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Executive summary

This white paper provides an overview of a significant technical Proof of Concept (PoC) project accomplished in October 2015 by the Wireless Transport project of Open Networking Foundation (ONF) in Leganés, Madrid, Spain. Two use cases are tested in the PoC: capacity-driven air interface and flow-based shaping. The planned tests, test configurations, test results and conclusions are presented in this paper.

1 Introduction

Wireless transport networks are a key component of existing network deployments. The need for capillarity (i.e., extension of the service reach) to provide the sufficient network coverage demanded by end users resides greatly on wireless transport networks connecting access nodes to aggregation domains. Being a huge area of investment by network operators, it is a desirable objective to simplify and facilitate the roll-out and run of this network segment.

Wireless links traditionally utilize the microwave spectrum, however this is expected to expand to the millimeter wave spectrum, thus the term used in this paper is “wireless links” as opposed to “microwave links”.

Current mode of operation for wireless transport networks is tightly bound to vendor proprietary Network Management Systems (NMS) with specific interfaces. The configuration, operation and maintenance of those network segments are performed manually, in a static manner, by highly specialized technicians requiring vendor-specific procedures and skills to handle the network.

As part of the telecom industry in transition to 5G networks, agility and programmability are becoming key operational goals for operators to face challenges like the support of high traffic volumes, the capability for fast re-configurability, the efficient consumption of energy, an automate planning of frequencies, etc. This dynamicity is not affordable nowadays.

The use of software techniques, together with the logical centralization enabled by Software Defined Networking (SDN), helps significantly reduce the overall service setup and configuration time, to achieve a target of 90 minutes compared to the 90 days currently needed today, as mentioned by the 5G PPP objectives[1].

Concepts arising from the SDN approach including SDN controllers supporting standard open South Bound Interface (SBI) and North Bound Interface (NBI) are a key factor in changing the very essence of the wireless transport domain.

Once both open standard SBIs, for programming wireless transport network elements (NEs), and open standard NBIs, for developing apps over a full network segment, are available, it’s possible to innovate in a manner previously not perceived. To cover this gap in the case of wireless transport networks, the ONF Wireless Transport project is working towards the definition of OpenFlow™ extensions for management and control of wireless transport NEs.

New optimization applications for wireless transport networks, dynamically programming wireless NEs instead of configuring them, and adopting DevOps concepts for automating processes are just a few examples that can be accomplished with central control combined with standard open SBIs and NBIs.

A number of ONF major wireless transport vendors have joined forces with a leading telecom operator in order to test and experiment with real-world applications presenting a number of optimizations for wireless transport segments in an SDN realm, leveraging the work being done currently in the ONF.

This white paper provides an overview of the PoC performed by the ONF Wireless Transport project on two concrete use cases: capacity-driven air interface and flow-based shaping. The planned tests, test configurations, test results and conclusions from the tests are presented in this paper.

2 Test overview

The SDN architecture is defined as shown in Figure 1[2].

