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J. Ahlberg
S. Mansfield
Ericsson
M. Ye
I. Busi
Huawei Technologies
X. Li
NEC Laboratories Europe
D. Spreafico
Nokia - IT

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A YANG Data Model for Microwave Topology
draft-ietf-ccamp-mw-topo-yang-latest

Abstract

This document defines three YANG data models to describe topologies of microwave/millimeter radio links and bandwidth availability for a link in general, as well as to reference interface management information from a termination point.

Discussion Venues

This note is to be removed before publishing as an RFC.

Source for this draft and an issue tracker can be found at https://github.com/ietf-ccamp-wg/draft-ietf-ccamp-mw-topo-yang.

Status of This Memo

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Authors' Addresses

1. Introduction

This document defines three YANG data models to describe topologies of microwave/millimeter wave (hereafter microwave is used to simplify the text). The first YANG data model describes radio links, supporting carrier(s) and the associated termination points. A carrier is a description of a link providing transport capacity over the air by a single carrier. It is typically defined by its transmitting and receiving frequencies. A radio link is a link providing the aggregated transport capacity of the supporting carriers in aggregated and/or protected configurations, which can be used to carry traffic on higher topology layers such as Ethernet and TDM. A second YANG data model describes bandwidth availability for a link. It is an important characteristic of a microwave radio link, but it could also be applicable for other types of links. A third YANG data model introduces a way to reference the information in a YANG data model for interface management [RFC8343] from a termination point, which is useful for microwave termination points, but which could also be useful for other types of termination points. All three models augment "YANG Data Model for Traffic Engineering (TE) Topologies" defined in [RFC8795], which is based on "A YANG Data Model for Network Topologies" defined in [RFC8345].

The microwave point-to-point radio technology provides connectivity on L0/L1 over a radio link between two termination points, using one or several supporting carriers in aggregated or protected configurations. That application of microwave technology cannot be used to perform cross-connection or switching of the traffic to create network connectivity across multiple microwave radio links. Instead, a payload of traffic on higher topology layers, normally L2 Ethernet, is carried over the microwave radio link and when the microwave radio link is terminated at the endpoints, cross-connection and switching can be performed on that higher layer creating connectivity across multiple supporting microwave radio links.

The microwave topology, the bandwidth availability, and the interface reference models are expected to be used between a Provisioning

Network Controller (PNC) and a Multi Domain Service Coordinator(MDSC) [RFC8453]. Examples of use cases that can be supported are:

1. Correlation between microwave radio links and the supported links on higher topology layers. e.g. an L2 Ethernet topology. This information can be used to understand how changes in the performance/status of a microwave radio link affects traffic on higher layers.

2. Propagation of relevant characteristics of a microwave radio link, such as bandwidth, to higher topology layers, where it e.g. could be used as a criterion when configuring and optimizing a path for a connection/service through the network end to end.

3. Optimization of the microwave radio link configurations on a network level, e.g. with the purpose to minimize overall interference and/or maximize the overall capacity provided by the links.

4. A microwave radio link could dynamically adjust its bandwidth according to changes in the signal conditions. [RFC8330] defines a mechanism to report bandwidth-availability information through OSPF-TE, but it could also be useful for a controller to access such bandwidth-availability information as part of the topology model when performing a path/route computation.

Different use cases require access to different attributes and in order not to restrict what use cases can be supported, all attributes supported by the microwave radio link interface management model is accessible from the topology model.

1.1. Terminology and Definitions

The following acronyms are used in this document:

PNC Provisioning Network Controller

MDSC Multi Domain Service Coordinator

1.2. Tree Structure

A simplified graphical representation of the data models is used in chapters 3.1, 4.1, and 5.1 of this document. The meaning of the symbols in these diagrams is defined in [RFC8340].

2. Requirements Language

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.

3. Microwave Topology YANG Data Model

3.1. YANG Tree

```
module: ietf-microwave-topology

augment /nw:networks/nw:network/nw:network-types/tet:te-topology:
  +--rw mw-topology!
augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
  +--rw mw-tp-choice
     +--rw (mw-tp-option)?
        +--:(microwave-rltp)
        |  +--rw microwave-rltp!
```

```
         +--:(microwave-ctp)
            +--rw microwave-ctp!
augment
 /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  +--rw mw-link-choice
     +--rw (mw-link-option)?
        +--:(microwave-radio-link)
        |  +--rw microwave-radio-link!
        |     +--rw mode?   identityref
        +--:(microwave-carrier)
           +--rw microwave-carrier!
              +--rw tx-frequency?               uint32
              +--rw rx-frequency?               uint32
              +--rw channel-separation?         uint32
              +--ro actual-tx-cm?               identityref
              +--ro actual-snir?                decimal64
              +--ro actual-transmitted-level?   power
augment /nw:networks/nw:network/nt:link/tet:te/
          tet:te-link-attributes/tet:max-link-bandwidth/
          tet:te-bandwidth/tet:technology:
  +--:(microwave)
     +--ro mw-bandwidth?   uint64
```

3.2. Relationship between radio links and carriers

A microwave radio link is always an aggregate of one or multiple carries, in various configurations/modes. The supporting carriers are identified by its termination points and are listed in the container bundled-links as part of the te-link-config in the YANG Data Model for Traffic Engineering (TE) Topologies [RFC8795] for a radio-link. The exact configuration of the included carriers is further specified in the leaf mode (1+0, 2+0, 1+1, etc.) for the radio-link. Appendix A includes an JSON example of how such a relationship can be modelled.

3.3. Relationship with client topology model

A microwave radio link carries a payload of traffic on higher topology layers, normally L2 Ethernet. The leafs supporting-network, supporting-node, supporting-link, and supporting-termination-point in the generic YANG module for Network Topologies [RFC8345] are expected to be used to model a relationship/dependency from higher topology layers to a supporting microwave radio link topology layer. Appendix A includes an JSON example of an L2 Ethernet link transported over one supporting microwave link.

3.4. Applicability of the Data Model for Traffic Engineering (TE) Topologies

Since microwave is a point-to-point radio technology providing connectivity on L0/L1 over a radio link between two termination points and cannot be used to perform cross-connection or switching of the traffic to create network connectivity across multiple microwave radio links, a majority of the leafs in the Data Model for Traffic Engineering (TE) Topologies augmented by the microwave topology model are not applicable. An example of which leafs are considered applicable can be found in appendix "Examples of the application of the Topology Models" in this document. Appendix A

More specifically, admin-status and oper-status are recommended to be reported for links only. Status for termination points can be used when links are inter-domain and when the status of only one side of link is known, but since microwave is a point-to-point technology where both ends normally belong to the same domain it is not expected to be applicable in normal cases. Furthermore, admin-status is not applicable for microwave radio links. Enable and disable of a radio

link is instead done in the constituent carriers.

