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**YANG Modules for IPv4-in-IPv6 Address plus Port Softwires  
draft-ietf-softwire-yang-05**

Abstract

This document defines YANG modules for the configuration and operation of IPv4-in-IPv6 softwire Border Relays and Customer Premises Equipment for the Lightweight 4over6, MAP-E, and MAP-T softwire mechanisms.

Editorial Note (To be removed by RFC Editor)

Please update these statements within this document with the RFC number to be assigned to this document:

- o "This version of this YANG module is part of RFC XXXX;"
- o "RFC XXXX: YANG Modules for IPv4-in-IPv6 Address plus Port Softwires";
- o "reference: RFC XXXX"

Please update the "revision" date of the YANG module.

Status of This Memo

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## [1.](#) Introduction

The IETF softwire working group has developed several IPv4-in-IPv6 softwire mechanisms to address various deployment contexts and constraints. As a companion to the architectural specification documents, this document focuses on the provisioning of address plus port (A+P) softwire functional elements: Border Routers (BRs) and Customer Premises Equipment (CEs). The softwire mechanisms covered in this document are Lightweight 4 over 6 [[RFC7596](#)], MAP-E [[RFC7597](#)], and MAP-T [[RFC7599](#)].

This document focuses on A+P mechanisms; the reader can refer to [[I-D.ietf-softwire-dslite-yang](#)] for a YANG module for DS-Lite [[RFC6333](#)].

This document defines YANG data modules [[RFC7950](#)] that can be used to configure and manage A+P softwire elements using the NETCONF protocol [[RFC6241](#)] for:

- o Configuration
- o Operational State
- o Notifications

### [1.1.](#) Terminology

The reader should be familiar with the concepts and terms defined in [[RFC7596](#)], [[RFC7597](#)], [[RFC7599](#)], and the YANG data modelling language defined in [[RFC7950](#)].

The meaning of the symbols in tree diagrams is defined in [[RFC8340](#)].

## [2.](#) Overview of the Modules

### [2.1.](#) Overall Structure

The document defines the following two YANG data modules for the configuration and monitoring of softwire functional elements:

ietf-softwire-ce	Provides configuration and monitoring for softwire CE element. This module is defined as augments to the interface YANG module
------------------	--

[RFC8343].

ietf-softwire-br Provides configuration and monitoring for software BR element.

In addition, the following module is defined:

ietf-softwire-common Contains groups of common functions that are imported into the CE and BR modules.

This approach has been taken so that the various modules can be easily extended to support additional softwire mechanisms, if required.

Within the BR and CE modules, the YANG "feature" statement is used to distinguish which of the different softwire mechanism(s) is relevant for a specific element's configuration. For each module, a choice statement 'ce-type' is included for either 'binding' or 'algorithm'. 'Binding' is used for configuring Lightweight 4over6, whereas 'algorithm' is used for configuring MAP-T or MAP-E.

In the 'algo-instances' container, a choice statement 'data-plane' is included to specify MAP-E (encapsulation) or MAP-T (translation). Table 1 shows how these choices are used to indicate the desired softwire mechanism:

S46 Mechanism	ce-type?	data-plane?
Lightweight 4over6	binding	n/a
MAP-E	algorithm	encapsulation
MAP-T	algorithm	translation

Table 1: Softwire Mechanism Choice Statement Enumeration

NETCONF notifications are also included.

Note: Earlier versions of this specification combined the softwire mechanisms by their associated technologies rather than their function in the architecture. As the document was revised, it became apparent that dividing the modules by their role in the architecture (CE or BR) was a better approach as this follows the intended function and existing implementation approaches more closely.

## **2.2. Additional Components Configuration**

The softwire modules only aim to provide configuration relevant for softwires. In order to fully provision a CE element, the following may also be necessary:

- o IPv6 forwarding and routing configuration, to enable CE to obtain one or more IPv6 prefixes for softwire usage. A YANG module for routing management is described in [[RFC8349](#)]
- o IPv4 routing configuration, to add one or more IPv4 destination prefix(es) reachable via the configured softwire. A YANG module for routing management is described in [[RFC8349](#)]
- o Stateful NAT44/NAPT management, to optionally specify a port set (PSID) along with its length. A YANG module for NAT management is described in [[I-D.ietf-opsawg-nat-yang](#)]
- o Stateless NAT46 management, required by softwire translation based mechanisms (i.e. the assignment of a Network-Specific Prefix to use for IPv4/IPv6 translation). A YANG module for NAT management is described in [[I-D.ietf-opsawg-nat-yang](#)]

As YANG modules for the above functions are already defined in other documents, their functionality is not duplicated here and they should be imported here, as needed. [Appendix A.3](#) provides XML examples of how these modules can be used together.

The CE must already have minimal IPv6 configuration in place so it is reachable by the NETCONF client to obtain softwire configuration. If additional IPv6 specific configuration is necessary, the YANG modules defined in [[RFC8344](#)] and [[RFC8349](#)] may be used.

## **3. Softwire CE YANG Tree Diagram**

### **3.1. CE Tree Diagram**

The CE module provides configuration and monitoring for all of the softwire mechanisms covered in this document (i.e., Lightweight 4over6, MAP-E, and MAP-T).

This module augments "ietf-interfaces", defined in [[RFC8343](#)] with an entry for the softwire. This entry can be referenced to configure IPv4 forwarding features for the element.

Figure 1 describes the tree structure of the softwire CE YANG module.

```
module: ietf-softwire-ce
```

```

augment /if:interfaces/if:interface:
  +--rw software-payload-mtu?   uint16
  +--rw software-path-mru?     uint16
  +--rw (ce-type)?
    +--:(binding) {binding}?
      | +--rw binding-ipv6info?   union
      | +--rw br-ipv6-addr       inet:ipv6-address
    +--:(algorithm) {algorithm}?
      +--rw algo-instances
        +--rw algo-instance* [id]
          +--rw id                uint32
          +--rw enable?          boolean
          +--rw algo-versioning
            | +--rw version?     uint64
            | +--rw date?       yang:date-and-time
          +--rw name?            string
          +--rw (data-plane)?
            | +--:(encapsulation)
            | | +--rw br-ipv6-addr   inet:ipv6-address
            | +--:(translation)
            | | +--rw dmr-ipv6-prefix? inet:ipv6-prefix
          +--rw ea-len            uint8
          +--rw rule-ipv6-prefix  inet:ipv6-prefix
          +--rw rule-ipv4-prefix  inet:ipv4-prefix
          +--rw forwarding        boolean
augment /if:interfaces/if:interface/if:statistics:
  +--ro sent-ipv4-packets?
    | yang:zero-based-counter64
  +--ro sent-ipv4-bytes?
    | yang:zero-based-counter64
  +--ro sent-ipv6-packets?
    | yang:zero-based-counter64
  +--ro sent-ipv6-bytes?
    | yang:zero-based-counter64
  +--ro rcvd-ipv4-packets?
    | yang:zero-based-counter64
  +--ro rcvd-ipv4-bytes?
    | yang:zero-based-counter64
  +--ro rcvd-ipv6-packets?
    | yang:zero-based-counter64
  +--ro rcvd-ipv6-bytes?
    | yang:zero-based-counter64
  +--ro dropped-ipv4-packets?
    | yang:zero-based-counter64
  +--ro dropped-ipv4-bytes?
    | yang:zero-based-counter64
  +--ro dropped-ipv6-packets?
    | yang:zero-based-counter64

