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

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Abstract

The unification of control and management of microwave radio link interfaces is a precondition for seamless multilayer 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 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 node. Some parts of the resulting model may be generic which could also be used by other technologies, e.g., ETH technology.

Status of This Memo

This Internet-Draft will expire on November 19, 2018.

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Table of Contents

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

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 higher frequency bands with more band width. L2 Ethernet features are normally an integrated part of microwave nodes and more advanced L2 and 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 and Wi-Fi are not within the scope of this microwave model work.

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 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 transport functionality.

Already today there are numerous IETF data models, RFCs and drafts, with technology specific extensions that cover a large part of the L2 and L3 domains. Examples are IP Management [RFC8344], Routing Management [RFC8349] and Provider Bridge [PB-YANG]. They are based on the IETF YANG 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 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 is managed as one common entity including both the radio link and the L2 and L3 functionality, e.g. at basic configuration of node and 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. [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, 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 [RFC8343]                                              |
|                 +---------------+                                |
|                 | Ethernet Port |                                |
|                 +---------------+                                |
|                       \                                          |
|                     +---------------------+                      |
|                     | Radio Link Terminal |                      |
|                     +---------------------+                      |
|                        /              \                          |
|      +---------------------+      +---------------------+        |
|      | Carrier Termination |      | Carrier Termination |        |
|      +---------------------+      +---------------------+        |
+------------------------------------------------------------------+
```

Figure 1: 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.ietf-ccamp-mw-yang]). 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.

1.1. 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 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

While [RFC2119] [RFC8174] describes interpretations of these key words in terms of protocol specifications and implementations, they are used in this document to describe high level requirements to be met when defining the YANG Data Model for Microwave Radio Link.

This document does not define any protocol extension, hence only [RFC2119] [RFC8174] can be considered as a normative reference. However, the list of normative references includes a number of documents that can be useful for a better understanding of the context.

2. Terminology and Definitions

Microwave radio is a term commonly used for technologies that operate in both microwave and millimeter wave lengths 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 and in 70/80 GHz band up to 10 Gbps. Using multi-carrier systems operating in frequency bands with wider channels, the technology will be capable of providing capacities up 100 Gbps.

The microwave radio technology is widely used for point-to-point telecommunications because of its small wavelength that allows conveniently-sized antennas to direct them in narrow beams, and the comparatively higher frequencies that 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.

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

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

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 Ethernet capacity and/ or Time Division Multiplexing (TDM) capacity to the associated Ethernet and/or TDM interfaces in a node and used for setting up a transport service over a microwave radio link.

Figure 2 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| |
    ETH----| |           | |           | |           | |----ETH
           | +-----------+ |           | +-----------+ |
    TDM----|               |           |               |----TDM
           | +-----------+ |           | +-----------+ |
           | |           | | Carrier B | |           | |
           | |  Carrier  | |<--------->| |  Carrier  | |
           | |Termination| |           | |Termination| |
           | |           | |           | |           | |
           | +-----------+ |           | +-----------+ |
           |               |           |               |
           +---------------+           +---------------+

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

Figure 2: Radio Link Terminal and Carrier Termination

Software Defined Networking (SDN) is 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 as a term for automation of traditional network management, which can be implemented using a similar approach. The adoption of an SDN framework for management and control the microwave interface is the key purpose of this work.

3. 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 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(NMS), 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 standardized interfaces to program the nodes. It's noted that there's idea that the NMS and SDN are evolving towards a component, and the distinction between them is quite vague. Another fact is that there is still plenty of networks where NMS is still considered as the implementation of the management plane, while SDN is considered as the centralization of the control plane. They are still kept as separate components.

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 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.

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 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 Ethernet and L3 IP 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 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 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.

4. 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.

4.1. Configuration Management

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

4.1.1. 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.

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.

4.1.2. Initial Configuration

Initial configuration of a radio link terminal, enough to establish L1 connectivity to an associated radio link terminal on a device at 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.

4.1.3. Radio link re-configuration and 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.

