

Workgroup: ccamp
Internet-Draft:
draft-ietf-ccamp-mw-topo-yang-05
Published: 6 March 2023
Intended Status: Standards Track
Expires: 7 September 2023
Authors: J. Ahlberg S. Mansfield M. Ye
 Ericsson Ericsson Huawei Technologies
 I. Busi X. Li
 Huawei Technologies NEC Laboratories Europe
 D. Spreafico
 Nokia - IT

A YANG Data Model for Microwave Topology

Abstract

This document defines a YANG data model to describe microwave/millimeter radio links in a network topology.

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

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 7 September 2023.

Copyright Notice

Copyright (c) 2023 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

Table of Contents

- [1. Introduction](#)
 - [1.1. Terminology and Definitions](#)
 - [1.2. Tree Structure](#)
- [2. Requirements Language](#)
- [3. Microwave Topology YANG Data Model](#)
 - [3.1. YANG Tree](#)
 - [3.2. Relationship between radio links and carriers](#)
 - [3.3. Relationship with client topology model](#)
 - [3.4. Applicability of the Data Model for Traffic Engineering \(TE\) Topologies](#)
 - [3.5. Microwave Topology YANG Module](#)
- [4. Security Considerations](#)
- [5. IANA Considerations](#)
- [6. References](#)
 - [6.1. Normative References](#)
 - [6.2. Informative References](#)
- [Appendix A. Microwave Topology Model with base topology models](#)
 - [A.1. Instance data for 2+0 mode for a bonded configuration](#)
 - [A.2. Instance data for 1+1 mode for a protected configuration](#)
- [Appendix B. Microwave Topology Model with example extensions](#)
 - [B.1. Instance data for 2+0 mode](#)
 - [B.2. Instance data for geolocation information](#)
- [Acknowledgments](#)
- [Authors' Addresses](#)

1. Introduction

This document defines a YANG data model to describe topologies of microwave/millimeter wave (hereafter microwave is used to simplify the text). The 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.

The model augments "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 model is 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 affect 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.

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 model is used in chapter 3.1 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!
      |   +---u microwave-rltp-attributes
      +--:(microwave-ctp)
      +--rw microwave-ctp!
      +---u microwave-ctp-attributes
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!
      |   +---u microwave-radio-link-attributes
      +--:(microwave-carrier)
      +--rw microwave-carrier!
      +---u microwave-carrier-attributes
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:max-link-bandwidth
  /tet:te-bandwidth/tet:technology:
  +--:(microwave)
  +---u microwave-bandwidth
```

3.2. Relationship between radio links and carriers

A microwave radio link is always an aggregate of one or multiple carriers, 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 rlt-mode container (1+0, 2+0, 1+1, etc.) for the radio-link. Appendix A includes JSON examples 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 JSON examples 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 appendices [Appendix A](#) and [Appendix B](#) in this document.

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. Microwave Topology YANG Module

<CODE BEGINS> file "ietf-microwave-topology.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 Web: <https://datatracker.ietf.org/wg/ccamp/>
    WG List: <mailto:ccamp@ietf.org>

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

  ";
```

description

"This is a module for microwave topology.

Copyright (c) 2023 IETF Trust and the persons
identified as authors of the code. All rights reserved.

Redistribution and use in source and binary forms, with or
without modification, is permitted pursuant to, and subject
to the license terms contained in, the Revised BSD License
set forth in Section 4.c of the IETF Trust's Legal Provisions
Relating to IETF Documents
(<https://trustee.ietf.org/license-info>).

This version of this YANG module is part of RFC XXXX; see
the RFC itself for full legal notices.";

revision 2023-02-15 {

description

"Draft to be used as a basis for the continued microwave
team discussions";

reference "";

}

grouping rlt-mode {

description

"This grouping provides a flexible definition of number
of bonded carriers and protecting carriers of a radio
link.";

leaf num-bonded-carriers {

type uint32;

mandatory true;

description

"Number of bonded carriers.";

}

leaf num-protecting-carriers {

type uint32;

mandatory true;

description

"Number of protecting carriers.";

