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Wireless Backhaul Network and Services Automation: SDN SBI YANG models

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) millimetre Wave Transmission (mWT).

Modal verbs terminology

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Introduction

Software-Defined Networking (SDN) is an emerging architecture that is dynamic, manageable and cost-effective, making it ideal for the high-bandwidth, dynamic nature of today's applications. Initially, this architecture aimed to decouple the control plane from the data plane allowing the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services. The network devices are in that case limited to the data forwarding. On top of the network devices, an intelligent entity, called "controller" sees the network as a whole and directly injects the data processing rules on each device.

This concept did not get wide scale adoption into operator's networks. Therefore, the market quickly evolved and adopted SDN as the set of solutions removing the existing boundaries between the application and network worlds while conserving the integrity of the equipment data and control planes. As a matter of fact, the network is sometimes seen as a brake. Each modification still often requires manual intervention without orchestration in most organizations. Setting up a simple VLAN can sometimes take several days, with the need to configure many devices one by one: switches, routers, firewalls, etc. Thus, the target became naturally on real network issues: allowing applications to program the network in order to accelerate and improve its deployment and operation.

The wireless backhaul network, as with other network segments, is inherently effected by this transformation. As a matter of fact, having open and standardized MW equipment interfaces was identified as the prerequisite for operating a flexible network across different vendors' equipment and multiple technologies. Most MW vendors are currently developing NETCONF/YANG features enabling equipment openness. However, there is with no consensus today on the used data models. Two main MW SDN standards are working on different implementation approaches leading to the lack of a single clear path forward.

The goal of this work is to accelerate the standardization and implementation of necessary (physical and logical) interfaces as well as YANG data models by adopting a use cases-driven automation architecture for the wireless backhaul/X-Haul networks. By this, service providers can select the standards that fit best into their network architecture, while system vendors can develop solutions to address real customer needs.

To this end, a list of relevant attributes to be considered for each use case is proposed. Moreover, an analysis of existing standard YANG models (e.g. ONF, IETF, IEEE) is carried out providing gaps identification with respect to the defined use cases.

1 Scope

The present document provides information about the standardized YANG data models as they have been developed within IETF, IEEE and ONF to be used in a use cases-driven automation architecture for the wireless backhaul/X-Haul networks. Moreover, it provides gap analysis of existing standard YANG models (e.g. ONF, IETF, IEEE) and it discusses potential implementation issues.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

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

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

[i.1] ETSI GR mWT 016: "Applications and use cases of Software Defined Networking (SDN) as related to microwave and millimetre wave transmission".

[i.2] IETF RFC 6020 (October 2010): "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)".

[i.3] IETF RFC 7950 (August 2016): "The YANG 1.1 Data Modeling Language".

[i.4] IEEE 802.3.2™: "IEEE Standard for Ethernet - YANG Data Model Definitions".

[i.5] IEEE 802.1™: "IEEE Standard for Local and Metropolitan Area Networks".

[i.6] IEEE 802.1Qcp™: "IEEE Standard for Local and metropolitan area networks -- Bridges and Bridged Networks -- Amendment 30: YANG Data Model".

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

[i.8] IETF RFC 8348: "A YANG Data Model for Hardware Management".

[i.9] IETF RFC 8561: "A YANG Data Model for Microwave Radio Link ".

[i.10] IETF RFC 8575: "YANG Data Model for the Precision Time Protocol (PTP)".

[i.11] IETF RFC 8632: "A YANG Data Model for Alarm Management".

[i.12] draft-liu-dhc-dhcp-yang-model: "Yang Data Model for DHCP Protocol".

[i.13] draft-ietf-netmod-intf-ext-yang: "Common Interface Extension YANG Data Models".

[i.14] ONF TR-512 v1.4: "Core Information Model (CoreModel)".

NOTE: Available at https://opennetworking.org/wp-content/uploads/2018/12/TR-512_v1.4_OnfCoreIm-info.zip.

[i.15] ONF TR-532 v2.0: "Microwave Information Model".

[i.16] ONF TR-532 v1.1: "Microwave Information Model".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

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

AR	Availability Ratio
BBE	Background Block Error
BCA	Bands and Carrier Aggregation
BER	Bit Error Ratio
BSS	Business Support System
CBS	Committed Burst Size
CIR	Committed Information Rate
CM	Current Modulation
C-VLAN	Customer - Virtual Local Area Network
DHCP	Dynamic Host Configuration Protocol
DM	Data Model
EB	Errored Block
EBS	Excess Burst Size
EIR	Excess Information Rate
EMS	Element Management System
ES	Errored Second
FER	Frame Error Ratio
FLR	Frame Loss Ratio
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IM	Information Model
IP	Internet Protocol
LLDP	Link Layer Discovery Protocol
LOS	Line Of Sight
MAC	Media Access Control
MSE	Mean Square Error
MTBF	Mean Time Between Failures
MTU	Maximum Transmission Unit
MW	MicroWave
N.A	Not Available
NE	Network Element
NMS	Network Management System
OI	Outage Intensity
ONF	Open Networking Foundation
OPEX	Operational Expenditure
OSS	Operations Support System
PCP	Priority Code Point
PEA	Percent Ethernet service Availability
PEU	Percent Ethernet service Unavailability
QoS	Quality of Service
RF	Radio Frequency
RFC	Request For Comment
RSL	Received Signal Level

SBI	SouthBound Interface
SDN	Software Defined Networking
SES	Severely Errored Second
SNR	Signal to Noise Ratio
S-VLAN	Service - Virtual Local Area Network
TTL	Time To Live
UML	Unified Modeling Language
UR	Unavailability Ratio
VLAN	Virtual Local Area Network
XPIC	Cross-Polarization Interference Cancelling
YANG	Yet Another Next Generation

4 Centralized Wireless Backhaul/X-Haul Automation Controller Value

4.1 Benefits

One of the main challenges that service providers face today is to improve end-users' satisfaction - e.g. delivering or upgrading to a new service, whilst having to control multiple isolated-managed and often complicated network systems. This urgently results to the need to increase operational efficiency and enable network agility and programmability. The introduction of the concept of smart network and services automation can be a catalyst towards such business and operational objectives and figure 1 illustrates the foreseen benefits when deploying a centralized wireless backhaul/X-Haul domain controller to address automation.

