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6TiSCH Interoperability Test Specifications

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Foreword

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1 Scope

The present document aims to provide guidelines for performing 6TiSCH Conformance and Interoperability Tests. To this aim, it describes:

- The testbed architecture showing which IETF 6TiSCH systems and components are involved, and how they are going to inter-work in the interoperation focus.
- The configurations used during test sessions, including the relevant parameter values of the different layers (IEEE 802.15.4e TSCH and RPL).
- The interoperability test descriptions, describing the scenarios, which the participants will follow to perform the tests.
- The guidelines for participants on how to use the *golden device* to test against their implementation.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEEE 802.15.4e™: "IEEE Standard for Local and metropolitan area networks-- Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 1: MAC sublayer".

[i.2] IETF RFC 8180: "Minimal 6TiSCH Configuration", IETF 6TiSCH Working Group, X. Vilajosana, K. Pister. June 2015.

[i.3] IETF RFC 6550: "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", T. Winter, P. Thubert, A. Brandt, J. Hui, R. Kelsey, P. Levis, K. Pister, R. Struik, JP. Vasseur, and R. Alexander, March 2012.

[i.4] IETF RFC 6552: "Objective Function Zero for the Routing Protocol for Low-Power and Lossy Networks (RPL)", P. Thubert, March 2012.

[i.5] IETF RFC 6553: "The Routing Protocol for Low-Power and Lossy Networks (RPL) Option for Carrying RPL Information in Data-Plane Datagrams", J. Hui, and JP. Vasseur, March 2012.

[i.6] IETF RFC 6554: "An IPv6 Routing Header for Source Routes with the Routing Protocol for Low-Power and Lossy Networks (RPL)", J. Hui, JP. Vasseur, D. Culler, and V. Manral, March 2012.

[i.7] IETF RFC 4919: "IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals", N. Kushalnagar, G. Montenegro, and C. Schumacher, August 2007.

[i.8] draft-ietf-6tisch-6top-protocol-09: "6TiSCH Operation Sublayer (6top)", IETF 6TiSCH Working Group, Qin Wang, Xavier Vilajosana, November 2015.

[i.9] draft-ietf-6lo-routing-dispatch-02: "6LoWPAN Routing Header And Paging Dispatches", IETF 6lo Working Group, P. Thubert, C. Bormann, L. Toutain, January 2016.

[i.10] IETF RFC 7554: "Using IEEE 802.15.4e Time-Slotted Channel Hopping (TSCH) in the Internet of Things (IoT): Problem Statement", T. Watteyne, M. R. Palattella, L. A. Grieco, May 2015.

[i.11] ETSI EG 202 237: "Methods for Testing and Specification (MTS); Internet Protocol Testing (IPT); Generic approach to interoperability testing".

[i.12] ETSI EG 202 568: "Methods for Testing and Specification (MTS); Internet Protocol Testing (IPT); Testing: Methodology and Framework".

[i.13] IETF RFC 6282: "Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks".

[i.14] IETF RFC 6775: "Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)".

[i.15] draft-ietf-6tisch-6top-sf0-00: "6TiSCH 6top Scheduling Function Zero / Experimental (SFX)".

[i.16] draft-ietf-6tisch-6top-protocol-04: "6TiSCH Operation Sublayer (6top) Protocol (6P)".

[i.17] IEEE 802.15.4-2015™: "IEEE Standard for Low-Rate Wireless Networks".

[i.18] draft-ietf-6tisch-6top-protocol-01: "6top Protocol (6P)".

[i.19] draft-ietf-6tisch-minimal-security-03: "Minimal Security Framework for 6TiSCH".

[i.20] draft-ietf-6lo-backbone-router-01: "IPv6 Backbone Router".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

DAG root (DR): 6TiSCH Node acting as root of the DAG in the 6TiSCH network topology

6TiSCH Node (6N): any node within a 6TiSCH network other than the DAG root

NOTE: It may act as parent and/or child node within the DAG. It communicates with its children and it parent using the 6TiSCH minimal schedule, or any other TSCH schedule. In the test description, the term is used to refer to a non-DAG root node.

