TELECOM INFRA PROJECT

Disaggregated White Box

Technical Specification

Wireless Backhaul Project Group

Version 1.0

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1. Introduction

This is the technical specification document for Wireless Backhaul that aims to serve as wireless backhaul and fronthaul transport solution by adopting the principles of open and disaggregated architecture. Objective of this document is in the first place to analyze and assess the potential options that may apply towards an open wireless backhaul/fronthaul transport solution. Secondly, this document provides hardware and software requirements and features of Wireless Backhaul architecture. Information is based on the inputs provided by participating network operators and system vendors depending on respective market requirements and future network deployment scenarios as well as on technology trends and pragmatic capabilities.

1.1 Need of Wireless Backhaul

Today, wireless backhaul systems are vendor-specific implementations, where airframe, RF modules, modem (single-core, dual-core), network processor and internal interfaces are all proprietary. Only the external network (physical) interfaces are standardized to ensure interoperability with adjacent network elements (e.g. switches, routers, RAN transport interfaces, etc.). As a result, in wireless backhaul systems, hardware and software are tightly coupled and always come for the same supplier.

The notion of Wireless Backhaul is an open and disaggregated architecture, where hardware and (respective) software modules are decoupled and can be sourced from different suppliers. The foreseen benefits of such architecture are related to cost optimization and foster innovation and network development flexibility. Specifically,

- Reduce HW cost (commodity), using available COTS products
- Achieve financial transparency and avoid unreasonable licensing practices
- Accelerate innovation (quick deployment of future features, run different SW flavors)
- Bigger pool of potential suppliers, avoid vendor lock-in
- Fits into SDN-based transport architecture, which leads to performance, operational & cost advantages (automated provisioning)
- Integrate & manage NEs based on standard IT tools & processes (like servers)

Another task of the current Project Group is to investigate whether a frequency-agile, modular wireless backhaul system is a feasible and viable solution (RF components modularity). Instead of replacing entire ODU in case of failure or when capacity upgrade or different frequency should be allocated, a frequency-agile and modular wireless backhaul system permits the replacement of vendor-specific RF components with low-cost modules either in the field or in a lab environment, targeting rapid service activation. This task comes on top of the Wireless Backhaul, which is the foundation of the present document.

Wireless Backhaul strategy is to move towards disaggregation of different pieces of microwave system using phased approach to achieve software and hardware disaggregation and modularity in step by step fashion. Chapter 2 of this document describes phases of disaggregation in detail.

Based on the technical specifications and requirements from Project Group, it will be divided in two phases. Phase 1 will have immediate or more important requirements to fulfil network operator's need. Phase 2 has the requirements a wireless transport solution should have to meet in the future. Phases of product requirements and phases of disaggregation can be independent of each other and will be considered as two parallel tracks in one product. **At any rate, it should be noted that Wireless Backhaul architecture must not present any performance and operational limitations compared to existing black box wireless backhaul systems.**

Modularity of the product will be divided in two phases; the first phase is to disaggregate hardware and software using generic hardware to support L2/L3 functionalities with software coming from the same or different source and can work with RF components. To this end, the challenges for full-outdoor and split-mount architectures will be discussed.

RF components' modularity can be achieved in later phase to make Wireless Backhaul field upgradable when frequency band change or add is required or just capacity increment is needed by adding more frequency channels. In Phase 1 capacity or channel increment can be done by software and Phase 2 will be more focused on hardware modularity to achieve higher order flexibility of the system. Again, the challenges of RF components' modularity will be presented.

1.2 Scope of the document

This document describes:

- Potential options for disaggregated wireless backhaul systems, requirements and foreseen challenges.
- Typical wireless backhaul/fronthaul requirements (radio-related specifications, synchronization and control plane, management plane, physical dimensions, power consumption targets, etc.).
- Possible SDN approaches.

1.3 Document Structure

This document is structured as follows:

- Chapter 1: Introduction
- Chapter 2: Product Disaggregation
- Chapter 3: RF Component Modularity
- Chapter 4: General Requirements
- Chapter 5: Radio Specifications
- Chapter 6: Synchronization and control Plane
- Chapter 7: Management Plane
- Chapter 8: Software Defined Networks functionality
- Chapter 9: Product Road Map/Evolution
- Chapter 10: Glossary

2. Wireless Backhaul – Disaggregation Architecture

The concept of white box switch/router is not new, and it refers to a networking device, where HW is “bare metal”, while network operating system (NOS) comes from a software vendor. Figure below illustrates the main differences between a black box and white box switch/router.

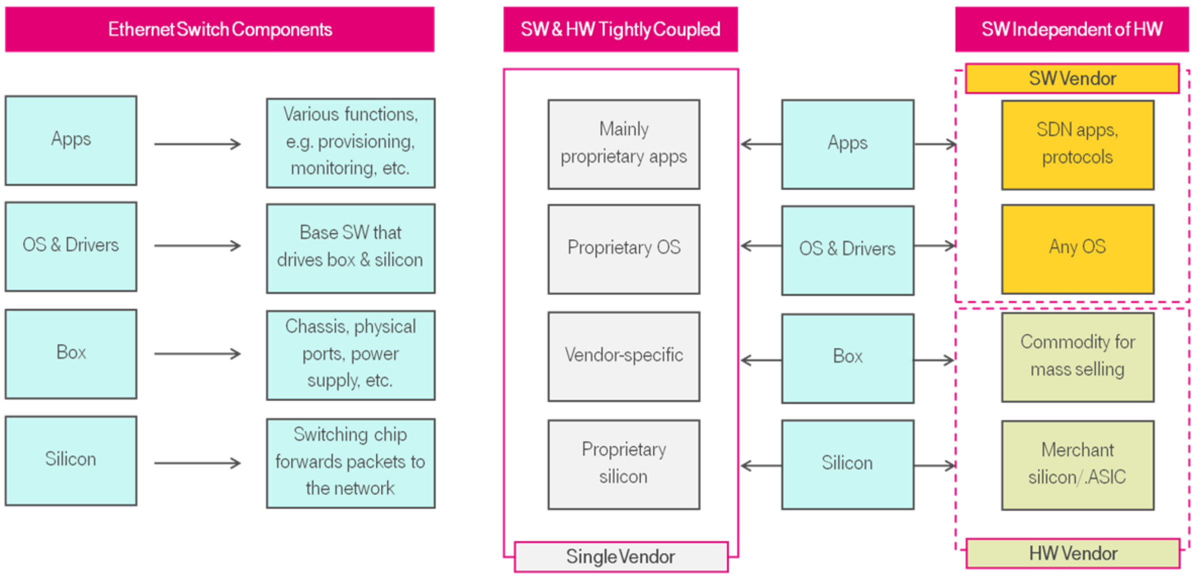

Figure 1 - Disaggregation Architecture

A typical wireless backhaul architecture consists of network L2 switch (or L3/MPLS router) and its physical external interfaces, modem, transceiver and radio interface towards the antenna (not shown) as per figure below. The wireless backhaul part that is within the green rectangle (dashed lines) presents common functional blocks and interfaces with a white box switch/router, whilst the wireless backhaul part within the blue rectangle (dashed lines) is not applicable to any switch/router network element. The additional functional blocks of wireless backhaul systems impose further challenges towards a disaggregated architecture of such a technology.

