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A Framework for Management and Control of
Microwave and Millimeter Wave Interface Parameters

Abstract

The unification of control and management of microwave radio link interfaces is a precondition for seamless multi-layer networking and automated network provisioning and operation.

This document describes the required characteristics and use cases for control and management of radio link interface parameters using a YANG data model.

The purpose is to create a framework to identify the necessary information elements and define a YANG data model for control and management of the radio link interfaces in a microwave node. Some parts of the resulting model may be generic and could also be used by other technologies, e.g., Ethernet technology.

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1. Introduction

Microwave radio is a technology that uses high-frequency radio waves to provide high-speed wireless connections that can send and receive voice, video, and data information. It is a general term used for systems covering a very large range of traffic capacities, channel separations, modulation formats, and applications over a wide range of frequency bands from 1.4 GHz up to and above 100 GHz.

The main application for microwave is backhaul for mobile broadband. Those networks will continue to be modernized using a combination of microwave and fiber technologies. The choice of technology depends on fiber presence and cost of ownership, not capacity limitations in microwave.

Today, microwave is already able to fully support the capacity needs of a backhaul in a radio access network and will evolve to support multiple gigabits in traditional frequency bands and more than 10 gigabits in higher-frequency bands with more bandwidth. Layer 2 (L2) Ethernet features are normally an integrated part of microwave nodes, and more advanced L2 and Layer 3 (L3) features will be introduced over time to support the evolution of the transport services that will be provided by a backhaul/transport network. Note that wireless access technologies such as 3/4/5G and Wi-Fi are not within the scope of this document.

Open and standardized interfaces are a prerequisite for efficient management of equipment from multiple vendors, integrated in a single system/controller. This framework addresses management and control of the radio link interface(s) and their relationship to other interfaces (typically, Ethernet interfaces) in a microwave node. A radio link provides the transport over the air, using one or several carriers in aggregated or protected configurations. Managing and controlling a transport service over a microwave node involves both radio link and packet transport functionality.

Today, there are already numerous IETF data models, RFCs, and Internet-Drafts with technology-specific extensions that cover a large part of the L2 and L3 domains. Examples include IP Management [RFC8344], Routing Management [RFC8349], and Provider Bridge [IEEE802.1Qcp]. These are based on the IETF YANG data model for Interface Management [RFC8343], which is an evolution of the SNMP IF-MIB [RFC2863].

Since microwave nodes will contain more and more L2 and L3 (packet) functionality that is expected to be managed using those models, there are advantages if radio link interfaces can be modeled and managed using the same structure and the same approach. This is

especially true for use cases in which a microwave node is managed as one common entity that includes both the radio link and the L2 and L3 functionality, e.g., basic configuration of the node and connections, centralized troubleshooting, upgrade, and maintenance. All interfaces in a node, irrespective of technology, would then be accessed from the same core model, i.e., [RFC8343], and could be extended with technology-specific parameters in models augmenting that core model. The relationship/connectivity between interfaces could be given by the physical equipment configuration. For example, the slot where the Radio Link Terminal (modem) is plugged in could be associated with a specific Ethernet port due to the wiring in the backplane of the system, or it could be flexible and therefore configured via a management system or controller.