System Under Test (SUT): any composition of a number of Nodes Under Test implemented by different vendors

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACK	ACKnowledgement packet
ARO	Address Registration Option
BBR	BackBone Router

BBR-ND	BackBone Router – Neighbor Discovery
DAC	Duplicate Address Confirmation
DAD	Duplicate Address Detection
DAG	Directed Acyclic Graph
DAO	RPL Destination Advertisement Object
DAR	Duplicate Address Request
DG	DaG root
DIO	RPL DAG Information Object
DODAG	Destination Oriented DAG
DR	Dag Root
EARO	Extended ARO
EB	Enhanced Beacon packet
F	Frequency
GD	Golden Device
GD/root	Golden Device acting as DAG root
GD/root/SEC	GD/root with enabled security options
GD/sniffer	Golden Device acting as PS
GPIO	General-Purpose Input/Output
IE	Information Element
IOC	InterOperation and Conformance
IOP	InterOPeration
IP	Internet Protocol
JP	Join Protocol
JRC	Join Registrar/Coordinator
KA	Keep-Alive message
LA	Logic Analyser
LBR	Low-Power and Lossy Network Border Router
MIC	Message Intergrity Check
MMCX	Micro-Miniature CoaXial
NA	Neighbor Advertisement
ND	Neighbor Discovery
NS	Neighbor Solicitation
NUT	Node Under Test
OSC	OSCilloscope
PAN	Personal Area Network
PANID	PAN IDentifier
PS	Packet Sniffer
RPI	RPL Packet Information
RPL	Routing Protocol for Low power and Lossy Networks
SEC	SECurity
SMA	SubMiniature version A
SUT	System Under Test
SYN	SYNchronization
TD	Test Description
TID	Transaction IDentifier
u.FL	micro Flex
UDP	User Datagram Protocol

4 User defined clause(s) from here onwards

4.1 User defined subdivisions of clause(s) from here onwards

4.1.1 Introduction

According to well-established test methodology, such as ETSI EG 202 237 [i.11] and ETSI EG 202 568 [i.12], it is possible to distinguish two different and complementary ways for testing devices which implement a given standard: Conformance and Interoperability testing.

Conformance Testing aims at checking whether a product correctly implements a particular standardized protocol. Thus, it establishes whether or not the protocol Implementation Under Test (IUT) meets the requirements specified for the protocol itself. For example, it will test protocol *message contents and format* as well as the *permitted sequences of messages*.

Interoperability Testing aims at checking whether a product works with other similar products. Thus, it proves that end-to-end functionality between (at least) two devices (from different vendors) is, as required by the standard(s) on which those devices are based.

Conformance testing in conjunction with interoperability testing provides both the proof of conformance and the guarantee of interoperation. ETSI EG 202 237 [i.11] and ETSI EG 202 568 [i.12] describe several approaches on how to combine these two methods. The most common approach consists in Interoperability Testing with Conformance Checks, where reference points between the devices under test are monitored to verify the appropriate sequence and contents of protocol messages, API calls, interface operations, etc. This will be the approach used by the 6TiSCH Plugtests.

The test session will be mainly executed between two devices from different vendors. For some test descriptions, it may be necessary to have more than two devices involved. The information about the test configuration, like the number of devices or the roles required are indicated in clause 6.

4.1.2 The test description pro forma

The test descriptions are provided in pro forma tables, which include the different Steps of the Test Sequence. The Steps may be of different types, depending on their purpose:

- A stimulus corresponds to an event that triggers a specific protocol action on a NUT, such as sending a message.
- A configure corresponds to an action to modify the NUT or SUT configuration.
- An IOP check (IOP stands for "Interoperation") consists of observing that one NUT behaves as described in the standard: i.e. resource creation, update, deletion, etc. For each IOP check in the Test Sequence, a result is recorded.
- The overall IOP Verdict will be considered PASS if all the IOP checks in the sequence are PASS.