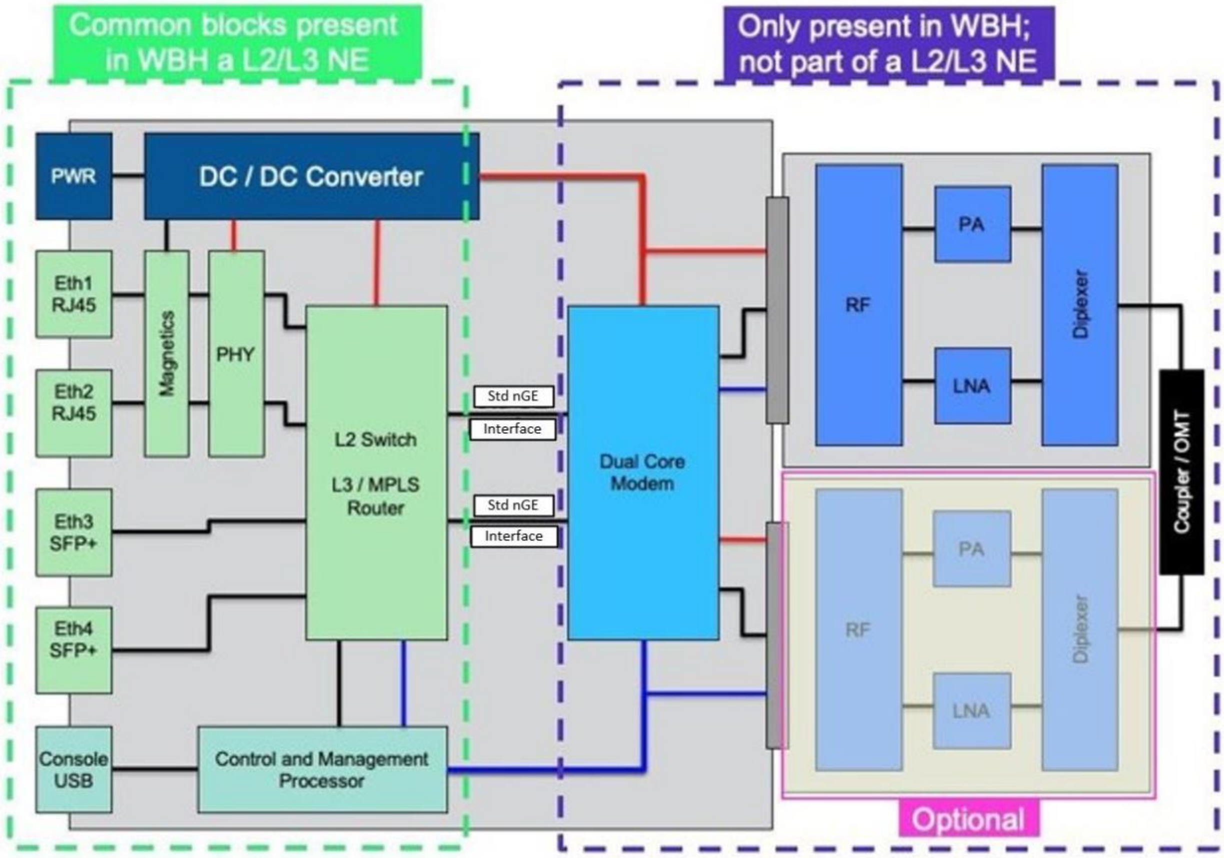

Figure 2 - System Architecture

The question is which functional blocks of a wireless backhaul system could be disaggregated, thus developing a feasible and viable future-proof solution. Of course, the disaggregation of functional blocks within the blue rectangle presents multiple challenges. It is well-understood that HW RF components are out of the scope. Moreover, there are no standardized modems based on merchant silicon implementations. In addition, modem SW and HW are tightly coupled. Close-loop functions that handle imbalances, linearity and non-linearity are calibrated to the specific HW and layout. Exact coding rate, pilot spacing, depend deeply on the HW performance. HW vendor need to tune them to reach the required performance. Transmitter pre-distortion require some tuning that is HW-specific. Internal interfaces between Network Processor – Modem – RF path should be standardized; in case the intention could be to be sourced from different suppliers. All in all, MW standardization (RF, modem) does not provide consistent economic benefit and generalization could imply loss of performances.

So, attempting to disaggregate the functional blocks within the green rectangle only seems to be a reasonable choice. By keeping the modem part of the black box architecture, a standardized interface is only needed to connect the white box part. This implementation also offers the flexibility of having more physical interfaces at a site, accessed within an indoor secure location.

The Forwarding engine should be a merchant silicon, this is going to help NOS vendors to develop software for an existing system rather than re-create it scratch. Merchant silicon is good match to incorporate DCSG with WBH, as both project groups will be using these. The SDK (Software Development Kit) will be common with the DCSG, the NPS (Node Provisioning System) will have a better chance to work in both platforms.

An architecture description follows:

- The full-outdoor wireless backhaul (WBH) system remains unchanged in terms of openness (Vendor A)
- The IDU plays the role of disaggregated radio-aware cell site gateway that controls and interacts with

full-outdoor (FO) WBH system. Therefore, it is a white box network element (NE) consisting of:
  - Bare metal/merchant silicon HW, including ONIE and driver layer (Vendor B)
  - NOS SW plus integrated functions, e.g. layer-3, radio link bonding, sync., etc. (Vendor C)
  - WBH management app to manage and control the FO WBH system (Vendor A or other)

A list of high-level requirements is:

- As far as it concerns the WBH use cases requirements, there are no additional features to be included compared to what is typically deployed to address use cases demands (e.g. mobile backhaul, B2B connectivity). However, the following ones – arising from the new architecture – should be considered:
  - As entire networking functionality is handled by IDU, the data path of the WBH should be able to be configured in pass-through mode meaning that entire traffic that enters the line port goes through the radio and vice versa. Special consideration needs to be given to in-band management of the WBH as this management traffic may come in the same interface as the payload in a different sub-interface.
  - WBH should at least support the following bandwidth and link control OAM Messages:
    - "Ethernet Bandwidth notification – ETH-BN" to inform the NOS about the actual capacity of the WBH radio. Reference models would be ITU G.8013/ Y.1731 from 2015, which define the format of ETH-BN, and G.8021 from 2016 which defines the behavior of the BNM (Bandwidth Notification Messages)
      There are two main scenarios where this signaling will be useful:
      - Adaptive modulation changes in the radio link(s). In this case, a drop in modulation can be anticipated and the signaling could be provided in anticipation of the drop in capacity. Increases in capacity can be signaled after the event takes place. When ACM is implemented, the modem has a threshold that trigger modulation downshift. This threshold has some spares to be able to downshift modulation before start seeing errors in the link. The modem lets radio system controller know ahead of time (~5 ms) that a reduction in capacity is going to happen. When this notification is received by the radio system controller the ETH-EBN message shall be generated towards the NE element. It is important that the unsolicited message option of ETH-EBN is implemented if the system needs to react as quickly as possible to the modem down shift notification. Hysteresis is built when setting the thresholds for downshift and upshift in modulation so that the link does not oscillate. Modulation shift can be based on receive level and/or SNR, or also looking onto the amount of errors that the FEC manage to repair. The implementation by the NOS vendors should comply to a minimum required performance (particularly for the capacity downshifts), i.e. at a minimum NOS should change the shaping rate of the interface feeding the radio link to the newly advertised capacity within a specific amount of time (~5ms). This will allow QoS engine in the NE to work properly to the new link capacity and apply the correct QoS policy as configured in the scheduler. The capacity increase (up shift) follow the same or little bit more shift time as it does not have tight timing restrictions.
      - Loss of one or more of the carriers in a link aggregation group. In this case the overall trunk is still carrying traffic, but one or more carriers have been lost and therefore the capacity has been reduced by the sum of the capacities of the lost carriers. This event cannot be anticipated and needs to be signaled after the event takes place. Carriers coming back from an outage will trigger an increase in capacity that can be signaled after the event takes place.
    - "Radio Link Status Notification" to inform the NOS when the radio link (or LA trunk) is

down and no longer carrying payload across. This will help the NOS realize that it should not continue to forward payload through the interface that is connected to this radio link. This is used to align the mismatch condition of the radio link being down but the Ethernet interface that connects the WBH to the NOS remaining up. Management of the WBH should remain operational. The recovery of the radio link will also cause a radio link status notification. Both cases should be notified after the event takes place. ETH-CSF should be used with reference to ITU G.8013/ Y.1731 from 2015 that define the format of ETH-CSF, and G.8021 from 2016 which defines the behavior of the CSF (Client Signal Failure Bandwidth notification messages.

