1 Introduction

This document provides an overview of the **Proofs of Concept** conducted within the Wireless Working Group (WWG) of the Open Networking Foundation (ONF) in conjunction with the first in a series of ONAP (Open Network Automation Platform) PoCs for Next Generation RF Technologies.

Impacts are summarized within the additional supporting documents pertaining to AT&T's "Big Wins."

The mission and long-term targets are as follows:

- Adoption of SDN architecture and principles for Wireless Networks. Identification of and execution of different use cases.
- Allowing non-proprietary **open source** SDN controller (e.g. ECOMP/ONAP's ODL-based SDN-C, dubbed "SDN-R" for RF Technologies) to manage multi-vendor wireless transport networks and coordinate them with other domains and layers of the network, e.g. RAN, Core, OTN; multi-layer and multi-domain hierarchical SDN solely based on open source models and open interfaces.
- Definition and standardization of open interfaces and open source information models
- Integration of information models into the open source ecosystem. Open standardized interfaces support connecting multi-vendor devices to an open source SDN Controller and the development of independent third-party applications "network programming" (NFV)). The operators/service provides do not differentiate by the functionality, which is provided by the controller itself, but by the applications.

The benefits of the SDN-based open standardized platform are as follows:

- Vendor-specific element management systems can eliminated and replaced by a unified/universal element management system that leverages open standardized SouthBound Interfaces "SBIs."
- The plethora of tools for network planning and operations support may be converged on a single platform, i.e., ECOMP/ONAP, with comparable functionality delivered by seamlessly integrated network applications. **IMPACT = Significant (measurable) reduction in the complexity of the overall network management solution; significant (measurable) cost reduction and time-savings.**
- Decoupling the functions from the device to centralized controller reduces the duration and costs of certification and integration processes - a new function is configured and tested just once.

1.1 SDN-based open standardized architecture

The overall SDN architecture is illustrated in Figure 1 below. The architecture identifies the main objects which are target of implementation and subsequent verification within PoCs:

- ECOMP/ONAP SDN controller (OpenDaylight)
- Vendor-specific/vendor-developed mediators that translate from proprietary CLI/MIB to open Netconf/YANG and vice versa
- Netconf southbound interface and the northbound applications

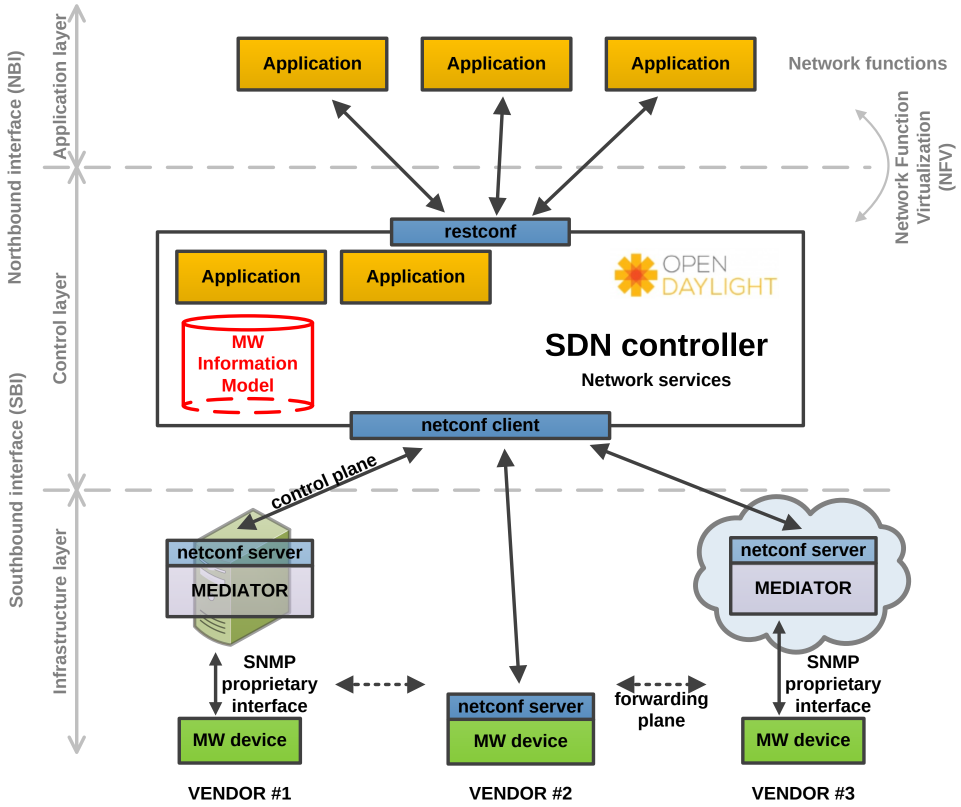

Figure 1 SDN-based architecture of Wireless Network

The open source SDN controller(s) are implemented on commercial-of-the-shelf "COTS" computers (white box).

