ETSI CTI Plugtests Report 1.0.0 (2023-04)

4th mWT Plugtests; Sophia Antipolis, France; 20-24 February 2023

Keywords

Testing, Interoperability, mWT, NETCONF

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Contents

1 Executive Summary

ETSI organised the fourth mWT (millimetre Wave Transmission) SDN (Software Defined Network) Plugtests™ event from 20 to 24 February 2023. The event took place at the ETSI headquarters, in Sophia Antipolis, France. Following previous events focused on RESTCONF [i.1], this event focused on the Southbound Interface (SBI) using the NETCONF [i.3] protocol. It aimed at proving the ability of an SDN to operate from an end to end service point of view, by controlling a chain of millimetre wave network devices. Scenarios for testing were derived from use cases described in ETSI Group Report GR mWT 025 [i.2] (Wireless Backhaul Network and Services Automation: SDN SBI YANG models) and test scripts were developed in the months leading up to the event. Seven organizations participated alongside four network operator observers. The event was highly successful: a final success rate of 99.2% was achieved over the 397 tests executed. A number of observations and opportunities for improvement were identified and are being fed back into the mWT ISG, and will be taken into account in future events on this topic.

2 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.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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] IETF RFC 8040: "RESTCONF protocol”

[i.2] ETSI GR mWT 025: “Wireless Backhaul Network and Services Automation: SDN SBI YANG models”

[i.3] IETF RFC 6241: “Network Configuration Protocol (NETCONF)”

[i.4] IEEE Std 802.1Qcw: “YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing”

[i.5] IEEE Std 802.1ABcu: “Local and metropolitan networks--Station and Media Access Control Connectivity Discovery Amendment 1: YANG Data Model”

[i.6] IETF RFC 6020: YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)

[i.7] IETF RFC 8343: “A YANG Data Model for Interface Management“

[i.8] IETF RFC 8561: “A YANG Data Model for Microwave Radio Link“

[i.9] IETF RFC 7317: “A YANG Data Model for System Management”

[i.10] IETF RFC 8348: “A YANG Data Model for Hardware Management”

[i.11] ETSI FORGE Repository: https://forge.etsi.org/rep/sdn/mwt/mwt-sdn-plugtests-4-materials

[i.12] ncclient: Python library for NETCONF clients: https://github.com/ncclient/ncclient

[i.13] ieee802-dot1q-bridge: https://yangcatalog.org/yang-search/module_details/ieee802-dot1q-bridge@2022-05-19

[i.14] ieee802-dot1ab-lldp: https://yangcatalog.org/yang-search/module_details/ieee802-dot1ab-lldp@2021-09-14

[i.15] ieee802-ethernet-interface: “https://yangcatalog.org/yang-search/module_details/ieee802-ethernet-interface"

[i.16] ieee802-dot1q-types: “https://yangcatalog.org/yang-search/module_details/ieee802-dot1q-types”

3 Abbreviations

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

CT	Carrier Termination
C-VLAN	Customer-side Virtual Local Area Network
DC	Domain Controller
DUT	Device Under Test

E2E	End to End
EVC	Ethernet Virtual Connection
FW	Firmware
GE	Gigabit Ethernet
GR	Group Report
HW	Hardware
IETF	Internet Engineering Task Force
IFS	Interoperability Feature Statement
IP	Inernet Protocol
ISG	Industry Specification Group
L2	Layer 2
LLDP	Link Layer Discovery Protocol
mmW	Millimetre wave
MW	Microwave
mWT	Millimetre Wave Transmission
NBI	Northbound Interface
NE	Network Element
NETCONF	Network Configuration Protocol
NMS	Network Management System
ONF	Open Networking Foundation
PVID	Port VLAN ID
RF	Radio Frequency
RLT	Radio Link Terminal
S-VLAN	Supplier-side Virtual Local Area Network
SBI	Southbound Interface
SDN	Software Defined Network
TLV	Type-Length-Value
TD	Test Description
XML	eXtensible Markup Language

4 Introduction

ETSI organised the fourth mWT (millimetre Wave Transmission) SDN (Software Defined Network) Plugtests™ event from 20 to 24 February 2023. The event took place at the ETSI headquarters, in Sophia Antipolis, France.