}

}

grouping microwave-radio-link-attributes {

description "Grouping used for attributes describing a microwave
radio link.";

container rlt-mode {

description

"This grouping provides a flexible definition of number
of bonded carriers and protecting carriers of a radio

```

        link.";
        uses rlt-mode;
    }
}

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-snr {
  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-snr in RFC 8561.";
  reference
    "RFC 8561: A YANG Data Model for Microwave Radio Link";
}
leaf actual-transmitted-level {
  type decimal64 {
    fraction-digits 1;
    range "0..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";
}
}

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.";
  }
}

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.";
                    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.";
                    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. Security Considerations

The YANG module specified in this document defines 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 module specified in this document imports and augments the ietf-network and ietf-network-topology models defined in [[RFC8345](#)]. The security considerations from [[RFC8345](#)] are applicable to the module in this document.

There are a several data nodes defined in this YANG module 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:

*rlt-mode: A malicious client could attempt to modify the mode in which the radio link is configured and thereby change the intended behaviour of the link.

*tx-frequency, rx-frequency and channel-separation: A malicious client could attempt to modify the frequency configuration of a carrier which could modify the intended behaviour or make the configuration invalid and thereby stop the operation of it.

5. 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.

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

6. References

6.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/rfc/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/rfc/rfc3688>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/rfc/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/rfc/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/rfc/rfc6242>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/rfc/rfc8040>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/rfc/rfc8174>>.
- [RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <<https://www.rfc-editor.org/rfc/rfc8341>>.
- [RFC8345] Clemm, A., Medved, J., Varga, R., Bahadur, N., Ananthakrishnan, H., and X. Liu, "A YANG Data Model for Network Topologies", RFC 8345, DOI 10.17487/RFC8345, March 2018, <<https://www.rfc-editor.org/rfc/rfc8345>>.

[RFC8446]

Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/rfc/rfc8446>>.

[RFC8795]

Liu, X., Bryskin, I., Beeram, V., Saad, T., Shah, H., and O. Gonzalez de Dios, "YANG Data Model for Traffic Engineering (TE) Topologies", RFC 8795, DOI 10.17487/RFC8795, August 2020, <<https://www.rfc-editor.org/rfc/rfc8795>>.

6.2. Informative References

[RFC8340]

Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/rfc/rfc8340>>.

[RFC8453]

Ceccarelli, D., Ed. and Y. Lee, Ed., "Framework for Abstraction and Control of TE Networks (ACTN)", RFC 8453, DOI 10.17487/RFC8453, August 2018, <<https://www.rfc-editor.org/rfc/rfc8453>>.

[RFC8944]

Dong, J., Wei, X., Wu, Q., Boucadair, M., and A. Liu, "A YANG Data Model for Layer 2 Network Topologies", RFC 8944, DOI 10.17487/RFC8944, November 2020, <<https://www.rfc-editor.org/rfc/rfc8944>>.

Appendix A. Microwave Topology Model with base topology models

This appendix provides some examples and illustrations of how the Microwave Topology Model can be used. The tree illustrates an example of a complete Microwave Topology Model including the relevant data nodes from network-topology and te-topology (base topology models). There are also JSON based instantiations of the Microwave Topology Model for a couple of small network examples.

The tree below shows an example of the relevant leafs for a complete Microwave Topology Model including the augmented Network Topology Model defined in [[RFC8345](#)] and the Traffic Engineering (TE) Topologies model defined in [[RFC8795](#)].

```

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
    |   -> /nw:networks/nw:network/nw:network-id
    +--rw node* [node-id]
    |   +--rw node-id                node-id
    |   +--rw supporting-node* [network-ref node-ref]
    |   |   +--rw network-ref
    |   |   -> ../../../../nw:supporting-network/nw:network-ref
    |   |   +--rw node-ref
    |   |   -> /nw:networks/nw:network/nw:node/nw: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/nw:network-ref
    |   |   |   +--rw nt:node-ref
    |   |   |   -> ../../../../nw:supporting-node/nw:node-ref
    |   |   |   +--rw nt:tp-ref                leafref
    |   |   +--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
    |   |   +--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 tet:te-node-id?                te-types:te-node-id
    |   +--rw tet:te!
    |   +--ro tet:geolocation
    |   |   +--ro tet:altitude?                int64
    |   |   +--ro tet:latitude?                geographic-coordinate-degree
    |   |   +--ro tet:longitude?                geographic-coordinate-degree
    +--rw nt:link* [link-id]
    |   +--rw nt:link-id                link-id
    |   +--rw nt:source
    |   |   +--rw nt:source-node? -> ../../../../nw:node/nw:node-id
    |   |   +--rw nt:source-tp?                leafref