3.5. Model applicability to other technology

TBD

3.6. Microwave Topology YANG Module

```
<CODE BEGINS> file "ietf-microwave-topology@2021-10-20.yang"
 module ietf-microwave-topology {
   yang-version "1.1";
   namespace
   "urn:ietf:params:xml:ns:yang:ietf-microwave-topology";

   prefix "mwtopo";

   import ietf-network {
     prefix "nw";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-network-topology {
     prefix "nt";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-te-topology {
     prefix "tet";
     reference "RFC 8795: YANG Data Model for Traffic Engineering
                (TE) Topologies";
   }

   import ietf-microwave-types {
     prefix mw-types;
     reference "RFC 8561";
   }

   organization
     "Internet Engineering Task Force (IETF) CCAMP WG";
   contact
     "WG List: <mailto:ccamp@ietf.org>

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      Editor: Jonas Ahlberg
              <mailto:jonas.ahlberg@ericsson.com>
      Editor: Scott Mansfield
              <mailto:scott.mansfield@ericsson.com>
      Editor: Min Ye
              <mailto:amy.yemin@huawei.com>
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              <mailto:Italo.Busi@huawei.com>
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      Editor: Daniela Spreafico
              <mailto:daniela.spreafico@nokia.com>
     ";

  // Note to RFC Editor: replace XXXX with actual RFC number and
  // remove this note.
   description
     "This is a module for microwave topology.

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    This version of this YANG module is part of RFC XXXX
    (https://tools.ietf.org/html/rfcXXXX); see the RFC itself for
    full legal notices.";

  revision 2021-10-20   {
    description
    "Draft to be used as a basis for the continued microwave
     team discussions";
    reference "";
  }

  /*
   * Typedefs
   */

  typedef power {
    type decimal64 {
      fraction-digits 1;
    }
    description
      "Type used for the power values 'selected' and
       'measured'.";
  }

  /*
   * Groupings
   */
  grouping microwave-rltp-attributes {
    description "Grouping used for attributes describing a microwave
                 radio link termination point.";

//Any attributes to be included?
  }

  grouping microwave-ctp-attributes {
    description "Grouping used for attributes describing a microwave
                 carrier termination point.";

// Any attributes to be included?
  }

  grouping microwave-radio-link-attributes {
    description "Grouping used for attributes describing a microwave
                 radio link.";
    leaf mode {
      type identityref {
        base mw-types:rlt-mode;
      }
      description
        "A description of the mode in which the radio link
         is configured.  The format is X plus Y.
         X represents the number of bonded carriers.
         Y represents the number of protecting carriers.
         Related to the data node rlt-mode in RFC 8561.";
      reference
        "RFC 8561: A YANG Data Model for Microwave Radio Link";
    }
// Any other attributes to be included?
  }

  grouping microwave-carrier-attributes {
    description "Grouping used for attributes describing a microwave
```

```
            carrier.";
leaf tx-frequency {
  type uint32;
  units "kHz";
  description
    "Selected transmitter frequency.
     Related to the data node tx-frequency in RFC 8561.";
  reference
    "RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf rx-frequency {
  type uint32;
  units "kHz";
  description
    "Selected receiver frequency.
     Related to the data node actual-rx-frequency in RFC 8561.";
  reference
    "RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf channel-separation {
  type uint32;
  units "kHz";
  description
    "The amount of bandwidth allocated to a carrier.  The
     distance between adjacent channels in a radio
     frequency channels arrangement.
     Related to the data node channel-separation in RFC 8561.";
  reference
    "ETSI EN 302 217-1 and
     RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf actual-tx-cm {
  type identityref {
    base mw-types:coding-modulation;
  }
  config false;
  description
    "Actual coding/modulation in transmitting direction.
     Related to the data node actual-tx-cm in RFC 8561.";
  reference
    "RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf actual-snir {
  type decimal64 {
    fraction-digits 1;
    range "0..99";
  }
  units "dB";
  config false;
  description
    "Actual signal to noise plus the interference ratio
     (0.1 dB resolution).
     Related to the data node actual-snir in RFC 8561.";
  reference
    "RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf actual-transmitted-level {
  type power {
    range "-99..99";
  }
  units "dBm";
  config false;
  description
    "Actual transmitted power level (0.1 dBm resolution).
     Related to the data node actual-transmitted-level
     in RFC 8561.";
```

```
      reference
        "ETSI EN 301 129 and
         RFC 8561: A YANG Data Model for Microwave Radio Link";
    }

//Any other attributes to be included?
  }

  grouping microwave-bandwidth {
    description "Grouping used for microwave bandwidth.";
    leaf mw-bandwidth {
      type uint64;
      units "Kbps";
      config false;
      description
        "Nominal microwave radio link and carrier bandwidth.";
    }
  }

  /*
   * Data nodes
   */
  augment "/nw:networks/nw:network/nw:network-types/"
          + "tet:te-topology" {
    description
      "Augment network types to define a microwave network
       topology type.";
    container mw-topology {
      presence "Indicates a topology type of microwave.";
      description "Microwave topology type";
    }
  }

  augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
          + "tet:te" {
    when '../../../nw:network-types/tet:te-topology/'
         + 'mwtopo:mw-topology' {
      description
        "Augmentation parameters apply only for networks with an
         microwave network topology type.";
    }
    description
      "Augmentation to add microwave technology specific
       characteristics to a termination point.";
    container mw-tp-choice {
      description "Specification of type of termination point.";
      choice mw-tp-option {
        description "Selection of type of termination point.";
        case microwave-rltp {
          container "microwave-rltp" {
            presence
              "Denotes a microwave radio link termination point.
               It corresponds to a microwave RLT interface as
               defined in RFC 8561.";
            uses microwave-rltp-attributes;
            description
              "Denotes and describes a microwave radio link
               termination point.";
          }
        }
        case microwave-ctp {
          container "microwave-ctp" {
            presence
              "Denotes a microwave carrier termination point.
               It corresponds to a microwave CT interface as
               defined in RFC 8561.";
```

```
              uses microwave-ctp-attributes;
              description
                "Denotes and describes a microwave carrier
                 termination point.";
            }
          }
        }
      }
    }

    augment "/nw:networks/nw:network/nt:link/tet:te/"
            + "tet:te-link-attributes" {
      when '../../../nw:network-types/tet:te-topology/'
         + 'mwtopo:mw-topology' {
        description
          "Augmentation parameters apply only for networks with an
           microwave network topology type.";
      }
      description
        "Augmentation to add microwave technology specific
         characteristics to a link.";
      container mw-link-choice {
        description "Specification of type of link.";
        choice mw-link-option {
          description "Selection of type of link.";
          case microwave-radio-link {
            container "microwave-radio-link" {
              presence
                "Denotes a microwave radio link";
              uses microwave-radio-link-attributes;
              description
                "Denotes and describes a microwave radio link";
            }
          }
          case microwave-carrier {
            container "microwave-carrier" {
              presence "Denotes a microwave carrier";
              uses microwave-carrier-attributes;
              description "Denotes and describes a microwave carrier";
            }
          }
        }
      }
    }

    augment "/nw:networks/nw:network/nt:link/tet:te/"
            + "tet:te-link-attributes/"
            + "tet:max-link-bandwidth/"
            + "tet:te-bandwidth/tet:technology" {
      when '../../../../../nw:network-types/tet:te-topology/'
           + 'mwtopo:mw-topology' {
        description
          "Augmentation parameters apply only for networks with an
           microwave network topology type.";
      }
      description
        "Augmentation for TE bandwidth.";
      case microwave {
       uses microwave-bandwidth;
      }
    }
  }
<CODE ENDS>
```