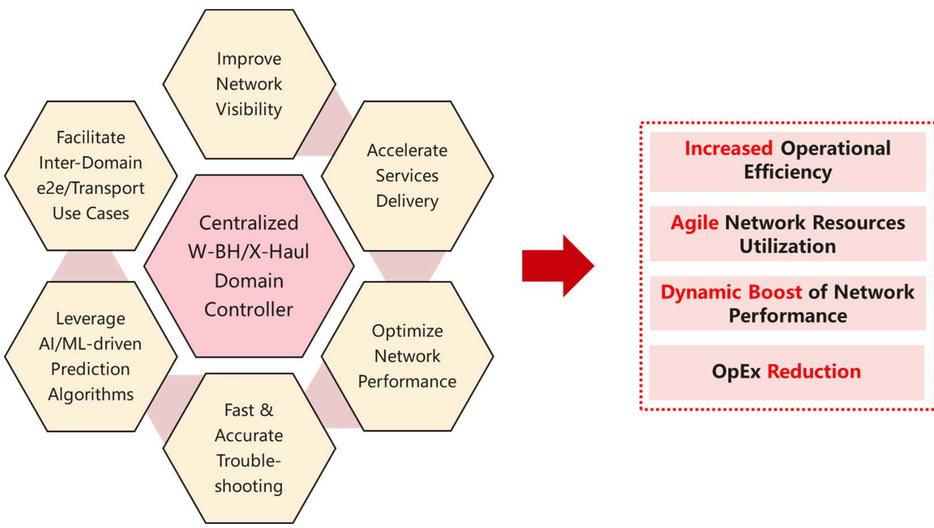

Figure 1: Smart Network and Services Automation Benefits

4.2 Key Success Factors

In order to benefit from automation, open and standardized network interfaces and data models should be used. In addition, the required set of data models have to be technically effective and mature, allowing ease of implementation and future upgrades whilst also taking care of backwards compatibility. Last, but not least, any use case driven automation initiative needs industry-wide collaboration, among service providers and technology makers, to achieve commonly accepted standardized and open interfaces at scale. Figure 2 captures the aforementioned key factors for successful deployments when establishing a network automation framework, which of course applies in the context of centralized wireless backhaul/X-Haul domain controller, as well.

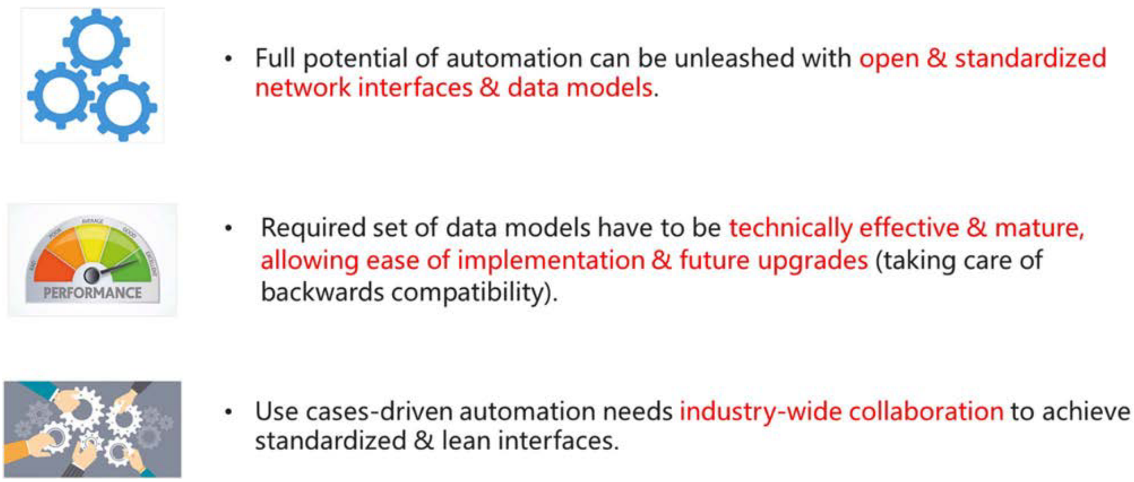

Figure 2: Key Success Factors for Smart Network & Services Automation

4.3 Architecture

The architecture considered in this work is depicted in figure 3. The focus is on the YANG data models to be implemented on the Network Element (NE) level to enable automated operations across multi-vendor MW domain through the SouthBound Interface (SBI) (red interface in figure 3). Any other interfaces that can exist in a real network topology (e.g. with the hierarchical controller, other transport domain controllers, etc.) are out of the scope of the present document and they are only shown to indicate that the wireless backhaul/X-haul domain controller can be part of a wider SDN architecture for transport and end-to-end network and services automation framework.