  - Flow Control Pause Frames – Pause (ON) to notify the NOS that it needs to stop sending traffic (of any kind) to the WBH over this interface. Pause(OFF) to notify the NOS that it can resume sending traffic to the WBH. This type of messages should be used as a last resource when the WBH is approaching a point where its input buffers are almost full and almost empty (watermarks) to try to avoid cropping packets in the WBH.

- Depending on the capacity requirements, the preferred solutions are to use standard Ethernet interface(s) for the easy interconnection between white box IDU and WBH system.
- NOS comes with a management service to provide reachability to the IP address of the WBH. The whole system IDU+WBHs or FO-WBH should behave as a single manageable entity and have one or two IP addresses through which the whole management functions should be executed. This is done to simplify the number of IP addresses required for each node making the operator's life and IP address assignment a lot easier. The use of hidden internal IP addresses for each WBH is possible and recommended but those addresses should not be accessible externally.

The described architecture provides further advantages in case service provider intends to apply a common strategy for the cell site gateway, namely the same radio-aware indoor white box switch/router to be network-wide used. A standardized and cheap HW device would also increase operational efficiency and minimize equipment count at sites. Foreseen cost savings are expected from optimized FO-WBH system, as well. As full networking functionality in split mount systems would be implemented by IDU, it could be stripped-off from the FO-WBH system (turning into a WBH), thus achieving reduced equipment cost.

2.1 Phase 1: Disaggregation of L2/L3 networking

During this phase, the network element component of the product will be disaggregated to allow separation of HW and SW, thus coming from different sources. The network element HW module will have to support the basic Open Network Install Environment (ONIE) and Open Network Linux (ONL), so that a third-party SW can implement the fundamental functions of the Network Operating System (NOS). The level of expected functionality should be coordinated with the DCSG group and if possible, the same NOS vendor for the DCSG should be able to run its software in the Wireless Backhaul NE component.

There will be interactions between the Modem/RF transceivers of the Wireless Backhaul product and the NE component that need to be defined and worked out. This interaction will have to be extended to the DCSG.

At this stage, the Management and the Modem/RF components of the Wireless Backhaul product will rely on proprietary implementations from the wireless backhaul HW vendor. The NE management depending on the level of maturity of the NOS may be part of the NOS itself.

Based on actual network requirements, IDU NW processor should be capable of managing traffic of multiple radio directions (links) and not being limited by any HW/SW constraint. Furthermore, any wireless backhaul radio should be agnostic to this feature. Depending on the required number of radio directions that would be needed, more than one variant of IDU could be developed.

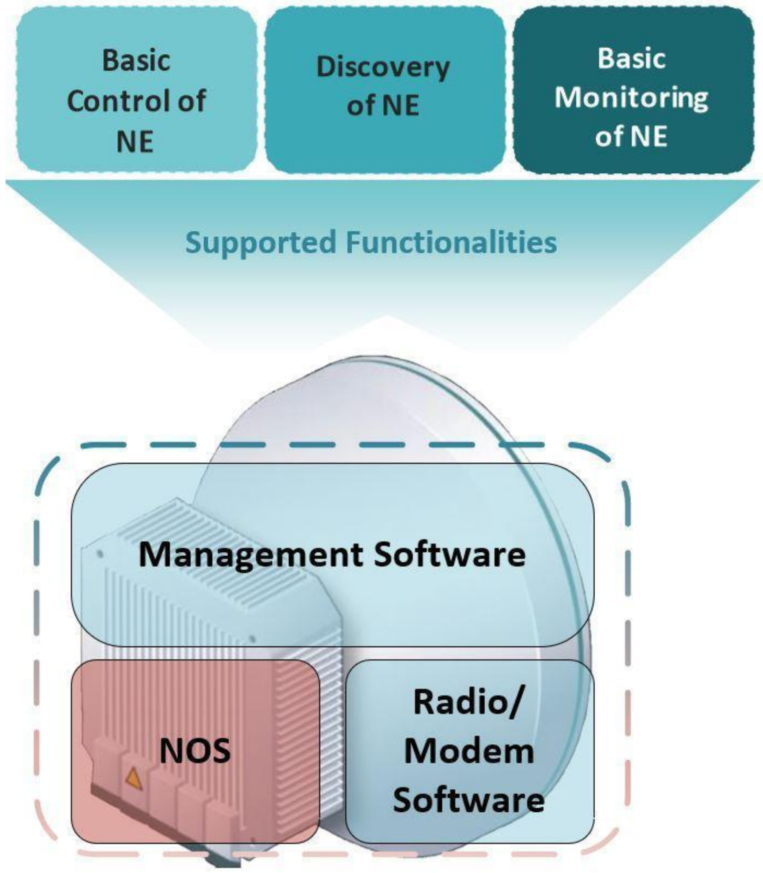

Figure 3 - Disaggregation of L2/L3 networking

2.2 Phase 2: Common Domain Controller

During this phase, the network management component of the Wireless Backhaul will be disaggregated. This will require all the internal components at the different layers; data plane, control plane, management plane and synchronization plane to be discovered, monitored, configured and controlled from a third-party software. The recommendation is to use standard NETCONF/YANG data models to achieve this purpose. In this case the expectation is that the full implementation of the YANG models and their interaction with the controllers and/or network management systems through NETCONF shall be complete and not partial as in Phase 1.

The implementation of the SW that provides the YANG models at this point in time could be done by a third party (not the WBH vendor) as long as it meets all the expected requirements or it can be an extension of the SW provided by the equipment vendors as long as it can operate over the different models of HW available. Complete architecture is going to have four components, namely:

- HW IDU
- NOS SW
- Wireless BH (Radio)
- SDN Controller

The management of the NE component should be processed by the NOS running on it at this point in time and it should follow the same principles of management disaggregation described above and in coordination with the DCSG group.