Following three previous mWT Plugtests events focused on a standard Northbound Interface (NBI) using the RESTCONF [i.1] protocol, this fourth event looked at the Southbound Interface (SBI) which uses the NETCONF [i.3] protocol.

This event focused on proving the ability of an SDN to operate from an end to end service point of view, by controlling a chain of millimetre wave network devices.

5 Technical Scope

ISG mWT has published the ETSI Group Report GR mWT 025 [i.2], Wireless Backhaul Network and Services Automation: SDN SBI YANG models. This report provided a comparison between standard YANG [i.6] Data Models developed by the IEEE, IETF and ONF, including performing a gap analysis.

This ETSI GR also identified a number of use cases where automation was desirable. This Plugtests event focused on the first two use cases, network and services auto-discovery, and services provisioning.

Using Python scripts developed for the event and with a set of agreed data models already implemented in vendors' equipment, the Plugtests event attempted to demonstrate the ability of a domain controller to manage an end-to-end service by controlling a chain of millimetre wave devices. Control was exercised via the NETCONF protocol (IETF RFC6241 [i.3]) operating on what is known as the South-bound interface (SBI).

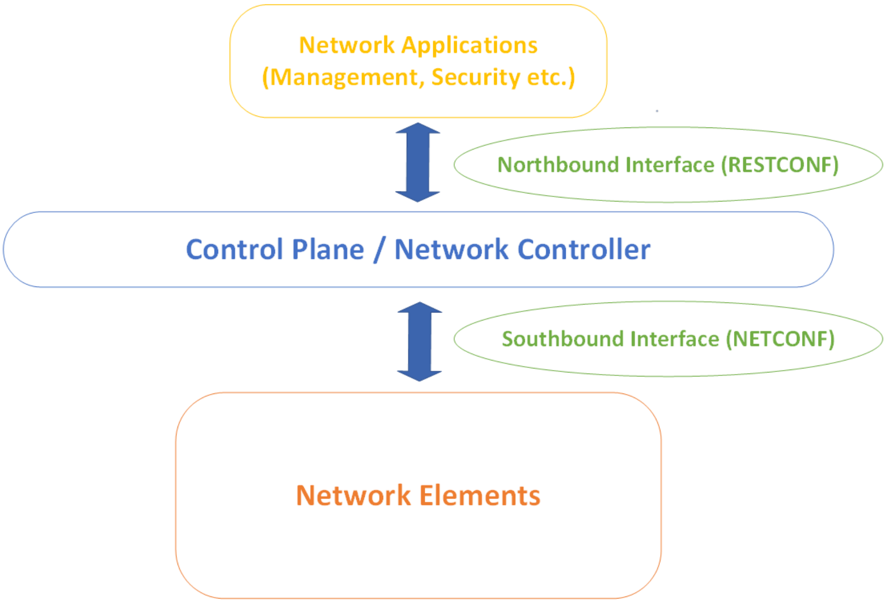

Figure 1: RESTCONF and NETCONF Northbound and Southbound interfaces

The objective of the event was to control a series of millimetre wave network devices over the NETCONF interface to establish an end-to-end service. In the process, the objective was also to establish a common set of parameters from the YANG Data Models used by the NETCONF protocol, required to enable interoperability and end-to-end service management.

6 Participants

The teams which executed tests during the Plugtest are listed in the table below.

Table 1: List of teams

#	Team
1	Ceragon Networks
2	Ericsson
3	Huawei
4	Intracom Telecom
5	NEC
6	Nokia
7	SIAE

Table 2: List of observers

#	Observer
1	BT
2	Deutsche Telekom

3	Orange
4	Vodafone

All the participating teams had team members present on site at ETSI, while some observers and some other team members were remotely located, participating in the daily wrap-up sessions or interacting directly with their own team members.

7 Architecture

7.1 Test network architecture

The basic test architecture is depicted below.