4. Bandwidth Availability Topology YANG Data Model

4.1. YANG Tree

```
module: ietf-bandwidth-availability-topology

augment
 /nw:networks/nw:network/nt:link/tet:te/tet:te-link-attributes:
  +--rw link-availability* [availability]
  |  +--rw availability      decimal64
  |  +--rw link-bandwidth?   uint64
  +--ro actual-bandwidth?    yang:gauge64
```

4.2. Bandwidth Availability Topology YANG Data Module

```
<CODE BEGINS> file "ietf-bandwidth-availability-topology.yang"
module ietf-bandwidth-availability-topology {
   yang-version "1.1";
   namespace
  "urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology";
   prefix "bwatopo";

   import ietf-yang-types {
     prefix yang;
     reference
       "RFC 6991";
   }

   import ietf-network {
     prefix "nw";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-network-topology {
     prefix "nt";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-te-topology {
     prefix "tet";
     reference "RFC 8795: YANG Data Model for Traffic Engineering
                (TE) Topologies";
   }

   organization
     "Internet Engineering Task Force (IETF) CCAMP WG";
   contact
     "WG List: <mailto:ccamp@ietf.org>

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       Editor: Xi Li
               <mailto:Xi.Li@neclab.eu>
       Editor: Daniela Spreafico
               <mailto:daniela.spreafico@nokia.com>
     ";

   // Note to RFC Editor: replace XXXX with actual RFC number and
   // remove this note.
   description
     "This is a module for defining bandwidth availability matrix,
```

```
    for links in a topology. It is intended to be used in
    conjunction with an instance of ietf-network-topology and its

    augmentations.
    Example use cases include:
    - Defining bandwidth availability matrix for a microwave link
    - Defining bandwidth availability matrix for a LAG link
      comprising of two or more member links

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    This version of this YANG module is part of RFC XXXX
    (https://tools.ietf.org/html/rfcXXXX); see the RFC itself for
    full legal notices.";

  revision 2021-10-20 {
    description
    "First rough draft.";
    reference "";
  }

  /*
   * Groupings
   */
  grouping link-bw-availability-table {

    description "Grouping used for bandwidth availability.";

    list link-availability{
      key "availability";
      description
        "Table describing the bandwidths available at corresponding
         availability level for a link.";

      leaf availability {
        type decimal64 {
          fraction-digits 4;
          range "0..99.9999";
        }
        description "Availability level";
      }

      leaf link-bandwidth {
        type uint64;
        units "Kbps";

        description
          "The link bandwidth corresponding to the availability
           level";
      }
    }
    leaf actual-bandwidth{
      type yang:gauge64;
      units "bits/second";
      config false;
      description
        "An estimate of the link's current bandwidth in bits per
         second. Related to the data node speed in RFC 8343.";
      reference
        "RFC 8343: A YANG Data Model for Interface Management";
```

```
      }
    }

    /*
     * Data nodes
     */

    augment "/nw:networks/nw:network/nt:link/tet:te/"
            + "tet:te-link-attributes" {
      description
        "Augmenting link with link bandwidth availability matrix.";
      uses link-bw-availability-table;
    }
  }
<CODE ENDS>
```

5. Termination Point to Interface Reference YANG Data Model

5.1. YANG Tree

```
module: ietf-tp-interface-reference-topology

augment /nw:networks/nw:network/nw:node/nt:termination-point/tet:te:
  +--rw tp-to-interface-path?   -> /if:interfaces/interface/name
```

5.2. Termination Point to Interface Reference YANG Data Module

```
<CODE BEGINS> file "ietf-tp-interface-reference-topology.yang"
module ietf-tp-interface-reference-topology {
  yang-version "1.1";
   namespace
  "urn:ietf:params:xml:ns:yang:ietf-tp-interface-reference-topology";

   prefix "ifref";

   import ietf-network {
     prefix "nw";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-network-topology {
     prefix "nt";
     reference "RFC 8345: A YANG Data Model for Network Topologies";
   }

   import ietf-te-topology {
     prefix "tet";
     reference "RFC 8795: YANG Data Model for Traffic Engineering
                (TE) Topologies";
   }

   import ietf-interfaces {
     prefix if;
     reference
       "RFC 8343";
   }

   organization
     "Internet Engineering Task Force (IETF) CCAMP WG";
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     "WG List: <mailto:ccamp@ietf.org>

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      Editor: Jonas Ahlberg
              <mailto:jonas.ahlberg@ericsson.com>
      Editor: Scott Mansfield
```

```
            <mailto:scott.mansfield@ericsson.com>
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    Editor: Italo Busi
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    Editor: Xi Li
            <mailto:Xi.Li@neclab.eu>
    Editor: Daniela Spreafico

            <mailto:daniela.spreafico@nokia.com>
    ";

  // Note to RFC Editor: replace XXXX with actual RFC number and
  // remove this note.
  description
    "This is a module for defining a reference from a termination
     point in a te topology to a list element in interfaces
     as defined in RFC 8343.

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     This version of this YANG module is part of RFC XXXX
     (https://tools.ietf.org/html/rfcXXXX); see the RFC itself for
     full legal notices.";

  revision 2021-10-20 {
    description
    "First rough draft.";
    reference "";
  }

  /*
   * Groupings
   */
  grouping tp-to-interface-ref {

    description
      "Grouping used for reference between a termination point and
       an interface.";
    leaf tp-to-interface-path {
      type leafref {
        path '/if:interfaces/if:interface/if:name';
      }
      description
        "Leafref expression referencing a list element, identified
         by its name, in interfaces as defined in RFC 8343.";
    }
  }

  /*
   * Data nodes

   */

  augment "/nw:networks/nw:network/nw:node/nt:termination-point/"
          + "tet:te" {
    description
      "Augmentation to add possibility to reference an element
       in the list of interfaces as defined by RFC 8343.";
    uses tp-to-interface-ref;
```

```
    }
  }
<CODE ENDS>
```

6. Security Considerations

The YANG modules specified in this document define schemas for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The NETCONF access control model [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

The YANG modules specified in this document import and augment the ietf-network and ietf-network-topology models defined in [RFC8345]. The security considerations from [RFC8345] are applicable to the modules in this document.

There are a several data nodes defined in these YANG modules that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

In the "ietf-microwave-topology" module:

* rlt-interface-path: A malicious client could set an arbitrary xpath that could allow a client to retrieve incorrect information. Troubleshooting would be difficult because the bad path would not be detectable until the client tries to use the leaf to identify to radio link terminal.