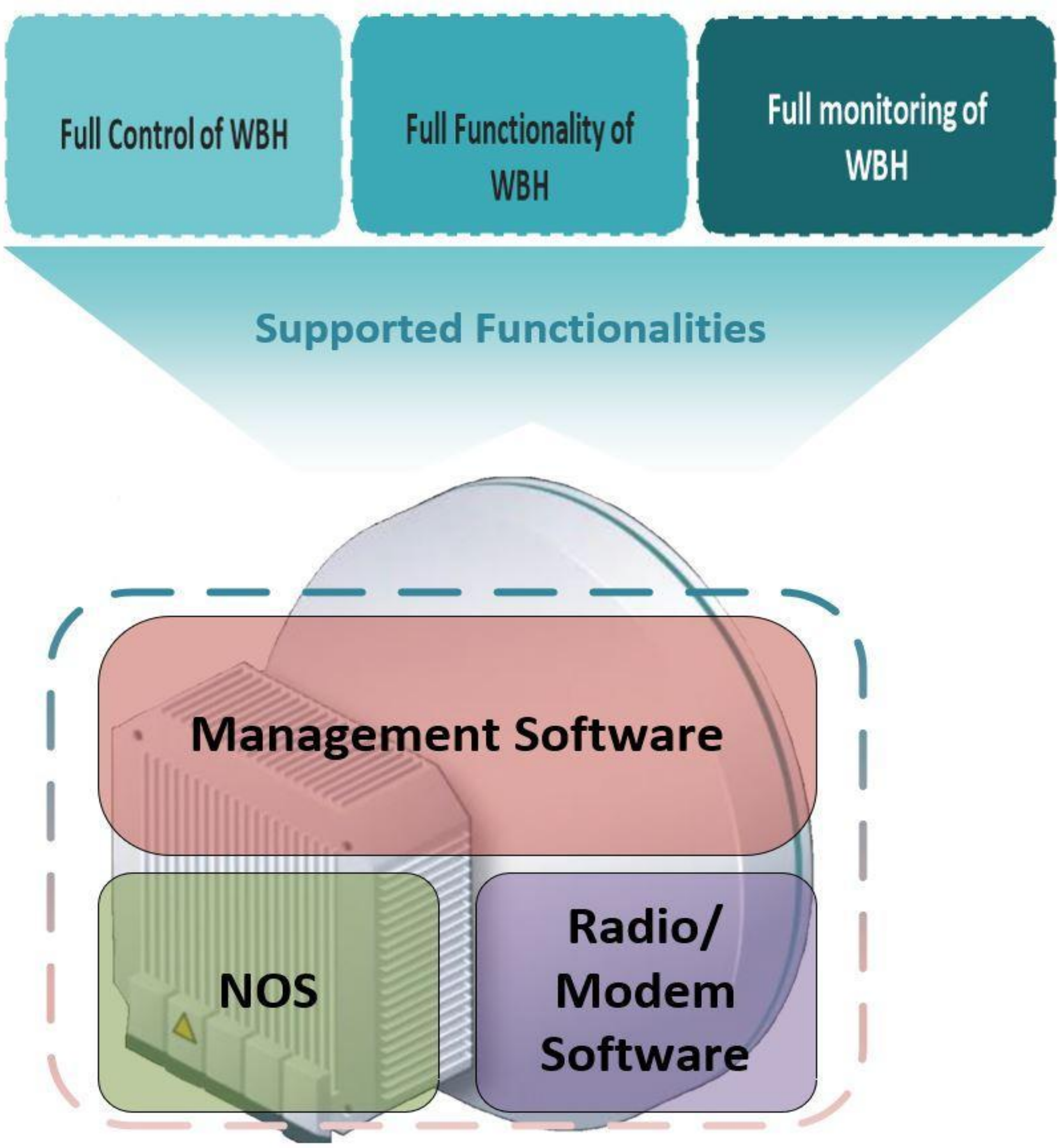

Figure 4 - Common Domain Controller

3. RF Components Modularity

The concept of RF components modularity is to allow the replacement of TRx, duplexers, couplers with low-cost modules, whenever is needed. A combination of different bands from conventional microwave frequency bands 6-42 GHz and mmWave frequency bands greater than 60 GHz can be supported.

As shown in the figure below, in case of capacity upgrade, a service provider can start with a single frequency channel and upgrade gradually to 2 or more (e.g. up to 4).

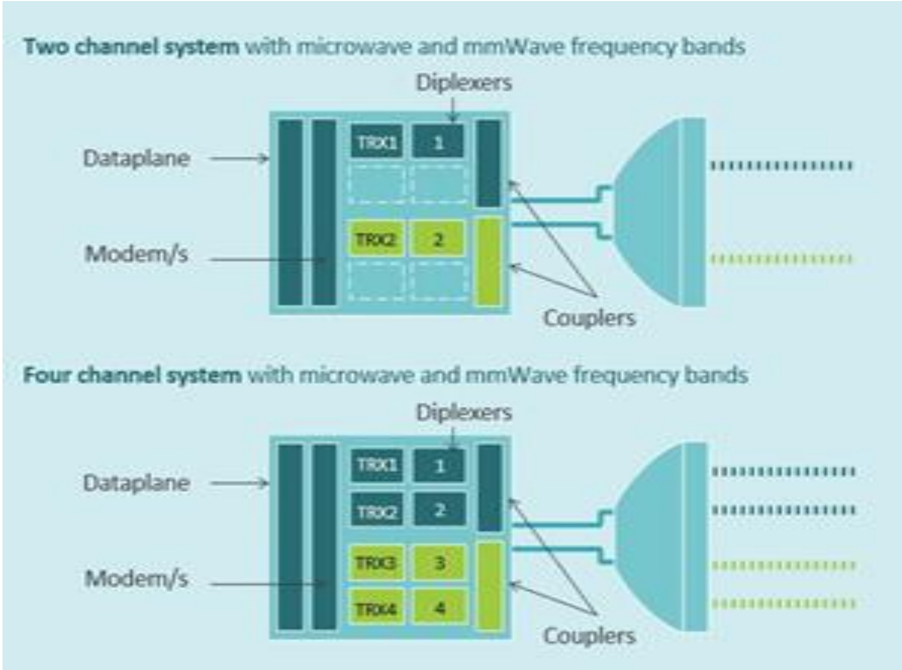

Figure 5 - RF Component Modularity

To this end, a novel mechanical design and standardized internal interfaces would be needed to enable modular radio box architecture, error-free and fast assembly by service provider without the need of highly advanced engineering skills, whilst ensuring that upgraded HW will be perfectly sealed.

Following the analysis of the PG, it was discussed that such a new mechanical design incurs:

- higher costs due to more expensive material and design
- bigger outdoor units
- higher internal costs due to module replacement in the field

Based on the above findings, this concept does not bring any benefit based on PG participants future network requirements.

4. General Requirements

Wireless Backhaul can be available in Outdoor Radio configuration connected to Radio-aware IDU via ethernet cable. Requirements of Wireless Backhaul are divided in two phases, Phase 1 is considered as immediate or minimum requirements and Phase 2 is the end picture with all the desired goals, product functionalities and requirements.

The system must not impose explicit restrictions that limit the software that can run on it. In other words, the system must allow users to install arbitrary operating systems on it, even if those are implementations from a third-party. If the platform provides the capability to verify that the software has been signed with a certificate or cryptographic key, it must be possible to disable such verification at any time, through software/firmware configuration, without the need for any specific or additional license. The WBH should be IPv4 and IPv6 compliant. Security is a critical requirement as we move towards WBH. Therefore, it is required that a high degree of user and platform security is ensured.

The main modules/components of the platform are described in the picture below:

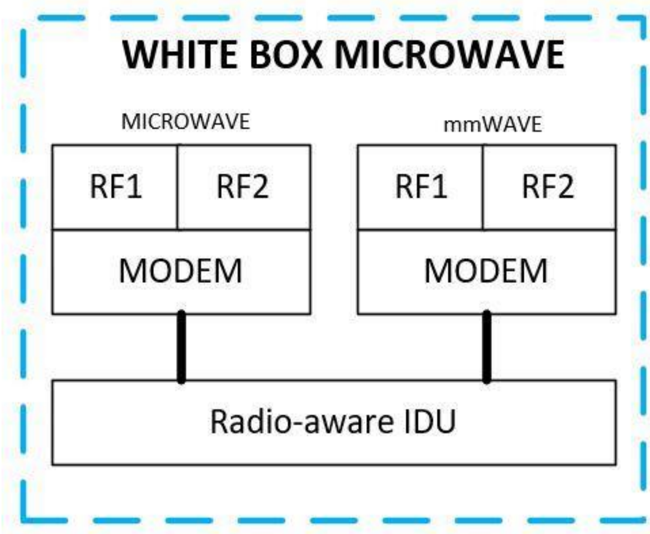

Figure 6 - Open MW Platform High-Level Architecture Components

4.1 Physical Dimensions, Environmental and Power Requirements

Phase 1:

Outdoor radios with Radio-aware IDU topology.