```

```

+--ro dropped-ipv6-bytes?
|   yang:zero-based-counter64
+--ro dropped-ipv4-fragments?
|   yang:zero-based-counter64
+--ro dropped-ipv4-fragment-bytes?
|   yang:zero-based-counter64
+--ro ipv6-fragments-reassembled?
|   yang:zero-based-counter64
+--ro ipv6-fragments-bytes-reassembled?
|   yang:zero-based-counter64
+--ro out-icmpv4-error-packets?
|   yang:zero-based-counter64
+--ro out-icmpv4-error-bytes?
|   yang:zero-based-counter64
+--ro out-icmpv6-error-packets?
|   yang:zero-based-counter64
+--ro out-icmpv6-error-bytes?
    yang:zero-based-counter64

```

notifications:

```

+---n software-ce-event {binding}?
    +--ro ce-binding-ipv6-addr-change    inet:ipv6-address

```

Figure 1: Software CE YANG Tree Diagram

### **3.2. Software CE Tree Diagram Description**

Additional information related to the operation of a CE element is provided below:

- o software-payload-mtu: optionally used to set the IPv4 MTU for the software. Needed if the software implementation is unable to correctly calculate the correct IPv4 Maximum Transit Unit (MTU) size automatically.
- o software-path-mru: optionally used to set the maximum IPv6 software packet size that can be received, including the encapsulation/translation overhead. Needed if the software implementation is unable to correctly calculate the correct IPv4 Maximum Receive Unit (MRU) size automatically.
- o ce-type: provides a choice statement allowing the binding or algorithmic software mechanisms to be selected.

Further details relevant to binding software elements are:

- o binding-ipv6info: used to set the IPv6 binding prefix type to identify which IPv6 address to use as the tunnel source. It can

be 'IPv6 prefix type' or ''IPv6 address type'.

- o br-ipv6-addr: defines the IPv6 address of the remote BR.

Additional details relevant to some of the important algorithmic elements are provided below:

- o algo-versioning: optionally used to add an incremental version number and/or timestamp to the algorithm. This can be used for logging/data retention purposes. The version number is incremented and a new timestamp value written whenever a change is made to the algorithm or a new instance is created.
- o forwarding: specifies whether the rule can be used as a Forward Mapping Rule (FMR). If not set, this rule is a Basic Mapping Rule (BMR) only and must not be used for forwarding. Refer to [Section 4.1 of \[RFC7598\]](#).
- o ea-len: used to set the length of the Embedded-Address (EA), which is defined in the mapping rule for a MAP domain.
- o data-plane: provides a choice statement for either encapsulation (MAP-E) or translation (MAP-T).
- o br-ipv6-addr: defines the IPv6 address of the BR. This information is valid for MAP-E.
- o dmr-ipv6-prefix: defines the Default Mapping Rule (DMR) IPv6 prefix of the BR. This information is valid for MAP-T.

Additional information on the notification node is listed below:

- o ce-binding-ipv6-addr-change: if the CE's binding IPv6 address changes for any reason, the NETCONF client will be notified.

#### **4. Softwire BR YANG Tree Diagram**

##### **4.1. BR Tree Diagram**

The BR YANG module provides configuration and monitoring for all of the softwire mechanisms covered in this document (i.e., Lightweight 4over6, MAP-E, and MAP-T).

Figure 2 provides the tree structure of this module.

```
module: ietf-softwire-br
  +--rw br-instances
    +--rw (br-type)?
```



```

+--:(binding) {binding}?
| +--rw binding {binding}?
|   +--rw bind-instance* [id]
|     +--rw binding-table-versioning
|       | +--rw version?   uint64
|       | +--rw date?     yang:date-and-time
|     +--rw id             uint32
|     +--rw name?         string
|     +--rw softwire-num-max   uint32
|     +--rw softwires-payload-mtu  uint16
|     +--rw softwire-path-mru   uint16
|     +--rw enable-hairpinning?  boolean
|     +--rw binding-table
|       | +--rw binding-entry* [binding-ipv6info]
|       |   +--rw binding-ipv6info  union
|       |   +--rw binding-ipv4-addr?
|       |     | inet:ipv4-address
|       |   +--rw port-set
|       |     | +--rw psid-offset?  uint8
|       |     | +--rw psid-len     uint8
|       |     | +--rw psid        uint16
|       |   +--rw br-ipv6-addr?
|       |     | inet:ipv6-address
|     +--rw icmp-policy
|       | +--rw icmpv4-errors
|       |   | +--rw allow-incoming-icmpv4?  boolean
|       |   | +--rw icmpv4-rate?           uint32
|       |   | +--rw generate-icmpv4-errors?  boolean
|       | +--rw icmpv6-errors
|       |   +--rw generate-icmpv6-errors?  boolean
|       |   +--rw icmpv6-rate?           uint32
|     +--ro traffic-stat
|       +--ro discontinuity-time      yang:date-and-time
|       +--ro sent-ipv4-packets?
|         | yang:zero-based-counter64
|       +--ro sent-ipv4-bytes?
|         | yang:zero-based-counter64
|       +--ro sent-ipv6-packets?
|         | yang:zero-based-counter64
|       +--ro sent-ipv6-bytes?
|         | yang:zero-based-counter64
|       +--ro rcvd-ipv4-packets?
|         | yang:zero-based-counter64
|       +--ro rcvd-ipv4-bytes?
|         | yang:zero-based-counter64
|       +--ro rcvd-ipv6-packets?
|         | yang:zero-based-counter64
|       +--ro rcvd-ipv6-bytes?

