                     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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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 1.4 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.

```
+-------------------------------------------------------------------+
| Interface [RFC8343]                                               |
|                  +---------------+                                |
|                  | Ethernet Port |                                |
|                  +---------------+                                |
|                     \                                             |
|                  +--------------------+                           |
|                  | Radio Link Terminal |                          |
|                  +--------------------+                           |
|                   /                \                              |
|    +--------------------+       +--------------------+            |
|    | Carrier Termination |       | Carrier Termination |         |
|    +--------------------+       +--------------------+            |
+-------------------------------------------------------------------+
```
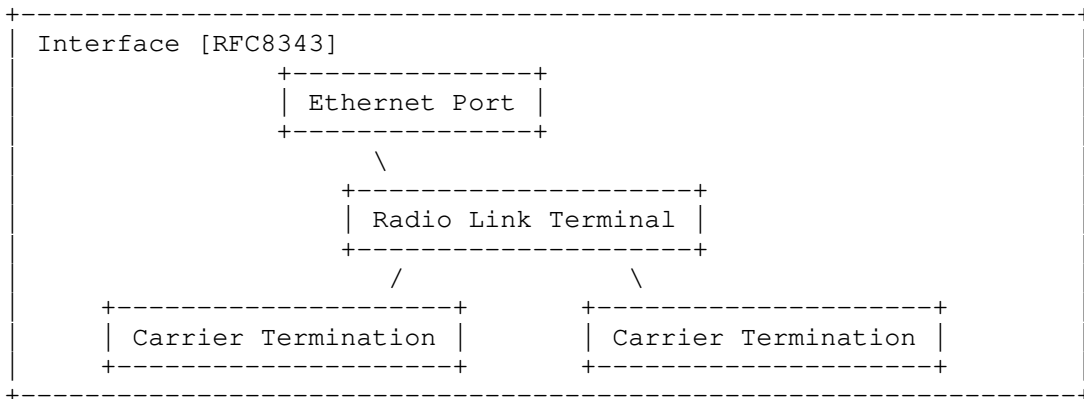
              Figure 1: Relationship between Interfaces in a Node

There will always be certain implementations that differ among
products, 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.

```
              /--------- 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 ---/
```
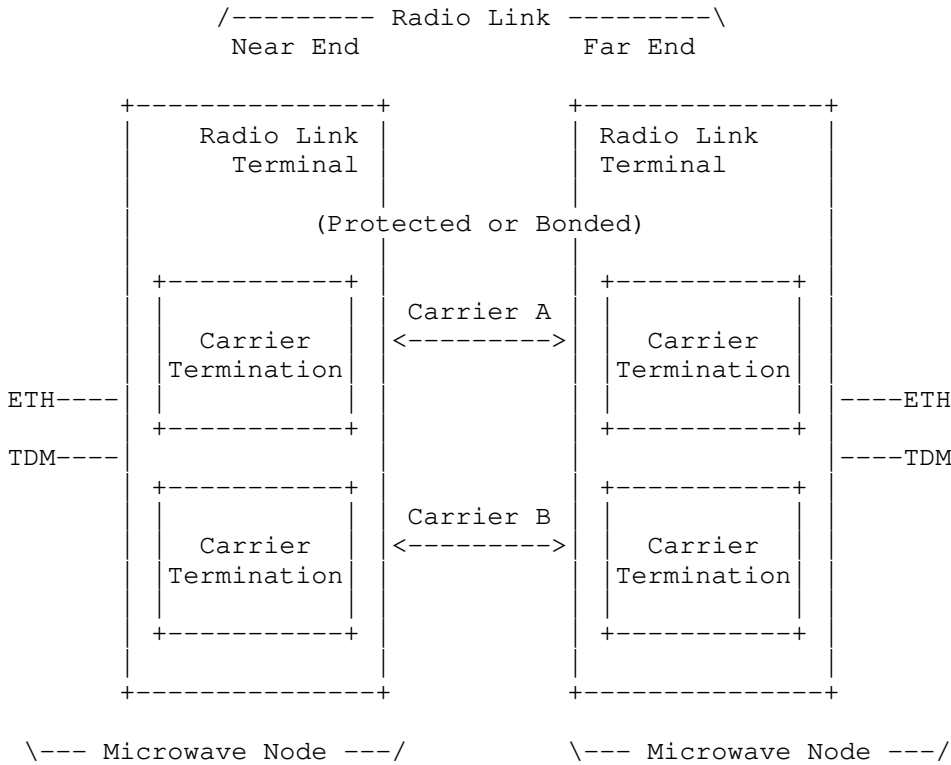
            Figure 2: Radio Link Terminal and Carrier Termination

   Software-Defined Networking (SDN): 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 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 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/	[YANG-ALARM]
Synchronization	
   +----------------------------------+----------------------------------+
2. Performance Management	
Performance Configuration/	[IETF-MW]
Activation	
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.

9. References

9.1. Normative References

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