In the "ietf-bandwidth-availability-topology" module:

* availability: A malicious client could attempt to modify the availability level which could modify the intended behavior.

* link-bandwidth: A malicious client could attempt to modify the link bandwidth which could either provide more or less link bandwidth at the indicated availability level, changing the resource allocation in unintended ways.

7. IANA Considerations

IANA is asked to assign a new URI from the "IETF XML Registry" [RFC3688] as follows:

URI: urn:ietf:params:xml:ns:yang:ietf-microwave-topology
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology
Registrant Contact: The IESG
XML: N/A; the requested URI is an XML namespace.

It is proposed that IANA should record YANG module names in the "YANG Module Names" registry [RFC6020] as follows:

Name: ietf-microwave-topology
Maintained by IANA?: N
Namespace: urn:ietf:params:xml:ns:yang:ietf-microwave-topology
Prefix: mwtopo
Reference: RFC XXXX

Name: ietf-bandwidth-availability-topology
Maintained by IANA?: N
Namespace:
urn:ietf:params:xml:ns:yang:ietf-bandwidth-availability-topology
Prefix: bwavtopo
Reference: RFC XXXX

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Appendix A. Examples of the application of the Topology Models

This appendix provides some examples and illustrations of how the Microwave Topology Model and the Bandwidth Availability Topology Model can be used. There is one extended tree to illustrate the complete Microwave Topology Model and a JSON based instantiation of the Microwave Topology Model for a small network example.

A.1. A tree for a complete Microwave Topology Model

The tree below shows the leafs for a complete Microwave Topology Model including the augmented Network Topology Model defined in [RFC8345], Traffic Engineering (TE) Topologies model defined in [RFC8795] and the associated Bandwidth Availability Model.

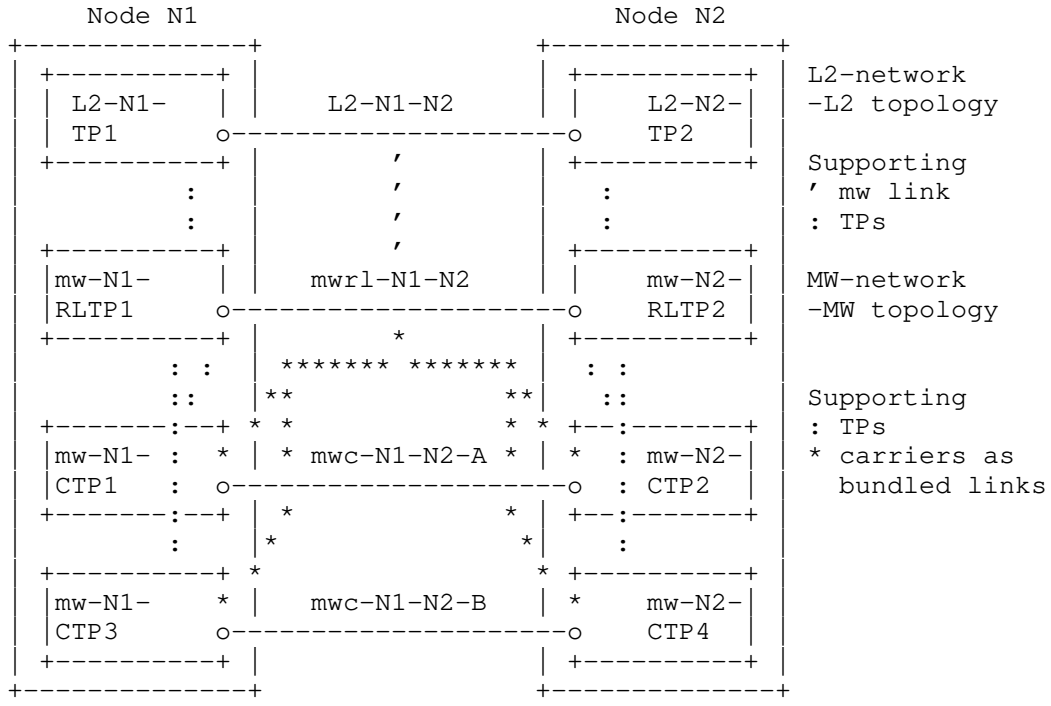
```
module: ietf-network
  +--rw networks
  +--rw network* [network-id]
     +--rw network-id            network-id
     +--rw network-types
     |  +--rw tet:te-topology!
     |     +--rw mwtopo:mw-topology!
     +--rw supporting-network* [network-ref]
     |  +--rw network-ref    -> /networks/network/network-id
     +--rw node* [node-id]
     |  +--rw node-id                 node-id
     |  +--rw supporting-node* [network-ref node-ref]
     |  |  +--rw network-ref
     |  |  |           -> ../../../supporting-network/network-ref
     |  |  +--rw node-ref       -> /networks/network/node/node-id
     |  +--rw nt:termination-point* [tp-id]
     |     +--rw nt:tp-id                           tp-id
     |     +--rw nt:supporting-termination-point*
```

```
|      |  |                      [network-ref node-ref tp-ref]
|      |  +--rw nt:network-ref
|      |  |        -> ../../../nw:supporting-node/network-ref
|      |  +--rw nt:node-ref
|      |  |           -> ../../../nw:supporting-node/node-ref
|      |  +--rw nt:tp-ref
|      |        -> /nw:networks/network[nw:network-id=current()
|      |           /../network-ref]/node[nw:node-id=current()
|      |           /../node-ref]/termination-point/tp-id
|      +--rw tet:te!
|         +--rw tet:admin-status?  te-types:te-admin-status
|         +--rw tet:name?          string
|         +--ro tet:oper-status?   te-types:te-oper-status
|         +--ro tet:geolocation
|         |  +--ro tet:altitude?   int64
|         |  +--ro tet:latitude?   geographic-coordinate-degree
|         |  +--ro tet:longitude?  geographic-coordinate-degree
|         +--rw ifref:tp-to-interface-path?
|         |       -> /if:interfaces/if:interface/if:name
|         +--rw mwtopo:mw-tp-choice
|            +--rw (mwtopo:mw-tp-option)?
|               +--:(mwtopo:microwave-rltp)
|               |  +--rw mwtopo:microwave-rltp!
|               +--:(mwtopo:microwave-ctp)
|                  +--rw mwtopo:microwave-ctp!
|
+--rw nt:link* [link-id]
   +--rw nt:link-id                link-id
   +--rw nt:source
   |  +--rw nt:source-node?   -> ../../../nw:node/node-id
   |  +--rw nt:source-tp?
   |         -> ../../../nw:node[nw:node-id=current()
   |           /../source-node]/termination-point/tp-id
   +--rw nt:destination
   |  +--rw nt:dest-node?   -> ../../../nw:node/node-id
   |  +--rw nt:dest-tp?
   |        -> ../../../nw:node[nw:node-id=current()
   |          /../dest-node]/termination-point/tp-id
   +--rw tet:te!
      +--rw (tet:bundle-stack-level)?
      |  +--:(tet:bundle)
      |     +--rw tet:bundled-links
      |        +--rw tet:bundled-link* [sequence]
      |           +--rw tet:sequence      uint32
      |           +--rw tet:src-tp-ref?   -> ../../../../../
      |           |     nw:node[nw:node-id current()/../../..
      |           |     /../nt:source/source-node]/
      |           |     termination-point/tp-id
      |           +--rw tet:des-tp-ref?   -> ../../../../../
      |                 nw:node[nw:node-id = current()/../../
      |                 ../../nt:destination/dest-node]/
      |                 termination-point/tp-id
      +--rw tet:te-link-attributes
      |  +--rw tet:name?            string
      |  +--rw tet:admin-status?    te-types:te-admin-status
      |  +--rw tet:max-link-bandwidth
      |  |  +--rw tet:te-bandwidth
      |  |     +--rw (tet:technology)?
      |  |        +--:(mwtopo:microwave)
      |  |           +--ro mwtopo:mw-bandwidth? uint64
      |  +--rw mwtopo:mw-link-choice
      |  |   +--rw (mwtopo:mw-link-option)?
      |  |     +--:(mwtopo:microwave-radio-link)
      |  |     |  +--rw mwtopo:microwave-radio-link!
      |  |     |     +--rw mwtopo:mode?   identityref
      |  |     +--:(mwtopo:microwave-carrier)
      |  |        +--rw mwtopo:microwave-carrier!
```