```

```

|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv4-packets?
|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv4-bytes?
|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv6-packets?
|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv6-bytes?
|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv4-fragments?
|         |         yang:zero-based-counter64
|         +--ro  dropped-ipv4-fragment-bytes?
|         |         yang:zero-based-counter64
|         +--ro  ipv6-fragments-reassembled?
|         |         yang:zero-based-counter64
|         +--ro  ipv6-fragments-bytes-reassembled?
|         |         yang:zero-based-counter64
|         +--ro  out-icmpv4-error-packets?
|         |         yang:zero-based-counter64
|         +--ro  out-icmpv4-error-bytes?
|         |         yang:zero-based-counter64
|         +--ro  out-icmpv6-error-packets?
|         |         yang:zero-based-counter64
|         +--ro  out-icmpv6-error-bytes?
|         |         yang:zero-based-counter64
|         +--ro  dropped-icmpv4-packets?
|         |         yang:zero-based-counter64
|         +--ro  dropped-icmpv4-bytes?
|         |         yang:zero-based-counter64
|         +--ro  hairpin-ipv4-packets?
|         |         yang:zero-based-counter64
|         +--ro  hairpin-ipv4-bytes?
|         |         yang:zero-based-counter64
|         +--ro  active-softwire-num?
|         |         uint32
+--:(algorithm) {algorithm}?
  +--rw  algorithm {algorithm}?
    +--rw  algo-instance* [id]
      +--rw  id                uint32
      +--rw  enable?          boolean
      +--rw  algo-versioning
        |  +--rw  version?    uint64
        |  +--rw  date?      yang:date-and-time
      +--rw  name?            string
      +--rw  (data-plane)?
        |  +--:(encapsulation)
        |  |  +--rw  br-ipv6-addr    inet:ipv6-address
        |  +--:(translation)

```

```

|     +-rw dmr-ipv6-prefix?   inet:ipv6-prefix
+--rw ea-len                  uint8
+--rw rule-ipv6-prefix       inet:ipv6-prefix
+--rw rule-ipv4-prefix       inet:ipv4-prefix
+--rw forwarding             boolean
+--rw port-set
|   +-rw psid-offset?        uint8
|   +-rw psid-len            uint8
|   +-rw psid                 uint16
+--ro traffic-stat
  +-ro discontinuity-time     yang:date-and-time
  +-ro sent-ipv4-packets?
  |   yang:zero-based-counter64
  +-ro sent-ipv4-bytes?
  |   yang:zero-based-counter64
  +-ro sent-ipv6-packets?
  |   yang:zero-based-counter64
  +-ro sent-ipv6-bytes?
  |   yang:zero-based-counter64
  +-ro rcvd-ipv4-packets?
  |   yang:zero-based-counter64
  +-ro rcvd-ipv4-bytes?
  |   yang:zero-based-counter64
  +-ro rcvd-ipv6-packets?
  |   yang:zero-based-counter64
  +-ro rcvd-ipv6-bytes?
  |   yang:zero-based-counter64
  +-ro dropped-ipv4-packets?
  |   yang:zero-based-counter64
  +-ro dropped-ipv4-bytes?
  |   yang:zero-based-counter64
  +-ro dropped-ipv6-packets?
  |   yang:zero-based-counter64
  +-ro dropped-ipv6-bytes?
  |   yang:zero-based-counter64
  +-ro dropped-ipv4-fragments?
  |   yang:zero-based-counter64
  +-ro dropped-ipv4-fragment-bytes?
  |   yang:zero-based-counter64
  +-ro ipv6-fragments-reassembled?
  |   yang:zero-based-counter64
  +-ro ipv6-fragments-bytes-reassembled?
  |   yang:zero-based-counter64
  +-ro out-icmpv4-error-packets?
  |   yang:zero-based-counter64
  +-ro out-icmpv4-error-bytes?
  |   yang:zero-based-counter64
  +-ro out-icmpv6-error-packets?

```

```

|          yang:zero-based-counter64
+--ro out-icmpv6-error-bytes?
|          yang:zero-based-counter64

notifications:
+--n software-binding-instance-event {binding}?
| +--ro bind-id?
| |       -> /br-instances/binding/bind-instance/id
| +--ro invalid-entry*   leafref
| +--ro added-entry*     inet:ipv6-address
| +--ro modified-entry*  leafref
+--n software-algorithm-instance-event {algorithm}?
+--ro algo-id
|       -> /br-instances/algorithm/algo-instance/id
+--ro invalid-entry-id*
|       -> /br-instances/algorithm/algo-instance/id
+--ro added-entry*
|       -> /br-instances/algorithm/algo-instance/id
+--ro modified-entry*
|       -> /br-instances/algorithm/algo-instance/id

```

Figure 2: Softwire BR YANG Tree

#### 4.2. Softwire BR Tree Diagram Description

The descriptions for leaves which are common with the CE module are provided in [Section 3.2](#). Descriptions for additional elements are provided below:

- o binding-table-versioning: optionally used to add an incremental version number and/or timestamp to the binding table. This can be used for logging or data retention purposes. The version number is incremented and a new timestamp value written whenever a change is made to the contents of the binding table or a new binding table list is created.
- o binding-entry: used to define the binding relationship between 3-tuples {lwB4's IPv6 address/prefix, the allocated IPv4 address, restricted port-set}. For detail information, please refer to [\[RFC7596\]](#).
- o software-num-max: used to set the maximum number of softwire binding rules that can be created on the lw4o6 element simultaneously.
- o active-softwire-num: holds the number of softwires currently provisioned on the element.

Additional information on some of the important notification nodes is listed below:

- o `invalid-entry`, `added-entry`, `modified-entry`: used to notify the NETCONF client that a specific binding entry or MAP rule has expired, been invalidated, added, or modified.