In the context of *Interoperability Testing with Conformance Checks*, an additional step type, CON checks (CON stands for "Conformance") may be used to verify the appropriate sequence and contents of protocol messages, API calls, interface operations, etc.

In this case, the IOP Verdict will be PASS if all the IOP checks are PASS, and CON Verdict will be PASS if all the CON checks are PASS. The IOP/CON Verdict will be FAIL if at least one of the IOP/CON checks is FAIL.

Every IOP check and CON check of a test description should be performed using a trace created by a monitor tool, as described in clause 4.2.

4.2 Tooling

Participant may use their own tools for logging and analysing messages for the "check" purpose. The monitor tools include:

Packet Sniffer: An IEEE 802.15.4e compliant Packet Sniffer (PS) and the relevant tools to be able to analyse packets exchanges over the air. Participant will be free to use their own PS, or a GD/sniffer made available by the 6TiSCH Plug tests organizers.

Logic Analyser or Oscilloscope: A Logic Analyser (LA) to display the state of a GPIO (a pin on a board). Tools to convert the captured data into timing diagrams are necessary.

Debug Pins (GPIOs): To the scope of the tests, at least two programmable Digital I/O pins are recommended. One of the Debug pins should be used to track the slotted activity, and thus, be toggled at the beginning of each timeslot. The other debug pin should be toggled every time an action as defined by the timeslot template happens, i.e. the debug pin will toggle at tsTxOffset, tsRxAckDelay, etc.

Antenna Attenuators: The attenuators (which can be of different type: SMA, MMCX, u.FL) will be used to simulate distance between nodes. By doing so, multi-hop topologies can be constructed without the need of physically separating nodes. An attenuator can connect two motes using a *pigtail* (little wire) with the corresponding antenna connector (e.g. SMA, MMCX, u.FL, etc.). Several attenuators (10 dB, 20 dB, 30 dB, etc.) will be used. It is also preferable that they can be connected in a *daisy chain*.

4.3 Test Description naming convention

All the tests described in the present document, which will be performed during the Plugtests, can be classified in different groups, based on the type of features they verify. There are four different groups of tests: Synchronization (SYN), Packet Format (FORMAT), RPL features (RPL), and Security (SEC).

For each group, several tests are performed.

To identify each test, this TD uses a Test ID following the following naming convention: TD_6TiSCH_<test group>_<test number within the group>.