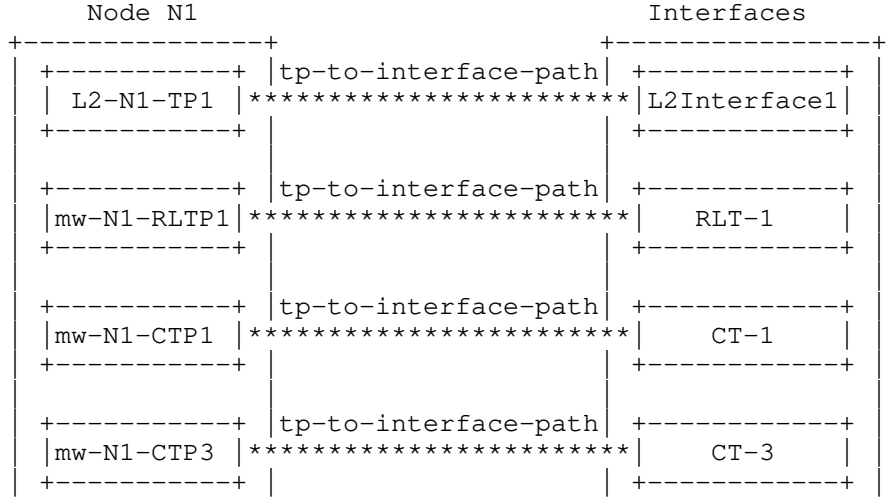
```
          |  |          +--rw mwtopo:tx-frequency?       uint32
          |  |          +--rw mwtopo:rx-frequency?       uint32
          |  |          +--rw mwtopo:channel-separation? uint32
          |  |          +--rw mwtopo:actual-tx-cm?       identityref
          |  |          +--rw mwtopo:actual-snir?        decimal64
          |  |          +--rw mwtopo:actual-transmitted-level? power
          |  +--rw bwatopo:link-availability* [availability]
          |  |  +--rw bwatopo:availability      decimal64
          |  |  +--rw bwatopo:link-bandwidth?   uint64
          |  +--rw bwatopo:actual-bandwidth?    yang:gauge64
          +--ro tet:oper-status?         te-types:te-oper-status
```

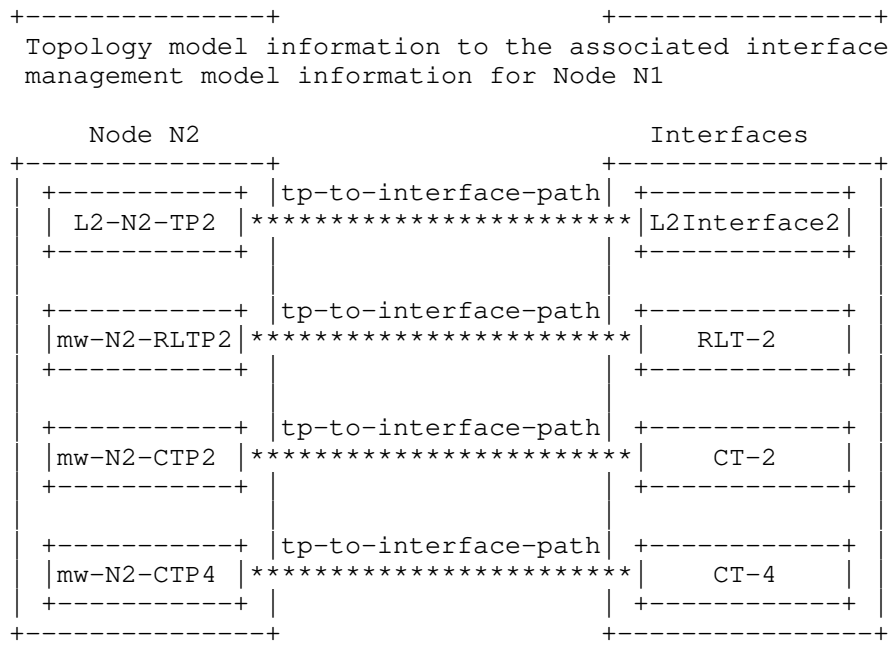
A.2. A topology with single microwave radio link

Microwave is a transport technology which can be used to transport client services, such as L2 Ethernet links. When an L2 link is transported over a single supporting microwave radio link, the topologies could be as shown below. Note that the figure just shows an example, there might be other possibilities to demonstrate such a topology. The example of the instantiation encoded in JSON is using only a selected subset of the leafs from the L2 topology model [RFC8944] and the Microwave Interface Management Model [RFC8561].



L2 transported over a (2+0) microwave radio link





The example above, a L2 network with a supporting microwave network, including microwave-topology (MW) and bandwidth-availability-topology (BWA) models as well as the reference to the associated interface management information, is encoded in JSON as follows:

This example shows a 2+0 mode for a bonded configuration.