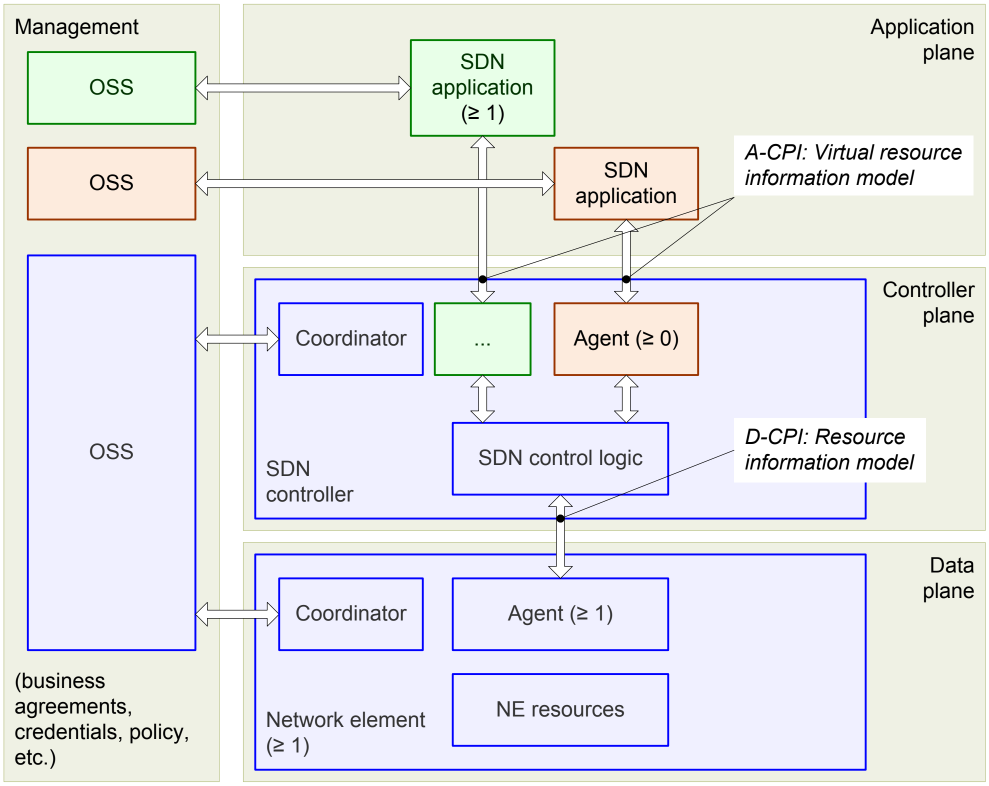

Figure 1 - The SDN Architecture

Implementation of the SDN model layers and test topology in PoC was as shown in Figure 2:

- The Infrastructure Layer consisted of multiple types of Network Elements, including Ethernet switches and wireless transport devices;
- The Controller Layer consisted of an open sourced platform ONOS, using OpenFlow 1.3 or OpenFlow1.4 as the SBI. The OpenFlow with wireless transport extension[3] and test specification[4] are developed by the wireless transport project under the Open Transport Working Group (OTWG) in ONF;

- The Application Layer consisted of two applications: capacity-driven air interface and flow-based shaping.

