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YANG Modules for IPv4-in-IPv6 Address plus Port Softwires
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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 with the RFC number to be assigned to this document:

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

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

Status of This Memo

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

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This Internet-Draft will expire on October 7, 2018.

Table of Contents

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

- Configuration
- Operational State
- 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 softwire 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 is included for either 'binding' or 'algorithmic'. 'Binding' is used for configuring Lightweight 4over6, whereas 'Algorithmic' is used for configuring MAP-T or MAP-E.

In the 'algo-instances' container, a choice statement 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]

- 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]

- 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]

- 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 YANG CE Tree Diagram

3.1. CE Tree Diagram

The CE module provides configuration and monitoring for all of the softwire mechanisms listed in Section 1.

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 CE softwire YANG module.

```
  module: ietf-softwire-ce
    augment /if:interfaces/if:interface:
      +--rw softwire-payload-mtu?   uint16
      +--rw softwire-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 softwire-ce-event {binding}?
          +--ro ce-binding-ipv6-addr-change    inet:ipv6-address
```

Figure 1: Softwire YANG CE Tree Diagram

3.2. Softwire CE Tree Diagram Description

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

- softwire-payload-mtu: optionally used to set the IPv4 MTU for the softwire. Needed if the softwire implementation is unable to correctly calculate the correct IPv4 Maximum Transit Unit (MTU) size automatically.

- softwire-path-mru: optionally used to set the maximum IPv6 softwire packet size that can be received, including the encapsulation/translation overhead. Needed if the softwire implementation is unable to correctly calculate the correct IPv4 Maximum Receive Unit (MRU) size automatically.

- ce-type: provides a choice statement allowing the binding or algorithmic softwire mechanisms to be selected.

Further details relevant to binding softwire elements are:

- 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'.

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

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

- 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.

- 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].

- ea-len: used to set the length of the Embedded-Address (EA), which is defined in the mapping rule for a MAP domain.

- data-plane: provides a choice statement for either encapsulation (MAP-E) or translation (MAP-T).

- br-ipv6-addr: defines the IPv6 address of the BR. This information is valid for MAP-E.

- 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:

- 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 listed in Section 1. 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-threshold      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 softwire-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 softwire-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 YANG BR Tree

4.2. Softwire BR Tree Diagram Description

The descriptions for leaves which are common with the CE module are provided in Figure 1. Descriptions for additional elements are provided below:

- binding-table-versioning: optionally used to add an incremental version number and/or timestamp to the binding table. 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 contents of the binding table or a new binding table list is created.

- binding-entry: used to define the binding relationship between 3-tuples, which contains the lwB4's IPv6 address/prefix, the allocated IPv4 address and restricted port-set. For detail information, please refer to [RFC7596].

- softwire-num-threshold: used to set the maximum number of softwire binding rules that can be created on the lw4o6 element simultaneously.

- 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:

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

5. Softwire CE YANG Module

This module imports typedefs from [RFC6991].

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

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

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

  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";
  }
```

```
  /*
   * 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
      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 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 CE softwire interface
  augment "/if:interfaces/if:interface" {
    when "if:type = 'ianaift:tunnel'";
    description "CE Softwire 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 CE softwire 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 softwire-common:algorithm-instance;
          }
        }
      }
    }
  }

  augment "/if:interfaces/if:interface/if:statistics" {
```

```
    when "../if:type = 'ianaift:tunnel'";
    description "CE Softwire interface statistics.";
      uses softwire-common:traffic-stat;
    }

  /*
   * Notifications
   */

  notification softwire-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-softwire-br@2018-03-16.yang"

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

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

  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 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 NAPT.";

    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 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
      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 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
      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 softwire-num-threshold {
      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 softwire.";
    }
    leaf softwire-path-mru {
      type uint16;
      units bytes;
      mandatory true;
      description
        "The path MRU for binding softwire.";
    }
    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
              "Seciton 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 softwire-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 softwire-common:traffic-stat;
            }
          }
        }
      }
    }
```

```
  }

  /*
   * Notifications
   */
  notification softwire-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 softwire-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 Softwire Element Groups YANG Module

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

```
<CODE BEGINS>file "ietf-softwire-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:softwire-ce
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.

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

URI: urn:ietf:params:xml:ns:yang:softwire-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-softwire-ce
namespace: urn:ietf:params:xml:ns:yang:softwire-ce
prefix: softwire-ce
reference: RFC XXXX

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

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

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Appendix A. Configutation 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:

- IPv6 Address for a single lwB4
- Public IPv4 Address
- 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 IPv6 Address: 123

lwB4 PSID Length 8

BR IPv6 Address: 2001:db8:1::2

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <softwire-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>123</psid>
                  <psid-len>8</psid-len>
                </port-set>
                <br-ipv6-addr>2001:db8:1::2</br-ipv6-addr>
              </binding-entry>
            </binding-table>
            <softwire-num-threshold>1024</softwire-num-threshold>
            <softwire-path-mru>1540</softwire-path-mru>
            <softwire-payload-mtu>1500</softwire-payload-mtu>
          </br-instance>
      </binding>
    </br-instances>
  </softwire-config>
</config>
```

Figure 3: lw4o6 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 clients it is serving. In this example (taken from [RFC7597], Appendix A, Example 2), the following parameters are required:

- Rule IPv6 Prefix
- Rule IPv4 Prefix
- Rule EA-bit bit length
- 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

Here is the example MAP-E BR configuration xml:

```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <softwire-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>
      </algorithm>
    </br-instances>
  </softwire-config>
</config>
```

Figure 4: MAP-E FMR Configuration XML

A.3. lw4o6 CE Configuration Example

The following section provides XML examples for configuring a lw4o6 CE. Examples for routing and NAT44 are also provided for convienience.

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 IPv6 Address: 123

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 above example, the interface name is defined for the softwire tunnel. This name is then referenced by the routing configuration for the IPv4 route. The following section provides 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

The following section provides example configuration for the CE's NAPT44 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>
```

```
          <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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