## 5. Software CE YANG Module

This module imports typedefs from [[RFC6991](#)].

```
<CODE BEGINS>file "ietf-software-ce@2018-03-16.yang"
```

```
module ietf-software-ce {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-software-ce";
  prefix "software-ce";

  import ietf-inet-types {prefix inet; }
  import ietf-interfaces {prefix if; }
  import iana-if-type {prefix ianaift; }
  import ietf-software-common {prefix software-common; }

  organization
    "IETF Software Working Group";

  contact
    "WG Web:  <https://datatracker.ietf.org/wg/software/>
    WG List:  <mailto:software@ietf.org>

    Qi Sun <sunqi.ietf@gmail.com>
    Linhui Sun <lh.sunlinh@gmail.com>
    Yong Cui <yong@csnet1.cs.tsinghua.edu.cn>
    Ian Farrer <ian.farrer@telekom.de>
    Sladjana Zoric <sladjana.zoric@telekom.de>
    Mohamed Boucadair <mohamed.boucadair@orange.com>
    Rajiv <Asati\_rajiva@cisco.com>
    ";

  description
    "This document defines a YANG data module for the configuration and
    management of A+P Software Customer Premises Equipment (CEs). It
    covers Lightweight 4over6, MAP-E, and MAP-T mechanisms.
    Copyright (c) 2018 IETF Trust and the persons identified
    as authors of the code. All rights reserved.
    This version of this YANG module is part of RFC XXX; see the RFC
    itself for full legal notices.";
```

```
revision 2018-03-16 {
  description
    "Initial revision.";
  reference
    "RFC XXXX: YANG Modules for IPv4-in-IPv6 Address plus Port
      Softwires";
}

/*
 * Features
 */

feature binding {
  description
    "Binding is used for configuring the Lightweight 4over6 mechanism.

    Binding based softwire mechanisms are IPv4-over-IPv6 tunnelling
    transition mechanisms specifically intended for complete
    independence between the IPv6 subnet prefix (and IPv6 address)
    and IPv4 address, with or without IPv4 address sharing.

    This is accomplished by maintaining state for each softwire
    (per-subscriber state) in the central Border Relay (BR) and using
    a hub-and-spoke forwarding architecture. In order to delegate the
    NATP function and achieve IPv4 address sharing, port-restricted
    IPv4 addresses needs to be allocated to CEs.

    This feature indicates that the instance functions as a binding
    based softwire instance.";

  reference
    "RFC7596: Lightweight 4over6: An Extension to the Dual-Stack Lite
      Architecture
    RFC7597: Mapping of Address and Port with Encapsulation (MAP-E)
    RFC7599: Mapping of Address and Port using Translation (MAP-T)";
}

feature algorithm {
  description
    "MAP-E is an IPv6 transition mechanism for transporting IPv4
    packets across an IPv6 network using IP encapsulation. MAP-E
    allows for a reduction of the amount of centralized state using
    rules to express IPv4/IPv6 address mappings. This introduces an
    algorithmic relationship between the IPv6 subnet and IPv4 address.

    MAP-T is an IPv6 transition mechanism for transporting IPv4
    packets across an IPv6 network using IP translation. It leverages
    a double stateless NAT64 based solution as well as the stateless
```

```
    algorithmic address & transport layer port mapping algorithm
    defined for MAP-E.

    This feature indicates that the instance functions as a MAP-E or
    MAP-T instance.";

reference
  "RFC7597: Mapping of Address and Port with Encapsulation (MAP-E)
  RFC7599: Mapping of Address and Port using Translation (MAP-T)";
}

// Binding Entry
grouping binding-entry {
  description
    "The binding BR maintains an address binding table that
    contains the binding between the CE's IPv6 address,
    the allocated IPv4 address and restricted port-set.";

  leaf binding-ipv6info {

    type union {
      type inet:ipv6-address;
      type inet:ipv6-prefix;
    }

    description
      "The IPv6 information for a binding entry.

      When the IPv6 prefix type is used,
      the IPv6 source address of the CE is constructed
      according to the description in RFC7596.

      If the IPv6 address type is used, the CE can use
      any valid /128 address from a prefix assigned to
      the CE.";
    reference
      "Section 5.1 of RFC7596.";
  }

  leaf br-ipv6-addr {
    type inet:ipv6-address;
    mandatory true;
    description
      "The IPv6 address for of the binding BR.";
  }
}

// configuration and stateful parameters for softwire CE interface
```

```
augment "/if:interfaces/if:interface" {
  when "if:type = 'ianaift:tunnel'";
  description "Softwire CE interface configuration";

  leaf softwire-payload-mtu {
    type uint16;
    units bytes;
    description
      "The payload IPv4 MTU for the Softwire tunnel.";
  }

  leaf softwire-path-mru {
    type uint16;
    units bytes;
    description
      "The path MRU for the softwire (payload + encapsulation
      overhead).";
  }

  choice ce-type {
    description "Sets the softwire CE mechanism";

    case binding {
      if-feature binding;
      description "CE binding configuration";
      uses binding-entry;
    }

    case algorithm {
      if-feature algorithm;
      description "CE algorithm configuration";

      container algo-instances {
        description
          "Indicates that the instances supports the MAP-E and MAP-T
          function. The instances advertise the MAP-E/MAP-T
          feature through the capability exchange mechanism
          when a NETCONF session is established.";
        list algo-instance {
          key "id";
          description
            "MAP forwarding rule instance for
            MAP-E/MAP-T";
          leaf id {
            type uint32;
            mandatory true;
            description "Algorithm Instance ID";
          }
        }
      }
    }
  }
}
```



```

        uses software-common:algorithm-instance;
    }
}
}
}
}

augment "/if:interfaces/if:interface/if:statistics" {
    when "../if:type = 'ianaift:tunnel'";
    description "Softwire CE interface statistics.";
    uses software-common:traffic-stat;
}

/*
 * Notifications
 */

notification software-ce-event {
    if-feature binding;
    description "CE notification";
    leaf ce-binding-ipv6-addr-change {
        type inet:ipv6-address;
        mandatory true;
        description
            "If the CE's binding IPV6 address changes for any reason,
            it should notify the NETCONF client.";
    }
}
}
}
<CODE ENDS>

```

## 6. BR Softwire YANG Module

This module imports typedefs from [[RFC6991](#)].

```

<CODE BEGINS>file "ietf-software-br@2018-03-16.yang"

module ietf-software-br {
    yang-version 1.1;
    namespace "urn:ietf:params:xml:ns:yang:ietf-software-br";
    prefix "software-br";

    import ietf-inet-types {prefix inet; }
    import ietf-yang-types {prefix yang; }
    import ietf-software-common {prefix software-common; }

    organization
        "IETF Softwire Working Group";
}

```

## contact

"WG Web: <<https://datatracker.ietf.org/wg/software/>>  
WG List: <mailto:software@ietf.org>

Qi Sun <sunqi.ietf@gmail.com>  
Linhui Sun <lh.sunlinh@gmail.com>  
Yong Cui <yong@csnet1.cs.tsinghua.edu.cn>  
Ian Farrer <ian.farrer@telekom.de>  
Sladjana Zoric <sladjana.zoric@telekom.de>  
Mohamed Boucadair <mohamed.boucadair@orange.com>  
Rajiv <Asati rajiva@cisco.com>  
";

## description

"This document defines a YANG data module for the configuration and management of A+P Softwire Border Routers. It covers Lightweight 4over6, MAP-E, and MAP-T mechanisms.

Copyright (c) 2018 IETF Trust and the persons identified as authors of the code. All rights reserved.  
This version of this YANG module is part of RFC XXX; see the RFC itself for full legal notices.";

## revision 2018-03-16 {

## description

"Initial revision.";

## reference

"RFC XXXX: YANG Modules for IPv4-in-IPv6 Address plus Port Softwires";

}

/\*

\* Groupings

\*/

## grouping port-set {

## description

"Describes a set of layer 4 port numbers.

This may be a simple port range, or use the PSID algorithm to represent a range of transport layer ports which will be used by a NAT.";

## leaf psid-offset {

type uint8 {

range 0..16;