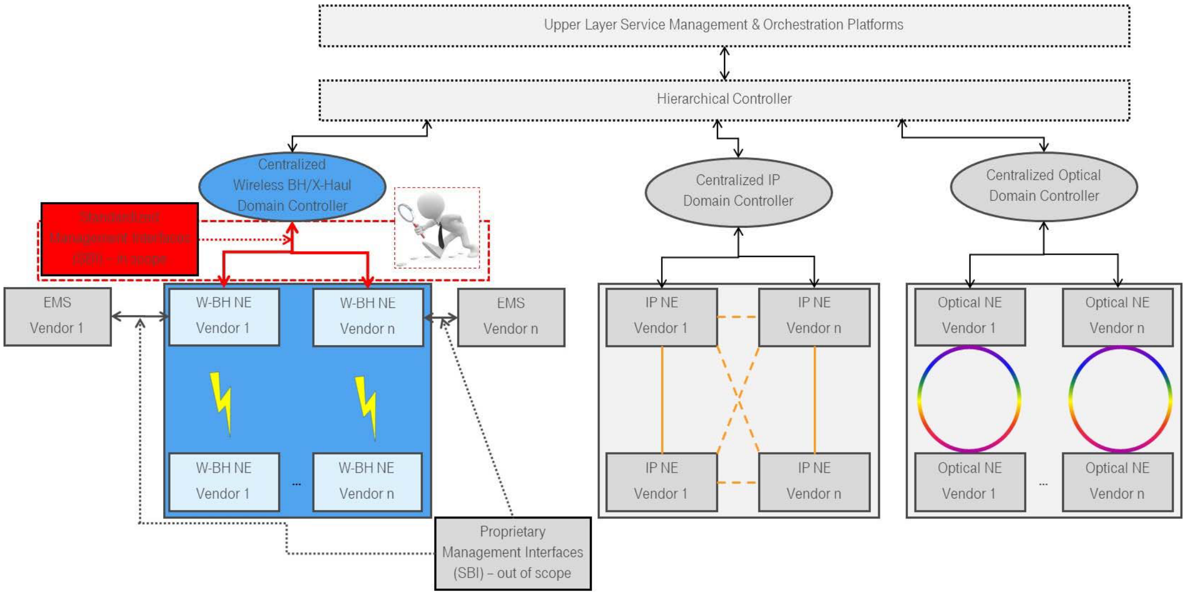

Figure 3: Centralized Wireless Backhaul/X-Haul Domain Controller Architecture

5 Automation Use Cases Analysis

5.1 Network and Service Auto-discovery

5.1.1 Motivation

The use case area of network and service discovery can be broken down into two logical applications.

Auto-Discovery - Traditional microwave NE deployment procedures can often be more complex than other transport technology domains due to the detailed planning, coordination, spectrum license applications and configuration of physical layer radio attributes before commissioning can take place. In addition, the initial installation procedure typically requires significant time and effort from expert resource before higher layer protocols can be established for further configuration and service provisioning. A standardized and interoperable SBI has the potential for near real-time integration of multi-vendor NE with centralized network planning tools to automate or assist commissioning, optimization and validation of new radio links.

NE Capabilities and Domain Characteristics - The ability to track and query configuration capabilities and active topology of the network underpin the management ability of the operator. An SDN ambition for the operator is the ability to provision end to end services regardless of the underlying transport technology. This can only be realized with effective technology domain abstraction where technology specific automation (based on NE capabilities and topology) can be handled by domain controllers. A standardized super-set of technology specific capabilities (e.g. physical links, ports, HW profile and services) would allow network services to be implemented in multi-vendor, multi-technology domain.

5.1.2 Expected value

The most significant benefit for operators of automatic discovery of NE (which in turn facilitates automated or semi-automated commissioning and inventory systems) is through OPEX cost savings. Deployment of microwave transmission equipment is a particularly costly and time consuming procedure where standardized interfaces and data models can enable faster time to market and enable greater flexibility of suppliers and supplier equipment without the (often cost prohibitive) proprietary NMS/OSS/BSS integration.

Auto-discovery of network equipment topology and capabilities also could enable seamless integration of new applications for near real-time visualization of microwave link information relevant to planning and operational teams. New applications could permit accurate and frequent asset and inventory management tasks, track upgrades and their impacts, re-configuration and security patching across all domains. Where such procedures are currently manual or part-manual processes there is significant scope for error and inaccuracy which could be removed through automated configuration audits and automatic correction against the target/desired configuration.

5.1.3 Functionality description

Network and Services auto-discovery is a function that will allow to automatically detect and connect new microwave nodes to a management system and to retrieve inventory information from the node.

5.1.4 Gap analysis in standard models

Table 1: UC1 Gap Analysis

Attribute	ONF		IETF/IEEE	
	Parameter Name	Model/Submodel	Parameter Name	Model/Submodel
Per Hardware Instance (i)				
Model Number	model-identifier	ONF TR-512 v1.4 [i.14]	model-name/ physical-index	ietf-hardware (IETF RFC 8348 [i.8])
Model Version	version	ONF TR-512 v1.4 [i.14]	model-name	ietf-hardware (IETF RFC 8348 [i.8])
Serial Number	serial-number	ONF TR-512 v1.4 [i.14]	serial-num	ietf-hardware (IETF RFC 8348 [i.8])
Hardware Version	part-type-identifier	ONF TR-512 v1.4 [i.14]	hardware-rev	ietf-hardware (IETF RFC 8348 [i.8])
Modem Version	n.a (under development)	-	firmware-rev/ software-rev	ietf-hardware (IETF RFC 8348 [i.8])
NE Name	control-construct/name or control-construct/label	ONF TR-512 v1.4 [i.14]	name	ietf-hardware (IETF RFC 8348 [i.8])
NE Description	control-construct/name or control-construct/label	ONF TR-512 v1.4 [i.14]	description	ietf-hardware (IETF RFC 8348 [i.8])
Firmware Version	n.a (under development)	-	firmware-rev	ietf-hardware (IETF RFC 8348 [i.8])
Software Version	n.a (under development)	-	software-rev	ietf-hardware (IETF RFC 8348 [i.8])
Data Model Version	n.a but communicated during netconf session	-	Revision statement	ietf-hardware (IETF RFC 8348 [i.8])
Interface Id	control-construct/logical-termination-point/layer-protocol/local-id	ONF TR-512 v1.4 [i.14]	Uuid(IETF RFC 8348 [i.8])/ if-index(IETF RFC 8343 [i.7])/ id(IETF RFC 8561 [i.9])	ietf-hardware (IETF RFC 8348 [i.8])/ ietf-interfaces(IETF RFC 8343 [i.7])/ ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Chassis id	control-construct/top-level-equipment/uuid (core-model)	ONF TR-512 v1.4 [i.14]	physical-index	ietf-hardware (IETF RFC 8348 [i.8])
Per Radio Interface (i)				
RF Enabled	transmitter-is-on receiver-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-enabled	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Channel Spacing/Duplex	duplex-distance-list	ONF TR-532 v2.0 [i.15]/air-interface-capability	channel-separation/ duplex-distance	ietf-microwave-radio-link (IETF RFC 8561 [i.9])