<CODE BEGINS> file "example2plus0-f.json"
=============== NOTE: '\' line wrapping per RFC 8792 ================

```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "L2-network",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-eth-te-topology:eth-tran-topology": {
            }
          }
        },
        "supporting-network": [
          {
            "network-ref": "mw-network"
          }
        ],
        "node": [
          {
            "node-id": "L2-N1",
            "supporting-node": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N1"
              }
            ],
            "ietf-network-topology:termination-point": [
              {
                "tp-id": "L2-N1-TP1",
                "supporting-termination-point": [
                  {
```

```
                "network-ref": "mw-network",
                "node-ref": "mw-N1",
                "tp-ref": "mw-N1-RLTP1"
              }
            ]
          }
        ]
      },
      {
        "node-id": "L2-N2",
        "supporting-node": [
          {
            "network-ref": "mw-network",
            "node-ref": "mw-N2"
          }
        ],
        "ietf-network-topology:termination-point": [
          {
            "tp-id": "L2-N2-TP2",
            "supporting-termination-point": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N2",
                "tp-ref": "mw-N2-RLTP2"
              }
            ]
          }
        ]
      }
    ],
    "ietf-network-topology:link": [
      {
        "link-id": "L2-N1-N2",
        "source": {
          "source-node": "L2-N1",
          "source-tp": "L2-N1-TP1"
        },
        "destination": {
          "dest-node": "L2-N2",
          "dest-tp": "L2-N2-TP2"
        },
        "supporting-link": [
          {
            "network-ref": "mw-network",
            "link-ref": "mwrl-N1-N2"
          }
        ]
      }
    ]
  },
  {
    "network-id": "mw-network",
    "network-types": {
      "ietf-te-topology:te-topology": {
        "ietf-microwave-topology:mw-topology": {
        }
      }
    },
    "supporting-network": [
      {
        "network-ref": "mw-network"
      }
    ],
    "node": [
      {
        "node-id": "mw-N1",
```

```
            "supporting-node": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N1"
              }
            ],
            "ietf-network-topology:termination-point": [
              {
                "tp-id": "mw-N1-RLTP1",
                "supporting-termination-point": [
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N1",
                    "tp-ref": "mw-N1-CTP1"
                  },
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N1",
                    "tp-ref": "mw-N1-CTP3"
                  }
                ],
                "ietf-te-topology:te-tp-id": "10.10.10.1",
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-rltp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"RLT-1"
                }
              },
              {
                "tp-id": "mw-N1-CTP1",
                "ietf-te-topology:te-tp-id": 1,
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"CT-1"
                }
              },
              {
                "tp-id": "mw-N1-CTP3",
                "ietf-te-topology:te-tp-id": 2,
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"CT-3"
                }
              }
            ]
          },
          {
            "node-id": "mw-N2",
            "supporting-node": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N2"
              }
            ],
            "ietf-network-topology:termination-point": [
              {
                "tp-id": "mw-N2-RLTP2",
                "supporting-termination-point": [
```

```
                    {
                      "network-ref": "mw-network",
                      "node-ref": "mw-N2",
                      "tp-ref": "mw-N2-CTP2"
                    },
                    {
                      "network-ref": "mw-network",
                      "node-ref": "mw-N2",
                      "tp-ref": "mw-N2-CTP4"
                    }
                  ],
                  "ietf-te-topology:te-tp-id": "10.10.10.1",
                  "ietf-te-topology:te": {
                    "ietf-microwave-topology:mw-tp-choice": {
                      "microwave-rltp": {}
                    },
                    "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"RLT-2"
                  }
                },
                {
                  "tp-id": "mw-N2-CTP2",
                  "ietf-te-topology:te-tp-id": 1,
                  "ietf-te-topology:te": {
                    "ietf-microwave-topology:mw-tp-choice": {
                      "microwave-ctp": {}
                    },
                    "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"CT-2"
                  }
                },
                {
                  "tp-id": "mw-N2-CTP4",
                  "ietf-te-topology:te-tp-id": 2,
                  "ietf-te-topology:te": {
                    "ietf-microwave-topology:mw-tp-choice": {
                      "microwave-ctp": {}
                    },
                    "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path":"CT-4"
                  }
                }
              ]
            }
          ],
          "ietf-network-topology:link": [
            {
              "link-id": "mwrl-N1-N2",
              "source": {
                "source-node": "mw-N1",
                "source-tp": "mw-N1-RLTP1"
              },
              "destination": {
                "dest-node": "mw-N2",
                "dest-tp": "mw-N2-RLTP2"
              },
              "ietf-te-topology:te": {
                "bundled-links": {
                  "bundled-link": [
                    {
                      "sequence": 1,
                      "src-tp-ref": "mw-N1-CTP1",
                      "des-tp-ref": "mw-N2-CTP2"
                    },
                    {
                      "sequence": 2,
```

```
                    "src-tp-ref": "mw-N1-CTP3",
                    "des-tp-ref": "mw-N2-CTP4"
                  }
                ]
              },
              "te-link-attributes": {
                "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                  {
                    "availability": "0.999",
                    "link-bandwidth": "1572864"
                  },
                  {
                    "availability": "0.95",
                    "link-bandwidth": "2097152"
                  }
                ],
                "ietf-microwave-topology:mw-link-choice": {
                  "microwave-radio-link": {
                    "mode": "ietf-microwave-types:two-plus-zero"
                  }
                }
              }
            }
          },
          {
            "link-id": "mwc-N1-N2-A",
            "source": {
              "source-node": "mw-N1",
              "source-tp": "mw-N1-CTP1"
            },
            "destination": {
              "dest-node": "mw-N2",
              "dest-tp": "mw-N2-CTP2"
            },
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                  {
                    "availability": "0.99",
                    "link-bandwidth": "1048576"
                  }
                ],
                "ietf-microwave-topology:mw-link-choice": {
                  "microwave-carrier": {
                    "tx-frequency": 10728000,
                    "rx-frequency": 10615000,
                    "channel-separation": 28000
                  }
                }
              }
            }
          },
          {
            "link-id": "mwc-N1-N2-B",
            "source": {
              "source-node": "mw-N1",
              "source-tp": "mw-N1-CTP3"
            },
            "destination": {
              "dest-node": "mw-N2",
              "dest-tp": "mw-N2-CTP4"
            },
```

```
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                  {
                    "availability": "0.99",
                    "link-bandwidth": "1048576"
                  }
                ],
                "ietf-microwave-topology:mw-link-choice": {
                  "microwave-carrier": {
                    "tx-frequency": 10528000,
                    "rx-frequency": 10415000,
                    "channel-separation": 28000
                  }
                }
              }
            }
          }
        ]
      }
    ]
  },
  "ietf-interfaces:interfaces": {
    "interface": [
      {
        "name": "L2Interface1",
        "description": "'Ethernet Interface 1'",
        "type": "iana-if-type:ethernetCsmacd"
      },
      {
        "name": "L2Interface2",
        "description": "'Ethernet Interface 2'",
        "type": "iana-if-type:ethernetCsmacd"
      },
      {
        "name": "RLT-1",
        "description": "'Radio Link Terminal 1'",
        "type": "iana-if-type:microwaveRadioLinkTerminal",
        "ietf-microwave-radio-link:mode":
        "ietf-microwave-types:two-plus-zero",
        "ietf-microwave-radio-link:carrier-terminations": [
          "CT-1",
          "CT-3"
        ]
      },
      {
        "name": "RLT-2",
        "description": "'Radio Link Terminal 2'",
        "type": "iana-if-type:microwaveRadioLinkTerminal",
        "ietf-microwave-radio-link:mode":
        "ietf-microwave-types:two-plus-zero",
        "ietf-microwave-radio-link:carrier-terminations": [
          "CT-2",
          "CT-4"
        ]
      },
      {
        "name": "CT-1",
        "description": "'Carrier Termination 1'",
        "type": "iana-if-type:microwaveCarrierTermination",
        "ietf-microwave-radio-link:tx-frequency": 10728000,
        "ietf-microwave-radio-link:duplex-distance": 644000,
        "ietf-microwave-radio-link:channel-separation": 28000,
        "ietf-microwave-radio-link:rtpc": {
```

```
          "maximum-nominal-power": "20.0"
        },
        "ietf-microwave-radio-link:single": {
          "selected-cm": "ietf-microwave-types:qam-512"
        }
      },
      {
        "name": "CT-3",
        "description": "'Carrier Termination 3'",
        "type": "iana-if-type:microwaveCarrierTermination",
        "ietf-microwave-radio-link:tx-frequency": 10528000,
        "ietf-microwave-radio-link:duplex-distance": 644000,
        "ietf-microwave-radio-link:channel-separation": 28000,
        "ietf-microwave-radio-link:rtpc": {
          "maximum-nominal-power": "20.0"
        },
        "ietf-microwave-radio-link:single": {
          "selected-cm": "ietf-microwave-types:qam-512"
        }
      },
      {
        "name": "CT-2",
        "description": "'Carrier Termination 2'",
        "type": "iana-if-type:microwaveCarrierTermination",
        "ietf-microwave-radio-link:tx-frequency": 10615000,
        "ietf-microwave-radio-link:duplex-distance": 644000,
        "ietf-microwave-radio-link:channel-separation": 28000,
        "ietf-microwave-radio-link:rtpc": {
          "maximum-nominal-power": "20.0"
        },
        "ietf-microwave-radio-link:single": {
          "selected-cm": "ietf-microwave-types:qam-512"
        }
      },
      {
        "name": "CT-4",
        "description": "'Carrier Termination 4'",
        "type": "iana-if-type:microwaveCarrierTermination",
        "ietf-microwave-radio-link:tx-frequency": 10415000,
        "ietf-microwave-radio-link:duplex-distance": 644000,
        "ietf-microwave-radio-link:channel-separation": 28000,
        "ietf-microwave-radio-link:rtpc": {
          "maximum-nominal-power": "20.0"
        },
        "ietf-microwave-radio-link:single": {
          "selected-cm": "ietf-microwave-types:qam-512"
        }
      }
    ]
  }
}
<CODE ENDS>
```