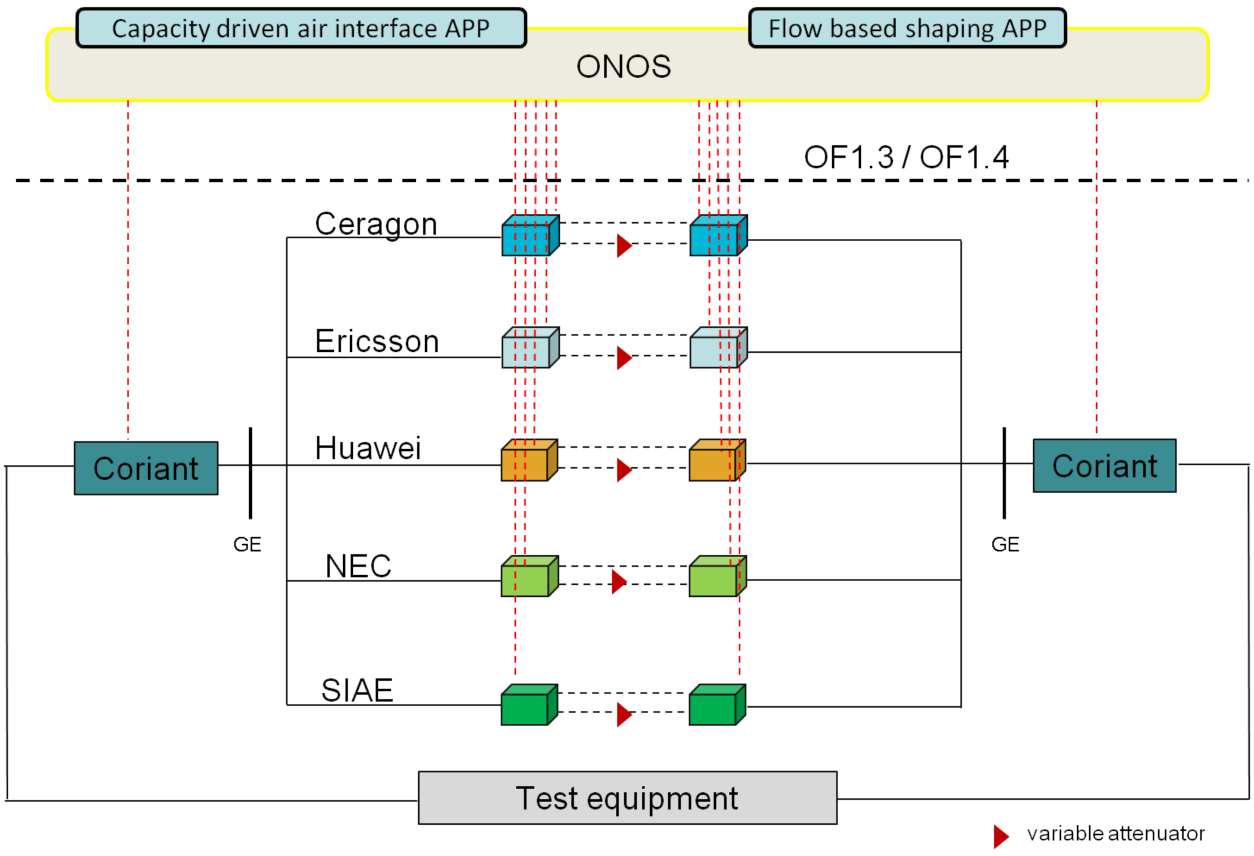

Figure 2 - Implementation of the SDN model layers and test topology

The setup includes a number of wireless transport links connected to switching aggregation nodes emulating a real deployment.

The PoC was held in October, 2015, in Madrid, Spain. Telefónica and IMDEA Networks together hosted the PoC. Six vendors (in alphabetical order) namely Ceragon, Coriant, Ericsson, Huawei, NEC and SIAE participated in the tests, providing a variety of types of equipment and software consistent with the SDN architecture, leveraging ONOS as controller, and with the support of the Universidad Carlos III de Madrid.

3 Test case 1 – Capacity-Driven Air Interface

3.1 Test Case Description

Mobile data traffic is increasing rapidly[1]. In addition to the usage of higher modulation format, link aggregation technique is often used in wireless transport networks to meet the traffic demand.

On the other hand, operational costs of the wireless transport network correlate to some degree with the capacity provided. The capacity for network links is typically designed for the expected peak condition. However, because of the variable nature of the traffic patterns, the peak condition is only reached occasionally. Thus, the network wastes power for the majority of time.

Considering the above, this test case shows how the SDN controller optimizes the total power consumption in a wireless transport network. The controller disables underlying physical ports of wireless L1 LAG (also unknown as a "Link Aggregation Group" or a "Multi Radio Group", or a "Physical Link Aggregation", or "Radio Link Bonding") links when the utilization is below certain thresholds.

The test case addresses the following functionality:

1. Connectivity between the controller and wireless transport NEs, including exchange of OpenFlow messages for session establishment and retrieval of capability information from the NEs.
2. Ability of the controller to use OpenFlow messages to install flow entries for Ethernet services.
3. Ability of the wireless transport NEs to install flow entries for Ethernet services, according to the OpenFlow messages sent by the controller.
4. Ability of the wireless transport NEs to forward data packets, according to the flow entries.
5. Ability of the controller to use OpenFlow messages to monitor Tx current capacity and statistics of wireless transport ports.
6. Ability of the wireless transport NEs to use OpenFlow messages to report Tx current capacity and statistics of wireless transport ports.
7. Ability of the controller to use OpenFlow messages to configure mute status of wireless transport ports.
8. Ability of the wireless transport NEs to configure mute status of wireless transport ports, according to the OpenFlow messages sent by the controller.

