
Stream: Internet Engineering Task Force (IETF)
RFC: [9656](#)
Category: Standards Track
Published: September 2024
ISSN: 2070-1721
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RFC 9656

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.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

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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 [RFC8561]. 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 Time-Division Multiplexing (TDM). The model augments the [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 Layer 0 / Layer 1 (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 Layer 2 (L2) Ethernet, is carried over the microwave radio link. 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 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, with the purpose to minimize overall interference and/or maximize the overall capacity provided by the links.

1.1. Abbreviations

The following abbreviations are used in this document:

CTP: Carrier Termination Point

RLT: Radio Link Terminal

RLTP: Radio Link Termination Point

1.2. Tree Structure

A simplified graphical representation of the data model is used in [Section 2](#) of this document. The meaning of the symbols in these diagrams is defined in [\[RFC8340\]](#).

1.3. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in [Table 1](#).

Prefix	YANG Module	Reference
mwt	ietf-microwave-topology	RFC 9656
nw	ietf-network	[RFC8345]
nt	ietf-network-topology	[RFC8345]
mw-types	ietf-microwave-types	[RFC8561]
tet	ietf-te-topology	[RFC8795]

Table 1: Prefixes for Imported YANG Modules

2. Microwave Topology YANG Data Model

2.1. 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/tet:te
  /tet:te-node-attributes:
  +--rw mw-node!
augment /nw:networks/nw:network/nw:node/nt:termination-point
  /tet:te:
  +--rw mw-tp!
  +--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!
  +--rw (mw-link-option)
  +--:(microwave-radio-link)
  | +--rw microwave-radio-link!
  |   +--rw rlt-mode
  |     +--rw num-bonded-carriers          uint32
  |     +--rw num-protecting-carriers     uint32
  +--:(microwave-carrier)
  +--rw microwave-carrier!
  +--rw tx-frequency?                    uint32
  +--rw rx-frequency?                    uint32
  +--rw channel-separation?              uint32
  +--ro actual-tx-cm?                     identityref
  +--ro actual-snr?                       decimal64
  +--ro actual-transmitted-level?        decimal64
augment /nw:networks/nw:network/nt:link/tet:te
  /tet:te-link-attributes/tet:max-link-bandwidth
  /tet:te-bandwidth:
  +--ro mw-bandwidth?                    uint64

```

Figure 1: Microwave Topology Tree

2.2. 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 their 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 modeled.

2.3. 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.

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

Since microwave is a point-to-point radio technology, a majority of the leafs in the Data Model for Traffic Engineering (TE) Topologies augmented by the microwave topology model are not applicable. Examples of which leafs are considered applicable can be found in [Appendices A](#) and [B](#) in this document.

More specifically in the context of the microwave-specific augmentations of te-topology, admin-status, and oper-status leafs (from te-topology) are only applicable to microwave carriers (in the mw-link tree) and not microwave radio links. Radio links are instead enabled or disabled in the constituent carriers. Furthermore, the status leafs related to mw-tp can be used with inter-domain links and when the status of only one side of the link is known. However, 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.

2.5. Microwave Topology YANG Module

This module imports typedefs and modules from [\[RFC8345\]](#), [\[RFC8561\]](#), and [\[RFC8795\]](#). It references [\[EN301129\]](#) and [\[EN302217-1\]](#).

```
<CODE BEGINS> file "ietf-microwave-topology@2024-09-18.yang"

module ietf-microwave-topology {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-microwave-topology";
  prefix mwt;

  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: A YANG Data Model for Microwave Radio Link";
  }
}
```

```
organization
  "Internet Engineering Task Force (IETF) CCAMP WG";
contact
  "WG Web: <https://datatracker.ietf.org/wg/ccamp/>
  WG List: <ccamp@ietf.org>

  Editor: Jonas Ahlberg
          <jonas.ahlberg@ericsson.com>
  Editor: Scott Mansfield
          <scott.mansfield@ericsson.com>
  Editor: Min Ye
          <amy.yemin@huawei.com>
  Editor: Italo Busi
          <Italo.Busi@huawei.com>
  Editor: Xi Li
          <Xi.Li@neclab.eu>
  Editor: Daniela Spreafico
          <daniela.spreafico@nokia.com>
";
description
  "This is a module for microwave topology.