The vendor-specific mediator is a piece of software-per-device, integrated inside MW device or running outside MW device on a server or cloud, that translates standard Netconf/YANG into the device-specific proprietary language (SNMP) and vice-versa (the firmware inside MW devices is not modified).

The Netconf configuration & control protocol manipulates the YANG configuration and state data that are auto-generated from the generic UML Information Model of a wireless network device.

OpenYuma (written in C) has been chosen as the Netconf server/client to be the basis of the mediator. It can easily become part of the firmware of the wireless devices later on. There are a few equipment vendors, however, that have elected to implement Cisco's ConfD, originally from Tail-f Systems.

2 Overview of Proofs of Concept & Impacts

A Proof of Concept is executed roughly every half a year to demonstrate progress being made in development and to verify the functionality and completeness of enhancements implemented in a multi-vendor wireless network using real network devices (PNFs).

The results and conclusions of PoCs are published in the form of ONF Technical Recommendations (TR) and White Papers.

The following table summarizes key components used during PoCs such as version of SDN controller, ONF CoreModel and SBI protocol.

	SDN controller	ONF CoreModel	SBI protocol
1st PoC	ONOS		OpenFlow
2nd PoC	ODL Lithium SR4		Netconf/YANG
3rd PoC	ODL Beryllium SR2	CM 1.1	Netconf/YANG
4th PoC	ODL Boron SR1	CM 1.2	Netconf/YANG
4.1th PoC	ODL Boron SR3	CM 1.2	Netconf/YANG

2.1 PoC 1

The 1st PoC was performed in Madrid, Spain in **October 2015** and hosted by Telefónica Global CTO unit, IMDEA Networks in cooperation with Universidad Carlos III. OpenFlow protocol was used at Soutbound Interface (SBI) while ONOS was used as SDN controller. The use cases supported by the following applications were demonstrated:

- Capacity-Driven Air Interface - switching on/off one polarization of the microwave link in dependence on the traffic demand to efficiently optimize wireless resources for a more energy efficient operation of the transport network.
- Flow-based Shaping - illustrating inter-domain interaction between microwave devices and routers by activating policing at the router in case of packet loss at the microwave device due to the weather changing conditions

2.2 PoC 2

The 2nd PoC was performed in Munich, Germany in **April 2016** and hosted by Telefónica Germany. In contrast to 1st PoC, Netconf/YANG protocol was used at SBI while OpenDaylight (ODL) was used as SDN controller. The initial simplified MW Information Model (reduced set of attributes) was developed and implemented. The use cases supported by the following applications focusing mainly on the management and configuration of a multi-vendor wireless transport network were demonstrated:

- Detection and configuration of new wireless devices
- Detection and operator-driven correction of discrepancies between actual and planned network configuration
- Detection and visualization of the configured transport network
- Detection and visualization of the currently effective transport network
- Receiving, displaying and storing of network-related alarms and events

2.3 PoC 3

The 3rd PoC was performed in New Jersey, USA in **October 2016 and hosted by AT&T in cooperation with WINLAB (Wireless Information Network Laboratory) at Rutgers University**. The complete MW/mmW Information Model (including all the attributes) was developed and implemented. The use cases supported by the following applications were demonstrated:

- The above mentioned applications from 2nd PoC
- Spectrum management – comparison of configured and planned frequencies and reallocation in case of mismatch
- Closed-loop automation (“zero-touch deployment and maintenance”) – a basic response to external/internal/time triggers

2.4 PoC 4

The 4th PoC was performed in Bonn, Germany in **June 2017** and hosted by Deutsche Telekom. The existing Cloud environment was used for the first time to run ODL SDN controller, applications and vendor-specific mediators.

