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A framework for Management and Control of microwave and millimeter wave interface parameters
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Abstract

To ensure an efficient data transport, meeting the requirements requested by today's transport services, the unification of control and management of microwave and millimeter wave radio link interfaces is a precondition for seamless multilayer networking and automated network wide 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. It focuses on the benefits of a standardized management model that is aligned with how other packet technology interfaces in a microwave/millimeter wave node are modeled, the need to support core parameters and at the same time allow for optional product/feature specific parameters supporting new, unique innovative features until they have become mature enough to be included in the standardized model.

The purpose is to create a framework for identification of the necessary information elements and definition of a YANG Data Model for control and management of the radio link interfaces in a microwave/millimeter wave node.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Terminology and Definitions

Microwave is a band of spectrum with wavelengths ranging from 1 meter to 1 millimeter and with frequencies ranging between 300 MHz and 300 GHz. Microwave radio technology is widely used for point-to-point telecommunications because of their small wavelength that allows conveniently-sized antennas to direct them in narrow beams, and their comparatively higher frequencies that allows broad bandwidth and high data transmission rates.

Millimeter wave is also known as extremely high frequency (EHF) or very high frequency (VHF) by the International Telecommunications Union (ITU), which can be used for high-speed wireless broadband communications. Millimeter wave can be used for a broad range of fixed and mobile services including high-speed, point-to-point wireless local area networks (WLANs) and broadband access. This band has short wavelengths that range from 10 millimeters to 1 millimeter, namely millimeter band or millimeter wave. The 71 - 76 GHz, 81 - 86 GHz and 92-95 GHz bands are used for point-to-point high-bandwidth communication links, which allows for higher data rates up to 10 Gbit/s but requires a license. Unlicensed short-range data links can be used on 60 GHz millimeter wave. For instance, the upcoming IEEE Wi-Fi standard 802.11ad will run on the 60 GHz spectrum with data transfer rates of up to 7 Gbit/s.

Carrier Termination is 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 is an interface providing packet capacity and/or TDM capacity to the associated Ethernet and/or TDM interfaces in a node and used for setting up a transport service over a microwave/millimeter wave link.

Figure 1 provides a graphical representation of Carrier Termination and Radio Link Terminal concepts.

```
                  /--------- Radio Link ---------\
                   Near End              Far End

            +---------------+           +---------------+
            |    Radio Link |           | Radio Link    |
            |      Terminal |           | Terminal      |
            |               |           |               |
            |           (Protected or Bonded)           |
            |               |           |               |
            | +-----------+ |           | +-----------+ |
            | |           | | Carrier A | |           | |
            | |  Carrier  | |<--------->| |  Carrier  | |
            | |Termination| |           | |Termination| |
    Packet--| |           | |           | |           | |--Packet
            | +-----------+ |           | +-----------+ |
     TDM----|               |           |               |----TDM
            | +-----------+ |           | +-----------+ |
            | |           | | Carrier B | |           | |
            | |  Carrier  | |<--------->| |  Carrier  | |
            | |Termination| |           | |Termination| |
            | |           | |           | |           | |
            | +-----------+ |           | +-----------+ |
            |               |           |               |
            +---------------+           +---------------+

      \--- Microwave Node ---/          \--- Microwave Node ---/
```

Figure 1. Radio Link Terminal and Carrier Termination

Software Defined Networking (SDN) is an emerging 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. This results in an extremely dynamic, manageable, cost-effective, and adaptable architecture that gives administrators unprecedented programmability, automation, and control. The SDN concept is widely applied for network management, the adoption of SDN framework to manage and control the microwave and millimeter wave interface is one of the key applications of this work.

2. Introduction

Network requirements vary between operators globally as well as within individual countries. The overall goal is however the same - to deliver the best possible network performance and quality of experience in a cost-efficient way.

Microwave/millimeter wave (hereafter referred to as microwave, but including the frequency bands represented by millimeter wave) are important technologies to fulfill this goal today, but also in the future when demands on capacity and packet features increases.