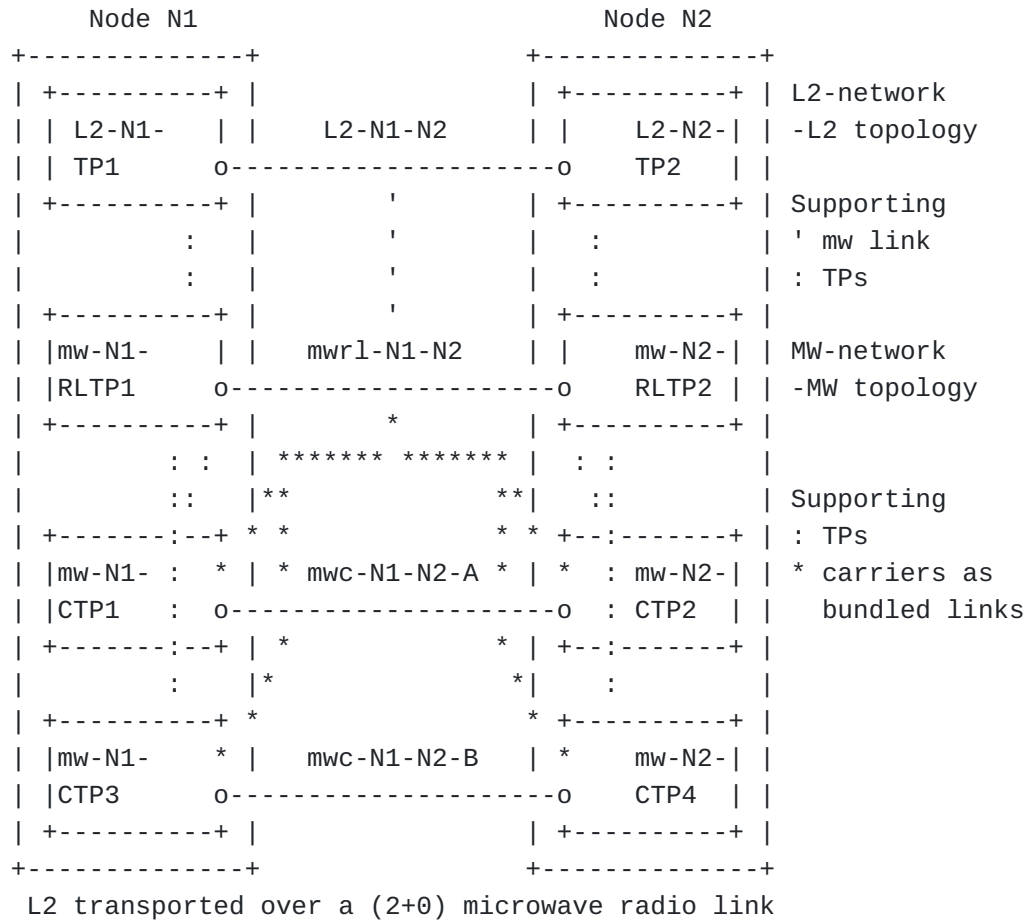
```

```

+--rw nt:destination
| +--rw nt:dest-node?  -> ../../../../nw:node/nw:node-id
| +--rw nt:dest-tp?    leafref
+--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?   leafref
  |       +--rw tet:des-tp-ref?   leafref
  +--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:rlt-mode
  | | +--rw mwtopo:num-bonded-carriers
  | | |       uint32
  | | +--rw mwtopo:num-protecting-carriers
  | | |       uint32
  | +--:(mwtopo:microwave-carrier)
  | +--rw mwtopo:microwave-carrier!
  | +--rw mwtopo:tx-frequency?
  | |       uint32
  | +--rw mwtopo:rx-frequency?
  | |       uint32
  | +--rw mwtopo:channel-separation?
  | |       uint32
  | +--ro mwtopo:actual-tx-cm?
  | |       identityref
  | +--ro mwtopo:actual-snr?
  | |       decimal64
  | +--ro mwtopo:actual-transmitted-level?
  | |       power
  +--ro tet:oper-status?

```

The Microwave Topology Model augments the TE Topology Model.



A.1. Instance data for 2+0 mode for a bonded configuration

```

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "L2-network",
        "network-types": {
          "ietf-te-topology:te-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"
                  }
                ]
              }
            ]
          }
        ],
        "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": "mwr1-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": {}
      }
    }
  },
  {
    "tp-id": "mw-N1-CTP1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
      "ietf-microwave-topology:mw-tp-choice": {
        "microwave-ctp": {}
      }
    }
  },
  {
    "tp-id": "mw-N1-CTP3",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
      "ietf-microwave-topology:mw-tp-choice": {
        "microwave-ctp": {}
      }
    }
  }
],
},
{
  "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": {}
        }
      }
    },
    {
      "tp-id": "mw-N2-CTP2",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp-choice": {
          "microwave-ctp": {}
        }
      }
    },
    {
      "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-network-topology:link": [
  {
    "link-id": "mwr1-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-microwave-topology:mw-link-choice": {
                "microwave-radio-link": {
                    "rlt-mode": {
                        "num-bonded-carriers": 2,
                        "num-protecting-carriers": 0
                    }
                }
            }
        }
    },
    {
        "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-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-microwave-topology:mw-link-choice": {
                "microwave-carrier": {
                    "tx-frequency": 10528000,
                    "rx-frequency": 10415000,
                    "channel-separation": 28000
                }
            }
        }
    }
}
]
}
}

```

A.2. Instance data for 1+1 mode for a protected configuration