This example shows a 1+1 mode for protection.


```
<CODE BEGINS> file "example1plus1-f.json"
=============== NOTE: '\' line wrapping per RFC 8792 ================

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "L2-network",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-eth-te-topology:eth-tran-topology": {
```

```
      }
    }
  },
  "supporting-network": [
    {
      "network-ref": "mw-network"
    }
  ],
  "node": [
    {
      "node-id": "L2-N1",
      "supporting-node": [
        {
          "network-ref": "mw-network",
          "node-ref": "mw-N1"
        }
      ],
      "ietf-network-topology:termination-point": [
        {
          "tp-id": "L2-N1-TP1",
          "supporting-termination-point": [
            {
              "network-ref": "mw-network",
              "node-ref": "mw-N1",
              "tp-ref": "mw-N1-RLTP1"
            }
          ]
        }
      ]
    },
    {
      "node-id": "L2-N2",
      "supporting-node": [
        {
          "network-ref": "mw-network",
          "node-ref": "mw-N2"
        }
      ],
      "ietf-network-topology:termination-point": [
        {
          "tp-id": "L2-N2-TP2",
          "supporting-termination-point": [
            {
              "network-ref": "mw-network",
              "node-ref": "mw-N2",
              "tp-ref": "mw-N2-RLTP2"
            }
          ]
        }
      ]
    }
  ],
  "ietf-network-topology:link": [
    {
      "link-id": "L2-N1-N2",
      "source": {
        "source-node": "L2-N1",
        "source-tp": "L2-N1-TP1"
      },
      "destination": {
        "dest-node": "L2-N2",
        "dest-tp": "L2-N2-TP2"
      },
      "supporting-link": [
        {
          "network-ref": "mw-network",
```

```
                "link-ref": "mwrl-N1-N2"
              }
            ]
          }
        ]
      },
      {
        "network-id": "mw-network",
        "network-types": {
          "ietf-te-topology:te-topology": {
            "ietf-microwave-topology:mw-topology": {
            }
          }
        },
        "supporting-network": [
          {
            "network-ref": "mw-network"
          }
        ],
        "node": [
          {
            "node-id": "mw-N1",
            "supporting-node": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N1"
              }
            ],
            "ietf-network-topology:termination-point": [
              {
                "tp-id": "mw-N1-RLTP1",
                "supporting-termination-point": [
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N1",
                    "tp-ref": "mw-N1-CTP1"
                  },
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N1",
                    "tp-ref": "mw-N1-CTP3"
                  }
                ],
                "ietf-te-topology:te-tp-id": "10.10.10.1",
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-rltp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "RLT-1"
                }
              },
              {
                "tp-id": "mw-N1-CTP1",
                "ietf-te-topology:te-tp-id": 1,
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "CT-1"
                }
              },
              {
                "tp-id": "mw-N1-CTP3",
                "ietf-te-topology:te-tp-id": 2,
```

```
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "CT-3"
                }
              }
            ]
          },
          {
            "node-id": "mw-N2",
            "supporting-node": [
              {
                "network-ref": "mw-network",
                "node-ref": "mw-N2"
              }
            ],
            "ietf-network-topology:termination-point": [
              {
                "tp-id": "mw-N2-RLTP2",
                "supporting-termination-point": [
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N2",
                    "tp-ref": "mw-N2-CTP2"
                  },
                  {
                    "network-ref": "mw-network",
                    "node-ref": "mw-N2",
                    "tp-ref": "mw-N2-CTP4"
                  }
                ],
                "ietf-te-topology:te-tp-id": "10.10.10.1",
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-rltp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "RLT-2"
                }
              },
              {
                "tp-id": "mw-N2-CTP2",
                "ietf-te-topology:te-tp-id": 1,
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "CT-2"
                }
              },
              {
                "tp-id": "mw-N2-CTP4",
                "ietf-te-topology:te-tp-id": 2,
                "ietf-te-topology:te": {
                  "ietf-microwave-topology:mw-tp-choice": {
                    "microwave-ctp": {}
                  },
                  "ietf-tp-interface-reference-topology:tp-to-interf\
ace-path": "CT-4"
                }
              }
            ]
          }
```

```
        ],
        "ietf-network-topology:link": [
          {
            "link-id": "mwrl-N1-N2",
            "source": {
              "source-node": "mw-N1",
              "source-tp": "mw-N1-RLTP1"
            },
            "destination": {
              "dest-node": "mw-N2",
              "dest-tp": "mw-N2-RLTP2"
            },
            "ietf-te-topology:te": {
              "bundled-links": {
                "bundled-link": [
                  {
                    "sequence": 1,
                    "src-tp-ref": "mw-N1-CTP1",
                    "des-tp-ref": "mw-N2-CTP2"
                  },
                  {
                    "sequence": 2,
                    "src-tp-ref": "mw-N1-CTP3",
                    "des-tp-ref": "mw-N2-CTP4"
                  }
                ]
              },
              "te-link-attributes": {
                "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                  {
                    "availability": "0.999",
                    "link-bandwidth": "998423"
                  },
                  {
                    "availability": "0.99",
                    "link-bandwidth": "1048576"
                  }
                ],
                "ietf-microwave-topology:mw-link-choice": {
                  "microwave-radio-link": {
                    "mode": "ietf-microwave-types:one-plus-one"