Single Carrier and Single Frequency Band Radio:

Radios support 1 frequency channel in one unit.

Radio Power Consumption: < 70 W, 6 to 42 GHz

Radio Power Consumption: < 60 W, 60 to 80 GHz

Cooling: No specific requirements (Fan or passive cooling)

Operating (including cold start) Temperature: -33 °C to +55 °C, plus solar loading

Physical Dimensions HxWxD (up to): 285 mm x 265 mm x 73 mm

Weight: < 4 Kg (not including antenna)

PoE Support: One PoE for pair of Transceivers (IEEE 802.3bt).

Power supply: PoE preferred for standard power, for high power options –38.4 V to –57.6 V

Standalone Operation: Required

Dual Carrier and Two Frequency Bands Radio:

Radios support up to 2 channels and 2 frequency bands in one unit.

Radio Power Consumption (Two Transceivers): < 100 W, 6 to 42 GHz

Radio Power Consumption (Two Transceivers): < 60 W, 60 to 80 GHz

Radio Power Consumption (Two Transceivers-combo. mmWave and microWave): < 80 W

Cooling: No specific requirements (Fan or passive cooling)

Operating (including cold start) Temperature: -33 °C to +55 °C, plus solar loading

Physical Dimensions HxWxD (up to): 285 mm x 265 mm x 73 mm

Weight: 5 Kg (not including antenna)

PoE Support: One PoE for a pair of Transceivers(IEEE 802.3bt).

Power supply: PoE preferred for standard power, for high power options –38.4 V to –57.6 V

Standalone Operation: Required

Radio-aware IDU:

1 RU chassis capable to be connected to Single Carrier, Dual Carrier radios and network elements. IDU can be available in these different configurations based on site configuration.

IDU 1: 4xGE+1x10GE client, 1x10GE line, 2xGE radio interfaces (PoE IEEE 802.3bt)

IDU 2: 4xGE+2x10GE client, 2x10GE line, 2x10GE radio interfaces (PoE IEEE 802.3bt)

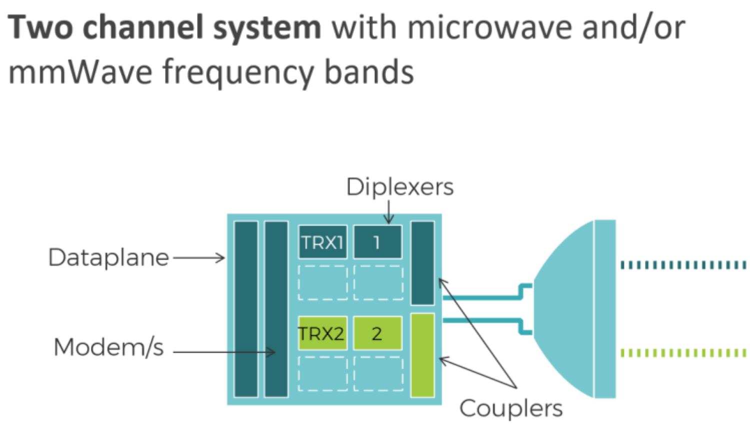

Figure 7 - Two Channel System

Phase 2:

Outdoor radios with Radio-aware IDU topology.

Radios support up to 4 channels and 2 frequency bands.

Radio Power Consumption (Two Transceivers): < 80 W, 6 to 42 GHz (with DCSG split mount)

Radio Power Consumption (Two Transceivers): < 60 W, 60 to 80 GHz (with DCSG split mount)

Cooling: No specific requirements (Fan or passive cooling)

Operating Temperature: -33 °C to +55 °C

Physical Dimensions HxWxD (up to): 285 mm x 265 mm x 73 mm (Outdoor Unit)

Weight: <5 Kg

PoE Support: One PoE for a pair of Transceivers

Power supply: PoE preferred for STD power, for high power options –38.4 V to –57.6 V

Standalone Operation: Optional

Radio-aware IDU:

1 RU chassis capable to be connected to Single Carrier, Dual Carrier radios and network elements. IDU can be available in these different configurations based on site configuration. About 25G interfaces, eCPRI and/or other 3GPP standards will be investigated.

IDU 1: 4xGE+1x10GE client, 1x10GE line, 4xGE radio interfaces (PoE IEEE 802.3bt)

IDU 2: 4xGE+2x10GE client, 2x10GE line, 4x10GE radio interfaces (PoE IEEE 802.3bt)

IDU 3: 4xGE+2x10GE client, 2x25GE line, 4x10GE radio interfaces (PoE IEEE 802.3bt)

IDU 4: 25xGE+16x10GE+8x25GE client, 2x100GE line, 4x25GE radio interfaces (PoE IEEE 802.3bt)

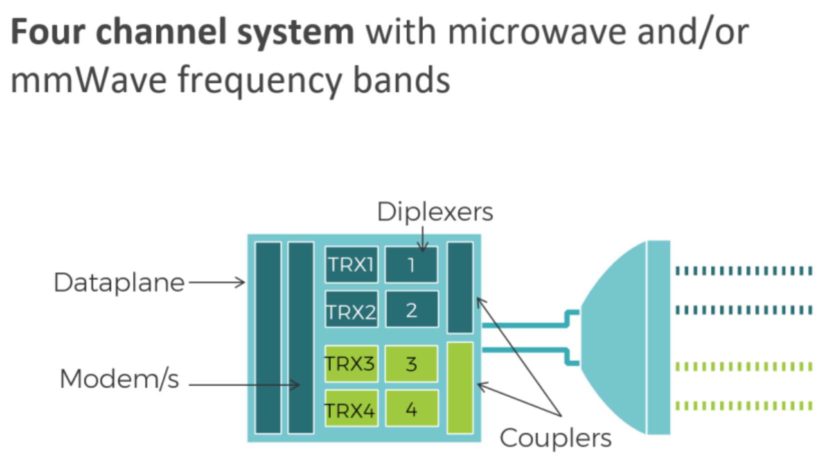

Figure 8 - Four Channel System

4.2 Data Plane Requirements

Phase 1:

Transmission Protocol support: Ethernet

Minimum Switch Capacity: 30 Gbps non-blocking

Physical Ports: As described above.

- 10/100/1000 Base-T: 2 ports
- 2.5 Gbps Electrical SFP: Not required.
- 10000 Base -T: Not required
- 2.5 Gbps Base-X : Not required
- 10GBASE-X: 2 ports (Ethernet)
- 25GBASEX (eCPRI and Ethernet): Not required

Phase 2:

Transmission Protocol support: Ethernet and eCPRI (or other 3GPP standard)

Minimum Switch Capacity: 100 Gbps non-blocking

Physical Ports: As described above.

- 10/100/1000 Base-T: 02 ports
- 2.5 Gbps Electrical SFP: Not required.
- 10000 Base -T: Not required
- 2.5 Gbps Base-X: Not required
- 25GBASEX/10GBASE-X: 4 ports (eCPRI and Ethernet): Required

5. Radio Specifications

This section describes the radio specifications for "Wireless Backhaul", including (but not limited to) number of carriers, number of RF modules, frequency bands, combinations of frequency bands (microwave and mmWave), channel bandwidths, supported modulations (microwave and mmWave), Adaptive Code Modulation (ACM), Cross polarization (XPIC), Automatic Power Control (ATPC), interface and radio link protection.