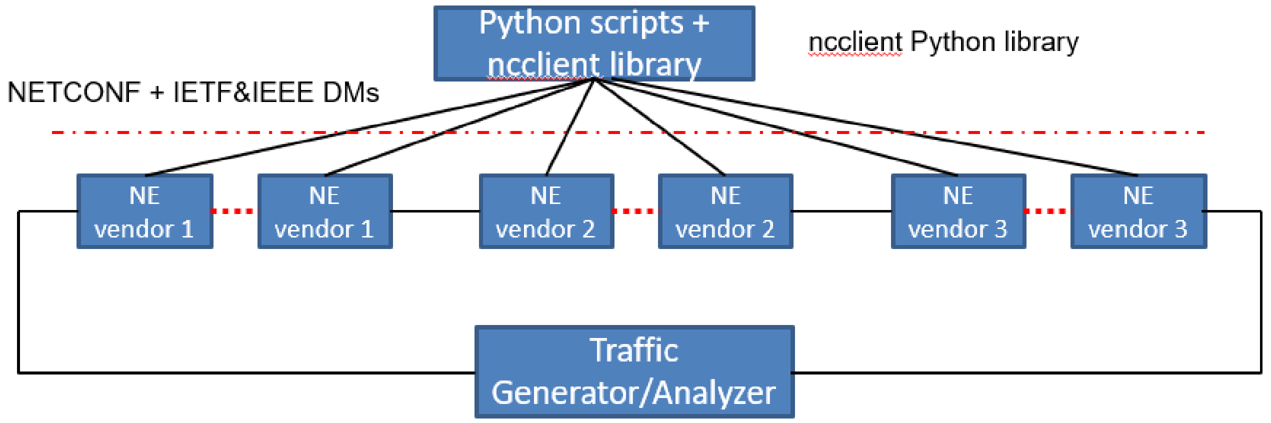

Figure 1: Test Architecture

Each network equipment vendor provided a pair of network elements, both ends of a millimetre wave or microwave link. The physical connection between the two RF units of the radio link was realized with coaxial cable or waveguide plus attenuators, no antenna and no free space radiation was allowed.

The goal was to arrange the links in a linear topology to enable an end-to-end service to be configured.

Each network element was connected to the adjacent one via an optical fibre connection, via a patch panel. The first and the last network elements in the total chain were connected to a packet traffic generator / analyzer also via optical fibre connections.

A Python script with the ncclient Python library [i.12] simulated a network controller, and exchanged YANG model payloads with the network elements. The script pushes XML-formatted data structured according to selected YANG data models.

The connection between the controller executing the Python scripts and each network element or each vendor's domain was performed using Ethernet connections.

For the "inventory" usecase, The script used transformed the returned XML into Excel files. Manual verification of the resulting Excel file was required. Using conditional formatting in Excel to highlight correct and incorrect fields returned made manual verification easier. For the "service provisioning" usecase, the script edited the configuration of network elements. It used a template for XML document, replace required fields and push to the network elements.

While each vendor had already executed the script prior to attending the event, during the event a central machine was used to execute all the scripts, ensuring that any differences in behaviour, such as different levels of NETCONF or YANG data model support, were easily identified and noted.

7.2 Locical Topology

Figure 2 shows the logical topology of the Plugtest network.