}

description

```
    "The number of offset bits. In Lightweight 4over6,
    the default value is 0 for assigning one contiguous
    port range. In MAP-E/T, the default value is 6,
    which means the system ports (0-1023) are excluded by
    default and the assigned port ranges are distributed across the
    entire port space, depending on either psid-len or the
    number of contiguous ports.";
}

leaf psid-len {
  type uint8 {
    range 0..15;
  }
  mandatory true;
  description
    "The length of PSID, representing the sharing
    ratio for an IPv4 address. This, along with ea-len, can
    be used to calculate the number of contiguous ports per
    port range";
}

leaf psid {
  type uint16;
  mandatory true;
  description
    "Port Set Identifier (PSID) value, which
    identifies a set of ports algorithmically.";
}
}

grouping binding-entry {
  description
    "The binding BR maintains an address binding table that
    contains the binding between the CE's IPv6 address,
    the allocated IPv4 address and restricted port-set.";
  leaf binding-ipv6info {
    type union {
      type inet:ipv6-address;
      type inet:ipv6-prefix;
    }
    description
      "The IPv6 information for a CE binding entry.
      When the IPv6 prefix type is used,
      the IPv6 source address of the CE is constructed
      according to the description in RFC7596;
      if the IPv6 address type is used, the CE can use
      any valid /128 address from a prefix assigned to
      the CE.";
  }
}
```

```
reference
  "RFC7596: Lightweight 4over6: An Extension to the Dual-Stack
    Lite Architecture";
}
leaf binding-ipv4-addr {
  type inet:ipv4-address;
  description
    "The IPv4 address assigned to the binding CE,
    which is used as the IPv4 external address
    for binding CE local NAPT44.";
}
container port-set {
  description
    "For Lightweight 4over6, the default value
    for offset should be 0, to configure one contiguous
    port range.";
  uses port-set {
    refine "psid-offset" {
      default "0";
    }
  }
}
leaf br-ipv6-addr {
  type inet:ipv6-address;
  description
    "The IPv6 address for binding BR.";
}
}
/*
 * Features
 */

feature binding {
  description
    "Binding is used for configuring the Lightweight 4over6 mechanism.

    Binding based software mechanisms are IPv4-over-IPv6 tunnelling
    transition mechanisms specifically intended for complete
    independence between the IPv6 subnet prefix (and IPv6 address) and
    IPv4 address, with or without IPv4 address sharing.

    This is accomplished by maintaining state for each software
    (per-subscriber state) in the central Border Relay (BR) and using
    a hub-and-spoke forwarding architecture. In order to delegate the
    NAPT function and achieve IPv4 address sharing, port-restricted
    IPv4 addresses needs to be allocated to CEs.
```

This feature indicates that the instance functions as a binding based software instance.";

reference

[RFC7596](#): Lightweight 4over6: An Extension to the Dual-Stack Lite Architecture

[RFC7597](#): Mapping of Address and Port with Encapsulation (MAP-E)

[RFC7599](#): Mapping of Address and Port using Translation (MAP-T)";

}

feature algorithm {

description

"MAP-E is an IPv6 transition mechanism for transporting IPv4 packets across an IPv6 network using IP encapsulation. MAP-E allows for a reduction of the amount of centralized state using rules to express IPv4/IPv6 address mappings. This introduces an algorithmic relationship between the IPv6 subnet and IPv4 address.

MAP-T is an IPv6 transition mechanism for transporting IPv4 packets across an IPv6 network using IP translation. It leverages double stateless NAT64 based solution as well as the stateless algorithmic address & transport layer port mapping algorithm defined for MAP-E.

This feature indicates that the instance functions as a MAP-E or MAP-T instance.";

reference

[RFC7597](#): Mapping of Address and Port with Encapsulation (MAP-E)

[RFC7599](#): Mapping of Address and Port using Translation (MAP-T)";

}

container br-instances {

description

"BR Instances";

choice br-type {

description

"Select binding or algorithmic BR functionality.";

case binding {

if-feature binding;

container binding {

if-feature binding;

description

"binding mechanism (binding table) configuration.";

list bind-instance {

key "id";

description

```
    "A set of binding BRs to be configured.";
  container binding-table-versioning {
    description "binding table's version";
    leaf version{
      type uint64;
      description "Incremental version number of the binding
        table";
    }
    leaf date {
      type yang:date-and-time;
      description "Timestamp of the binding
        table";
    }
  }
  leaf id {
    type uint32;
    mandatory true;
    description "An instance identifier.";
  }
  leaf name {
    type string;
    description "The name for the binding BR.";
  }
  leaf software-num-max {
    type uint32;
    mandatory true;
    description
      "The maximum number of softwires that can be created on
        the binding BR.";
  }
  leaf softwires-payload-mtu {
    type uint16;
    units bytes;
    mandatory true;
    description
      "The payload IPv4 MTU for binding software.";
  }
  leaf software-path-mru {
    type uint16;
    units bytes;
    mandatory true;
    description
      "The path MRU for binding software.";
  }
  leaf enable-hairpinning {
    type boolean;
    default true;
    description
```

```
        "Enables/disables support for locally forwarding
        (hairpinning) traffic between two CEs.";
    reference
        "RFC7596 Section 6.2";
}
container binding-table {
    description "binding table";
    list binding-entry {
        key "binding-ipv6info";
        description "binding entry";
        uses binding-entry;
    }
}
container icmp-policy {
    description
        "The binding BR can be configured to process or drop
        incoming ICMP messages, and to generate outgoing ICMP
        error messages.";

    container icmpv4-errors {
        description
            "ICMPv4 error processing configuration";
        leaf allow-incoming-icmpv4 {
            type boolean;
            default true;
            description
                "Enables the processing of incoming ICMPv4
                packets.";
            reference
                "RFC7596: Lightweight 4over6: An Extension to the
                Dual-Stack Lite Architecture";
        }
        leaf icmpv4-rate {
            type uint32;
            description
                "Rate limit threshold in messages per-second
                for processing incoming ICMPv4 errors messages";
        }
        leaf generate-icmpv4-errors {
            type boolean;
            default true;
            description
                "Enables the generation of outgoing ICMPv4 error
                messages on receipt of an inbound IPv4 packet with
                no matching binding table entry.";
            reference
                "Section 5.2 of RFC7596.";
        }
    }
}
```

```
    }  
  
    container icmpv6-errors {  
      description  
        "ICMPv6 error processing configuration";  
      leaf generate-icmpv6-errors {  
        type boolean;  
        default true;  
        description  
          "Enables the generation of ICMPv6 errors messages if  
          no matching binding table entry is found for a  
          received packet.";  
        reference  
          "Section 6.2 of RFC7596.";  
      }  
      leaf icmpv6-rate {  
        type uint32;  
        description  
          "Rate limit threshold in messages per-second  
          for sending ICMPv6 errors messages";  
        reference  
          "Section 9 of RFC7596.";  
      }  
    }  
  }  
}  
  
container traffic-stat {  
  config false;  
  description  
    "Traffic statistics information for the BR.";  
  
  leaf discontinuity-time {  
    type yang:date-and-time;  
    mandatory true;  
    description  
      "The time of the most recent occasion on which the BR  
      instance suffered a discontinuity. This must be  
      initialized when the BR instance is configured  
      or rebooted.";  
  }  
  
  uses software-common:traffic-stat;  
  
  leaf dropped-icmpv4-packets {  
    type yang:zero-based-counter64;  
    description  
      "ICMPv4 packets that are dropped as a result  
      of the ICMP policy. Typically, this can be any
```



incoming ICMPv4 packets if ICMPv4 processing is disabled or incoming ICMPv4 packets that exceed the ICMPv4 rate-limit threshold.