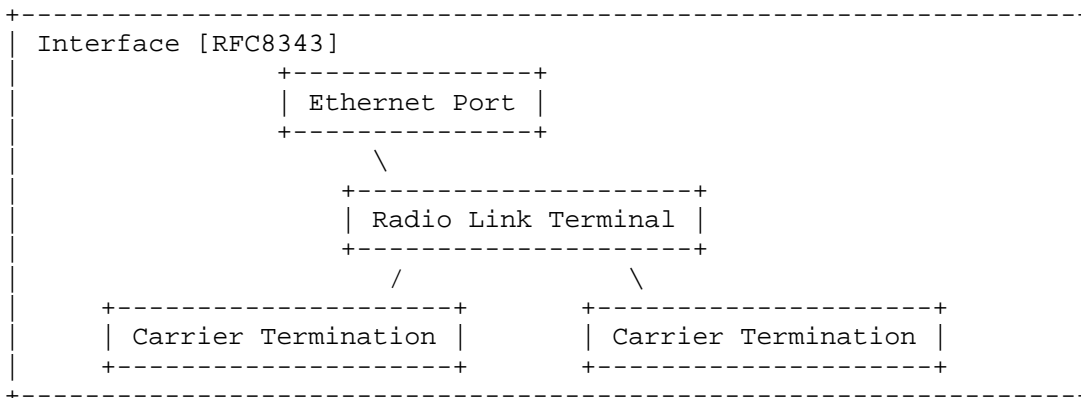


Figure 1: Relationship between Interfaces in a Node

There will always be certain implementations that differ among products, so it is practically impossible to achieve industry consensus on every design detail. It is therefore important to focus on the parameters that are required to support the use cases applicable for centralized, unified, multi-vendor management and to allow other parameters to either be optional or be covered by extensions to the standardized model. Furthermore, a standard that allows for a certain degree of freedom encourages innovation and competition, which benefits the entire industry. Thus, it is important that a radio link management model covers all relevant functions but also leaves room for product- and feature-specific extensions.

Models are available for microwave radio link functionality: "Microwave Information Model" by the ONF [ONF-MW] and "Microwave Radio Link YANG Data Models" submitted to and discussed by the CCAMP Working Group [CCAMP-MW]. The purpose of this document is to reach

consensus within the industry around one common approach with respect to the use cases and requirements to be supported, the type and structure of the model, and the resulting attributes to be included. This document describes the use cases, requirements, and expected characteristics of the model. It also includes an analysis of how the models in the two ongoing initiatives fulfill these expectations and recommendations for what can be reused and what gaps need to be filled by a new and evolved model ("A YANG Data Model for Microwave Radio Link" by the IETF [IETF-MW]).

1.1. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Terminology and Definitions

Microwave radio: a term commonly used for technologies that operate in both microwave and millimeter wavelengths and in frequency bands from 1.4 GHz up to and beyond 100 GHz. In traditional bands, it typically supports capacities of 1-3 Gbps; in the 70/80 GHz band, it supports up to 10 Gbps. Using multi-carrier systems operating in frequency bands with wider channels, the technology will be capable of providing capacities of up to 100 Gbps.

Microwave radio technology: widely used for point-to-point telecommunications because its small wavelength allows conveniently sized antennas to direct radio waves in narrow beams and its comparatively higher frequencies allow broad bandwidth and high data-transmission rates. It is used for a broad range of fixed and mobile services, including high-speed, point-to-point wireless local area networks (WLANs) and broadband access.

The ETSI EN 302 217 series defines the characteristics and requirements of microwave equipment and antennas. In particular, ETSI EN 302 217-2 [EN302217-2] specifies the essential parameters for the systems operating from 1.4 GHz to 86 GHz.

Carrier Termination and Radio Link Terminal: two concepts defined to support modeling of microwave radio link features and parameters in a structured yet simple manner.

* **Carrier Termination:** an interface for the capacity provided over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies.

- * Radio Link Terminal: an interface providing Ethernet capacity and/or Time Division Multiplexing (TDM) capacity to the associated Ethernet and/or TDM interfaces in a node. It is used for setting up a transport service over a microwave radio link.

Figure 2 provides a graphical representation of the Carrier Termination and Radio Link Terminal concepts.