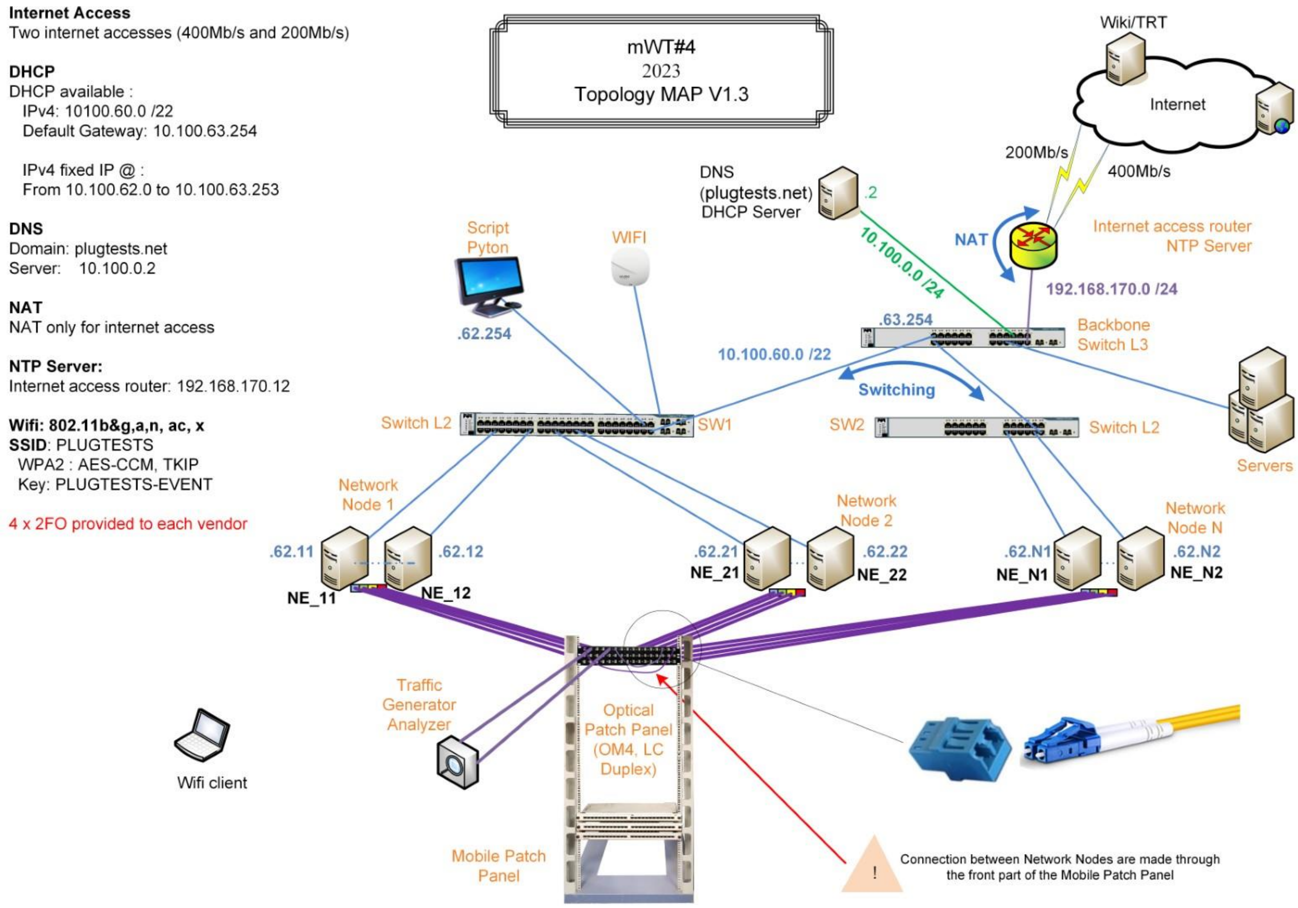

Figure 2: Logical Topology of the Test Network

Static IP addresses were used for each element on the network, with a range of static addresses provided to each participating organization.