Microwave is already today 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 beyond 10 gigabits in the millimeter wave. L2 packet features are normally an integrated part of microwave nodes and more advanced L2 & L3 features will over time be introduced to support the evolution of the transport services to be provided by a backhaul/transport network. Note that the wireless access technologies such as 3/4/5G & WiFi are not within the scope of this microwave model work.

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 is a question about fiber presence and cost of ownership, not about capacity limitations in microwave.

Open and standardized interfaces are a pre-requisite 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 the relationship to other packet interfaces, typically to 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 functionality.

Already today there are numerous IETF data models, RFCs and drafts, with technology specific extensions that cover a large part of the packet domain. Examples are IP Management [RFC7277], Routing Management [I-D.ietf-netmod-routing-cfg] and Provider Bridge [PB-YANG] They are based on RFC 7223 [RFC7223], which is the IETF YANG model for Interface Management, and is an evolution of the SNMP IF-MIB [RFC2863].

Since microwave nodes will contain more and more packet functionality which is expected to be managed using those models, there are advantages if radio link interfaces can be modeled and be managed using the same structure and the same approach, specifically for use cases in which a microwave node are managed as one common entity including both the radio link and the packet functionality, e.g. at basic configuration of node & connections, centralized trouble shooting, upgrade and maintenance. All interfaces in a node, irrespective of technology, would then be accessed from the same core model, i.e. RFC 7223, 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, e.g the slot in which 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.

```
   +-------------------------------------------------------------------+
   | Interface [RFC7223]                                               |
   |                +-------------------+                              |
   |                |Ethernet Port      |                              |
   |                +-------------------+                              |
   |                      \                                            |
   |                    +------------------------+                     |
   |                    |Radio Link Terminal     |                     |
   |                    +------------------------+                     |
   |                               \                                   |
   |                            +------------------------+             |
   |                            |Carrier Termination     |             |
   |                            +------------------------+             |
   +-------------------------------------------------------------------+
```

Figure 2: Relationship between interfaces in a node

There will always be certain implementations that differ among products and it is therefore 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 be optional or to be covered by extensions to the standardized model. Furthermore, a standard that allows for a certain degree of freedom encourages innovation and competition which is something that benefits the entire industry. It is therefore important that a radio link management model covers all relevant functions but also leaves room for product/feature-specific extensions.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The purpose of this effort 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 and requirements agreed to be covered, the expected characteristics of the model and at the end includes an analysis of how the models in the two on-going initiatives fulfill these expectations and a recommendation on what can be reused and what gaps need to be filled by a new and evolved radio link model.

3. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

While [RFC2119] describes interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe requirements for the YANG Data Model for Microwave Radio Link.

4. Approaches to manage and control radio link interfaces

This framework addresses the definition of an open and standardized interface for the radio link functionality in a microwave/millimeter wave node. The application of such an interface used for management and control of nodes and networks typically vary from one operator to another, in terms of the systems used and how they interact. A traditional solution is network management system, while an emerging one is SDN. SDN solutions can be used as part of the network management system, allowing for direct network programmability and automated configurability by means of a centralized SDN control and defining standardized interfaces to program the nodes.

4.1. Network Management Solutions

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

4.2. 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 E2E network service management. The vision is to have a global view of the network conditions spanning across different vendors? equipment and multiple technologies.

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

On top of SDN applications to configure, manage and control the nodes and their associated transport interfaces including the L2 and L3 packet/Ethernet interfaces as well as the radio interfaces, there are also a large variety of other more advanced SDN applications that can be exploited and/or developed.

A potential flexible approach for the operators is to use SDN in a logical control way to manage 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 avail- ability	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 into certain set of attributes is out of scope of this document. Effort on a standardizing operation mode is required to implement a smoothly operator environment.

5. Use Cases

The use cases described should be the basis for identification and definition of the parameters to be supported by a YANG Data model for management of radio links, applicable for centralized, unified, multi-vendor management.

Other product specific use cases, addressing e.g. installation, on-site trouble shooting 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.