3.2 Test Configuration

The test topology is shown in Figure 2. Each wireless transport NE has at least four OpenFlow ports (one wireless transport L1 LAG port, two underlying wireless transport physical ports and one Ethernet port). The wireless transport L1 LAG port is configured by some offline method other than OpenFlow as OpenFlow still doesn't support L1 LAG at this moment.

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[1] By 2019 mobile data traffic will be nearly six times 2014's traffic, according to CTIA's "Mobile Data Demand: Growth Forecasts Met", June 2015, downloadable at http://www.ctia.org/docs/default-source/default-document-library/062115mobile-data-demands-white-paper.pdf

The SDN controller sends Flow Modification messages to install flow entries. The tester generates data traffic and the NEs forward it according to the flow entries. The SDN controller periodically collects port descriptions by exchanging Multipart Request/Reply messages. The NEs support at least OFPWTIPPT_TX_CURRENT_CAPACITY and OFPWTIPPT_TX_MUTE to inform the controller of Tx current capacity of wireless transport L1 LAG ports and mute status of underlying wireless transport physical ports. The SDN controller also periodically collects port statistics to calculate utilization of the wireless transport L1 LAG links.

When the link utilization is below certain thresholds, the controller sends Port Modification messages to mute one of the underlying wireless transport physical ports. The messages include at least OFPWTIPPT_TX_MUTE. On the other hand, when the link utilization is beyond certain thresholds, the controller unmutes the muted wireless transport physical port.

4 Test case 2 – Flow-Based Shaping

4.1 Test Case Description

Link quality degradation on the wireless link can occur because of different reasons, for instance fading, which will lead to traffic congestion. Once a congestion situation is generated, all the connections traversing the bottleneck suffer from buffering and, in the worst case, packet dropping. Sophisticated QoS handling capabilities are not commonly available today at the wireless transport equipment. Furthermore, the load in the network can benefit from an early application of shaping deep in the network for those flows traversing congested paths.

Thus, it is important to have in place mechanisms that dynamically adapt high throughput flows to the transport capacity currently available in the relevant section of the backhaul network.

This use case is centered on control of both wireless transport and switching equipment from the same SDN controller. As the current OpenFlow protocol doesn’t still support shaping function, policing is used instead in the PoC.

An Ethernet service flow is configured through the wireless transport NE and router. The controller gets the current link capacity by polling from the wireless transport NE. The wireless link capacity can be varied by means of a variable attenuator on the link. When the current capacity falls under a threshold, the controller will enable the corresponding policer on the router. When the current capacity returns above the threshold, the controller will disable the policer on the router.

The test case tested the following functionality:

1. Connectivity between the controller and wireless transport NEs and router NEs including exchange of OpenFlow messages for session establishment and retrieval of capability information from the NEs.
2. Ability of the controller to use OpenFlow messages to install flow entries for Ethernet services.
3. Ability of the wireless transport NEs and router NEs to install flow entries for Ethernet services, according to the OpenFlow messages sent by the controller.

4. Ability of the wireless transport NEs and router NEs to forward data packets, according to the flow entries.
5. Ability of the controller to use OpenFlow messages to monitor Tx current capacity and statistics of wireless transport ports.
6. Ability of the wireless transport NEs to use OpenFlow messages to report Tx current capacity and statistics of wireless transport ports.
7. Ability of the controller to use OpenFlow messages to configure policing on router ports.
8. Ability of the router NEs to configure policing on router ports, according to the OpenFlow messages sent by the controller.

4.2 Test Configuration

The test topology is shown in Figure 2. Each wireless transport NE has at least four OpenFlow ports (one wireless transport L1 LAG port, two underlying wireless transport physical ports and one Ethernet port). The SDN controller sends Flow Modification messages to install flow entries. The tester generates data traffic and the NEs forward it according to the flow entries.