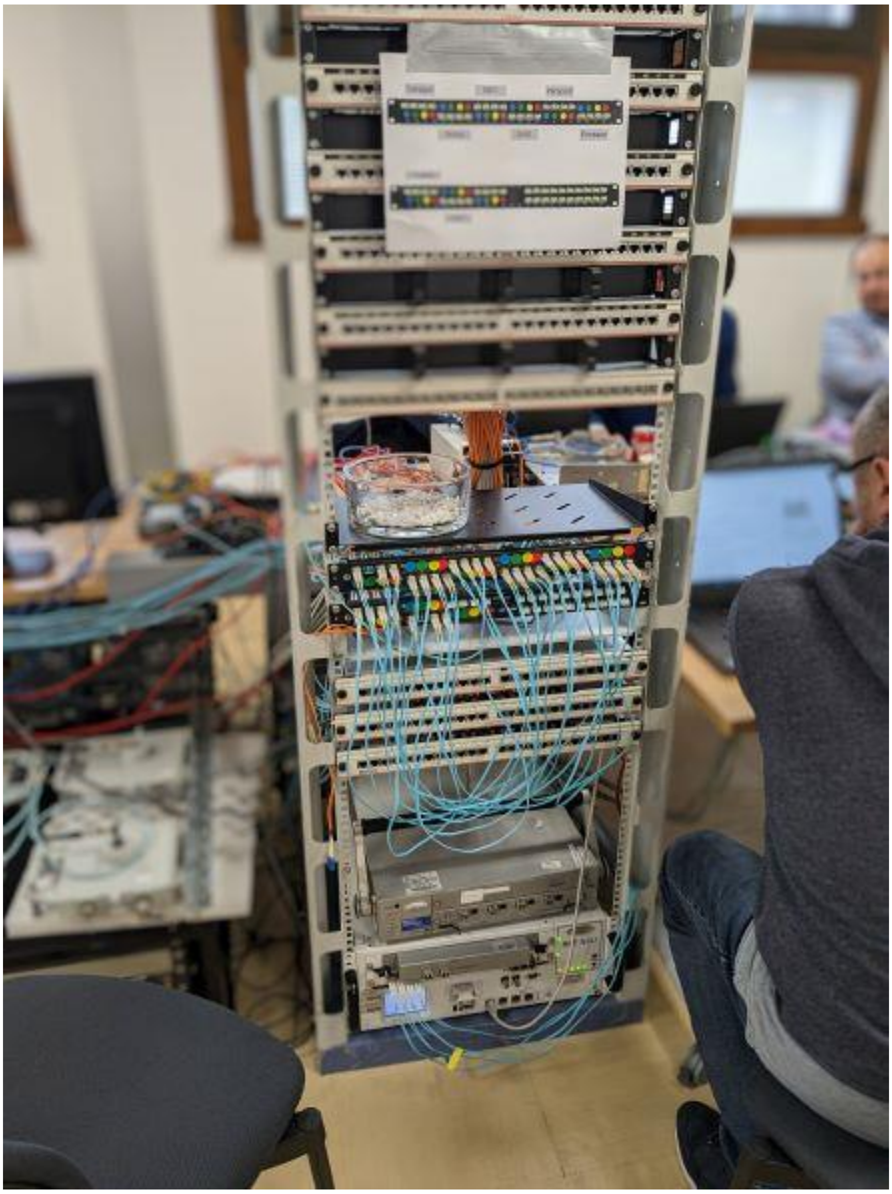

Figure 3: View of the optical patch panel used in the testing

7.3 Data Plane Network

The test cases that create and delete a L2 service required the use of a Test Instrument (Spirent TestCenter C1) to generate the traffic, and to confirm that it was flowing correctly when the circuit was set up.

This data-plane network was closed, i.e. not connected to any other network (test network, internet etc.)

8 Pre-event preparation

Preparation for this event commenced almost one year before the event. The participants in the previous three editions of the mWT Plugtests events re-convened to prepare for this new event. ETSI set up a Wiki space and also a repository on the ETSI Forge Gitlab server [i.11] to assist with file and information sharing. Regular conference calls were held every two weeks, starting on 10 May 2022.

During the preparation phase, the participants developed the Python test script to be used in the event, and finalised the set of required YANG models and parameters to be tested during the event. In addition, the test cases and scenarios to be tested were developed and agreed.