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  without modification, is permitted pursuant to, and subject
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  (https://trustee.ietf.org/license-info).

  This version of this YANG module is part of RFC 9656; see
  the RFC itself for full legal notices.";

revision 2024-09-18 {
  description
    "Last call comment resolutions.";
  reference
    "";
}

grouping rlt-mode {
  description
    "This grouping provides a flexible definition of the 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 the 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 channel 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;
    }
    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;
    }
    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 "bits/seconds";
        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/tet:te"
```



```

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

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

```

3. 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 number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes can 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 behavior 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 behavior or make the configuration invalid and, thereby, stop the operation of it.

4. IANA Considerations

IANA has assigned 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.

IANA has recorded the 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: mwt

Reference: RFC 9656

5. References

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- [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/info/rfc8453>>.
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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 mwt: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      leafref
| | +--rw tet:te-tp-id?
| | | te-types:te-tp-id
| | +--rw tet:te!
| | | +--rw tet:name?          string
| | | +--ro tet:geolocation
| | | | +--ro tet:altitude?    int64
| | | | +--ro tet:latitude?
| | | | | geographic-coordinate-degree
| | | | +--ro tet:longitude?
| | | | | geographic-coordinate-degree
| | | +--rw mwt:mw-tp!
| | | | +--rw (mwt:mw-tp-option)?
| | | | | +--:(mwt:microwave-rltp)
| | | | | | +--rw mwt:microwave-rltp!
| | | | | +--:(mwt:microwave-ctp)
| | | | | | +--rw mwt:microwave-ctp!
| | +--rw tet:te-node-id?    te-types:te-node-id
+--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?    leafref
+--rw nt:destination
| +--rw nt:dest-node?     -> ../../../../nw:node/node-id
| +--rw nt:dest-tp?      leafref
+--rw nt:supporting-link* [network-ref link-ref]
| +--rw nt:network-ref
| | -> ../../../../nw:supporting-network/network-ref
| +--rw nt:link-ref      leafref
+--rw tet:te!
| +--rw (tet:bundle-stack-level)?
| | +--:(tet:bundle)
| | | +--rw tet:bundled-links