Attribute	ONF		IETF/IEEE	
	Parameter Name	**Model/Submodel**	**Parameter Name**	**Model/Submodel**
Reference Modulation	min modulation proposed instead	-	selected-cm *In case of adaptive mode, this attribute is not defined.	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Modulation	adaptive-modulation-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	adaptive	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Maximum Physical Modulation (see note 1)	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	available-max-acm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Current Physical Modulation (see note 2)	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	actual-tx-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Frequency	tx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Rx Frequency	rx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	rx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Channel Bandwidth	channel-bandwidth	ONF TR-532 v2.0 [i.15]/air-interface-capability	channel-separation	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Power	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	actual-transmitted-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power	tx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	atpc	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Minimum	atpc-tx-power-min	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-lower-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Maximum	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-upper-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Polarization	polarization	ONF TR-532 v2.0 [i.15]/air-interface-configuration	polarization	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
XPIC	xpic-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	xpic-pairs	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
BCA	n.a.	-	n.a.	-
Per Ethernet/Port (i)				
Port Enabled	interface-is-on	ONF TR-532 v2.0 [i.15]/wire-interface-configuration	enabled	ietf-interfaces(IETF RFC 8343 [i.7])
Port ID	local-id	ONF TR-532 v2.0 [i.15]/core-model	if-index	ietf-interfaces(IETF RFC 8343 [i.7])
Port Name	wire-interface-name	ONF TR-532 v2.0 [i.15]/wire-interface-configuration	name	ietf-interfaces(IETF RFC 8343 [i.7])
Physical Layer Speed	fixed-pmd-kind	ONF TR-532 v2.0 [i.15]/wire-interface-configuration	speed	ietf-interfaces(IETF RFC 8343 [i.7])
Duplex Mode	fixed-pmd-kind	ONF TR-532 v2.0 [i.15]/wire-interface-configuration	type	ietf-interfaces(IETF RFC 8343 [i.7])
MAC Address	configured-mac-address	ONF TR-532 v2.0 [i.15]/mac-interface-configuration	phys-address/ mac-address	ietf-interfaces(IETF RFC 8343 [i.7])/ ietf-if-ethernet-like(draft-ietf-netmod-intf-ext-yang [i.13])

Attribute	ONF		IETF/IEEE	
	Parameter Name	Model/Submodel	Parameter Name	Model/Submodel
Flow Control	auto-pmd-negotiation-is-on	ONF TR-532 v2.0 [i.15]/wire-interface-configuration	flow-control	ieee802-ethernet-interface(IEEE 802.3.2 [i.4])
Sync Ethernet	n.a	-	ietf-ptp	ietf-ptp(IETF RFC 8575 [i.10])
LLDP	n.a	-	lldp-cfg	ieee802-dot1ab-lldp(IEEE 802.1 [i.5] Abcu)
LLDP TTL	n.a	-	message-tx-hold-multiplier	ieee802-dot1ab-lldp(IEEE 802.1 [i.5] Abcu)
DHCP	n.a	-	ietf-dhcp	ietf-dhcp(draft-liu-dhc-dhcp-yang-model [i.12])
MTU Size	mac-interface-configuration/maximum-frame-size	ONF TR-532 v2.0 [i.15]/mac-interface	max-frame-size	ietf-if-extensions(draft-ietf-netmod-intf-ext-yang [i.13])
NOTE 1: To retrieve the maximum modulation start from "air-interface-configuration/transmission-mode-max", find the element in "air-interface-capability/supported-channel-plan-list/transmission-mode-list" whose "transmission-mode-id" matches "transmission-mode-min" and then read "modulation-scheme" of this element. NOTE 2: To retrieve the current modulation scheme it is necessary to start from "air-interface-status/transmission-mode-cur", find the element in "air-interface-capability/supported-channel-plan-list/transmission-mode-list" whose "transmission-mode-id" matches "transmission-mode-cur" and then read "modulation-scheme" of this element.				

5.2 Services Provisioning

5.2.1 Motivation

The process of creating new backhaul services is currently separated mainly between IP and MW teams. IP service provisioning is usually done using command line interface by IP teams while MW services creation (usually Layer2) is performed on the Element Management System which implies laborious configuration on each NE. Thus, service provisioning is time consuming and could likely encounter human errors.

Another scenario met in operators' networks is the provisioning of a single service over a multi-vendor MW network which requires multiple configurations on different Element Managers, automation based on standardized equipment interfaces would significantly improve the efficiency of such operations.

Moreover, the emergence of 5G and specifically the E2E network slicing will require "on the fly" bandwidth provisioning between two nodes in a transport network according to several criteria (e.g. Latency, Bandwidth, physical routing constraints, etc.), this can be enabled by automating the services creation.

5.2.2 Expected value

The target eventually will be to have a seamless and automated service provisioning over IP+MW networks which will bring OPEX savings thanks to time-effective operation and more reliable networks because no human errors. The focus in this work item will be on the automation of the services provisioning on the MW segment only.