5.1. Configuration Management

Configuration of a radio link terminal, the constituent carrier terminations and when applicable the relationship to packet/Ethernet and TDM interfaces.

5.1.1. Understand the capabilities & limitations

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

Support for the XPIC (Cross Polarization Interference Cancellation) feature or not and the maximum modulation supported are two examples on information that could be exchanged.

5.1.2. Initial Configuration

Initial configuration of a radio link terminal, enough to establish L1 connectivity over the hop to an associated radio link terminal on a device at far end. 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.

5.1.3. Radio link re-configuration & optimization

Re-configuration, update or optimization of an existing radio link terminal. Output power and modulation for a carrier termination and protection schemas and activation/de-activation of carriers in a radio link terminal are examples on parameters that can be re-configured and used for optimization of the performance of a network.

5.1.4. Radio link logical configuration

Radio link terminals comprising 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.

5.2. Inventory

5.2.1. Retrieve logical inventory & configuration from device

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

5.2.2. Retrieve physical/equipment inventory from device

Request from manager about physical and/or equipment inventory associated with the radio link terminals and carrier terminations.

5.3. Status & statistics

5.3.1. Actual status & 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.

5.4. Performance management

5.4.1. Configuration of historical measurements to be performed

Configuration of historical measurements to be performed on a radio link interface and/or its constituent parts is a subset of the configuration use case to be supported. See 5.1 above.

5.4.2. 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 same cases required as a complement to the retrieval in bulk as described above.

5.5. Fault Management

5.5.1. 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 5.1 above.

5.5.2. Alarm management

Alarm synchronization, visualization & handling, and notifications & events are generic use cases for a device and not specific to a radio link interface and should be supported accordingly.

5.6. Troubleshooting and Root Cause Analysis

Information and 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.

6. Requirements

For managing a microwave node including both the radio link and the packet functionality, a unified data model is desired to unify the modeling of the radio link interfaces and the packet interfaces using the same structure and the same modelling approach.

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

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

1) It MUST be possible to configure, manage and control a radio link terminal and the constituent carrier terminations.

   a) Frequency, channel bandwidth, modulation, coding and transmitter power are examples of parameters typically configured 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.

2) It MUST be possible to map different traffic types (e.g. TDM, 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 5.4) to be performed on a radio link interface, e.g. minimum, maximum and average transmit power and receive level in dBm.

4) It MUST be possible to configure and retrieve alarms reporting associated with the radio interfaces, e.g. configuration of alarm severity, supported alarms like configuration fault, signal lost, modem fault, radio fault.

7. Gap Analysis on Models

The purpose of the gap analysis is to identify and recommend what existing and established models as well as draft models under definition to support the use cases and requirements specified in the previous chapters. It shall also make a recommendation on how the gaps not supported should be filled, including the need for development of new models and evolution of existing models and drafts.

For microwave radio link functionality work has been initiated (ONF: Microwave Modeling [ONF-model], IETF: Radio Link Model [I-D.ahlbergccamp-microwave-radio-link]. The analysis is expected to take these initiatives into consideration and make a recommendation on how to make use of them and how to complement them in order to fill the gaps identified.

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

7.1. 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. Data plane technology specific properties are acquired in a runtime solution via "filled in" cases of specification (LtpSpec etc). These can be used to augment the CoreModel to provide a data plane technology specific representation.

IETF Data Model defines an implementation and NETCONF-specific details. YANG is a data modeling language used to model the configuration and state data. It is well aligned with the structure of the Yang data models proposed for the different packet interfaces which are all based on RFC 7223. Furthermore, several YANG data models have been proposed in the IETF for other transport technologies such as optical transport; e.g., RFC 7277 [RFC7277], [I.D.zhang-ccamp-l1-topo-yang], [I.D.ietf-ospf-yang]. In light of this trend, the IETF data model is becoming a popular approach for modeling most packet transport technology interfaces and it is thereby well positioned to become an industry standard.