The following YANG data models were initially identified:

Table 3: Set of YANG models identified

module name	revision	Reference	Required parameters	UC1	UC2	Notes
ieee802-dot1q-bridge [i.13]	2022-05-19	see on YANG Catalog	?	Yes	Yes	part of IEEE Std 802.1Qcw [i.4]. Decided E2E L2 Service Provisioning Test Description#YANG data model.
ieee802-dot1ab-lldp [i.14]	2021-09-14	see on YANG Catalog	12	Yes	No	IEEE Std 802.1ABcu [i.5].
ieee802-ethernet-interface [i.15]	2019-06-21	see on YANG Catalog	4	Yes	No	Initial and last revision as of October 2022.
ieee802-dot1q-types [i.16]	*TBD*	to check on YANG Catalog	imported	Yes	Yes	*To be decided*
ietf-interfaces	2018-02-20	RFC8343 [i.7]	5	Yes	No	Last version as of October 2022.
ietf-microwave-radio-link	2019-06-19	RFC8561 [i.8]	17	Yes	No	Initial and last revision as of October 2022.
ietf-system	2014-08-06	RFC7317 [i.9]	2	Yes	No	Initial and last revision as of October 2022.
ietf-hardware	2018-03-13	RFC8348 [i.10]	3	Yes	No	Initial and last revision as of October 2022.

Two use cases were identified to be tested:

- Use case 1 – Network and services auto-discovery: The application detects the network elements, their topology and interconnection, and the services already provisioned.
    - HW/FW Inventory
    - Carrier Inventory
    - Port Inventory
    - Services Inventory
    - Network Discovery
- Use case 2 – E2E L2 Service Provisioning: An E-LINE service is configured E2E, traversing a chain of different Vendors' equipment.
    - C-VLAN support
    - S-VLAN/C-VLAN support

9 Testing phase

9.1 Test Cases

Based on the two use cases identified in the preparatory phase, two groups of tests cases were defined:

- Network and services auto-discovery test cases
- End to End L2 service provisioning test cases

9.1.1 Network and services auto-discovery test cases

Table 4: Inventory or Network and services auto-discovery test cases

Test ID	Objective
INV_HW_01	Requests the Hardware inventory from all NEs, using the YANG module ietf-hardware.
INV_FW_01	Requests the Software inventory from all NEs, using the YANG module ietf-system.
INV_CARRIER_01	Requests the microwave carrier inventory from all NEs, using the YANG module ietf-microwave-radio-link. Both RLTs and CTs are collected.
INV_PORT_01	Requests the Ethernet carrier inventory from all NEs.
INV_SRV_01	Requests the EVC service inventory from all NEs, using the YANG module ieee802-dot1q-bridge, in Customer Bridge mode.
INV_SRV_SC_01	*Requests the EVC service inventory from all NEs, using the YANG module ieee802-dot1q-bridge, in Provider Bridge mode (**optional**).*
INV_SRV_SC_02	*Requests the EVC service inventory from all NEs, using the YANG module ieee802-dot1q-bridge, in Provider Edge Bridge mode (**optional**).*
INV_NET_01	Build a network topology using LLDP adjacencies information: Requests the neighbors inventory from all NEs, using the YANG module ieee802-dot1ab-lldp.

In each test, the Equipment Under Test was required to return a list of required parameters.

9.1.2 End to End L2 service provisioning test cases

Table 5: E2E L2 service provisioning test cases

Test ID	Objective	Status
PROV_C_01	Create a C-VLAN-based E-Line Service, crossing all NEs, in Customer Bridge mode.	Mandatory
PROV_SC_01	*Provision a S-VLAN-based E-Line Service carrying 2 C-VLANs, crossing all NEs, in Provider Bridge mode.*	*Optional*
PROV_SC_02	*Provision a S-VLAN-based E-Line Service carrying 2 C-VLANs, crossing all NEs, in Provider Edge Bridge mode.*	*Optional*

PROV_C_01 was required to be executed twice, once for tagged traffic, once for untagged traffic.

9.2 Test plan and execution

Following setup and installation of the equipment, an initial day of testing focused on single-vendor testing, where each vendor demonstrated its capability of executing each test alone. There followed a day and a half of testing pairs of vendors together. Finally, all seven vendors were combined into a single chain of vendors. In these final two phases, testing focused on the provisioning or establishment of an end-to-end service. Most of the auto-discovery or inventory tests did not need to be re-executed during these phases.