5.2.3 Functionality description

The operator requests a service creation between two end-points, enters a VLAN number and potentially some QoS settings. The service is set up within few seconds.

5.2.4 Gap analysis in standard models

Table 2: UC2 Gap Analysis

Attribute	ONF		IETF/IEEE	
	Parameter Name	**Model/Submodel**	**Parameter Name**	**Model/Submodel**
Component type (e.g. c-vlan, s-vlan)	vlan-fc-configuration/sub-layer-protocol-name	ONF TR-532 v2.0 [i.15]/vlan-fc	/dot1q:bridges/bridge / component/type	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Default VLAN ID	vlan-interface-configuration/default-vlan-id	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/pvid	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Default Priority	vlan-interface-configuration/default-priority	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/default-priority	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Enable Ingress VLAN filtering	vlan-interface-configuration/ingress-vlan-id-filtering-is-on	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/enable-ingress-filtering	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Ingress Tag filtering	vlan-interface-configuration/ingress-tag-filtering	ONF TR-532 v2.0 [i.15]/vlan-interface	/dot1q:bridges/bridge / component/ bridge-vlan/ vlan/egress-ports	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
PCP selection	vlan-interface-configuration/pcp-bits-interpretation-kind	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/pcp-selection	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
P-bit to priority queue mapping list	vlan-interface-configuration/pcp-bit-to-priority-mapping-list	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/pcp-decoding-table	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Priority queue to P-bit mapping list	vlan-interface-configuration/pcp-bits-encoding-mapping-list	ONF TR-532 v2.0 [i.15]/vlan-interface	/if:interfaces/interface/dot1q:bridge-port/pcp-encoding-table	ieee802-dot1q-bridge (IEEE 802.1Qcp [i.6])
Network Element interfaces (board/ port)	-	ONF TR-532 v2.0 [i.15]/core-model	/if:interfaces/interface/name	ietf-interfaces (IETF RFC 8343 [i.7])
MTU size	mac-interface-configuration/maximum-frame-size	ONF TR-532 v2.0 [i.15]/mac-interface	/if:interfaces/interface/ieee802-eth-if:max-frame-length	ieee802-ethernet-interface (IEEE 802.3.2 [i.4])
Flow control	mac-interface	ONF TR-532 v2.0 [i.15]/flow-control-mode	flow-control	ieee802-ethernet-interface(IEEE 802.3.2 [i.4])
Bandwidth profile (CIR, CBS, EIR, EBS, CM)	n.a	-	n.a	-

5.3 Performance Analysis & Prediction

5.3.1 Motivation

Network performance analysis based on intelligent algorithms and network built-in automated processes is considered as a fundamental path to serve end-users requirements in an agile approach, achieve optimum network resources utilization, minimize risks of network failures and increase operational efficiency and productivity, whilst keeping OpEx at acceptable levels. In the context of wireless backhaul/X-Haul domain, intelligent algorithms can be applied to perform smart performance analysis (in the first place) and prediction (at subsequent stages).

With respect to the wireless backhaul/X-haul, there are largely three (3) layers to focus:

- Equipment layer.

- Radio link layer.
- Service layer (IP/Ethernet).

5.3.2 Expected Value

This category can consist of numerous use cases that of course can be populated over time. As a starting point, the proposal is to introduce a use case, where radio performance data is tracked and collected in real-time. In the mid/long-term, AI/ML-powered prediction algorithms can recognize the causes of any radio impairments and failures, create timely notifications, propose and/or enable the most appropriate mitigation techniques (out of scope of the present document).

5.3.3 Functionality description

Radio performance degradation, unavailability and/or outage can be due to:

- Rain Attenuation.
- Diffraction Loss (obstructed LOS).
- Atmospheric Multipath Fading:
  - Refraction: flat fading, selective fading.
  - Ducting.
- Terrain Reflections (multipath).
- RF Interference.
- IF Interference.

In order to characterize the above phenomena certain information (attributes) would be needed to be recorded and reported by NEs. Additional information collected from external sources, e.g. local weather status, terrain type, could be also used, so to be correlated to identify the actual cause of any signal degradation.

5.3.4 Gap analysis in standard models

Table 3: UC3 Gap Analysis

Attribute	ONF		IETF/IEEE	
	Parameter name	**Model/Submodel**	**Parameter Name**	**Model/Submodel**
Link Configuration	n.a. but retrievable from the model architecture (1+0, 1+1, 2+0, etc.)	-	mode	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
RF Enabled	transmitter-is-on receiver-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-enabled	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Reference Modulation	Min modulation proposed instead	ONF TR-532 v2.0 [i.15]/air-interface	selected-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Modulation	adaptive-modulation-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	adaptive	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Frequency	tx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Rx Frequency	rx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	rx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Channel Bandwidth	channel-bandwidth	ONF TR-532 v2.0 [i.15]/air-interface-capability	channel-separation	ietf-microwave-radio-link (IETF RFC 8561 [i.9])