RFC 3444 [RFC3444] explains the difference between Information Model(IM) and Data Models(DM). IM is to model managed objects at a conceptual level for designers and operators, DM is defined at a lower level and includes many details for implementers. In addition, the protocol-specific details are usually included in DM. Since conceptual models can be implemented in different ways, multiple DMs can be derived from a single IM. To ensure better interoperability, it is better to focus on DM directly.

RFC 7223 describes an interface management model, however it doesn?t include technology specific information, e.g., for radio interface. [I-D.ahlberg-ccamp-microwave-radio-link] provides a model proposal for radio interfaces, which includes support for basic configuration, status and performance but lacks full support for alarm management and interface layering, i.e. the connectivity of the transported capacity (TDM & Ethernet) with other internal technology specific interfaces in a microwave node.

The recommendation is to use the structure of the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point, since it is a data model providing the wanted alignment with RFC 7223. For the definition of the detailed leafs/parameters, the recommendation is to use the IETF: Radio Link Model and the ONF: Microwave Modeling [ONF-model] as the basis and to define new ones to cover identified gaps. The parameters in those models have been defined by both operators and vendors within the industry and the implementations of the ONF Model have been tested in the Proof of Concept events in multi-vendor environments, showing the validity of the approach proposed in this framework document.

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 RFC 7223 should be used as a basis.

7.2. Generic Functionality

For generic functionality, not specific for radio link, the recommendation is to refer to existing RFCs or emerging drafts according to the table in figure 4 below. New Radio Link Model is used in the table for the cases where the functionality is recommended to be included in the new radio link model as described in chapter 7.1.

Generic Functionality	Recommendation
1.Fault Management	
Alarm Configuration	New Radio Link Model
Alarm notifications/ synchronization	[I-D.vallin-netmod- alarm-module]
2.Performance Management	
Performance Configuration/ Activation	New Radio Link Model
Performance Collection	New Radio Link Model & XML files
3.Physical/Equipment Inventory	[I-D.ietf-netmod-entity]

Figure 4. Recommendation on how to support generic functionality

Microwave specific alarm configurations are recommended to be included in the new radio link model and could be based on what is supported in the IETF and ONF Radio Link Models. Alarm notifications and synchronization are general and is recommended to be supported by a generic model, such as [I-D.vallin-netmod-alarm-module].

Activation of interval counters & thresholds could be a generic function but it is recommended to be supported by the new radio link specific model and can be based on both the ONF and IETF Microwave Radio Link models.

Collection of interval/historical counters is a generic function that needs to be supported in a node. File based collection via SFTP and collection via a Netconf/YANG interfaces are two possible options and the recommendation is to include support for the latter in the new radio link specific model. The ONF and IETF Microwave Radio Link models can be used as a basis also in this area.

Physical and/or equipment inventory associated with the radio link terminals and carrier terminations is recommended to be covered by a model generic for the complete node, e.g. [I-D.ietf-netmod-entity] and it is thereby outside the scope of the radio link specific model.

7.3. Summary

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

1) A Microwave Radio Link YANG Data Model should be defined with a scope enough to support the use cases and requirements in chapter 5 and 6 of this document.

2) Use the structure in the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] as the starting point. It augments RFC 7223 and is thereby as required aligned with the structure of the models for management of the packet domain.

3) Use the IETF: Radio Link Model [I-D.ahlberg-ccamp-microwave-radio-link] and the ONF: Microwave Modeling [ONF-model] as the basis for the definition of the detailed leafs/parameters to support the specified use cases and requirements, and 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 RFC 7223 as a basis.

5) Include support for configuration of microwave specific alarms in the Microwave Radio Link model and rely on a generic model such as [I.D.vallin-netmod-alarm-module] for notifications and alarm synchronization.

6) Use a generic model such as [I-D.ietf-netmod-entity] for physical/equipment inventory.

It is furthermore recommended that the Microwave Radio Link YANG Date Model should be validated by both operators and vendors as part of the process to make it stable and mature.

8. Security Considerations

TBD

9. IANA Considerations

This memo includes no request to IANA.

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