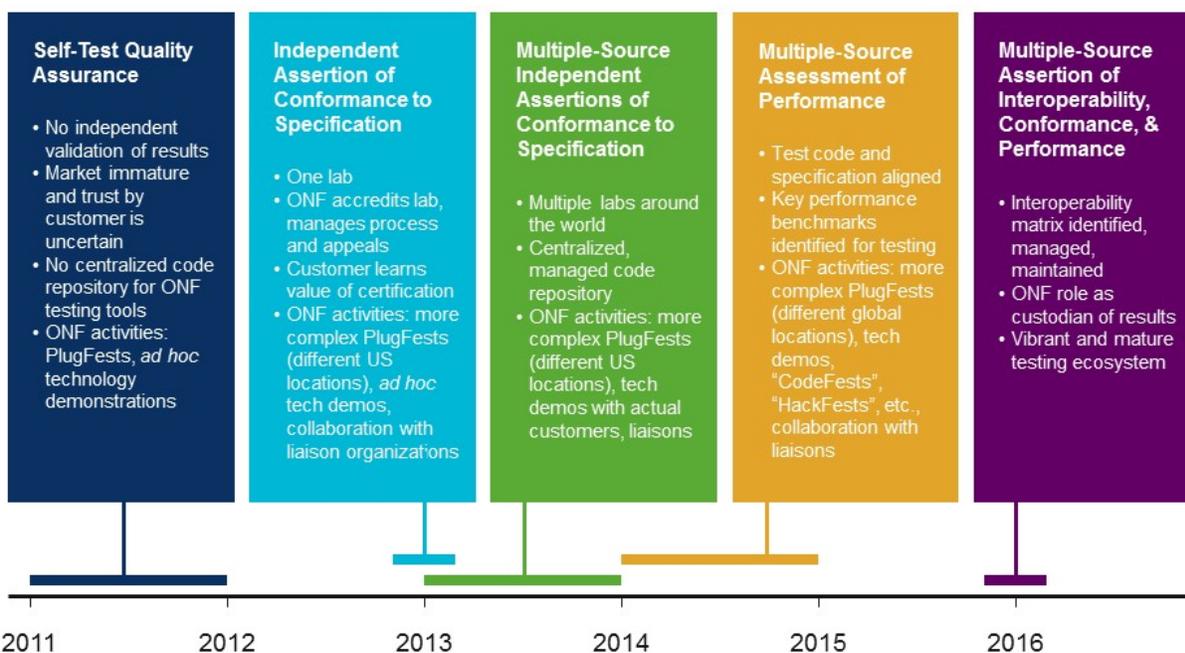


Figure 2: ONF testing development roadmap

SWITCH CONFORMANCE DEVELOPMENT STATUS

The test specification for OpenFlow 1.3 is currently in development. The Testing and Interoperability Working Group identified over 500 mandatory test cases and over 600 additional test cases for optional parts of the OpenFlow Switch Specification v1.3.4⁷. The working group is now in the process of finalizing these test cases and editing the test specification document. This well vetted process was also followed for the v1.0 test specification development.

One challenge for the 1.3 testing program is the multi-table pipeline definition. The working group is currently analyzing ways to define meaningful profiles for the 1.3 specification, and how to group optional features in ways that are useful for the market. These profiles might target different device types, device classes, or applications/use cases.

The working group is also looking into TTP descriptions for these profiles to provide an unambiguous way of describing the required functionality.

The definition of profiles and function groups will be accompanied by a parallel pilot program in 2014Q3 & Q4 to ensure that the developed test cases are meaningful and applicable for current hardware implementations. This pilot program will be open to all ONF member companies developing test suites for OpenFlow 1.3, and several selected, representative switch

implementations. The pilot program requires providing the necessary engineering resources to ensure that the program can be run effectively.

To speed up providing a first operable certification program, several proposals were made at the ONF F2F member meeting in Santa Clara, California, in March 2014. These proposals covered four major changes:

- Separating most of the optional features into subgroups that can be certified independently from the main conformance test suite. Several functional groups were proposed for this. Examples include:
 - Multiple controllers
 - Auxiliary connections
 - Group tables
 - Meters and queues
 - Advanced actions
 - Advanced matching
 - Multiple Tables
 - Advanced Counters
 - Additional Optional Features
- Defining a base conformance suite covering the bare minimum of the functionality provided by the 1.3 specification, and applied to a most basic pipeline description. This means:
 - Only one table (no pipeline, instructions, Goto, etc.)
 - Only mandatory match fields
 - Only mandatory actions and instructions
- In addition to the 13 mandatory match fields, the 27 optional match fields provided by the spec might be differently supported by different implementations, and may also be sorted into related functional groups, for example:
 - Metadata
 - VLAN
 - IP QoS
 - Additional L4
 - IPv4 helper
 - IPv6 full
 - Provider backbone
- Covering different pipelines and multiple table layouts in later iterations of the 1.3 conformance program.

These changes will surely speed up development of a first 1.3 conformance program, but there is a non-negligible risk that this may only be relevant to software implementations and might not provide enough coverage of customer requirements to increase market acceptance. The problem of defining relevant profiles and TTPs for different hardware pipelines used in the 1.3 conformance program still exists, and needs to be solved for broader coverage of hardware implementations. TTPs are proposed as one possible way to describe and define these different hardware pipelines.

The Testing and Interoperability Working Group has defined a sample test suite from the existing 1.3 test cases to meet the requirements of a basic conformance profile as outlined in the first two proposals. Proposals 3 and 4 are intertwined, and depend on the result of further profile discussions.

Conclusion

New technologies, regardless of how widely they are being adopted, still require customer trust in order to thrive. End-user customer acceptance and deployment of new standards can be greatly assisted by the creation of independent, third-party validation of technical assertions made by product vendors.⁸ ONF's OpenFlow Conformance Testing Program supplies that necessary verification of conformance to the specification, and will soon provide useful benchmarking of performance characteristics, and device interoperability that will provide great benefits to customers. As more customers insist on that validation, a beneficial reinforcing process thus begins: customers ask for certification, vendors include certification, and more trusted sales cycles allow this new market to flourish.

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The Open Networking Foundation is a nonprofit organization founded in 2011, whose goal is to accelerate the adoption of open SDN. ONF emphasizes the interests of end users throughout the Data Center, Enterprise, and Carrier network environments.

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¹ <https://www.opennetworking.org/images/stories/downloads/sdn-resources/onf-specifications/openflow-test/conformance-test-spec-openflow-1.0.1.pdf>

² <https://www.opennetworking.org/images/stories/downloads/sdn-resources/onf-specifications/openflow/openflow-spec-v1.0.1.pdf>

³ <https://www.opennetworking.org/openflow-conformance-certified-products>

⁴ <https://www.opennetworking.org/images/stories/downloads/about/onf-operating-documents/trademark-policies/onf-trademark-usage-guidelines.pdf>

⁵ <https://www.opennetworking.org/images/stories/downloads/about/onf-operating-documents/trademark-policies/onf-logo-guide.pdf>

⁶ <https://github.com/InCNTRE/oftest>

⁷ <https://www.opennetworking.org/images/stories/downloads/sdn-resources/onf-specifications/openflow/openflow-switch-v1.3.4.pdf>

⁸ The Adoption and Diffusion of Interorganizational System Standards and process Innovations, by Matthew Nelson and Michael J. Shaw. Available at <http://www.comp.nus.edu.sg/~teohh/tenure/shaw.pdf>