                  }
                }
              }
            }
          },
          {
            "link-id": "mwc-N1-N2-A",
            "source": {
              "source-node": "mw-N1",
              "source-tp": "mw-N1-CTP1"
            },
            "destination": {
              "dest-node": "mw-N2",
              "dest-tp": "mw-N2-CTP2"
            },
            "ietf-te-topology:te": {
              "te-link-attributes": {
                "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                  {
                    "availability": "0.99",
                    "link-bandwidth": "998423"
```

```
                    },
                    {
                      "availability": "0.95",
                      "link-bandwidth": "1048576"
                    }
                  ],
                  "ietf-microwave-topology:mw-link-choice": {
                    "microwave-carrier": {
                      "tx-frequency": 10728000,
                      "rx-frequency": 10615000,
                      "channel-separation": 28000
                    }
                  }
                }
              }
            },
            {
              "link-id": "mwc-N1-N2-B",
              "source": {
                "source-node": "mw-N1",
                "source-tp": "mw-N1-CTP3"
              },
              "destination": {
                "dest-node": "mw-N2",
                "dest-tp": "mw-N2-CTP4"
              },
              "ietf-te-topology:te": {
                "te-link-attributes": {
                  "ietf-bandwidth-availability-topology:link-availabil\
ity":
 [
                    {
                      "availability": "0.99",
                      "link-bandwidth": "998423"
                    },
                    {
                      "availability": "0.95",
                      "link-bandwidth": "1048576"
                    }
                  ],
                  "ietf-microwave-topology:mw-link-choice": {
                    "microwave-carrier": {
                      "tx-frequency": 10728000,
                      "rx-frequency": 10615000,
                      "channel-separation": 28000
                    }
                  }
                }
              }
            }
          ]
        }
      ]
    },
      "ietf-interfaces:interfaces": {
      "interface": [
        {
          "name": "L2Interface1",
          "description": "'Ethernet Interface 1'",
          "type": "iana-if-type:ethernetCsmacd"
        },
        {
          "name": "L2Interface2",
          "description": "'Ethernet Interface 2'",
          "type": "iana-if-type:ethernetCsmacd"
        },
```

```
    {
      "name": "RLT-1",
      "description": "'Radio Link Terminal 1'",
      "type": "iana-if-type:microwaveRadioLinkTerminal",
      "ietf-microwave-radio-link:mode":
"ietf-microwave-types:one-plus-one",
      "ietf-microwave-radio-link:carrier-terminations": [
        "CT-1",
        "CT-3"
      ]
    },
    {
      "name": "RLT-2",
      "description": "'Radio Link Terminal 2'",
      "type": "iana-if-type:microwaveRadioLinkTerminal",
      "ietf-microwave-radio-link:mode":
    "ietf-microwave-types:one-plus-one",
      "ietf-microwave-radio-link:carrier-terminations": [
        "CT-2",
        "CT-4"
      ]
    },
    {
      "name": "CT-1",
      "description": "'Carrier Termination 1'",
      "type": "iana-if-type:microwaveCarrierTermination",
      "ietf-microwave-radio-link:tx-frequency": 10728000,
      "ietf-microwave-radio-link:duplex-distance": 644000,
      "ietf-microwave-radio-link:channel-separation": 28000,
      "ietf-microwave-radio-link:rtpc": {
        "maximum-nominal-power": "20.0"
      },
      "ietf-microwave-radio-link:adaptive": {
        "selected-min-acm": "ietf-microwave-types:qam-256",
        "selected-max-acm": "ietf-microwave-types:qam-512"
      }
    },
    {
      "name": "CT-3",
      "description": "'Carrier Termination 3'",
      "type": "iana-if-type:microwaveCarrierTermination",
      "ietf-microwave-radio-link:tx-frequency": 10728000,
      "ietf-microwave-radio-link:duplex-distance": 644000,
      "ietf-microwave-radio-link:channel-separation": 28000,
      "ietf-microwave-radio-link:rtpc": {
        "maximum-nominal-power": "20.0"
      },
      "ietf-microwave-radio-link:adaptive": {
        "selected-min-acm": "ietf-microwave-types:qam-256",
        "selected-max-acm": "ietf-microwave-types:qam-512"
      }
    },
    {
      "name": "CT-2",
      "description": "'Carrier Termination 2'",
      "type": "iana-if-type:microwaveCarrierTermination",
      "ietf-microwave-radio-link:tx-frequency": 10615000,
      "ietf-microwave-radio-link:duplex-distance": 644000,
      "ietf-microwave-radio-link:channel-separation": 28000,
      "ietf-microwave-radio-link:rtpc": {
        "maximum-nominal-power": "20.0"
      },
      "ietf-microwave-radio-link:adaptive": {
        "selected-min-acm": "ietf-microwave-types:qam-256",
        "selected-max-acm": "ietf-microwave-types:qam-512"
      }
```

```
        },
        {
          "name": "CT-4",
          "description": "'Carrier Termination 4'",
          "type": "iana-if-type:microwaveCarrierTermination",
          "ietf-microwave-radio-link:tx-frequency": 10615000,
          "ietf-microwave-radio-link:duplex-distance": 644000,
          "ietf-microwave-radio-link:channel-separation": 28000,
          "ietf-microwave-radio-link:rtpc": {
            "maximum-nominal-power": "20.0"
          },
          "ietf-microwave-radio-link:adaptive": {
            "selected-min-acm": "ietf-microwave-types:qam-256",
            "selected-max-acm": "ietf-microwave-types:qam-512"
          }
        }

      ]
    }
  }
  <CODE ENDS>
```

Note that the examples above show one particular link (unidirectional) and not a complete network topology.

Authors' Addresses

Jonas Ahlberg
Ericsson

Email: jonas.ahlberg@ericsson.com

Scott Mansfield
Ericsson

Email: scott.mansfield@ericsson.com

Min Ye
Huawei Technologies

Email: amy.yemin@huawei.com

Italo Busi
Huawei Technologies

Email: italo.busi@huawei.com

Xi Li
NEC Laboratories Europe

Email: xi.li@neclab.eu

Daniela Spreafico
Nokia - IT

Email: daniela.spreafico@nokia.com