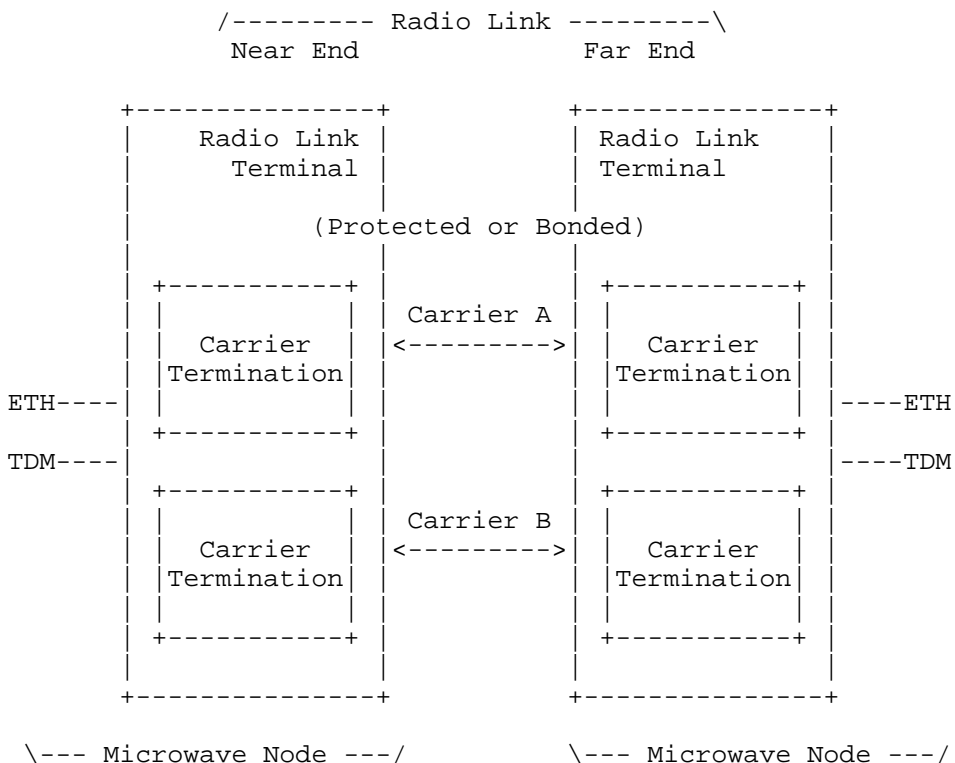


Figure 2: Radio Link Terminal and Carrier Termination

Software-Defined Networking (SDN): an architecture that decouples the network control and forwarding functions, enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services. SDN can be used for automation of traditional network management functionality using an SDN approach of standardized programmable interfaces for control and management [RFC7426].

3. Approaches to Manage and Control Radio Link Interfaces

This framework addresses the definition of an open and standardized interface for radio link functionality in a microwave node. The application of such an interface used for management and control of nodes and networks typically varies from one operator to another in terms of the systems used and how they interact. Possible approaches include using a Network Management System (NMS), Software-Defined Networking (SDN), or some combination of the two. As there are still many networks where the NMS is implemented as one component/interface and the SDN controller is scoped to control-plane functionality as a separate component/interface, this document does not preclude either model. The aim of this document is to provide a framework for development of a common YANG data model for both management and control of microwave interfaces.

3.1. Network Management Solutions

The classic network management solutions, with vendor-specific domain management combined with cross-domain functionality for service management and analytics, still dominate the market. These solutions are expected to evolve and benefit from an increased focus on standardization by simplifying multi-vendor management and removing the need for vendor- or domain-specific management.

3.2. Software-Defined Networking

One of the main drivers for applying SDN from an operator perspective is simplification and automation of network provisioning as well as end-to-end network service management. The vision is to have a global view of the network conditions spanning different vendors' equipment and multiple technologies.

If nodes from different vendors are managed by the same SDN controller via a node management interface without the extra effort of introducing intermediate systems, all nodes must align their node management interfaces. Hence, an open and standardized node management interface is required in a multi-vendor environment. Such a standardized interface enables unified management and configuration of nodes from different vendors by a common set of applications.

In addition to SDN applications for configuring, managing, and controlling the nodes and their associated transport interfaces (including the L2 Ethernet, L3 IP, and radio interfaces), there are also a large variety of more advanced SDN applications that can be utilized and/or developed.

A potentially flexible approach for operators is to use SDN in a logically controlled way, managing the radio links by selecting a predefined operation mode. The operation mode is a set of logical metrics or parameters describing a complete radio link configuration, such as capacity, availability, priority, and power consumption.

An example of an operation mode table is shown in Figure 3. Based on its operation policy (e.g., power consumption or traffic priority), the SDN controller selects one operation mode and translates that into the required configuration of the individual parameters for the Radio Link Terminals and the associated Carrier Terminations.