4.4 6TiSCH Tests Summary

Table 1: 6TiSCH Tests

Test Number	Test ID	Test Summary	Test Group
1	TD_6TiSCH_SYN_01	Check that a 6N synchronizes and keeps synchronized by receiving EBs.	SYN
5	TD_6TiSCH_MINIMAL_01	Check the format of the IEEE 802.15.4e [i.1] EB packet is correctly assembled.	MINIMAL
6	TD_6TiSCH_MINIMAL_02	Check the timing template of TSCH time slot defined in IETF RFC 8180 [i.2] is correctly implemented.	MINIMAL
7	TD_6TiSCH_MINIMAL_03	Check channel hopping is correctly implemented according to IETF RFC 8180 [i.2].	MINIMAL
8	TD_6TiSCH_MINIMAL_04	Check the number of retransmissions is implemented following IETF RFC 8180 [i.2].	MINIMAL
9	TD_6TiSCH_MINIMAL_05	Check the minimal schedule is implemented according to IETF RFC 8180 [i.2].	MINIMAL
10	TD_6TiSCH_MINIMAL_06	Check the 6N sets its slot frame size correctly when joining the network.	MINIMAL
11	TD_6TiSCH_RPL_01	Check the value of EB join priority of a child 6N and a parent DR.	RPL
12	TD_6TiSCH_RPL_02	Check the rank of 6N is computed correctly according to IETF RFC 8180 [i.2].	RPL
13	TD_6TiSCH_RPL_03	Check a 6N child changes its time source neighbour (parent) correctly.	RPL
14	TD_6TiSCH_RPL_04	Check the format of RPL DIO message.	RPL
15	TD_6TiSCH_RPL_05	Check the format of RPL DAO message.	RPL
16	TD_6TiSCH_RPL_06	Check IP extension header in 6LoWPAN.	RPL
19	TD_6TiSCH_6P_01	Check that a 6N can ADD a cell in the schedule according to draft-ietf-6tisch-6top-protocol-09 [i.8].	6P
20	TD_6TiSCH_6P_02	Check that a 6N can COUNT the cells allocated in the schedule to a given neighbour, according to draft-ietf-6tisch-6top-protocol-09 [i.8].	6P
21	TD_6TiSCH_6P_03	Check that a 6N can obtain the LIST of cells in the schedule, according to draft-ietf-6tisch-6top-protocol-09.	6P
22	TD_6TiSCH_6P_04	Check that a 6N can CLEAR the schedule of a node, according to draft-ietf-6tisch-6top-protocol-09.	6P
23	TD_6TiSCH_6P_05	Check that a 6N can DELETE a cell in the schedule according to draft-ietf-6tisch-6top-protocol-09 [i.8].	6P
24	TD_6TiSCH_6P_06	Check the correct implementation of the 6P timeout (after a 6P request is received), according to draft-ietf-6tisch-6top-protocol-09 [i.8]	6P
25	TD_6TiSCH_6LoRH_01	Check that the source routing header is correctly encoded as a 6LoRH Critical RH3, according to draft-ietf-6lo-routing-dispatch-02 [i.9].	6LoRH

Test Number	Test ID	Test Summary	Test Group
26	TD_6TiSCH_6LoRH_02	Check that, when the packet's sent towards the DR, the RPL Information Option is correctly encoded as a 6LoRH RPI, according to draft-ietf-6lo-routing-dispatch-02 [i.9].	6LoRH
27	TD_6TiSCH_6LoRH_03	Check that, when the packet's travel inside the RPL domain, the IP in IP 6LoRH will not be presented in the packet.	6LoRH
28	TD_6TiSCH_6LoRH_04	Check that, when the packet travel outside a RPL domain, IP in IP 6LoRH is present in the packet.	6LoRH
29	TD_6TiSCH_SF0_01	Check SF0 initial overprovision of cells at bootstrap, according to draft-ietf-6tisch-6top-sf0-00 [i.15].	SF0
30	TD_6TiSCH_SF0_02	Check SF0 progressive allocation of cells as traffic demand increases, according to draft-ietf-6tisch-6top-sf0-00 [i.15].	SF0
31	TD_6TiSCH_SF0_03	Check SF0 progressive de-allocation of slots as traffic demand decreases, according to draft-ietf-6tisch-6top-sf0-00 [i.15].	SF0
32	TD_6TiSCH_SECJOIN_01	check that the join request is correctly received at the JRC.	SECJOIN
33	TD_6TiSCH_SECJOIN_02	check that the join response is correctly received at the Pledge.	SECJOIN
34	TD_6TiSCH_SECJOIN_03	check that JP correctly forwards (proxies) the Join Request to the JRC, on behalf of the Pledge.	SECJOIN
35	TD_6TiSCH_SECJOIN_04	check that the join response is correctly received at the Pledge (after having been proxied by the JP).	SECJOIN
36	TD_6TiSCH_SECJOIN_05	Resistance to alteration of requests.	SECJOIN
37	TD_6TiSCH_SECJOIN_06	Resistance to replay of requests.	SECJOIN
38	TD_6TiSCH_SECJOIN_07	Resistance to eavesdropping.	SECJOIN
39	TD_6TiSCH_SECJOIN_08	Detection of flaws in the authentication.	SECJOIN
40	TD_6TISCH_BBR-ND_01	Check registration of nodes to BBR based on ND.	BBR-ND
41	TD_6TISCH_BBR-ND_02	Check registration of nodes to BBR based on RPL.	BBR-ND
42	TD_6TISCH_BBR-ND_03	Check de-registration of nodes to the Backbone router.	BBR-ND
43	TD_6TISCH_BBR-ND_04	Check that a node can move to another backbone router while still keeping the registration.	BBR-ND
44	TD_6TISCH_BBR-ND_05	Check that a collision is detected when a node registers to the backbone with an already registered EUI64.	BBR-ND