```

{
  "ietf-network:networks": {
    "network": [
      {
        "network-id": "L2-network",
        "network-types": {
          "ietf-te-topology:te-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"
                  }
                ]
              }
            ]
          }
        ],
        "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": "mwr1-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": {}
      }
    }
  },
  {
    "tp-id": "mw-N1-CTP1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
      "ietf-microwave-topology:mw-tp-choice": {
        "microwave-ctp": {}
      }
    }
  },
  {
    "tp-id": "mw-N1-CTP3",
    "ietf-te-topology:te-tp-id": 2,
    "ietf-te-topology:te": {
      "ietf-microwave-topology:mw-tp-choice": {
        "microwave-ctp": {}
      }
    }
  }
],
},
{
  "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": {}
        }
      }
    },
    {
      "tp-id": "mw-N2-CTP2",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp-choice": {
          "microwave-ctp": {}
        }
      }
    },
    {
      "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-network-topology:link": [
  {
    "link-id": "mwr1-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-microwave-topology:mw-link-choice": {
                "microwave-radio-link": {
                    "rlt-mode": {
                        "num-bonded-carriers": 1,
                        "num-protecting-carriers": 1
                    }
                }
            }
        }
    },
    {
        "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-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-microwave-topology:mw-link-choice": {
                "microwave-carrier": {
                    "tx-frequency": 10728000,
                    "rx-frequency": 10615000,
                    "channel-separation": 28000
                }
            }
        }
    }
}
]
}
]
}
}

```

Appendix B. Microwave Topology Model with example extensions

This appendix provides an examples of how the Microwave Topology Model can be used with the interface reference topology (ifref) and the bandwidth-availability-topology (bwa) models. There is also a snippet of json to show geolocation information instance data.

The tree below shows an example of the relevant leafs for a complete Microwave Topology Model including interface reference topology (ifref) and bandwidth-availability-topology (bwa) models.

```

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
    |   -> /nw:networks/nw:network/nw:network-id
    +--rw node* [node-id]
    |   +--rw node-id                node-id
    |   +--rw supporting-node* [network-ref node-ref]
    |   |   +--rw network-ref
    |   |   -> ../../../../nw:supporting-network/nw:network-ref
    |   |   +--rw node-ref
    |   |   -> /nw:networks/nw:network/nw:node/nw: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/nw:network-ref
    |   |   |   +--rw nt:node-ref
    |   |   |   -> ../../../../nw:supporting-node/nw:node-ref
    |   |   |   +--rw nt:tp-ref                leafref
    |   |   +--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
    |   |   +--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 ifref:tp-to-interface-path? ->
    |   |   |   |   /if:interfaces/interface/name
    |   +--rw tet:te-node-id?            te-types:te-node-id
    |   +--rw tet:te!
    |   +--ro tet:geolocation
    |   |   +--ro tet:altitude?            int64
    |   |   +--ro tet:latitude?            geographic-coordinate-degree
    |   |   +--ro tet:longitude?           geographic-coordinate-degree
    +--rw nt:link* [link-id]
    |   +--rw nt:link-id                link-id
    |   +--rw nt:source

```

```

| +--rw nt:source-node?  -> ../../../../nw:node/nw:node-id
| +--rw nt:source-tp?    leafref
+--rw nt:destination
| +--rw nt:dest-node?   -> ../../../../nw:node/nw:node-id
| +--rw nt:dest-tp?    leafref
+--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?   leafref
  |           +--rw tet:des-tp-ref?   leafref
+--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:rlt-mode
  | | | | +--rw mwtopo:num-bonded-carriers
  | | | | | uint32
  | | | | +--rw mwtopo:num-protecting-carriers
  | | | | | uint32
  | | | +--:(mwtopo:microwave-carrier)
  | | | +--rw mwtopo:microwave-carrier!
  | | | +--rw mwtopo:tx-frequency?
  | | | | uint32
  | | | +--rw mwtopo:rx-frequency?
  | | | | uint32
  | | | +--rw mwtopo:channel-separation?
  | | | | uint32
  | | | +--ro mwtopo:actual-tx-cm?
  | | | | identityref
  | | | +--ro mwtopo:actual-snr?
  | | | | decimal64
  | | | +--ro mwtopo:actual-transmitted-level?
  | | | | decimal64
  | +--rw bwatopo:link-availability* [availability]
  | | +--rw bwatopo:availability      decimal64
  | | +--rw bwatopo:link-bandwidth?   uint64

```