ID	Description	Capacity	Availability	Priority	Power
1	High capacity	400 Mbps	99.9%	Low	High
2	High availability	100 Mbps	99.999%	High	Low

Figure 3: Example of an Operation Mode Table

An operation mode bundles together the values of a set of different parameters. How each operation mode maps a certain set of attributes is out of the scope of this document.

4. Use Cases

The use cases described should be the basis for identifying and defining the parameters to be supported by a YANG data model for management of radio links that will be applicable to centralized, unified, multi-vendor management. The use cases involve configuration management, inventory, status and statistics, performance management, fault management, and troubleshooting and root cause analysis.

Other product-specific use cases, e.g., addressing installation or on-site troubleshooting and fault resolution, are outside the scope of this framework. If required, these use cases are expected to be supported by product-specific extensions to the standardized model.

4.1. Configuration Management

Configuration management involves configuring a Radio Link Terminal, the constituent Carrier Terminations, and, when applicable, the relationship to IP/Ethernet and TDM interfaces.

- o Understand the capabilities and limitations

Exchange of information between a manager and a device about the capabilities supported and specific limitations in the parameter values and enumerations that can be used.

Examples of information that could be exchanged include the maximum modulation supported and support (or lack of support) for the Cross Polarization Interference Cancellation (XPIC) feature.

- o Initial Configuration

Initial configuration of a Radio Link Terminal, enough to establish Layer 1 (L1) connectivity to an associated Radio Link Terminal on a device at the far end over the hop. It may also include configuration of the relationship between a Radio Link Terminal and an associated traffic interface, e.g., an Ethernet interface, unless that is given by the equipment configuration.

Frequency, modulation, coding, and output power are examples of parameters typically configured for a Carrier Termination and type of aggregation/bonding or protection configurations expected for a Radio Link Terminal.

- o Radio link reconfiguration and optimization

Reconfiguration, update, or optimization of an existing Radio Link Terminal. Output power and modulation for a Carrier Termination as well as protection schemas and activation/deactivation of carriers in a Radio Link Terminal are examples on parameters that can be reconfigured and used for optimization of the performance of a network.

- o Radio link logical configuration

Radio Link Terminals configured to include a group of carriers are widely used in microwave technology. There are several kinds of groups: aggregation/bonding, 1+1 protection/redundancy, etc. To avoid configuration on each Carrier Termination directly, a logical control provides flexible management by mapping a logical configuration to a set of physical attributes. This could also be

applied in a hierarchical SDN environment where some domain controllers are located between the SDN controller and the Radio Link Terminal.

4.2. Inventory

- o Retrieve logical inventory and configuration from device

Request from manager and response by device with information about radio interfaces, e.g., their constitution and configuration.

- o Retrieve physical/equipment inventory from device

Request from manager about physical and/or equipment inventory associated with the Radio Link Terminals and Carrier Terminations.

4.3. Status and Statistics

- o Actual status and performance of a radio link interface

Manager requests and device responds with information about actual status and statistics of configured radio link interfaces and their constituent parts. It's important to report the effective bandwidth of a radio link since it can be configured to dynamically adjust the modulation based on the current signal conditions.

4.4. Performance Management

- o Configuration of historical performance measurements

Configuration of historical performance measurements for a radio link interface and/or its constituent parts. See Section 4.1.

- o Collection of historical performance data

Collection of historical performance data in bulk by the manager is a general use case for a device and not specific to a radio link interface.

Collection of an individual counter for a specific interval is in some cases required as a complement to the retrieval in bulk as described above.

4.5. Fault Management

- o Configuration of alarm reporting

Configuration of alarm reporting associated specifically with radio interfaces, e.g., configuration of alarm severity, is a subset of the configuration use case to be supported. See Section 4.1.

- o Alarm management

Alarm synchronization, visualization, handling, notifications, and events are generic use cases for a device and should be supported on a radio link interface. There are, however, radio-specific alarms that are important to report. Signal degradation of the radio link is one example.

4.6. Troubleshooting and Root Cause Analysis

Provide information and suggest actions required by a manager/operator to investigate and understand the underlying issue to a problem in the performance and/or functionality of a Radio Link Terminal and the associated Carrier Terminations.