5.1 Radio carriers, combination of micro and mmWave bands

Phase 1:

Single Carrier and Single Frequency Band Radio:

Number of Carriers: 1

Number of RF modules Supported: 1

Microwave bands (6-42 GHz): Yes

mmWave (>60 GHz) : Yes

RF frequency channels Link Aggregation (Layer 1 aggregation): Yes

Dual Carrier and Two Frequency Bands Radio:

Number of Carriers: 2 (one carrier per band)

Number of RF modules Supported: 2

Combination of two microwave bands (6-42 GHz): Yes

Combination of mmWave (>60 GHz) and microwave frequency bands (6-42 GHz): Yes

RF frequency channels Link Aggregation (Layer 1 aggregation): Yes

Phase 2:

Number of Carriers: 4 (Two carriers per band)

Number of RF modules Supported: 4

Combination of two microwave bands (6-42 GHz): Yes

Combination of mmWave (>60 GHz) and microwave frequency bands (6-42 GHz): Yes

RF frequency channels Link Aggregation (Layer 1 aggregation): Yes

5.2 Frequency bands

Objective is to combine frequency bands using one antenna to have a single radio and single antenna footprint.

Phase 1:

Supported Frequency bands combinations:

- 18 GHz and 80 GHz
- 23 GHz and 80 GHz
- 15 GHz and 80 GHz

- 26 GHz and 80 GHz

Phase 2:

- 18 GHz and 80 GHz
- 23 GHz and 80 GHz
- 15 GHz and 80 GHz
- 26 GHz and 80 GHz
- 6 GHz and 11 GHz
- 7/8 GHz and 13 GHz
- 11GHz and 23 or 32GHz
- 60 GHz

5.3 Frequency channel bandwidths

Phase 1:

Supported Channel Bandwidths:

- For microwave frequency bands: ETSI: 27.5, 28, 55, 56, 110 and 112 MHz, ANSI: 10, 20, 30, 40, 50, 60 and 80 MHz
- For mmWave frequency bands: 250, 500, 1000, 2000 MHz

Phase 2:

Supported Channel Bandwidths:

- For microwave frequency bands: ETSI: 27.5, 28, 55, 56, 110 and 112, 224 MHz, ANSI: 10, 20, 30, 40, 50, 60 and 80 MHz
- For mmWave frequency bands: 250, 500, 1000, 2000, 2500 MHz

5.4 Supported Modulations schemes, ACM, Power Control, LOS MIMO:

- For microwave frequency bands: BPSK, QPSK, 16 QAM, 32 QAM, 64 QAM, 128 QAM, 256 QAM, 512 QAM, 1024 QAM, 2048 QAM, 4096 QAM
- For mmWave frequency bands: BPSK, QPSK, 16 QAM, 32 QAM, 64 QAM, 128 QAM, 256 QAM, 512 QAM, 1024 QAM

ACM (Non-traffic affecting on High Priority Traffic): Adaptive code modulation step-up and step-down based on atmospheric conditions should be hit-less and should not be affecting high priority traffic.

XPIC (Cross polarization): Radio should be able to support XPIC functionality when using the same frequency channel in dual polarity configuration without any interference.

Power Control: Automatic Power Control (ATPC) is necessary as a means to reduce unneeded TX power and overall power consumption of radio system. Power control can also be used to minimize inter-channel interference in extremely frequency congested areas.

Protection Schemes: Radio system should have protection scheme when an interface and/or radio fails to avoid loops and disruption of traffic.

Phase 2:

Supported modulation schemes:

- For microwave frequency bands: BPSK, QPSK, 16 QAM, 32 QAM, 64 QAM, 128 QAM, 256 QAM, 512 QAM, 1024 QAM, 2048 QAM, 4096 QAM, 8192 QAM and 16384 QAM
- For mmWave frequency bands: BPSK, QPSK, 16 QAM, 32 QAM, 64 QAM, 128 QAM, 256 QAM, 512 QAM, 1024 QAM and 2048 QAM

ACM (Non-traffic affecting on High Priority Traffic): Adaptive code modulation step-up and step-down based on atmospheric conditions should be hit less and should not be affecting high priority traffic.

XPIC (Cross polarization): Radio should be able to support XPIC functionality when using the same frequency channel in dual polarity configuration without any interference.

Power Control: Automatic Power Control (ATPC) is necessary as a means to reduce unneeded TX power and overall power consumption of radio system. Power control can also be used to minimize inter-channel interference in extremely frequency congested areas.

Protection Schemes: Radio system should have protection scheme when an interface and/or radio fails to avoid loops and disruption of traffic.

LOS MIMO: Line-of-Sight Multiple-Input Multiple-Output is a spectral efficient technique for multiplying the capacity of a radio link (typically, x2 or x4) using multiple transmission and receiving antennas and by using a single frequency channel.

6. Synchronization and Control Plane

This section comprises synchronization and control plane features required for Wireless Backhaul. This includes supported types and sources of synchronization, Layer 2 switching, QoS priority mapping, OAM requirements, Loop protection schemes, L2 link aggregation. Layer 3 MPLS based signaling, IP addressing and routing protocols.

6.1 Synchronization Sources

Synchronization is extremely important and often required in Transmission networks. Wireless Backhaul should able to support synchronization from below mentioned sources:

- Ethernet interfaces (Electrical and Optical): Yes
- IEEE 1588v2 (Slave / Client): Yes
- 1 PPS: No
- GPS / GNSS: No
- SyncE: Yes
- ESMC: Yes (as part of SyncE)
- IEEE 1588v2
    - PTP Agnostic: Yes
    - Transparent Clock Operation: Yes

- Boundary Clock Operation: Yes

The internal oscillator shall be class B as minimum, according to G.8273.2.

It will be also interesting to receive a detailed information on the electronics used to build up the phase sync regeneration capability (type of oscillator, type of Best Master d Clock Algorithm, whether it is implemented via SW or HW, etc.).

6.2 Control Plane, QoS, Traffic scheduling and OAM

Wireless Backhaul should be able to support L2 switching based on VLAN tagging of traffic frames and determine the priority of each frame depending upon QnQ traffic priority queues maintained in the control plane. QoS priority mapping should be based on:

- Port Based: Yes
- VLAN mapping (802.1p tags): Yes
- Diffserv mapping (IPv4): Yes
- Traffic Class and Flow Level mapping (IPv6): Yes
- MPLS Mapping (Including experimental bits): Yes

Wireless Backhaul should be capable of supporting Traffic scheduling which depends on Strict Priority, WRR/WFQ and Hybrid mode. Traffic shaping should have H-QoS, Traffic Policing and Storm Control.

Wireless Backhaul should support OAM, Connectivity Fault Management and Performance Monitoring defined in IEEE 802.1ag and ITU Y.1731 (Fault and Performance Monitoring)

Capabilities such as ETH-BN (Ethernet Bandwidth Notification across different Maintenance End Point) for microwave systems defined in Y.1731 should be supported.

Maximum Frame Size of at least 9600bytes (L2 frame starting from 1st bit of MAC DA up to and including last bit of FCS) across the system must be supported.

6.2.1 SW Scalability figures

As a reference, the following scalability figures shall be supported by the platform SW:

IPv4 prefixes	80K
IPv6 prefixes	40K
MAC table size	80K
Maximum number of IS-IS adjacencies	TBD
Maximum number IS-IS concurrent instances (simultaneous IGP areas the router can belong to)	TBD
Maximum number of NEs per IS-IS area	TBD
Maximum number of prefixes per Global Routing Table	TBD
Support of Jumbo frame (The vendor shall specify the max value in bytes) - min 9k	TBD
Maximum Number of QoS queues	TBD
Queue depth range	TBD
Maximum number of Simultaneously active QoS policies (ACLs)	TBD
Maximum Number of schedulers	TBD
Number of Internet (IPv6/IPv4) routes	TBD

6.2.2 Performance monitoring and telemetry

The Platform shall support the following performance monitoring requirements:

- ITU-T Y.1564 support:
    - Y.1564 Tech Specifications
    - Y.1564 IOT with Third Party
    - Y.1564 IOT with JDSU
    - Y.1564 Layer 2
    - Y.1564 Layer 3
    - Y.1564 CoS Tests
    - Y.1564 Time Stamping
    - Y.1564 Loopback tests
    - Y.1564 Full line rate
- RFC 5357 TWAMP support:
    - TWAMP Active Performance Monitoring
    - TWAMP Active Performance Monitoring IOT with Third Party Controller
    - TWAMP Sessions & CoS
    - TWAMP Time Stamping Accuracy
    - TWAMP HW Time Stamping
    - TWAMP No Traffic Impacts
    - TWAMP-light support
- Telemetry communication using OpenConfig with gPRC

6.3 Loop Resolution & Protection

Wireless Backhaul should be capable of avoiding any loops in the network by using STP, RSTP and MSTP protocols depending on user's choice any one of these protocols can be used to avoid loops.