5 6TiSCH Test Configurations

5.1 Node Under Test (NUT)

In the context of 6TiSCH, and according to IETF RFC 8180 [i.2], a Node Under Test is a low-power wireless node equipped with a IEEE 802.15.4-compliant radio, and implementing **at least:**

- the IEEE 802.15.4e [i.1] TSCH MAC protocol
- the RPL routing protocol [i.3]
- the 6LoWPAN adaptation layer [i.7]

In the scope of this Test Description, a NUT also implements:

- draft-ietf-6tisch-6top-protocol-09 [i.8]
- draft-ietf-6lo-routing-dispatch-02 [i.9]
- the UDP protocol

When executing the tests described in the present document, the relevant parameter values of the protocols adopted at different layers (IEEE 802.15.4e TSCH and RPL) are set according to [i.2], [i.8] and [i.9]. Those not defined in [i.2], [i.8] and [i.9] are specified in this TD.

Additionally, the NUT needs to implement specific functions not defined in the draft or standard but necessary for conducting the tests. In the scope of this Test Description, a NUT also implements:

- A way to issue a 6P Request.
- A way to disable and enable 6P Response.

Issuing a 6P Request can be triggered either by pressing a button event or by serial command input. There is no specific requirement for how to implement this function as long as the node support that. The disabling and enabling 6P Response functions are required when conducting the timeout test (TD_6TiSCH_6P_06). "Disable the 6P Response" means the node do not send response even it is available to send. This makes node stuck at the current 6P transaction. Then "Enable the 6P Responses" operation makes the node back to normal. However, the node only able to send the response after TIMEOUT.

5.2 System under Test (SUT)

5.2.1 Single-hop scenario

For most tests, the SUT will be a 6TiSCH single-hop topology, including a DAG root and a 6TiSCH Node. The DR will be implemented with a golden device (GD/root or GD/root/SEC), or a vendor node based on the type of test performed (conformance and interoperability tests, respectively). For some tests, in order to check specific features (e.g. packet format, minimal schedule), a packet sniffer will be also needed, in order to listen to the packets on the air, exchanged between the DR and the 6N. Each vendor will be free to use its own PS, or a golden device acting as PS (GD/sniffer) will be provided.

Figure 1: Single-hop scenario

5.2.2 Multi-hop_1 scenario

The multi-hop scenario includes a DAG root and two 6TiSCH Nodes, connected as displayed in Figure 2, in a linear topology. The DR will be either a GD/root (or GD/root/SEC) or a vendor node. For some tests, another GD/sniffer or a vendor PS will be used for capturing the packets exchanged in the multi-hop network.

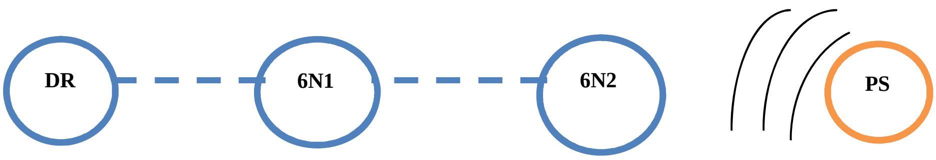

Figure 2: Multi-hop scenario

Moreover, in order to check if a 6N child can change its time source neighbour (parent) correctly (test #13) the multi-hop scenario will be extended, by including another 6N in the network.