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YANG Data Model for Babel  
draft-ietf-babel-yang-model-06

## Abstract

This document defines a data model for the Babel routing protocol.  
The data model is defined using the YANG data modeling language.

## Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119][RFC8174] when, and only when, they appear in all capitals, as shown here.

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## 1. Introduction

This document defines a data model for the Babel routing protocol [I-D.ietf-babel-rfc6126bis]. The data model is defined using YANG 1.1 [RFC7950] data modeling language and is Network Management Datastore Architecture (NDMA) [RFC8342] compatible. It is based on the Babel Information Model [I-D.ietf-babel-information-model].

### 1.1. Note to RFC Editor

Artwork in this document contains shorthand references to drafts in progress. Please apply the following replacements and remove this note before publication.

- o "XXXX" --> the assigned RFC value for this draft both in this draft and in the YANG models under the revision statement.

- o "ZZZZ" --> the assigned RFC value for Babel Information Model [I-D.ietf-babel-information-model]
- o Revision date in model, in the format 2020-06-28 needs to get updated with the date the draft gets approved. The date also needs to get reflected on the line with <CODE BEGINS>.

## 1.2. Tree Diagram Annotations

For a reference to the annotations used in tree diagrams included in this draft, please see YANG Tree Diagrams [RFC8340].

## 2. Babel Module

This document defines a YANG 1.1 [RFC7950] data model for the configuration and management of Babel. The YANG module is based on the Babel Information Model [I-D.ietf-babel-information-model].

### 2.1. Information Model

There are a few things that should be noted between the Babel Information Model and this data module. The information model mandates the definition of some of the attributes, e.g. babel-implementation-version or the babel-self-router-id. These attributes are marked as read-only objects in the information module as well as in this data module. However, there is no way in the data module to mandate that a read-only attribute be present. It is up to the implementation of this data module to make sure that the attributes that are marked read-only and are mandatory are indeed present.

### 2.2. Tree Diagram

The following diagram illustrates a top level hierarchy of the model. In addition to information like the version number implemented by this device, the model contains subtrees on constants, interfaces, routes and security.

```

module: ietf-babel
  augment /rt:routing/rt:control-plane-protocols
    /rt:control-plane-protocol:
      +--rw babel!
        +--ro version?      string
        +--rw enable        boolean
        +--ro router-id?    binary
        +--ro seqno?        uint16
        +--rw stats-enable? boolean
        +--rw constants
        |   ...
        +--rw interfaces* [reference]
        |   ...
        +--rw mac* [name]
        |   ...
        +--rw dtls* [name]
        |   ...
        +--ro routes* [prefix]
        |   ...

```

The interfaces subtree describes attributes such as interface object that is being referenced, the type of link as enumerated by metric-algorithm and split-horizon and whether the interface is enabled or not.

The constants subtree describes the UDP port used for sending and receiving Babel messages, and the multicast group used to send and receive announcements on IPv6.

The routes subtree describes objects such as the prefix for which the route is advertised, a reference to the neighboring route, and next-hop address.

Finally, for security two subtree are defined to contain MAC keys and DTLS certificates. The mac subtree contains keys used with the MAC security mechanism. The boolean flag default-apply indicates whether the set of MAC keys is automatically applied to new interfaces. The dtls subtree contains certificates used with DTLS security mechanism. Similar to the MAC mechanism, the boolean flag default-apply indicates whether the set of DTLS certificates is automatically applied to new interfaces.

### 2.3. YANG Module

This YANG module augments the YANG Routing Management [RFC8349] module to provide a common framework for all routing subsystems. By augmenting the module it provides a common building block for routes, and Routing Information Bases (RIBs). It also has a reference to an

interface defined by A YANG Data Model for Interface Management [RFC8343].

A router running Babel routing protocol can determine the parameters it needs to use for an interface based on the interface name. For example, it can detect that eth0 is a wired interface, and that wlan0 is a wireless interface. This is not true for a tunnel interface, where the link parameters need to be configured explicitly.

For a wired interface, it will assume '2-out-of-3' 'metric-algorithm', and 'split-horizon' set to true. On other hand, for a wireless interface it will assume 'etx' 'metric-algorithm', and 'split-horizon' set to false. However, if the wired link is connected to a wireless radio, the values can be overridden by setting 'metric-algorithm' to 'etx', and 'split-horizon' to false. Similarly, an interface that is a metered 3G link, and used for fallback connectivity needs much higher default time constants, e.g. 'mcast-hello-interval', and 'update-interval', in order to avoid carrying control traffic as much as possible.