```

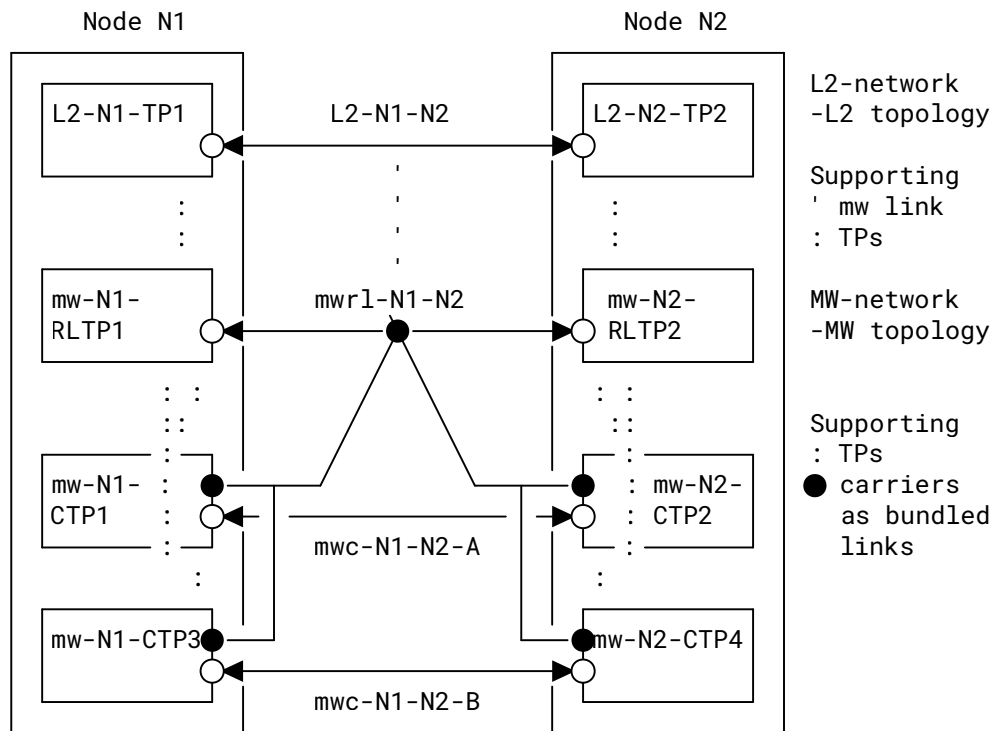



Figure 3: Example for L2 over Microwave

A.1. Instance Data for 2+0 Mode for a Bonded Configuration

An L2 network with a supporting microwave network, showing a 2+0 microwave configuration. The num-bonded-carriers = 2, and the num-protecting-carriers = 0. This means both carriers are active, so there is no redundancy and there is more capacity. The JSON encoding of the 2+0 example data follows:

```
{
  "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"
          }
        ]
      }
    ]
  },
  {
    "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"
          }
        ]
      },
      {
        "tp-id": "mw-N1-CTP1",
        "ietf-te-topology:te-tp-id": "192.0.2.3",
        "ietf-te-topology:te": {
          "ietf-microwave-topology:mw-tp": {
            "microwave-rltp": {}
          }
        }
      }
    ],
    {
      "tp-id": "mw-N1-CTP1",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "microwave-ctp": {}
        }
      }
    }
  },
}

```

```

    {
      "tp-id": "mw-N1-CTP3",
      "ietf-te-topology:te-tp-id": 2,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "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": "192.0.2.4",
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "microwave-rltp": {}
        }
      }
    },
    {
      "tp-id": "mw-N2-CTP2",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "microwave-ctp": {}
        }
      }
    },
    {
      "tp-id": "mw-N2-CTP4",
      "ietf-te-topology:te-tp-id": 2,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "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": {
      "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": {
        "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": {
          "microwave-carrier": {
            "tx-frequency": 10528000,
            "rx-frequency": 10415000,
            "channel-separation": 28000
          }
        }
      }
    }
  }
]
}

```

A.2. Instance Data for 1+1 Mode for a Protected Configuration

An L2 network with a supporting microwave network, showing a 1+1 microwave configuration. The num-bonded-carriers = 1, and the num-protecting-carriers = 1. This means there is a standby carrier protecting the active carrier. The JSON encoding of the 1+1 example data follows:

```

{
  "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"
          }
        ]
      }
    ]
  },
  {
    "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": "192.0.2.3",
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "microwave-rltp": {}
        }
      }
    }
  ],
  {
    "tp-id": "mw-N1-CTP1",
    "ietf-te-topology:te-tp-id": 1,
    "ietf-te-topology:te": {
      "ietf-microwave-topology:mw-tp": {
        "microwave-ctp": {}
      }
    }
  },
  {
    "tp-id": "mw-N1-CTP3",

```



```

        "ietf-te-topology:te-tp-id": 2,
        "ietf-te-topology:te": {
          "ietf-microwave-topology:mw-tp": {
            "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": "192.0.2.4",
          "ietf-te-topology:te": {
            "ietf-microwave-topology:mw-tp": {
              "microwave-rltp": {}
            }
          }
        }
      ],
    },
    {
      "tp-id": "mw-N2-CTP2",
      "ietf-te-topology:te-tp-id": 1,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "microwave-ctp": {}
        }
      }
    },
    {
      "tp-id": "mw-N2-CTP4",
      "ietf-te-topology:te-tp-id": 2,
      "ietf-te-topology:te": {
        "ietf-microwave-topology:mw-tp": {
          "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": {
          "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": {
            "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": {
          "microwave-carrier": {
            "tx-frequency": 10728000,
            "rx-frequency": 10615000,
            "channel-separation": 28000
          }
        }
      }
    }
  }
]
}

```

Appendix B. Microwave Topology Model with Example Extensions

This non-normative appendix provides examples of how the Microwave Topology Model can be used with the interface reference topology (ifref) [\[YANG-IF-REF-TOPO\]](#) and the bandwidth-availability-topology (bwa) [\[YANG-BWA-TOPO\]](#) models. There is also a snippet of JSON to show geolocation information instance data. When the JSON files have long lines, the long lines are wrapped as described in [\[RFC8792\]](#).