5. Requirements

For managing a microwave node including both the radio link and the packet transport functionality, a unified data model is desired to unify the modeling of the radio link interfaces and the L2/L3 interfaces using the same structure and the same modeling approach. If some part of the model is generic for other technology usage, it should be clearly stated.

The purpose of the YANG data model is for management and control of the radio link interface(s) and the relationship/connectivity to other interfaces, typically to Ethernet interfaces, in a microwave node.

The capability of configuring and managing microwave nodes includes the following requirements for the model:

1. It MUST be possible to configure, manage, and control a Radio Link Terminal and the constituent Carrier Terminations.
 - A. Configuration of frequency, channel bandwidth, modulation, coding, and transmitter output power MUST be supported for a Carrier Termination.

- B. A Radio Link Terminal MUST configure the associated Carrier Terminations and the type of aggregation/bonding or protection configurations expected for the Radio Link Terminal.
 - C. The capability (e.g., the maximum modulation supported) and the actual status/statistics (e.g., administrative status of the carriers) SHOULD also be supported by the data model.
 - D. The definition of the features and parameters SHOULD be based on established microwave equipment and radio standards, such as ETSI EN 302 217 [EN302217-2], which specifies the essential parameters for microwave systems operating from 1.4 GHz to 86 GHz.
- 2. It MUST be possible to map different traffic types (e.g., TDM and Ethernet) to the transport capacity provided by a specific Radio Link Terminal.
 - 3. It MUST be possible to configure and collect historical measurements (for the use case described in Section 4.4) to be performed on a radio link interface (e.g., minimum, maximum, average transmit power, and received level in dBm).
 - 4. It MUST be possible to configure and retrieve alarms reporting associated with the radio interfaces (e.g., configuration fault, signal lost, modem fault, and radio fault).
6. Gap Analysis on Models

The purpose of the gap analysis is to identify and recommend what models to use in a microwave device to support the use cases and requirements specified in the previous sections. This document also makes a recommendation for how the gaps not supported should be filled, including the need for development of new models and evolution of existing models and documents.

Models are available for microwave radio link functionality: "Microwave Information Model" by the ONF [ONF-MW] and "Microwave Radio Link YANG Data Models" submitted to and discussed by the CCAMP Working Group [CCAMP-MW]. The analysis in this document takes these initiatives into consideration and makes a recommendation on how to use and complement them in order to fill the gaps identified.

For generic functionality, not functionality specific to radio link, the ambition is to refer to existing or emerging models that could be applicable for all functional areas in a microwave node.

6.1. Microwave Radio Link Functionality

[ONF-CIM] defines a CoreModel of the ONF Common Information Model. An information model describes the things in a domain in terms of objects, their properties (represented as attributes), and their relationships. The ONF information model is expressed in Unified Modeling Language (UML). The ONF CoreModel is independent of specific data-plane technology. The technology-specific content, acquired in a runtime solution via "filled in" cases of specification, augments the CoreModel by providing a forwarding technology-specific representation.

IETF data models define implementations and protocol-specific details. YANG is a data modeling language used to model the configuration and state data. [RFC8343] defines a generic YANG data model for interface management that doesn't include technology-specific information. To describe the technology-specific information, several YANG data models have been proposed in the IETF to augment [RFC8343], e.g., the data model defined in [RFC8344]. The YANG data model is a popular approach for modeling interfaces for many packet transport technologies and is thereby well positioned to become an industry standard. In light of this trend, [CCAMP-MW] provides a YANG data model proposal for radio interfaces that is well aligned with the structure of other technology-specific YANG data models augmenting [RFC8343].

[RFC3444] explains the difference between Information Models (IMs) and Data Models (DMs). An IM models managed objects at a conceptual level for designers and operators, while a DM is defined at a lower level and includes many details for implementers. In addition, the protocol-specific details are usually included in a DM. Since conceptual models can be implemented in different ways, multiple DMs can be derived from a single IM.

It is recommended to use the structure of the model described in [CCAMP-MW] as the starting point, since it is a data model providing the wanted alignment with [RFC8343]. To cover the identified gaps, it is recommended to define new leafs/parameters and include those in the new model [IETF-MW] while taking reference from [ONF-CIM]. It is also recommended to add the required data nodes to describe the interface layering for the capacity provided by a Radio Link Terminal and the associated Ethernet and TDM interfaces in a microwave node. The principles and data nodes for interface layering described in [RFC8343] should be used as a basis.