ITU-T G.8032v2 ERPS (Ethernet Ring Protection Switching) may be supported to provide microwave ring topology and avoid loops in ring configurations, port-based protection is required, flow-based protection is optional.

6.4 L2 Link Aggregation (line interfaces)

Layer 2 link aggregation (LAG) should be supported by IDU, both Static LAG and LACP. LAG should be configurable using links of the same speed (as described above) and should support active-active and active-standby schemes. Load balancing based on L2 or L3 hash information should be supported.

6.5 Layer 3 MPLS

Wireless Backhaul should be capable of supporting layer 3 suit, which includes Layer 3 MPLS, Dual IP stacking IPv4/v6, OAM protocols ping, Trace and BFD. Routing protocols OSPF, ISIS, BGP and static routing. MPLS signalling Static LSP, LDP, T-LDP and RSVP-TE. MPLS OAM support including BFD, LSP Ping, LSP Trace and LSP Protection and Resiliency. VPN services should support both L2 and L3 VPN. MPLS-TP (Transport Profile) Path provisioning should include Static Provisioning, Dynamic Provisioning, Quality of service, OAM and Failure Detection and Protection.

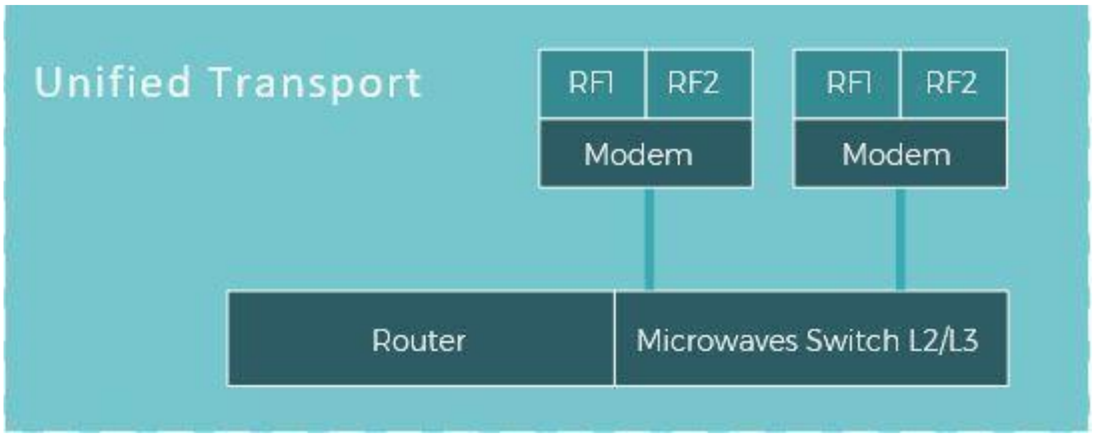

Figure 9 - Unified Transport Solution

7. Management Plane

This section describes required attributes for the Management plane of Wireless Backhaul. NMS Access interface requirements supported network management protocols, software and license management. Performance monitoring, Alarms and event management.

7.1 NMS Access

Wireless Backhaul should be able to have NMS access through Console port as a physical connection. In-band and out-band ethernet-based NMS access also required to discover over the network. For network interfaces, Layer 2 NMS and L3 or routed NMS also required. Web GUI is a requirement for this solution should be capable of configuring, Monitoring, Control, Diagnostics. CLI would be an additional way of accessing to configure equipment.

7.2 Network Management Protocols

Wireless Backhaul is required to have below mentioned Management protocols:

- Netconf / Yang
- MW Standards: IETF, ONF
- SNMPv3
- Access authentication (i.e. RADIUS)

7.3 Software and License Management

Software management section focuses on, Initial or upgraded software version/s download to the memory card should be non-service disruptive, software upgrade is a service interruptive process, time to restore service depends on the configuration of physical elements attached to the node etc. License management is not a requirement for Wireless Backhaul can be added as a feature in later versions of the product.

7.4 Alarm Monitoring and Diagnostics

Alarms related to all the physical components of the radio system, including, TRXs, physical ports, Modems etc. should be monitored and flagged. Performance parameters like LAG, port Ingress/Egress, frame loss/error, loss of signal, modulation changes, bandwidth changes of the link, should be monitored and flagged with the different classes of severity. Radio statistics including G.826 Statistics, synchronization and control plane parameters should be part of monitoring software suit.

Diagnostics of Wireless Backhaul should include but not limited to Interface status, loopbacks and Mute/Unmute of a frequency channel or LAG group.

7.5 Security and Anti-Theft

Security of the traffic is required to be maintained using L2 and/or L3 VPNs, no payload encryption or secure management or protocol authentication is required as part of primary requirements for Wireless Backhaul. These requirements may be added at later versions depending upon use cases and requirements.

In general, the solution must support the necessary security mechanisms to authenticate and encrypt communications between the network element and its management system or controller. The network element should offer the possibility of only enabling local traffic after the device has been authenticated by the management platform/controller. The system should also offer the possibility to enable anti-theft mechanisms that prevent the use of the equipment in any other environment than the one it was conceived in.

8. Software Defined Networks Functionality

As explained in the previous sections, additionally to the CLI support for local & SSH based configuration, the intention is to have a centralised control entity (an SDN Controller) managing the DCSG in a smart and automatic way.

The SDN controller shall manage and optimize the DCSG domains in order to perform SLA fulfilment and service provisioning. All the configuration and management of the DCSG shall be done using Netconf (RFC 7803). Additionally, the controller will also use BGP-LS to collect all the OSPF-TE/L2 topology information in the DCSG domains.