For each inventory test, execution took place only once but verdicts were reported in three test cases, for each execution:

- At least 70% of required parameters present for this test
- At least 90% of required parameters present for this test
- 100% of required parameters present for this test

For example, where 100% of required parameters were present when a test was executed, ‘OK’ verdicts were recorded for all three related test cases.

The final day was focused on building the full chain of all seven vendors participating in the event. Once interconnectivity was established along this chain, the testing demonstrated the capability of a network controller to provision an end-to-end service in a single set of commands.

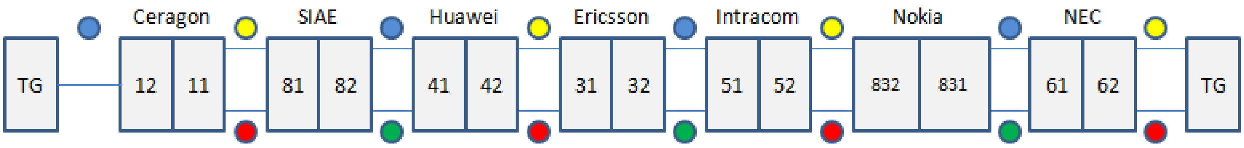

Figure 4: Diagram of the chain of interconnected equipment

Tagged

Tx Port Name	Stream Block	Rx Port Names	Tx Count (Frames)	Rx Count (Frames)	Tx Rate (fps)	Rx Rate (fps)	Tx Rate (bps)	Rx Rate (bps)	Dropped Count (Frames)	Avg Latency (us)
Port //1/1	CB CVLAN 101 RIGHT (BLUE PORT)	Port //1/3	2.435.459	2.266.639	84.459	84.458	86.486.328	86.485.352	0	1.020.39
Port //1/1	CB Untagged traffic to CERAGON (BLUE PORT)		2.435.460	0	84.459	0	86.486.328	0	0	0
Port //1/3	CB VLAN 101 LEFT (YELLOW PORT)	Port //1/1	2.435.459	2.266.597	84.459	84.460	86.486.328	86.487.304	0	1.021.67
Port //1/4	CB Untagged LEFT (RED PORT)		2.435.459	0	84.459	0	86.486.328	0	0	0

Tagged+Untagged

Port //1/1	CB CVLAN 101 RIGHT (BLUE PORT)		5.712.259	5.720.554	84.459	84.452	86.486.328	86.478.512	0	1.038.66
Port //1/1	CB Untagged traffic to CERAGON (BLUE PORT)		5.712.260	26.274	84.459	1.833	86.486.328	1.876.952	1.184.638	184.650.28
Port //1/3	CB VLAN 101 LEFT (YELLOW PORT)		5.712.259	5.720.516	84.459	84.467	86.486.328	86.494.144	0	1.039.59
Port //1/4	CB Untagged LEFT (RED PORT)		5.712.259	26.478	84.459	1.837	86.486.328	1.880.856	1.169.542	182.009.1

Tx Port Name	Stream Block	Rx Port Names	Tx Count (Frames)	Rx Count (Frames)	Tx Rate (fps)	Rx Rate (fps)	Tx Rate (bps)	Rx Rate (bps)	Dropped Count (Frames)	Avg Latency (us)
Port //1/1	CB CVLAN 101 RIGHT (BLUE PORT)	Port //1/3	101.425.419	101.433.721	84.459	84.469	86.486.328	86.496.096	0	1.092.69
Port //1/1	CB Untagged traffic to CERAGON (BLUE PORT)	Port //1/4	103.617.730	4.275.573	84.459	1.829	86.486.328	1.873.048	27.732.046	93.342.9
Port //1/3	CB VLAN 101 LEFT (YELLOW PORT)	Port //1/1	101.452.587	101.460.838	84.459	84.452	86.486.328	86.478.512	0	1.102.48
Port //1/4	CB Untagged LEFT (RED PORT)	Port //1/1	103.617.730	4.255.307	84.460	1.837	86.486.816	1.880.856	27.737.158	93.781.24

Figure 5: Screenshot of traffic generator for the full chain of interconnected equipment

Figure 6: View of the testbench

10 Achieved Interoperability Results

A final interoperability result of **99.2%** of the 397 tests executed were considered to have passed.