6.2. Generic Functionality

For generic functionality, not functionality specific to radio links, the recommendation is to refer to existing RFCs or emerging Internet-Drafts according to Figure 4. "[IETF-MW]" is used in Figure 4 for the cases where the functionality is recommended to be included in the new model [IETF-MW] as described in Section 6.1.

Generic Functionality	Recommendation
1. Fault Management	
Alarm Configuration	[IETF-MW]
Alarm Notifications/ Synchronization	[YANG-ALARM]
2. Performance Management	
Performance Configuration/ Activation	[IETF-MW]
Performance Collection	[IETF-MW] and XML files
3. Physical/Equipment Inventory	[RFC8348]

Figure 4: Recommendation for How to Support Generic Functionality

Microwave-specific alarm configurations are recommended to be included in the new model [IETF-MW] and could be based on what is supported in the models described in [ONF-MW] and [CCAMP-MW]. Alarm notifications and synchronization are general and are recommended to be supported by a generic model, such as [YANG-ALARM].

Activation of interval counters and thresholds could be a generic function, but it is recommended to be supported by the new model [IETF-MW]. It can be based on the models described in [ONF-MW] and [CCAMP-MW].

Collection of interval/historical counters is a generic function that needs to be supported in a node. File-based collection via the SSH File Transfer Protocol (SFTP) and collection via NETCONF/YANG interfaces are two possible options; the recommendation is to include

support for the latter in the new model [IETF-MW]. The models described in [ONF-MW] and [CCAMP-MW] can also be used as a basis in this area.

Physical and/or equipment inventory associated with the Radio Link Terminals and Carrier Terminations is recommended to be covered by a generic model for the complete node, e.g., the model defined in [RFC8348]. It is thereby outside the scope of the new model [IETF-MW].

6.3. Summary

The conclusions and recommendations from the analysis can be summarized as follows:

1. A new YANG data model for radio link [IETF-MW] should be defined with enough scope to support the use cases and requirements in Sections 4 and 5 of this document.
2. Use the structure of the model described in [CCAMP-MW] as the starting point. It augments [RFC8343] and is thereby as required aligned with the structure of the models for management of the L2 and L3 domains.
3. Use established microwave equipment and radio standards (such as [EN302217-2], the model described in [CCAMP-MW], and the model described in [ONF-MW]) as the basis for the definition of the detailed leafs/ parameters to support the specified use cases and requirements, proposing new ones to cover identified gaps.
4. Add the required data nodes to describe the interface layering for the capacity provided by a Radio Link Terminal and the associated Ethernet and TDM interfaces, using the principles and data nodes for interface layering described in [RFC8343] as a basis.
5. Include support for configuration of microwave-specific alarms in the new YANG data model [IETF-MW] and rely on a generic model such as [YANG-ALARM] for notifications and alarm synchronization.
6. Use a generic model such as [RFC8348] for physical/equipment inventory.

7. Security Considerations

The configuration information may be considered sensitive or vulnerable in network environments. Unauthorized access to configuration data nodes can have a negative effect on network operations, e.g., interrupting the ability to forward traffic or increasing the interference level of the network. The status and inventory reveal some network information that could be very helpful to an attacker. A malicious attack to that information may result in a loss of customer data. Security issues concerning the access control to management interfaces can be generally addressed by authentication techniques providing origin verification, integrity, and confidentiality. In addition, management interfaces can be physically or logically isolated by configuring them to be only accessible out-of-band, through a system that is physically or logically separated from the rest of the network infrastructure. In cases where management interfaces are accessible in-band at the client device or within the microwave transport network domain, filtering or firewalling techniques can be used to restrict unauthorized in-band traffic. Additionally, authentication techniques may be used in all cases.

This framework describes the requirements and characteristics of a YANG data model for control and management of the radio link interfaces in a microwave node. It is supposed to be accessed via a management protocol with a secure transport layer, such as NETCONF [RFC6241].

8. IANA Considerations

This document has no IANA actions.

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