In addition to the modules used above, this module imports definitions from Common YANG Data Types [RFC6991], and references HMAC: Keyed-Hashing for Message Authentication [RFC2104], Using HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512 [RFC4868], Datagram Transport Layer Security Version 1.2 [RFC6347], The Blake2 Cryptographic Hash and Message Authentication Code (MAC) [RFC7693], Babel Information Model [I-D.ietf-babel-information-model], and The Babel Routing Protocol [I-D.ietf-babel-rfc6126bis].

<CODE BEGINS> file "ietf-babel@2020-06-28.yang"

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

  import ietf-yang-types {
    prefix yt;
    reference
      "RFC 6991: Common YANG Data Types.";
  }
  import ietf-inet-types {
    prefix inet;
    reference
      "RFC 6991: Common YANG Data Types.";
  }
  import ietf-interfaces {
    prefix if;
```

```
reference
  "RFC 8343: A YANG Data Model for Interface Management";
}
import ietf-routing {
  prefix "rt";
  reference
    "RFC 8349: YANG Routing Management";
}

organization
  "IETF Babel routing protocol Working Group";

contact
  "WG Web: http://tools.ietf.org/wg/babel/
  WG List: babel@ietf.org

  Editor: Mahesh Jethanandani
         mjethanandani@gmail.com
  Editor: Barbara Stark
         bs7652@att.com";

description
  "This YANG module defines a model for the Babel routing
  protocol.

  The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
  NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
  'MAY', and 'OPTIONAL' in this document are to be interpreted as
  described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
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  (https://trustee.ietf.org/license-info).

  This version of this YANG module is part of RFC XXXX
  (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
  for full legal notices.";

revision 2020-06-28 {
  description
    "Initial version.";
```

```
    reference
      "RFC XXXX: Babel YANG Data Model.";
  }

  /*
   * Features
   */
  feature two-out-of-three-supported {
    description
      "This implementation supports two-out-of-three metric
      comp algorithm.";
  }

  feature etx-supported {
    description
      "This implementation supports Expected Transmission Count
      (ETX) metric comp algorithm.";
  }

  feature mac-supported {
    description
      "This implementation supports MAC based security.";
  }

  feature dtls-supported {
    description
      "This implementation supports DTLS based security.";
  }

  feature hmac-sha256-supported {
    description
      "This implementation supports hmac-sha256 MAC algorithm.";
  }

  feature blake2s-supported {
    description
      "This implementation supports blake2 MAC algorithm.";
  }

  feature x-509-supported {
    description
      "This implementation supports x-509 certificate type.";
  }

  feature raw-public-key-supported {
    description
      "This implementation supports raw-public-key certificate type.";
  }
}
```

```
/*
 * Identities
 */
identity metric-comp-algorithms {
  description
    "Base identity from which all Babel metric comp algorithms
    are derived.";
}

identity two-out-of-three {
  if-feature two-out-of-three-supported;
  base "metric-comp-algorithms";
  description
    "2-out-of-3 algorithm.";
}

identity etx {
  if-feature etx-supported;
  base "metric-comp-algorithms";
  description
    "Expected Transmission Count.";
}

/*
 * Babel MAC algorithms identities.
 */
identity mac-algorithms {
  description
    "Base identity for all Babel MAC algorithms.";
}

identity hmac-sha256 {
  if-feature mac-supported;
  if-feature hmac-sha256-supported;
  base mac-algorithms;
  description
    "HMAC-SHA256 algorithm supported.";
  reference
    "RFC 4868: Using HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512
    with IPsec.";
}

identity blake2s {
  if-feature mac-supported;
  if-feature blake2s-supported;
  base mac-algorithms;
  description
    "BLAKE2s algorithm supported.";
```

```
    reference
      "RFC 7693: The BLAKE2 Cryptographic Hash and Message
       Authentication Code (MAC).";
  }