Discontinuities in the value of this counter can occur at re-initialization of the management system, and at other times as indicated by the value of 'discontinuity-time'.";

```
}
leaf dropped-icmpv4-bytes {
  type yang:zero-based-counter64;
  description
    "ICMPv4 messages, in bytes, that are dropped as
    a result of the ICMP policy. Typically, it
    can be any incoming ICMPv4 packets if ICMPv4
    processing is disabled or incoming ICMPv4
    packets that exceed the ICMPv4 rate-limit
    threshold.

    Discontinuities in the value of this counter can
    occur at re-initialization of the management
    system, and at other times as indicated by
    the value of 'discontinuity-time'.";
}
leaf hairpin-ipv4-packets {
  type yang:zero-based-counter64;
  description
    "IPv4 packets locally routed between two CEs
    (hairpinned).

    Discontinuities in the value of this counter can
    occur at re-initialization of the management
    system, and at other times as indicated by
    the value of 'discontinuity-time'.";
}
leaf hairpin-ipv4-bytes {
  type yang:zero-based-counter64;
  description
    "IPv4 bytes locally routed between two CEs
    (hairpinned).

    Discontinuities in the value of this counter can
    occur at re-initialization of the management
    system, and at other times as indicated by
    the value of 'discontinuity-time'.";
}
leaf active-softwire-num {
  type uint32;
```

```

    config false;
    description
      "The number of currently active softwires on the
      binding instance.

      Discontinuities in the value of this counter can
      occur at re-initialization of the management
      system, and at other times as indicated by
      the value of 'discontinuity-time'.";
  }
}
}
}
}
case algorithm {
  if-feature algorithm;
  container algorithm {
    if-feature algorithm;
    description
      "Indicate that the instance supports the MAP-E and MAP-T
      function. The instances advertise the MAP-E/MAP-T feature
      through the capability exchange mechanism when a NETCONF
      session is established.";
    list algo-instance {
      key "id";
      description "Instances of algorithm";
      leaf id {
        type uint32;
        mandatory true;
        description "id";
      }
      uses softwire-common:algorithm-instance;
      container port-set {
        description "Indicates a set of ports.";
        uses port-set;
      }
      container traffic-stat {
        config false;
        description
          "Traffic statistics information for the BR.";
        leaf discontinuity-time {
          type yang:date-and-time;
          mandatory true;
          description
            "The time of the most recent occasion on which the BR
            instance suffered a discontinuity. This must be
            initialized when the BR instance is configured
            or rebooted.";
        }
      }
    }
  }
}

```

```
        }
        uses software-common:traffic-stat;
    }
}
}
}
}
}
}
}
}
}

/*
 * Notifications
 */
notification software-binding-instance-event {
  if-feature binding;
  description "Notifications for binding instance.";
  leaf bind-id {
    type leafref {
      path
        "/br-instances/binding/"
        + "bind-instance/id";
    }
    description "...";
  }
  leaf-list invalid-entry {
    type leafref {
      path
        "/br-instances/binding/"
        + "bind-instance[id=current()/../bind-id]/"
        + "binding-table/binding-entry/binding-ipv6info";
    }
    description
      "Notify the client that a specific binding entry has been
      expired/invalid. The binding-ipv6info identifies an entry.";
  }
  leaf-list added-entry {
    type inet:ipv6-address;
    description
      "Notify the client that a binding entry has been added.
      The ipv6 address of that entry is the index. The client
      gets other information from the binding BR about the entry
      indexed by that ipv6 address.
      ";
  }
  leaf-list modified-entry {
    type leafref {
      path
        "/br-instances/binding/"
        + "bind-instance[id=current()/../bind-id]/"

```

```

        + "binding-table/binding-entry/binding-ipv6info";
    }
    description "...";
}
}

notification software-algorithm-instance-event {
  if-feature algorithm;
  description "Notifications for algorithmic instance.";
  leaf algo-id {
    type leafref {
      path
        "/br-instances/algorithm/algo-instance/id";
    }
    mandatory true;
    description "algorithmic instance event.";
  }
  leaf-list invalid-entry-id {
    type leafref {
      path
        "/br-instances/algorithm/algo-instance/id";
    }
    description "Invalid entry event.";
  }
  leaf-list added-entry {
    type leafref {
      path
        "/br-instances/algorithm/algo-instance/id";
    }
    description "Added entry.";
  }
  leaf-list modified-entry {
    type leafref {
      path
        "/br-instances/algorithm/algo-instance/id";
    }
    description "Modified entry.";
  }
}
}
}
<CODE ENDS>