Attribute	ONF		IETF/IEEE	
	Parameter name	Model/Submodel	Parameter Name	Model/Submodel
Tx Power	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	actual-transmitted-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Minimum	atpc-tx-power-min	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-lower-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Maximum	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-upper-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Polarization	polarization	ONF TR-532 v2.0 [i.15]/air-interface-configuration	polarization	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
XPIC	xpic-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	xpic-pairs	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
BCA	n.a.	-	n.a.	-
RSL	rx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-received-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
RSL Thresholds	am-upshift-level am-downshift-level	ONF TR-532 v2.0 [i.15]/air-interface-capability	received-level-alarm-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
SNR (MSE)	snir-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-snir	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
SNR (MSE) Thresholds	n.a. but not mandatory	n.a. but not mandatory	n.a. but not mandatory	-
Maximum Physical Modulation (see note 1)	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	available-max-acm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Current Physical Modulation (see note 2)	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	actual-tx-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Maximum Radio Capacity	n.a but calculable	-	n.a but calculable	-
Minimum Radio Capacity	n.a but calculable	-	n.a but calculable	-
Actual Radio Capacity	n.a but calculable	-	n.a but calculable	-
Fade Margin	n.a.	-	n.a.	-
BER	n.a.	-	n.a.	-
Errored Block (EB)	n.a.	-	n.a.	-
Errored Second (ES)	es	ONF TR-532 v2.0 [i.15]/air-interface-current-performances air-interface-historical-performances	es	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Severely Errored Second (SES)	ses	ONF TR-532 v2.0 [i.15]/air-interface-current-performances air-interface-historical-performances	ses	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Background Block Error (BBE)	n.a.	-	bbe	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Availability Ratio (AR)	n.a.	-	uas discontinuity-type	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Unavailability Ratio (UR)	n.a.	-	uas discontinuity-type	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Mean Time between outages (Mo)	n.a.	-	n.a.	-
Outage Intensity (OI)	n.a.	-	n.a.	-

Attribute	ONF		IETF/IEEE	
	Parameter name	Model/Submodel	Parameter Name	Model/Submodel
Severe Errored Second (SESETH)	n.a.	-	ses	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Percent Ethernet service Unavailability (PEU)	n.a.	-	n.a.	-
Percent Ethernet service Availability (PEA)	n.a.	-	n.a.	-
ethernet Frame Error Ratio (FER)	n.a.	-	in-error-fcs-frames in-total-frames	ieee802-ethernet-interface (IEEE 802.3.2 [i.4])
ethernet Frame Loss Ratio (FLR)	n.a.	-	n.a.	-
Latency	n.a.	-	n.a.	-

NOTE 1: To retrieve the maximum modulation start from "air-interface-configuration/transmission-mode-max", find the element in "air-interface-capability/supported-channel-plan-list/transmission-mode-list" whose "transmission-mode-id" matches "transmission-mode-min" and then read "modulation-scheme" of this element.

NOTE 2: To retrieve the current modulation scheme it is necessary to start from "air-interface-status/transmission-mode-cur", find the element in "air-interface-capability/supported-channel-plan-list/transmission-mode-list" whose "transmission-mode-id" matches "transmission-mode-cur" and then read "modulation-scheme" of this element.

5.4 Smart Alarm Analysis and Fault Prediction

5.4.1 Motivation

Fault management is one of the most critical operational aspects of the network. Typically there may be small supervision teams overseeing the end to end network who utilize or aggregate proprietary EMSs of different networks and vendors, this may generate thousands of alarms every day. Reliable troubleshooting, prioritization and escalation are often a highly manual and time consuming process. The area of fault management and fault prediction is one of the most promising areas for the application of machine learning where the aim is to realize a proactive fault prediction and mitigation solution based on current and historical alarm patterns.

5.4.2 Expected value

Automating fault management or preventative maintenance through the introduction of machine learning has the potential for huge OPEX cost saving, improved network availability and quality of service to the end customer. Standardized fault definitions and classifications relevant to wireless transport solutions would allow an SDN domain controller real time information about the radio interface and associated hardware which could be stored, analysed and correlated with equivalent information in the wider SDN solution. Such information could be used to actively predict and prevent future network issues. A robust, cross technology domain root-cause analysis capability would underpin an 'ultra-reliable' network of the future.

5.4.3 Functionality description

The alarms raised by the MW nodes are sent through a standardized interface to the controller; the alarms structure being based on a standardized YANG model.

5.4.4 Gap analysis in standard models

Assumed alarm definitions are hard coded and openly defined including reporting mechanism (e.g. Notify, Pole or Log) and classification of severity (e.g. Informational, Minor, Major, Critical). It is expected that alarm definitions consist of common and proprietary alarm events.

Table 4: UC4 Gap Analysis

Attribute	ONF		IETF /IEEE	
	Parameter name	Model/Submodel	Parameter Name	Model/Submodel
Current Alarm Id	problem-name	ONF TR-532 v2.0 [i.15]/MwCurrentProblem	resource alarm-type-id alarm-type-qualifier	ietf-alarms (IETF RFC 8632 [i.11])
Current Alarm Notification Id	sequence-number	ONF TR-532 v2.0 [i.15]/MwCurrentProblem	/alarm-notification/resource /alarm-notification/alarm-type-id /alarm-notification/alarm-type-qualifier /alarm-notification/time	ietf-alarms (IETF RFC 8632 [i.11])
Current Alarm Creation Time Stamp	timestamp	ONF TR-532 v2.0 [i.15]/MwCurrentProblem	last-raised	ietf-alarms (IETF RFC 8632 [i.11])
Current Alarm Event Type	n.a.	-	event-type	ietf-alarms-x733 (RFC8362)
Current Alarm Probable Cause	n.a.	-	probable-cause probable-cause-string	ietf-alarms-x733 (RFC8362)
Current Alarm Specific Problem	n.a.	-	n.a.	-
Current Alarm Reporting Mechanism	n.a.	-	/alarms/alarm-list/alarm /alarms/shelved-alarms/alarm	ietf-alarms (IETF RFC 8632 [i.11])
Current Alarm Severity	problem-severity	ONF TR-532 v2.0 [i.15]/MwCurrentProblem	perceived-severity	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Id	n.a. (planned to be developed)	-	resource alarm-type-id alarm-type-qualifier status-change/time	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Notification Id	n.a. (planned to be developed)	-	/alarm-notification/resource /alarm-notification/alarm-type-id /alarm-notification/alarm-type-qualifier /alarm-notification/time	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Creation Time Stamp	n.a. (planned to be developed)	-	status-change/time	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Cleared Time Stamp	n.a. (planned to be developed)	-	status-change/time	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Event Type	n.a. (planned to be developed)	-	event-type	ietf-alarms-x733 (IETF RFC 8632 [i.11])
Historical Alarm Probable Cause	n.a. (planned to be developed)	-	probable-cause probable-cause-string	ietf-alarms-x733 (IETF RFC 8632 [i.11])
Historical Alarm Specific Problem	n.a. (planned to be developed)	-	n.a.	-
Historical Alarm Reporting Mechanism	n.a. (planned to be developed)	-	/alarms/alarm-list/alarm /alarms/shelved-alarms/alarm	ietf-alarms (IETF RFC 8632 [i.11])
Historical Alarm Severity	n.a. (planned to be developed)	-	status-change/perceived-severity	ietf-alarms (IETF RFC 8632 [i.11])