The tree below shows an example of the relevant leafs for a complete Microwave Topology Model including interface reference topology (ifref) [\[YANG-IF-REF-TOPO\]](#) and bandwidth-availability-topology (bwa) [\[YANG-BWA-TOPO\]](#) models.

```

module: ietf-network
+--rw networks
  +--rw network* [network-id]
    | +--rw network-id                network-id
    | +--rw network-types
    | | +--rw tet:te-topology!
    | | +--rw mwt: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            leafref
    | +--rw tet:te-tp-id?
    | | te-types:te-tp-id
    | +--rw tet:te!
    | | +--rw tet:name?                string
    | | +--ro tet:geolocation
    | | | +--ro tet:altitude?          int64
    | | | +--ro tet:latitude?
    | | | | geographic-coordinate-degree
    | | | +--ro tet:longitude?
    | | | | geographic-coordinate-degree
    | | +--rw mwt:mw-tp!
    | | | +--rw (mwt:mw-tp-option)?
    | | | | +--:(mwt:microwave-rltp)
    | | | | | +--rw mwt:microwave-rltp!
    | | | | +--:(mwt:microwave-ctp)
    | | | | | +--rw mwt:microwave-ctp!
    | | | +--rw ifref:tp-to-interface-path?
    | | | | -> /if:interfaces/interface/name
    | +--rw tet:te-node-id?            te-types:te-node-id
  +--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?          leafref
    | +--rw nt:destination
    | | +--rw nt:dest-node?          -> ../../../../nw:node/node-id
    | | +--rw nt:dest-tp?            leafref
    | +--rw nt:supporting-link* [network-ref link-ref]
    | | +--rw nt:network-ref
    | | | -> ../../../../nw:supporting-network/network-ref
    | | +--rw nt:link-ref            leafref
    | +--rw tet:te!
    | | +--rw (tet:bundle-stack-level)?