```

## **7. Common Software Element Groups YANG Module**

The following YANG module contains definitions that are used by both the software CE and software BR YANG modules.

```
<CODE BEGINS>file "ietf-software-common@2018-03-16.yang"
```

```
module ietf-softwire-common {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-softwire-common";
  prefix "softwire-common";

  import ietf-inet-types { prefix inet; }
  import ietf-yang-types { prefix yang; }

  organization
    "IETF Softwire Working Group";

  contact
    "WG Web: <https://datatracker.ietf.org/wg/softwire/>
    WG List: <mailto:softwire@ietf.org>

    Qi Sun <sunqi.ietf@gmail.com>
    Linhui Sun <lh.sunlinh@gmail.com>
    Yong Cui <yong@csnet1.cs.tsinghua.edu.cn>
    Ian Farrer <ian.farrer@telekom.de>
    Sladjana Zoric <sladjana.zoric@telekom.de>
    Mohamed Boucadair <mohamed.boucadair@orange.com>
    Rajiv <Asati rajiva@cisco.com>
    ";

  description
    "This document defines a YANG data module for the configuration and
    management of A+P Softwire Customer Premises Equipment (CEs). It
    covers Lightweight 4over6, MAP-E and MAP-T mechanisms.

    Copyright (c) 2018 IETF Trust and the persons identified
    as authors of the code. All rights reserved.
    This version of this YANG module is part of RFC XXX; see the RFC
    itself for full legal notices.";

  revision 2018-03-16 {
    description
      "Initial revision.";
    reference
      "RFC XXXX: YANG Modules for IPv4-in-IPv6 Address plus Port
      Softwires";
  }

  /*
   * Groupings
   */

  grouping algorithm-instance {
    description
```

```
"Indicates that the instance supports the MAP-E and MAP-T
function. The instance advertises the MAP-E/MAP-T feature
through the capability exchange mechanism when a NETCONF
session is established.";

leaf enable {
  type boolean;
  description
    "Enable/disable an individual MAP-E or MAP-T rule.";
}
container algo-versioning {
  description "algorithm's version";
  leaf version {
    type uint64;
    description "Incremental version number for the algorithm";
  }
  leaf date {
    type yang:date-and-time;
    description "Timestamp to the algorithm";
  }
}
leaf name {
  type string;
  description "The name for the instance.";
}
choice data-plane {
  description "Selects MAP-E (encapsulation) or MAP-T
(translation)";
  case encapsulation {
    description "encapsulation for MAP-E";
    leaf br-ipv6-addr {
      type inet:ipv6-address;
      mandatory true;
      description
        "The IPv6 address of the MAP-E BR.";
    }
  }
  case translation {
    description "translation for MAP-T";
    leaf dmr-ipv6-prefix {
      type inet:ipv6-prefix;
      description
        "The IPv6 prefix of the MAP-T BR.";
    }
  }
}
leaf ea-len {
  type uint8;
```

```
    mandatory true;
    description
      "Embedded Address (EA) bits are the IPv4 EA-bits in the IPv6
      address identify an IPv4 prefix/address (or part thereof) or
      a shared IPv4 address (or part thereof) and a port-set
      identifier. The length of the EA-bits is defined as part of
      a MAP rule for a MAP domain.";
  }
  leaf rule-ipv6-prefix {
    type inet:ipv6-prefix;
    mandatory true;
    description
      "The Rule IPv6 prefix defined in the mapping rule.";
  }
  leaf rule-ipv4-prefix {
    type inet:ipv4-prefix;
    mandatory true;
    description
      "The Rule IPv4 prefix defined in the mapping rule.";
  }
  leaf forwarding {
    type boolean;
    mandatory true;
    description
      "This parameter specifies whether the rule may be used for
      forwarding (FMR). If set, this rule is used as an FMR;
      if not set, this rule is a Basic Mapping Rule (BMR) only
      and must not be used for forwarding.";
  }
}

grouping traffic-stat {
  description "Traffic statistics";
  leaf sent-ipv4-packets {
    type yang:zero-based-counter64;
    description "Number of decapsulated and forwarded IPv4 packets.

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time'.";
  }
  leaf sent-ipv4-bytes {
    type yang:zero-based-counter64;
    description "Decapsulated/translated IPv4 traffic sent, in bytes

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
```

```
    other times as indicated by the value of
    'discontinuity-time.';
}
leaf sent-ipv6-packets {
    type yang:zero-based-counter64;
    description "Number of encapsulated IPv6 packets sent.

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time.';
}
leaf sent-ipv6-bytes {
    type yang:zero-based-counter64;
    description "Encapsulated IPv6 traffic sent, in bytes

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time.';
}
leaf rcvd-ipv4-packets {
    type yang:zero-based-counter64;
    description "Number of incoming IPv4 packets at the
    Internet-facing interface.

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time.';
}
leaf rcvd-ipv4-bytes {
    type yang:zero-based-counter64;
    description "IPv4 traffic received for processing, in bytes

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time.';
}
leaf rcvd-ipv6-packets {
    type yang:zero-based-counter64;
    description "Number of IPv4-in-IPv6 packets received

    Discontinuities in the value of this counter can occur
    at re-initialization of the management system, and at
    other times as indicated by the value of
    'discontinuity-time.';
}
```



```
}
leaf rcvd-ipv6-bytes {
  type yang:zero-based-counter64;
  description "IPv4-in-IPv6 traffic received, in bytes

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf dropped-ipv4-packets {
  type yang:zero-based-counter64;
  description "Number of IPv4 packets dropped at the
  Internet-facing interface.

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf dropped-ipv4-bytes {
  type yang:zero-based-counter64;
  description "IPv4 traffic dropped at the Internet-facing
  interface, in bytes.

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf dropped-ipv6-packets {
  type yang:zero-based-counter64;
  description "Number of IPv4-in-IPv6 packets dropped.

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf dropped-ipv6-bytes {
  type yang:zero-based-counter64;
  description "IPv4-in-IPv6 traffic dropped, in bytes

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
```

```
leaf dropped-ipv4-fragments {
  type yang:zero-based-counter64;
  description "Number of fragmented IPv4 packets dropped

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf dropped-ipv4-fragment-bytes {
  type yang:zero-based-counter64;
  description "Fragmented IPv4 traffic dropped, in bytes

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf ipv6-fragments-reassembled {
  type yang:zero-based-counter64;
  description "Number of IPv6 fragments successfully reassembled

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf ipv6-fragments-bytes-reassembled {
  type yang:zero-based-counter64;
  description "IPv6 fragments successfully reassembled, in bytes

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf out-icmpv4-error-packets {
  type yang:zero-based-counter64;
  description "Internally generated ICMPv4 error packets.

  Discontinuities in the value of this counter can occur
  at re-initialization of the management system, and at
  other times as indicated by the value of
  'discontinuity-time'.";
}
leaf out-icmpv4-error-bytes {
  type yang:zero-based-counter64;
  description "Internally generated ICMPv4 error messages, in bytes.
```

Discontinuities in the value of this counter can occur at re-initialization of the management system, and at other times as indicated by the value of 'discontinuity-time'.";

```
}  
leaf out-icmpv6-error-packets {  
  type yang:zero-based-counter64;  
  description "Internally generated ICMPv6 error packets.
```

Discontinuities in the value of this counter can occur at re-initialization of the management system, and at other times as indicated by the value of 'discontinuity-time'.";

```
}  
leaf out-icmpv6-error-bytes {  
  type yang:zero-based-counter64;  
  description "Internally generated ICMPv6 error messages, in bytes.
```

Discontinuities in the value of this counter can occur at re-initialization of the management system, and at other times as indicated by the value of 'discontinuity-time'.";

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

## 8. Security Considerations

The YANG module defined in this document 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 [[RFC5246](#)].

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.

All data nodes defined in the YANG modules which can be created, modified, and deleted (i.e., config true, which is the default) are considered sensitive. Write operations (e.g., edit-config) applied to these data nodes without proper protection can negatively affect network operations.

## **9. IANA Considerations**

This document requests IANA to register the following URIs in the "IETF XML Registry" [[RFC3688](#)].

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

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

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

This document requests that IANA registers the following YANG modules in the "YANG Module Names" registry [[RFC7950](#)].

```
name: ietf-software-ce
namespace: urn:ietf:params:xml:ns:yang:software-ce
prefix: software-ce
reference: RFC XXXX
```

```
name: ietf-software-br
namespace: urn:ietf:params:xml:ns:yang:software-br
prefix: software-br
reference: RFC XXXX
```

```
name: ietf-software-common
namespace: urn:ietf:params:xml:ns:yang:software-common
prefix: software-br
reference: RFC XXXX
```

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## **Appendix A. Configuration Examples**

The following sections provide examples of how the softwire YANG modules can be used for configuring softwire elements.

### **A.1. Configuration Example for a lw4o6 BR Binding-Table**

The lwAFTR maintains an address binding table which contains the following 3-tuples:

- o IPv6 Address for a single lwB4
- o Public IPv4 Address
- o Restricted port-set

The entry has two functions: the IPv6 encapsulation of inbound IPv4 packets destined to the lwB4 and the validation of outbound IPv4-in-IPv6 packets received from the lwB4 for de-capsulation.