4.1.4. 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.

4.2. Inventory

4.2.1. Retrieve logical inventory and configuration from device

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

4.2.2. Retrieve physical/equipment inventory from device

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

4.3. Status and statistics

4.3.1. 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

4.4.1. 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 Section 4.1 above.

4.4.2. 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.

4.5. Fault Management

4.5.1. 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 Section 4.1 above.

4.5.2. Alarm management

Alarm synchronization, visualization, handling, notifications and events are generic use cases for a device and not specific to a radio link interface and should be supported accordingly. It's important to report signal degradation of the radio link.

4.6. 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.

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 modelling approach. If some part of 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 modelling:

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 1.4GHz to 86GHz.

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.

6. 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.ietf-ccamp-mw-yang]. 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.

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. 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 interfaces which are all based on [RFC8343]. Furthermore, several YANG data models have been proposed in the IETF for other transport technologies such as optical transport; e.g. [RFC8344], [I-D.ietf-ccamp-otn-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.

[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.

[RFC8343] describes an interface management model, however it doesn't include technology specific information, e.g., for radio interface. [I-D.ietf-ccamp-mw-yang] 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 and 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.ietf-ccamp-mw-yang] as the starting point, since it is a data model providing the wanted alignment with [RFC8343]. 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 [RFC8343] should be used as a basis.

6.2. 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 Section 6.1.

Generic Functionality	Recommendation
1.Fault Management	
Alarm Configuration	New Radio Link Model
Alarm notifications/ synchronization	[I-D.ietf-ccamp-alarm-module]
2.Performance Management	
Performance Configuration/ Activation	New Radio Link Model
Performance Collection	New Radio Link Model and XML files
3.Physical/Equipment Inventory	[RFC8348]

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.ietf-ccamp-alarm-module].

Activation of interval counters and 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 SSH File Transfer Protocol(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. [RFC8348] and it is thereby outside the scope of the radio link specific model.

6.3. 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 Sections 4 and 5 of this document.

2. Use the structure in the IETF: Radio Link Model [I-D.ietf-ccamp-mw-yang] 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], and the IETF: Radio Link Model [I-D.ietf-ccamp-mw-yang] 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 [RFC8343] 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.ietf-ccamp-alarm-module] for notifications and alarm synchronization.

6. Use a generic model such as [RFC8348] for physical/equipment inventory.

It is furthermore recommended that the Microwave Radio Link YANG Data Model should be validated by both operators and vendors as part of the process to make it stable and mature. During the Hackathon in IETF 99, a project "SDN Applications for microwave radio link via

IETF YANG Data Model" successfully validated this framework and the YANG data model[I-D.ietf-ccamp-mw-yang]. The project also received the BEST OVERALL award from the Hackathon.

7. Security Considerations

Security issue 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 case 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. Authentication techniques may be additionally 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 memo includes no request to IANA.

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC2863] McCloghrie, K. and F. Kastenholz, "The Interfaces Group MIB", RFC 2863, DOI 10.17487/RFC2863, June 2000, <https://www.rfc-editor.org/info/rfc2863>.

[RFC3444] Pras, A. and J. Schoenwaelder, "On the Difference between Information Models and Data Models", RFC 3444, DOI 10.17487/RFC3444, January 2003, <https://www.rfc-editor.org/info/rfc3444>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8343] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 8343, DOI 10.17487/RFC8343, March 2018, <https://www.rfc-editor.org/info/rfc8343>.

[RFC8344] Bjorklund, M., "A YANG Data Model for IP Management", RFC 8344, DOI 10.17487/RFC8344, March 2018, <https://www.rfc-editor.org/info/rfc8344>.

9.2. Informative References

[EN302217-2]
"Fixed Radio Systems; Characteristics and requirements for point to-point equipment and antennas; Part 2: Digital systems operating in frequency bands from 1 GHz to 86 GHz; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU", EN 302 217-2 V3.1.1 , May 2017.

[I-D.ietf-ccamp-alarm-module]
Vallin, S. and M. Bjorklund, "YANG Alarm Module", draft-ietf-ccamp-alarm-module-01 (work in progress), February 2018.

[I-D.ietf-ccamp-mw-yang]
Ahlberg, J., Ye, M., Li, X., Spreafico, D., and M. Vaupotic, "A YANG Data Model for Microwave Radio Link", draft-ietf-ccamp-mw-yang-05 (work in progress), March 2018.

[I-D.ietf-ccamp-otn-topo-yang]
zhenghaomian@huawei.com, z., Fan, Z., Sharma, A., Liu, X., Belotti, S., Xu, Y., Wang, L., and O. Dios, "A YANG Data Model for Optical Transport Network Topology", draft-ietf-ccamp-otn-topo-yang-02 (work in progress), October 2017.

[I-D.ietf-ospf-yang]
Yeung, D., Qu, Y., Zhang, Z., Chen, I., and A. Lindem, "Yang Data Model for OSPF Protocol", draft-ietf-ospf-yang-11 (work in progress), April 2018.

[ONF-CIM] "Core Information Model", version 1.2 , September 2016, <https://www.opennetworking.org/wp-content/uploads/2014/10/TR-512_CIM_(CoreModel)_1.2.zip>.

[ONF-model] "Microwave Information Model", version 1.0 , December 2016, <https://www.opennetworking.org/images/stories/downloads/sdn-resources/technical-reports/TR-532-Microwave-Information-Model-V1.pdf>.

[PB-YANG] "IEEE 802.1X and 802.1Q Module Specifications", version 0.4 , May 2015, <http://www.ieee802.org/1/files/public/docs2015/new-mholness-YANG-8021x-0515-v04.pdf>.

[RFC8348] Bierman, A., Bjorklund, M., Dong, J., and D. Romascanu, "A YANG Data Model for Hardware Management", RFC 8348, DOI 10.17487/RFC8348, March 2018, <https://www.rfc-editor.org/info/rfc8348>.

[RFC8349] Lhotka, L., Lindem, A., and Y. Qu, "A YANG Data Model for Routing Management (NMDA Version)", RFC 8349, DOI 10.17487/RFC8349, March 2018, <https://www.rfc-editor.org/info/rfc8349>.

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