5.5 Power Consumption Optimization

5.5.1 Motivation

Decreasing the levels of power consumption in the running networks is a major goal for most operators as it contributes to significant OpEx reduction. The traffic load over wireless backhaul links is fluctuating at different moments of the day, while the power consumption - as not related to this dynamic behavior of the radio links - is not really optimized. To this end, network automation functions can be utilized to reduce power consumption in correlation to the actual throughput (Tput).

5.5.2 Expected value

Activation/deactivation of carriers in multi-carrier systems based on traffic data analysis can result to significant energy saving. The proposed use case assumes that there is no impact on equipment's MTBF due to repeated power cycling (nonetheless, this aspect should be guaranteed by system vendors).

5.5.3 Functionality description

In the case N+0 configurations are assumed, where $N \geq 2$ (extending the scope to 1+0 configurations may be investigated in next version of the present document).

For the sake of simplicity, an example with two RF carriers (2+0 link configuration) is considered. The main purpose is either to turn off or mute one of the two RF carriers, when a single one can serve the actual traffic load. Different approaches may be proposed in case of uniform bands (e.g. combining 11 GHz + 18 GHz) compared to non-uniform bands (e.g. E-band + 18 GHz).

5.5.4 Gap analysis in standard models

Table 5: UC5 Gap Analysis

Attribute	ONF		IETF/IEEE	
	Parameter name	Model/Submodel	Parameter Name	Model/Submodel
Link Configuration	n.a. but retrievable	-	mode	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
RF Enabled	transmitter-is-on receiver-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-enabled	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Reference Modulation	Min modulation proposed instead	ONF TR-532 v2.0 [i.15]/air-interface	selected-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Modulation	adaptive-modulation-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	adaptive	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Frequency	tx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Rx Frequency	rx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	rx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Channel Bandwidth	channel-bandwidth	ONF TR-532 v2.0 [i.15]/air-interface-capability	channel-separation	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Power	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	actual-transmitted-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power	tx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	atpc	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Minimum	atpc-tx-power-min	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-lower-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power Maximum	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	atpc-upper-threshold	ietf-microwave-radio-link (IETF RFC 8561 [i.9])

Attribute	ONF		IETF/IEEE	
	Parameter name	Model/Submodel	Parameter Name	Model/Submodel
XPIC	xpic-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	xpic-pairs	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
BCA	n.a.	-	n.a.	-
RSL	rx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-received-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
SNR (MSE)	snir-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-snir	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Maximum Physical Modulation	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	available-max-acm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Current Physical Modulation	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	actual-tx-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Maximum Radio Capacity	n.a but calculable	-	n.a but calculable	
Minimum Radio Capacity	n.a but calculable	-	n.a but calculable	
Actual Radio Capacity	n.a but calculable	-	n.a but calculable	
Maximum Link/Carrier Utilization %	n.a.	-	n.a.	
Actual Ethernet Tput	n.a.	-	n.a.	
Maximum Ethernet Tput	n.a.	-	n.a.	
Minimum Ethernet Tput	n.a.	-	n.a.	
Average Ethernet Tput	n.a.	-	n.a.	
Ethernet Bandwidth Utilization %	n.a.	-	n.a.	
Ethernet Drop Ratio %	n.a.	-	n.a.	
Power Consumption	n.a.	-	n.a.	

5.6 Interference Handling and Automated Frequency Allocation

5.6.1 Motivation

Risk of spectrum congestion in the MW frequency Bands (6 GHz - 42 GHz) and the necessity to optimize spectrum resources usage has driven several activities within ETSI ISG mWT during the last couple of years. mWT community agreed that geographical spectral efficiency is the direction to follow in order to achieve best possible spectrum resource usage.

Within framework of spectrum regulations that will grant the Operators either Block Assignment (a reality today in some Countries for some Bands) or Hybrid Scheme (as identified by ETSI ISG mWT for new bands assignment), the SDN capabilities can be empowered to dynamically orchestrate spectrum resources usage across links deployed over the same geographic area. Moreover, in the very long term, this SDN use case might also become applicable for Bands with Individual Licensing (e.g. provided a real time interference coordination web portal will be available).

5.6.2 Expected value

Considering that traditional MW network planning using "interference threshold degradation" concept is worst-case assumption that demands the usage of multiple channels in the same band to avoid worst-case risk, SDN capabilities to dynamically (when rain fading occurs) orchestrate spectrum resources usage across links deployed over the same geographic area can reduce overall number of channels to be used.

Therefore such SDN use case is an important enabler for maximizing "geographical spectral efficiency".

5.6.3 Functionality description

The concept of such functionality is generally described in clause 5.1.4 within ETSI GR mWT 016 [i.1], figure 4 is an extract of "Interference handling" use case described in that document.