Consider an example for the following lw4o6 binding table entry:

```
lwB4 Binding IPv6 Address:  2001:db8::1
lwB4 Binding IPv4 Address:  192.0.2.1
lwB4 PSID:                  0x34
lwB4 PSID Length            8
BR IPv6 Address:            2001:db8:1::2
```

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <software-config xmlns="urn:ietf:params:xml:ns:yang:ietf-softwire-br">
    <br-instances>
      <binding>
        <br-instance>
          <id>1</id>
          <binding-table>
            <binding-entry>
              <binding-ipv6info>2001:db8::1</binding-ipv6info>
              <binding-ipv4-addr>192.0.2.1</binding-ipv4-addr>
              <port-set>
                <psid>52</psid>
                <psid-len>8</psid-len>
              </port-set>
              <br-ipv6-addr>2001:db8:1::2</br-ipv6-addr>
            </binding-entry>
          </binding-table>
          <software-num-max>1024</software-num-max>
          <software-path-mru>1540</software-path-mru>
          <software-payload-mtu>1500</software-payload-mtu>
        </br-instance>
      </binding>
    </br-instances>
  </software-config>
</config>
```

Figure 3: lw406 Binding-Table Configuration XML

## **A.2. Configuration Example for a MAP-E BR**

A MAP-E BR is configured with forward mapping rules for the CEs it is serving. In this example (taken from [\[RFC7597\], Appendix A](#), Example 2), the following parameters are required:

- o Rule IPv6 Prefix
- o Rule IPv4 Prefix
- o Rule EA-bit bit length
- o IPv6 Address of MAP-BR

The mapping rule has two functions: identifying the destination CE IPv6 address for encapsulating inbound IPv4 packets and the validation of outbound IPv4-in-IPv6 packets received from the CE for de-capsulation.



The transport type for the data plane also needs to be configured for encapsulation to enable MAP-E and forwarding needs to be enabled.

Consider an example for the following MAP-E Forwarding Mapping Rule:

```
Data plane:          encapsulation
Rule IPv6 Prefix:    2001:db8::/40
Rule IPv4 Prefix:    192.0.2.0/24
Rule EA-bit Length: 16
BR IPv6 Address:     2001:db8:ffff::1
```

Figure 4 provides the example MAP-E BR configuration xml.

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <software-config xmlns="urn:ietf:params:xml:ns:yang:ietf-softwire-br">
    <br-instances>
      <algorithm>
        <algo-instance>
          <id>42</id>
          <algo-instances>
            <algo-instance>
              <id>1234</id>
              <data-plane>encapsulation</data-plane>
              <ea-len>16</ea-len>
              <rule-ipv4-prefix>192.0.2.0/24</rule-ipv4-prefix>
              <rule-ipv6-prefix>2001:db8::/40</rule-ipv6-prefix>
              <forwarding>true</forwarding>
              <br-ipv6-addr>2001:db8:ffff::1</br-ipv6-addr>
              <psid-offset>6</psid-offset>
              <psid-len>8</psid-len>
            </algo-instance>
          </algo-instances>
        </algo-instance>
      </br-instances>
    </software-config>
  </config>
```

Figure 4: MAP-E FMR Configuration XML

### [A.3.](#) lw4o6 CE Configuration Example

This section provides XML examples for configuring a lw4o6 CE. Examples for routing and NAT44 are also provided for convenience.

Consider an example for the following lw4o6 CE configuration:

lwB4 Binding IPv6 Address: 2001:db8::1  
lwB4 Binding IPv4 Address: 192.0.2.1  
lwB4 PSID: 0x34  
lwB4 PSID Length 8  
BR IPv6 Address: 2001:db8:1::2

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces">
    <interface>
      <name>lw4o6-wan</name>
      <type
        xmlns:iana="urn:ietf:params:xml:ns:yang:iana-if-type">
        iana:tunnel
      </type>
      <ce-interface
        xmlns="urn:ietf:params:xml:ns:yang:ietf-softwire-ce">
        <br-ipv6-addr>2001:db8:1::2</br-ipv6-addr>
        <binding-ipv6info>2001:db8::1</binding-ipv6info>
      </ce-interface>
    </interface>
  </interfaces>
</config>
```

Figure 5: lw4o6 CE Configuration XML

In the example depicted in Figure 5, the interface name is defined for the softwire tunnel. This name is then referenced by the routing configuration for the IPv4 route. Figure 6 provides an example configuration for the CE's IPv4 routing, using the YANG module described in [\[RFC8349\]](#).

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <routing xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
    <control-plane-protocols>
      <control-plane-protocol>
        <type>static</type>
        <name>v4</name>
        <static-routes>
          <ipv4
            xmlns="urn:ietf:params:xml:ns:yang:ietf-ipv4-unicast-routing">
            <route>
              <destination-prefix>0.0.0.0/0</destination-prefix>
              <next-hop>
                <outgoing-interface>lw4o6-wan</outgoing-interface>
              </next-hop>
            </route>
          </ipv4>
        </static-routes>
      </control-plane-protocol>
    </control-plane-protocols>
  </routing>
</config>
```

Figure 6: lw4o6 CE Routing Configuration XML

Figure 7 provides an example configuration for the CE's NAT44 function, using the YANG module described in [\[I-D.ietf-opsawg-nat-yang\]](#).

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <nat xmlns="urn:ietf:params:xml:ns:yang:ietf-nat">
    <instances>
      <instance>
        <id>1</id>
        <policy>
          <policy-id>1</policy-id>
          <external-ip-address-pool>
            <pool-id>1</pool-id>
            <external-ip-pool>192.0.2.1</external-ip-pool>
          </external-ip-address-pool>
          <port-set-restrict>
            <port-set-algo>
              <psid-offset>6</psid-offset>
              <psid-len>8</psid-len>
              <psid>52</psid>
            </port-set-algo>
          </port-set-restrict>
          <notify-pool-usage>
            <pool-id>1</pool-id>
          </notify-pool-usage>
        </policy>
      </instance>
    </instances>
  </nat>
</config>
```

```
    <high-threshold>80</high-threshold>
  </notify-pool-usage>
</policy>
<mapping-limits>
  <limit-per-protocol>
    <protocol-id>1</protocol-id>
    <limit>8</limit>
  </limit-per-protocol>
  <limit-per-protocol>
    <protocol-id>6</protocol-id>
    <limit>32</limit>
  </limit-per-protocol>
  <limit-per-protocol>
    <protocol-id>17</protocol-id>
    <limit>16</limit>
  </limit-per-protocol>
</mapping-limits>
<mapping-table>
  <mapping-entry>
    <index>1</index>
    <external-src-address>192.0.2.1/32</external-src-address>
    <internal-src-address>192.168.1.0/24</internal-src-address>
    <transport-protocol>6</transport-protocol>
  </mapping-entry>
  <mapping-entry>
    <index>2</index>
    <external-src-address>192.0.2.1/32</external-src-address>
    <internal-src-address>192.168.1.0/24</internal-src-address>
    <transport-protocol>17</transport-protocol>
  </mapping-entry>
  <mapping-entry>
    <index>3</index>
    <external-src-address>192.0.2.1/32</external-src-address>
    <internal-src-address>192.168.1.0/24</internal-src-address>
    <transport-protocol>1</transport-protocol>
  </mapping-entry>
</mapping-table>
</instance>
</instances>
</nat>
</config>
```

Figure 7: lw4o6 NAT Configuration XML

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