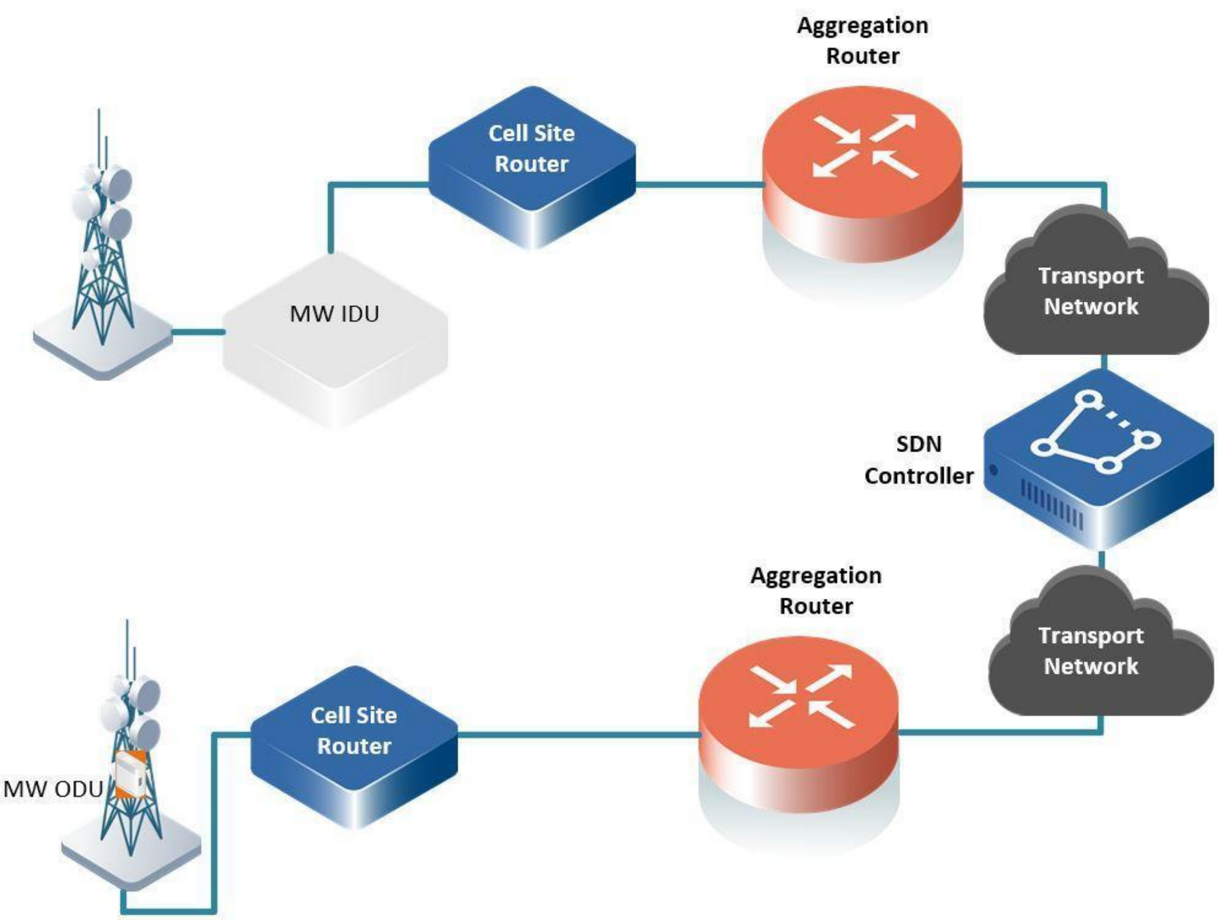

Figure 10 - SDN Controller Connectivity Architecture

Interfaces needed at both the Radio-aware IDU and the SDN controller are:

- Netconf (RFC 7803); connections could be encrypted using Transport Layer Security (TLS) [RFC5246] or Secure Shell (SSH) [RFC4251], being TLS the preferred option.
- PCEP (Included as part of PESW package in the equipment): IDU shall support PCEP protocol to support PCC (Path Computation Client) function, reporting LSP status in order to use PCEP protocol in NBI interface both to instantiate PCE initiated paths, and modify PCE delegated LSP involving the NE from the stateful PCE placed at the CO. Additionally, it shall support SDN controller PCE initiated PCEP.

Standard data models shall be used as much as possible. The definition/selection of the target/needed models will be done in future releases of this specification.

Current level of standardisation can be seen in the figure below:

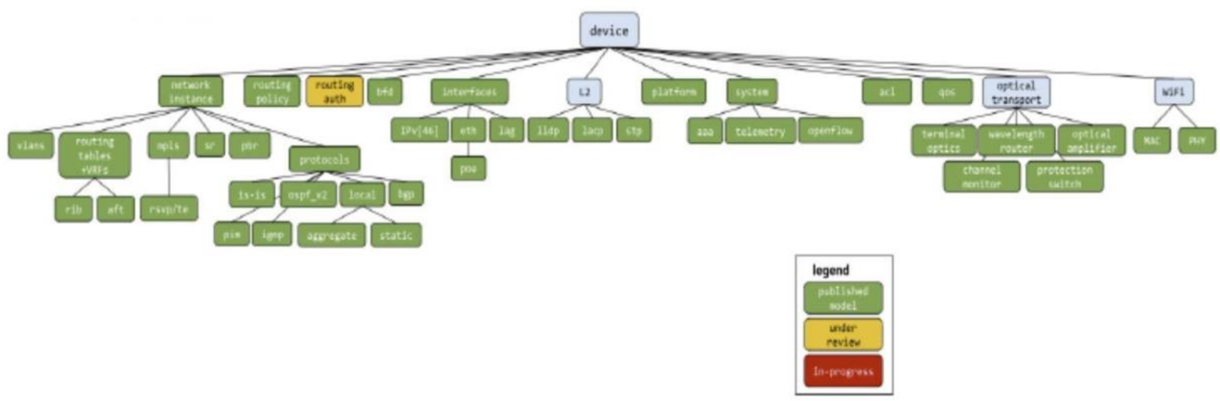

Figure 11 - Yang Models Architecture

In the case of the YANG models not covered by OpenConfig today we can augment with the standard IETF YANG models (for instance OSPFv3 not available at the moment in OpenConfig – see figure) until they are available in OpenConfig.

Regarding SDN features related to microwave applications, the product shall support ONF models TR-532, TR-512 and TR-541 and/or IETF models (subject to use cases' requirements).

SNMPv3 (RFC 3411 / RFC 3418) and SYSLOG (RFC 5424) shall be supported.

SDN use cases as below:

- Automatic NE Discovery
- Automatic traffic configuration, customization based on services
- Automatic software upgrades
- Intelligent power saving

9. Product Roadmap/Evolution

Roadmap or evolution of Wireless Backhaul is going to have a combination of Phased approach of requirements (Chapter 3 to 6) and Phased approach of disaggregation (Chapter 2). Phases of both tracks can be independent of each other and will be dependent on priority level determined by the market, which is going to be supported by participating OEMs.

Below is an example of the proposed timeline to combine both tracks:

Figure 12 - Product Evolution Timeline [Updated 2020]

The technical requirements may be broken down into further phases to align with the delivery of the disaggregation phases. That means that maybe some of the technical requirements may remain in phase 1 while others may progress to phase 2 and align with the different disaggregation phases.

10. GLOSSARY

RAN	Radio Access Network
L2	Layer 2 (Ethernet Layer)
L3	Layer 3 (Network Layer)
SDN	Software Defined Network
PoE	Power Over Ethernet
DCSG	Disaggregated Cell Site Gateway
CPRI	Common Public Radio Interface
ACM	Adaptive Code Modulation
ATPC	Automatic Power Control
ETSI	European Telecommunications Standards Institute
ANSI	American National Standards Institute
XPIC	Cross Polarization Interference Cancellation
QoS	Quality of Service
QnQ	Quality, Not Quantity
OAM	Operation And Maintenance
ERPS	Ethernet Ring Protection Switching
LAG	Link Aggregation
MPLS	Multiprotocol Label Switching
BFD	Bidirectional Forwarding Detection
LSP	Link State Protocol
LDP	Label Distribution Protocol
T-LDP	Targeted LDP
RSVP-TE	Resource Reservation Protocol - Traffic Engineering
MPLS-TP	Multiprotocol Label Switching - Transport Profile
NMS	Network Management System
GUI	Graphic User Interface
CLI	Command Line Interface

ONF	Open Networking Foundation
SNMP	Simple Network Management Protocol
RADIUS	Remote Authentication Dial-In User Service
TRX	Transmitter and Receiver
VPN	Virtual Private Network
TR	Technical Recommendation
IDU	Indoor Unit
WBH	Wireless Backhaul
ETH-BN	Ethernet Bandwidth notification
NOS	Network Operating System
mmWave	Millimeter Wave
SDK	Software Development kit
NPS	Node Provisioning System
BNM	Bandwidth Notification Messages