The controller periodically collects port descriptions by exchanging Multipart Request/Reply messages. The NEs support at least OFPWTIPPT_TX_CURRENT_CAPACITY to inform the controller of Tx current capacity of wireless transport port.

When the current capacity of a wireless link goes under the off-threshold, a Meter Modification message with a meter ID is sent to routers. The flow rule is updated with the meter ID. A Flow Modification message will be further sent to the routers to apply the updated flow rule. When the current capacity returns over the on-threshold, the SDN controller will send a Flow Modification message to cancel the updated flow rule.

5 Test Results

5.1 General Test Result

A total of 5 wireless transport vendors and one router vendor participated successfully in testing of OpenFlow wireless transport extensions. The tests were done with an ONOS SDN controller with applications for the use-cases tested.

The two use-cases that were tested are capacity-driven air interface and flow-based shaping. For each use -case a separate SDN application was used. The same south bound OpenFlow interface and specification were used between the ONOS controller to the wireless transport and switching equipment from different vendors.

The two use-cases were tested successfully between the ONOS controller and the different wireless transport and switching equipment.

5.2 Testing of Capacity-Driven Air Interface

The wireless transport NEs sent OFPWTIPPT_TX_CURRENT_CAPACITY messages to inform the SDN controller of Tx current capacity of the wireless transport L1 LAG ports. The SDN controller application also periodically collected port statistics to calculate utilization of the wireless transport L1 LAG links and when the link utilization was below the specified thresholds, the controller sent the Port Modification message OFPWTIPPT_TX_MUTE to mute one of the underlying wireless transport physical ports. When the link utilization was again going beyond the defined thresholds, the controller unmuted the wireless transport physical port.

The NEs from all 5 wireless transport vendors were sending and receiving the specified OpenFlow messages with the correct content and port actions to execute this test as specified in the test case description.

5.3 Testing of Flow-Based Shaping

The SDN controller periodically collected port descriptions from the NEs by exchanging OFPWTIPPT_TX_CURRENT_CAPACITY messages to inform the controller of Tx current capacity of wireless transport port. When the current capacity of a wireless link fell under the specified off-threshold, a Meter Modification message with a meter ID was sent to the routers steering the traffic flows to avoid the wireless links with decreased capacity. When the current capacity returned over the on-threshold, the SDN controller sent Flow Modification message to cancel the updated flow rule and the flows reverted to the previous state prior to the decreased capacity.

Also in this test the NEs from all 5 wireless transport vendors were sending, and the NE from the router vendor was receiving the specified OpenFlow messages with the correct content.

6 Conclusions

This PoC is a major milestone in insuring that wireless transport SDN becomes a reality in the industry and in achieving the final goal of a single transport control SDN domain for wireless and optical media.

It has been shown the implementation of the OpenFlow wireless transport extension defined in the context of ONF by wireless transport project under OTWG. It has been demonstrated the interoperability among five wireless transport vendor products (Ceragon, Ericsson, Huawei, NEC, SIAE) and a switch product (Coriant), implementing the same extensions, in an open environment with an ONOS based controller.

The demonstrated applications have shown how programmability at the network level and on top of the SDN Controller for managing a wireless transport network can provide a significant contribution to network OPEX reduction.

Looking forward, the work currently being done will be extended to support and demonstrate other elaborated sets of wireless transport capabilities. The next step of the activities in the wireless transport context will be the implementation on the same platform of additional use cases and applications. Furthermore, inside ONF it’s starting a new activity with the target to uniform the wireless transport model respect to the optical transport providing a more homogeneous view of the transport network.

7 References

[1] http://5g-ppp.eu/our-vision/

[2] SDN Architecture Overview, ONF TR-504, November, 2014

[3] Protocol Extension Proposal for Wireless Transport, onf-p0006.015.03, August, 2015

[4] Test Specification for wireless transport PoC, onf-p0006.019.02, August, 2015