```

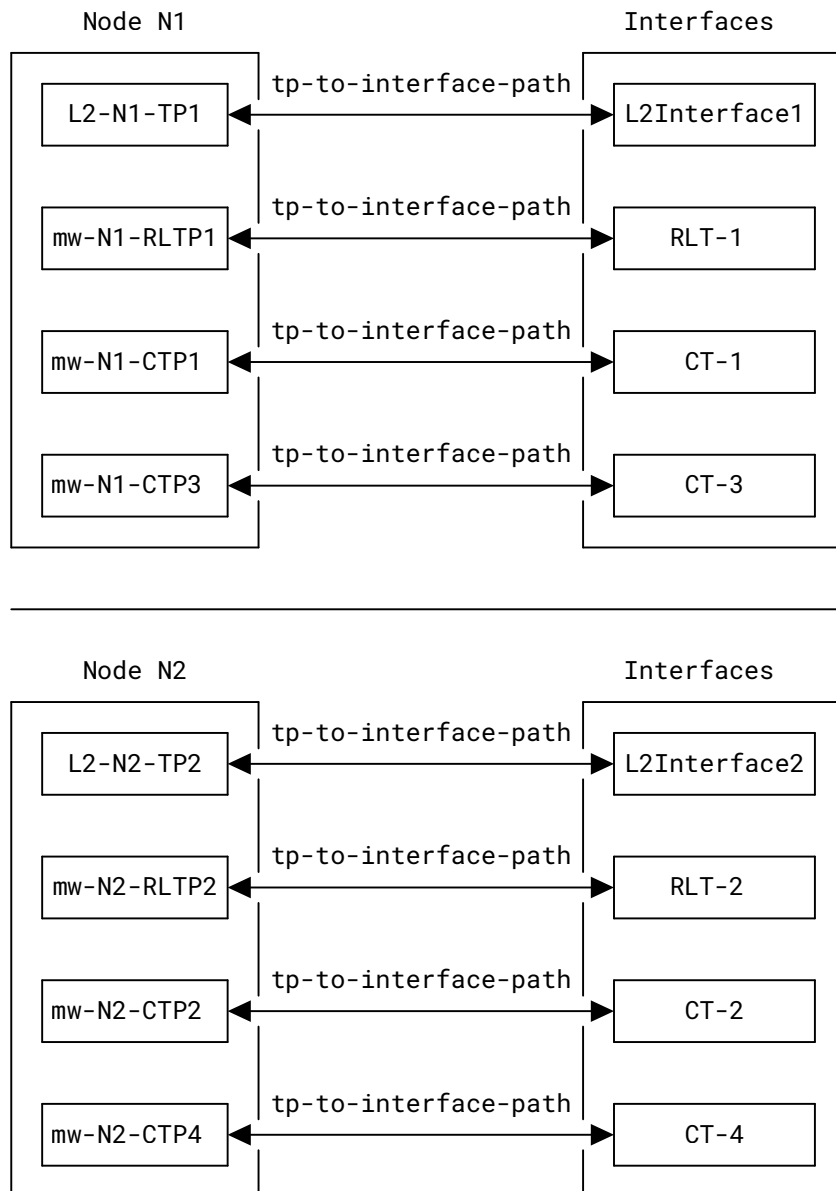



Figure 5: Interface Extension Example for L2 over Microwave

B.1. Instance Data for 2+0 Mode

An 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:

```
{
  "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"
      }
    ]
  },
  "ietf-te-topology:te-node-id": "192.0.2.1",
  "ietf-te-topology:te": {
    "te-node-attributes": {
      "ietf-eth-te-topology:eth-node": {}
    }
  },
  {
    "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-te-topology:te-node-id": "192.0.2.2",
    "ietf-te-topology:te": {
      "te-node-attributes": {
        "ietf-eth-te-topology:eth-node": {}
      }
    }
  },
  "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"
  }
],
"ietf-te-topology:te": {
  "te-link-attributes": {
    "interface-switching-capability": [
      {
        "switching-capability": "ietf-te-types:switching-l2sc",
        "encoding": "ietf-te-types:lsp-encoding-ethernet"
      }
    ]
  }
}
},
{
  "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"
        }
      ]
    },
    {
      "tp-id": "mw-N1-RLTP2",
      "supporting-termination-point": [
        {
          "network-ref": "mw-network",
          "node-ref": "mw-N1",
          "tp-ref": "mw-N1-CTP2"
        }
      ]
    }
  ],
  "ietf-te-topology:te-tp-id": "192.0.2.3",
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp": {
      "microwave-rltp": {}
    }
  },
  "ietf-tp-interface-reference-topology:tp-to-interface-path":

```

```

    "RLT-1"
  }
},
{
  "tp-id": "mw-N1-CTP1",
  "ietf-te-topology:te-tp-id": 1,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp": {
      "microwave-ctp": {}
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path":
    "CT-1"
  }
},
{
  "tp-id": "mw-N1-CTP3",
  "ietf-te-topology:te-tp-id": 2,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp": {
      "microwave-ctp": {}
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path":
    "CT-3"
  }
},
],
"ietf-te-topology:te-node-id": "192.0.2.1",
"ietf-te-topology:te": {
  "te-node-attributes": {
    "ietf-microwave-topology:mw-node": {}
  }
}
},
{
  "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": "192.0.2.4",
      "ietf-te-topology:te": {

```

```

    "ietf-microwave-topology:mw-tp": {
      "microwave-rltp": {}
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path":
    "RLT-2"
  }
},
{
  "tp-id": "mw-N2-CTP2",
  "ietf-te-topology:te-tp-id": 1,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp": {
      "microwave-ctp": {}
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path":
    "CT-2"
  }
},
{
  "tp-id": "mw-N2-CTP4",
  "ietf-te-topology:te-tp-id": 2,
  "ietf-te-topology:te": {
    "ietf-microwave-topology:mw-tp": {
      "microwave-ctp": {}
    },
    "ietf-tp-interface-reference-topology:tp-to-interface-path":
    "CT-4"
  }
},
],
"ietf-te-topology:te-node-id": "192.0.2.1",
"ietf-te-topology:te": {
  "te-node-attributes": {
    "ietf-microwave-topology:mw-node": {}
  }
}
],
"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"
          },
          {

```



```
    "dest-tp": "mw-N2-CTP4"
  },
  "ietf-te-topology:te": {
    "te-link-attributes": {
      "ietf-microwave-topology:mw-link": {
        "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 initially prepared using the kramdown RFC tool written and maintained by Carsten Bormann. Thanks to Martin Thomson for the GitHub integration of the kramdown RFC tool and for the aasvg tool, which is used for the ascii-to-SVG conversion.

The authors would like to thank Tom Petch, Éric Vyncke, and Rob Wilton for their reviews.

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