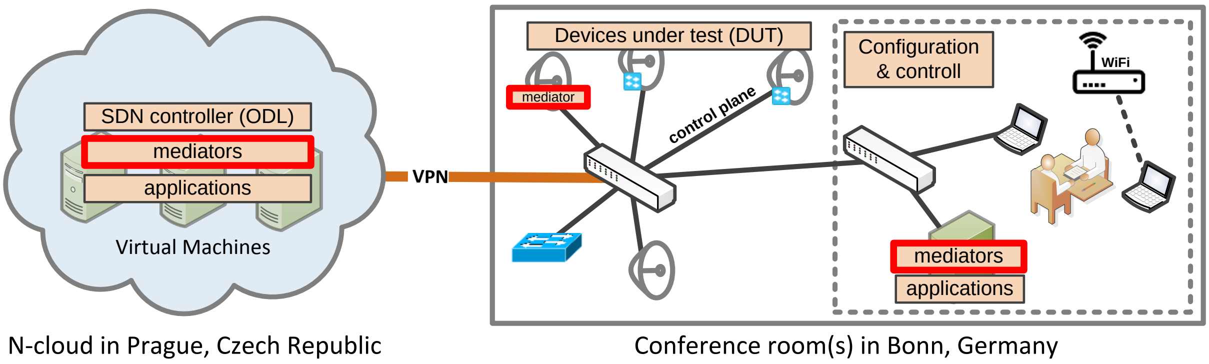

Figure 2 Network topology of 4th PoC

This PoC continues to expand on the ONF Wireless Information Model standard (TR-532) [TR532].

In addition to some basic Ethernet capabilities, the possibility to manage a synchronization network via SDN approach in order to distribute the frequency & phase/time information using PTP (IEEE 1588v2) [IEEE1588v2] was demonstrated.

Results and conclusions were reported in ONF White paper [WP_4PoC].

All the code (applications) developed during the PoC are stored and publicly available as open source at CENTENNIAL GitHUB [CENTEN].

3 Overview of first ONAP <-> ONF integrated PoC

The first joint ONAP <-> ONF PoC is being **hosted by AT&T in cooperation with WINLAB (Wireless Information Network Laboratory) at Rutgers University in New Jersey from Monday, 27th of November, 2017 to Friday, 1st of December, 2017**.

The ONF “piece” of this PoC is focused on the wireless transport domain, while the ONAP piece is focusing on more complex multi-domain multi-technology orchestration.

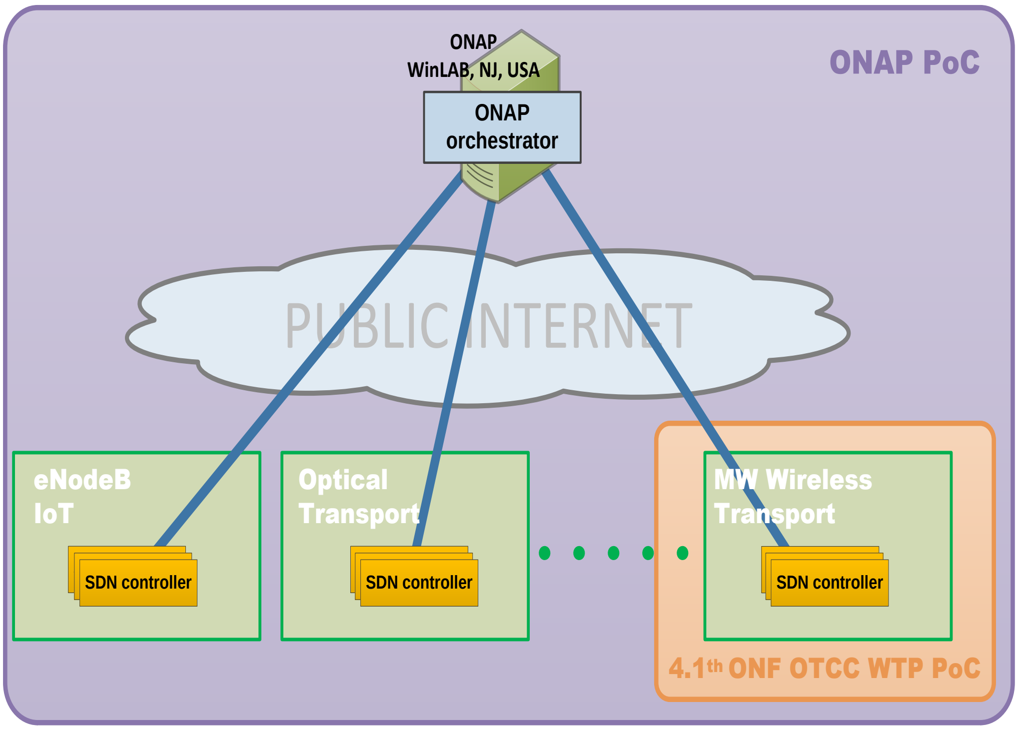

Figure 3 Multi-domain multi-technology ONAP architecture

3.1 Scope and objectives

The ONAP <-> ONF PoC in 4Q2017 is an evolution of previous PoCs Its objectives are as follows:

- Implementation of Equipment Model (in accordance with ONF CoreModel 1.2) in order to provide equipment/inventory information from the devices
  - Equipment model is implemented in ONF CoreModel 1.2
  - Extension of Equipment Model about specific alarms of wireless devices, e.g., MW, mmW, eNB, DAS
  - The inventory information is retrieved through the AAI (Active and Available Inventory) ONAP interface from a device via mediator and ODL SDN controller (device → mediator → ODL SDN controller → AAI ONAP
- Verification of remote cloud-based architecture
  - Remote connectivity among all the components (ONAP, ODL SDN controller, mediators, devices)
- Integration of ONF Wireless Information Model based on TR-532 into ONAP architecture

○ Alarms, performance values and inventory information are provided to ONAP components – checking whether TR-532 is in compliance with ONAP interfaces or an adjustment is needed.