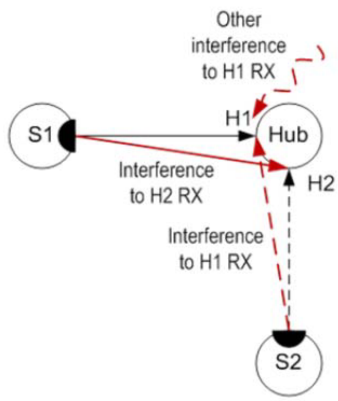

Figure 4: Interference Scenario

Interference scenario

In figure 4, the link S1-H1 can suffer from a fade while S2-H2 does not. In this case during the fade the interference to H1 may be more dominant than in clear sky.

SDN may mitigate this scenario in different ways:

1) During the fade when the interference is dominant, the SDN controller will temporarily reduce the bandwidth of S1-H1 and S2-H2 by half, each using different half of the spectrum. This will eliminate the interference, and the temporal capacity will drop by 2. When fade disappears, SDN may return to the original bandwidth allocation.

2) During the fade at S1-H1, the SDN controller will allocate a temporary channel for the fade duration from a pool of "spare" channels. This channel will return to the pool when the fade event is gone. The main idea is that fades do not happen at the same time in all links, so a small amount of channels in the pool may be enough.

3) During the fade the SDN controller will command a scanning of the frequency domain in order to select the best channel.

The actual behavior of the actions that SDN Controller may apply is not within the scope of the present document. The possible actions described above (as well as others that can be considered during current activity) can be used to identify a minimum set of attributes that can be managed over the SBI between SDN Controller and the Network Elements.

5.6.4 Gap analysis in standard models

Table 6: UC6 Gap Analysis

Attribute	ONF		IETF/IEEE	
	Parameter name	**Model/Submodel**	**Parameter Name**	**Model/Submodel**
Link Configuration	n.a. but retrievable	-	mode	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Band	tx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Channel Bandwidth	channel-bandwidth	ONF TR-532 v2.0 [i.15]/air-interface-capability	channel-separation	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
XPIC	xpic-is-on	ONF TR-532 v2.0 [i.15]/air-interface-configuration	xpic-pairs	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Adaptive Tx Power	tx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	atpc	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Power	tx-power	ONF TR-532 v2.0 [i.15]/air-interface-configuration	actual-transmitted-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
RSL	rx-level-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-received-level	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
SNR (MSE)	snir-cur	ONF TR-532 v2.0 [i.15]/air-interface-status	actual-snir	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Current Physical Modulation (see note)	modulation-scheme	ONF TR-532 v2.0 [i.15]/air-interface-capability	actual-tx-cm	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Tx Frequency	tx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	tx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
Rx Frequency	rx-frequency	ONF TR-532 v2.0 [i.15]/air-interface-configuration	rx-frequency	ietf-microwave-radio-link (IETF RFC 8561 [i.9])
NOTE: To retrieve the current modulation scheme it is necessary to start from "air-interface-status/transmission-mode-cur", find the element in "air-interface-capability/supported-channel-plan-list/transmission-mode-list" whose "transmission-mode-id" matches "transmission-mode-cur" and then read "modulation-scheme" of this element.				

6 YANG Models Evolution

With the continuous innovation in Wireless X-Haul networks, it is expected that new features keep emerging in Microwave equipment leading to the need to update the YANG model published in the equipment. However, changes to published YANG modules are not allowed if they have any potential to cause interoperability problems between a client using an original specification and a server using an updated specification. Compliance to IETF RFC 7950 [i.3] describing this requirement is therefore important.

In the case of IETF and IEEE, models are developed directly in YANG and the extensions of the models are done either through the augmentation feature described in IETF RFC 6020 [i.2] or through module revisions described in section 11 of IETF RFC 7950 [i.3], which guarantee backward compatibility with the anterior version.

In ONF, IMs are developed in UML then a tool (compiler), for instance the EAGLE UML-Yang Mapping Tool, is used to translate UML to YANG. Eventually, ONF 5G XHaul work group is responsible for converting IMs to YANG DMs and ONF provides both of them. The used compiler should be compatible with the previous rules to ensure backwards compatibility.

Starting ONF TR 532-v2.0 [i.15], a significant enhancement was carried out to make the model more modular making it possible to augment the model with new module without recompiling the whole model. The remaining issue is that the MW domain model is associated to a specific core model version (e.g. ONF TR-532-v1.1 [i.16] → Core 1.2 and TR-532-v2.0 → Core 1.4 [i.15]). Any changes in the core model version could break backward compatibility.

A solution could be to fix the core model to the version 1.4 starting ONF TR-532-v2.0 [i.15]. A major drawback of such solution is that the MW model will not benefit from the new features brought by every new version of the core model. Solving this backward compatibility issue is therefore necessary to guarantee that the model is future-proof.

7 Conclusions

SDN is an imminent technology for Wireless Xhaul networks and the microwave equipment openness is a pre-requisite for its implementation. NETCONF, the preferred interface providing such openness, started emerging in the new generation of microwave equipment but the used standard data models on this interface differs from a vendor to another driving fragmentation in the ecosystem and slowing the progress towards SDN deployment.

The work reported in the present document provided a use case-driven high level analysis of the ONF, IETF and IEEE YANG models relevant for Microwave automation. The analysis showed promising results for ONF on one hand, which initially focused on the radio layer but which proposed a more complete model in its new version. And for IETF on the other hand which proposes to augment its model with IEEE modules, in particular for L2 services. In fact, most features needed for the six use cases implementation were supported by both models. Some gaps were however identified in both potential implementations which resulted in communications with their respective SDOs in order to collaborate to provide complements to current standard models.

An additional aspect captured in the present document is the potential extensions of current models and their impact on backward compatibility. Indeed, the latter risks to be broken in ONF implementation with the evolution of the ONF core model. Efforts are therefore needed to make the ONF model future-proof.

Finally, this work allowed having a high-level assessment of microwave data models maturity. A more detailed analysis and implementation level recommendations will require plugtests where a use case implementation is supported by different equipment vendors based on a single set of standard data models.

History

Document history		
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