```
|  +--ro bwatopo:actual-bandwidth?      yang:gauge64
+--ro tet:oper-status?
```

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](#)].

Node N1		Node N2		
+-----+		+-----+		
+-----+		+-----+		L2-network
L2-N1-	L2-N1-N2	L2-N2-		-L2 topology
TP1 o-----o		TP2		
+-----+		+-----+		Supporting
:		:		' mw link
:		:		: TPs
+-----+		+-----+		
mw-N1-	mwr1-N1-N2	mw-N2-		MW-network
RLTP1 o-----o		RLTP2		-MW topology
+-----+		+-----+		
: :	*****	: :		
::	**	::		Supporting
+-----+	*	+-----+		: TPs
mw-N1- : *	* mwc-N1-N2-A *	* : mw-N2-		* carriers as
CTP1 : o-----o		: CTP2		bundled links
+-----+	*	+-----+		
:	*	:		
+-----+	*	+-----+		
mw-N1- *	mwc-N1-N2-B	* mw-N2-		
CTP3 o-----o		CTP4		
+-----+		+-----+		
+-----+		+-----+		

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

Node N1	Interfaces
+-----+	+-----+
+-----+ tp-to-interface-path	+-----+
L2-N1-TP1 *****	L2Interface1
+-----+	+-----+
+-----+ tp-to-interface-path	+-----+
mw-N1-RLTP1 *****	RLT-1
+-----+	+-----+
+-----+ tp-to-interface-path	+-----+
mw-N1-CTP1 *****	CT-1
+-----+	+-----+
+-----+ tp-to-interface-path	+-----+
mw-N1-CTP3 *****	CT-3
+-----+	+-----+
+-----+	+-----+

Topology model information to the associated interface management model information for Node N1

Node N2	Interfaces
+-----+	+-----+

+-----+	tp-to-interface-path	+-----+
L2-N2-TP2	*****	L2Interface2
+-----+		+-----+
+-----+	tp-to-interface-path	+-----+
mw-N2-RLTP2	*****	RLT-2
+-----+		+-----+
+-----+	tp-to-interface-path	+-----+
mw-N2-CTP2	*****	CT-2
+-----+		+-----+
+-----+	tp-to-interface-path	+-----+
mw-N2-CTP4	*****	CT-4
+-----+		+-----+
+-----+		+-----+

Topology model information to the associated interface
management model information for Node N2

B.1. Instance data for 2+0 mode

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:

===== NOTE: '\\' line wrapping per RFC 8792 =====

```
{
  "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": 113000,
        "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": 113000,
    "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": 113000,
    "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": 113000,
    "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"
    }
  }
]
},
"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": "mwr1-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-interface-reference-topology": {}
    },
    {
      "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-interface-reference-topology": {}
    },
    {
      "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-interface-reference-topology": {}
    }
  ]
}

```

```

    }
  }
]
},
"ietf-network-topology:link": [
  {
    "link-id": "mwr1-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-microwave-topology:mw-link-choice": {
          "microwave-radio-link": {
            "rlt-mode": {
              "num-bonded-carriers": 2,
              "num-protecting-carriers": 0
            }
          }
        }
      }
    }
  },
  {
    "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-availability": [
      {
        "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-availability": [
      {
        "availability": "0.99",
        "link-bandwidth": "998423"
      },
      {
        "availability": "0.95",
        "link-bandwidth": "1048576"
      }
    ],
    "ietf-microwave-topology:mw-link-choice": {

```

```
        "microwave-carrier": {
            "tx-frequency": 10528000,
            "rx-frequency": 10415000,
            "channel-separation": 28000
        }
    }
}
]
```

B.2. Instance data for geolocation information

This example provides a json snippet that shows geolocation information.

```
"node": [  
  {  
    "node-id": "mw-N1",  
  
    ...  
  
    "ietf-te-topology:te" : {  
      "ietf-te-topology:geolocation": {  
        "altitude": "200000",  
        "latitude": "45",  
        "longitude": "90"  
      }  
    },  
    "ietf-network-topology:termination-point": [  
      ...  
    ]  
  },  
  ...  
]
```

Acknowledgments

This document was prepared using kramdown

The authors would like to thank ...

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