Interoperability		Not Executed		Totals	
OK	NO	NA	OT	Run	Results
394 (99.2%)	3 (0.8%)	25 (5.9%)	(0.0%)	397 (94.1%)	422

Figure 7: Interoperability Results exported from ETSI's Test Reporting Tool

11 Lessons Learned

11.1 What went well and what could be improved

The following points were among the positive lessons learned:

- Time spent preparing for the event since May 2022 was well worth it;
- The availability of expert help for test execution (from CNIT) was highly appreciated;
- The Optical Patch Panel and overall IT preparation from the ETSI Plugtests service really helped to simplify connection and test configuration, saving valuable time.

The following points should be taken into account when preparing for a further event:

- More automation of the testing would be beneficial and would reduce the time to execute the tests;
- More time in the preparation phase, with the support of CNIT, should be spent designing the tests and test scenarios;
- A separate document should be provided containing the complete Test Specification. This event used the Wiki for this purpose but a separate document is useful in order to provide to colleagues in e.g. R&D, so that they can fully prepare for the event;
- Scheduling: single-vendor tests at the start created some bottlenecks on scheduling, because each vendor was supposed to to proceed its single-vendor tests set before proceeding to vendor-pair tests. As result, vendors were queueing for single-vendor tests;
- Do we want all testing to be performed or verified by a central ‘authority’ during the event (CNIT in this case)?
    - We need traffic generators for provisioning tests and attenuators for e.g. fault simulation. This requires a central test tool;
    - For single vendor tests, it is useful to have CNIT as a ‘reference’ or support. We need better scheduling for this. It is not so necessary for vendor-pair testing.
    - There is high interest in the activities of CNIT, especially for the full-chain of tests. We should consider having a large screen (or several) to allow more visibility to all participants;
- Clearer pass/fail or measurement criteria for tests should be set in advance.

11.2 Opportunities to improve Interoperability on the SBI

The following lessons and outcomes are specifically related to the standards tested in this event:

- More clarification is required on the PVID as different interpretations are possible. Alignment should be the goal;
- More complex provisioning use cases cause more issues. Can a YANG model with lots of flexibility be useful for interoperability or should a higher level of abstraction be used?
- IEEE Bridge model can accommodate more ‘modern’ configuration possibilities. The model can evolve further.
- We tested syntax, not semantics. Semantics may need to be addressed in future events or may need more specification
    - E.g. The reported serial number doesn’t always look like a serial number, even if within the specification. How to test this, can it be tested, should it be tested?
- LLDP test: the same parameter is reported with a different syntax from vendor to vendor – should follow the model.
- LLDP test: we should align on which TLVs are mandatory and which are not. We chose 4 for a particular use case of network discovery. We should ignore other optional TLVs;
- We were not able to use exactly the same script to control all the devices. The issues around PVID and service deletion required some vendor-specific tailoring: More alignment is needed. We were performing a very small set of tests & configurations and yet we have seen problems. This could be handled by more abstraction, or models could be more explicit (better specification) – the overall goal is automation;
    - Some of the issues are problems with the controller script which will be corrected, or could be handled by developing the script further.

11.3 Potential for future events

Follow-on events are expected to be required. The next opportunity for an event should be in H2 2024.

Until then, the ISG mWT should progress further on the draft ETSI GR mWT 025 [i.2], identifying new use cases and scenarios, which can then be tested in a Plugtests event.

As the current experimental approach was human-to-machine, based on the lessons learned, it would be useful to draft a workflow for machine-to-machine connectivity, i.e. between SDN-C and NEs in the spirit of full automation.

A future event can also look at some of the underlying NETCONF behaviour.

History

Document history		
0.0.1	28 Feb 2023	1st draft produced by CTI
0.0.2	4 April 2023	2nd draft for review by mWT Plugtests participants
0.0.3	April 2023	3rd draft
0.0.4	April 2023	V0.0.3 with revision marks accepted
1.0.0	April 2023	Version made publicly available on ETSI Portal