3.2 Network configuration – remote cloud-based architecture

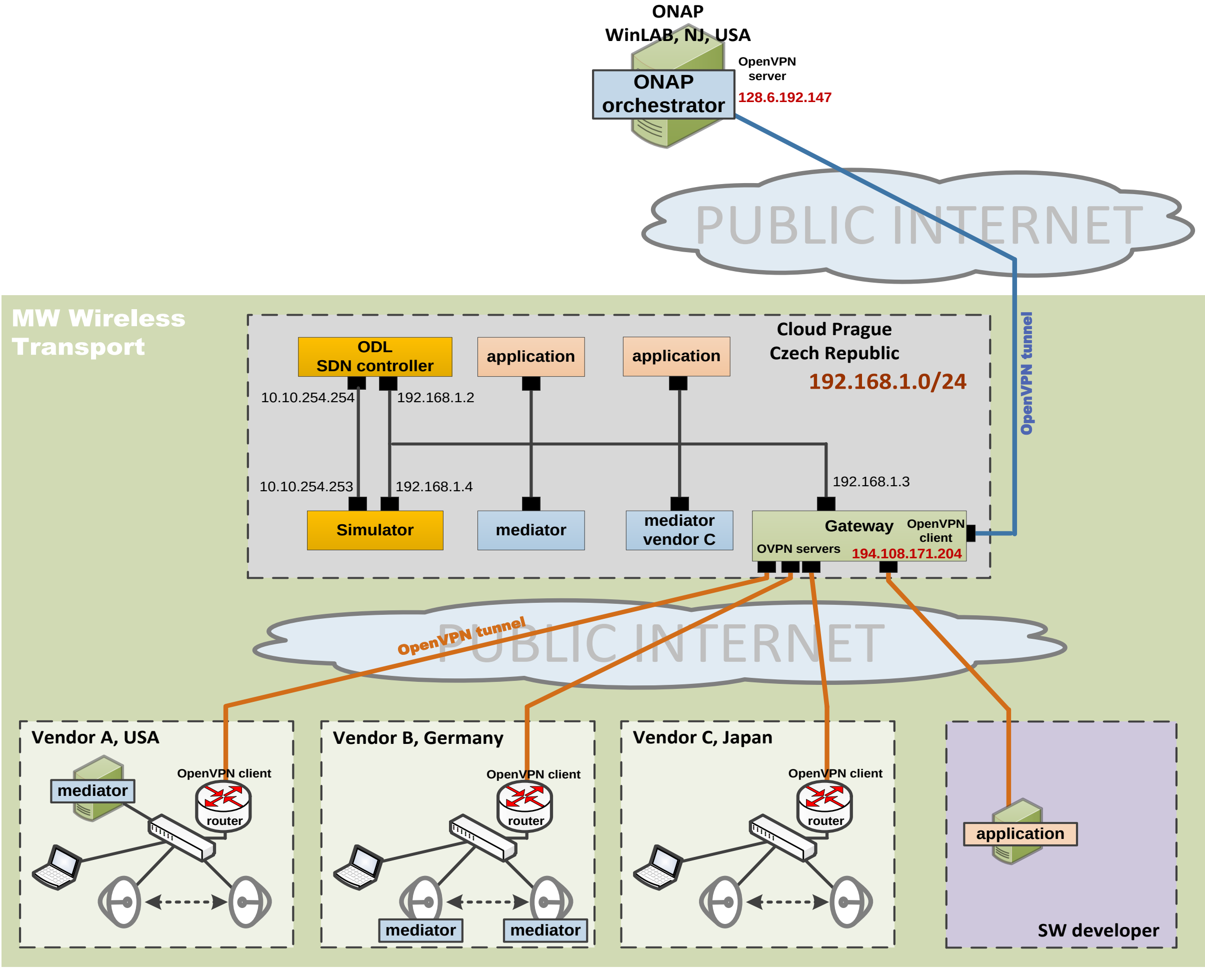

Figure 4 Remote cloud-based architecture inside MW Wireless Transport domain