  /*
   * Babel Cert Types
   */
  identity dtls-cert-types {
    description
      "Base identity for Babel DTLS certificate types.";
  }

  identity x-509 {
    if-feature dtls-supported;
    if-feature x-509-supported;
    base dtls-cert-types;
    description
      "X.509 certificate type.";
  }

  identity raw-public-key {
    if-feature dtls-supported;
    if-feature raw-public-key-supported;
    base dtls-cert-types;
    description
      "Raw Public Key type.";
  }

  /*
   * Babel routing protocol identity.
   */
  identity babel {
    base "rt:routing-protocol";
    description
      "Babel routing protocol";
  }

  /*
   * Groupings
   */
  grouping routes {
    list routes {
      key "prefix";
      config false;

      leaf prefix {
        type inet:ip-prefix;
      }
    }
  }
```

```
    description
      "Prefix (expressed in ip-address/prefix-length format) for
       which this route is advertised.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.6.";
  }

  leaf router-id {
    type binary;
    description
      "router-id of the source router for which this route is
       advertised.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.6.";
  }

  leaf neighbor {
    type leafref {
      path "/rt:routing/rt:control-plane-protocols/" +
          "rt:control-plane-protocol/babel/interfaces/" +
          "neighbor-objects/neighbor-address";
    }
    description
      "Reference to the neighbor-objects entry for the neighbor
       that advertised this route.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.6.";
  }

  leaf received-metric {
    type uint16;
    description
      "The metric with which this route was advertised by the
       neighbor, or maximum value (infinity) to indicate the
       route was recently retracted and is temporarily
       unreachable. This metric will be 0 (zero) if the route
       was not received from a neighbor but was generated
       through other means. At least one of
       calculated-metric or received-metric MUST be non-NULL.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.6,
       draft-ietf-babel-rfc6126bis: The Babel Routing Protocol,
       Section 3.5.5.";
  }

  leaf calculated-metric {
    type uint16;
    description
```

```
    "A calculated metric for this route. How the metric is
      calculated is implementation-specific. Maximum value
      (infinity) indicates the route was recently retracted
      and is temporarily unreachable. At least one of
      calculated-metric or received-metric MUST be non-NULL.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.6,
      draft-ietf-babel-rfc6126bis: The Babel Routing Protocol,
      Section 3.5.5.";
}

leaf seqno {
  type uint16;
  description
    "The sequence number with which this route was advertised.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.6.";
}

leaf next-hop {
  type inet:ip-address;
  description
    "The next-hop address of this route. This will be empty if
      this route has no next-hop address.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.6.";
}

leaf feasible {
  type boolean;
  description
    "A boolean flag indicating whether this route is feasible.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.6,
      draft-ietf-babel-rfc6126bis, The Babel Routing Protocol,
      Section 3.5.1.";
}

leaf selected {
  type boolean;
  description
    "A boolean flag indicating whether this route is selected,
      i.e., whether it is currently being used for forwarding and
      is being advertised.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.6.";
}
description
```

```
        "A set of babel-route-obj objects. Includes received and
        routes routes.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.1.";
    }
    description
        "Common grouping for routing used in RIB.";
}

/*
 * Data model
 */

augment "/rt:routing/rt:control-plane-protocols/" +
    "rt:control-plane-protocol" {
    when "derived-from-or-self(rt:type, 'babel')" {
        description
            "Augmentation is valid only when the instance of routing type
            is of type 'babel'.";
    }
    description
        "Augment the routing module to support a common structure
        between routing protocols.";
    reference
        "YANG Routing Management, RFC 8349, Lhotka & Lindem, March
        2018.";

    container babel {
        presence "A Babel container.";
        description
            "Babel Information Objects.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.";

        leaf version {
            type string;
            config false;
            description
                "The name and version of this implementation of the Babel
                protocol.";
            reference
                "RFC ZZZZ: Babel Information Model, Section 3.1.";
        }

        leaf enable {
            type boolean;
            mandatory true;
            description
```

"When written, it configures whether the protocol should be enabled. A read from the <running> or <intended> datastore therefore indicates the configured administrative value of whether the protocol is enabled or not.

A read from the <operational> datastore indicates whether the protocol is actually running or not, i.e. it indicates the operational state of the protocol.";

reference

"RFC ZZZZ: Babel Information Model, Section 3.1.";

}

leaf router-id {

type binary;

config false;

description

"Every Babel speaker is assigned a router-id, which is an arbitrary string of 8 octets that is assumed to be unique across the routing domain";

reference

"RFC ZZZZ: Babel Information Model, Section 3.1,  
draft-ietf-babel-rfc6126bis: The Babel Routing Protocol,  
Section 3.";

}

leaf seqno {

type uint16;

config false;

description

"Sequence number included in route updates for routes originated by this node.";

reference

"RFC ZZZZ: Babel Information Model, Section 3.1.";

}

leaf stats-enable {

type boolean;

description

"Indicates whether statistics collection is enabled (true) or disabled (false) on all interfaces.";

}

container constants {

description

"Babel Constants object.";

reference

"RFC ZZZZ: Babel Information Model, Section 3.1.";

```
leaf udp-port {
  type inet:port-number;
  default "6696";
  description
    "UDP port for sending and receiving Babel messages. The
    default port is 6696.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.2.";
}

leaf mcast-group {
  type inet:ip-address;
  default "ff02::1:6";
  description
    "Multicast group for sending and receiving multicast
    announcements on IPv6.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.2.";
}

list interfaces {
  key "reference";

  description
    "A set of Babel Interface objects.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";

  leaf reference {
    type if:interface-ref;
    description
      "References the name of the interface over which Babel
      packets are sent and received.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.3.";
  }

  leaf enable {
    type boolean;
    default "true";
    description
      "If true, babel sends and receives messages on this
      interface. If false, babel messages received on this
      interface are ignored and none are sent.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.3.";
  }
}
```

```
leaf metric-algorithm {
  type identityref {
    base metric-comp-algorithms;
  }
  mandatory true;
  description
    "Indicates the metric computation algorithm used on this
    interface. The value MUST be one of those identities
    based on 'metric-comp-algorithms'.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.X.";
}

leaf split-horizon {
  type boolean;
  description
    "Indicates whether or not the split horizon optimization
    is used when calculating metrics on this interface.
    A value of true indicates split horizon optimization
    is used.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.X.";
}

leaf mcast-hello-seqno {
  type uint16;
  config false;
  description
    "The current sequence number in use for multicast hellos
    sent on this interface.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf mcast-hello-interval {
  type uint16;
  units centiseconds;
  description
    "The current multicast hello interval in use for hellos
    sent on this interface.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf update-interval {
  type uint16;
  units centiseconds;
  description
```

```
        "The current update interval in use for this interface.
        Units are centiseconds.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf mac-enable {
    type boolean;
    description
        "Indicates whether the MAC security mechanism is enabled
        (true) or disabled (false).";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf-list mac-key-sets {
    type leafref {
        path "../..../mac/name";
    }
    description
        "List of references to the mac entries that apply
        to this interface. When an interface instance is
        created, all mac instances with default-apply 'true'
        will be included in this list.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf mac-verify {
    type boolean;
    description
        "A Boolean flag indicating whether MAC hashes in
        incoming Babel packets are required to be present and
        are verified. If this parameter is 'true', incoming
        packets are required to have a valid MAC hash.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf dtls-enable {
    type boolean;
    description
        "Indicates whether the DTLS security mechanism is enabled
        (true) or disabled (false).";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.3.";
}
```

```
leaf-list dtls-certs {
  type leafref {
    path "../..//dtls/name";
  }
  description
    "List of references to the dtls entries that apply to
    this interface. When an interface instance
    is created, all dtls instances with default-apply
    'true' will be included in this list.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf dtls-cached-info {
  type boolean;
  description
    "Indicates whether the cached_info extension is included
    in ClientHello and ServerHello packets. The extension
    is included if the value is 'true'.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf-list dtls-cert-prefer {
  type leafref {
    path "../..//dtls/certs/type";
  }
  ordered-by user;
  description
    "List of supported certificate types, in order of
    preference. The values MUST be among those listed in
    dtls-cert-types. This list is used to populate the
    server_certificate_type extension in a Client Hello.
    Values that are present in at least one instance in the
    certs object under dtls of a referenced dtls instance
    and that have a non-empty private-key will be used to
    populate the client_certificate_type extension in a
    Client Hello.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.3.";
}

leaf packet-log-enable {
  type boolean;
  description
    "If true, logging of babel packets received on this
    interface is enabled; if false, babel packets are not
    logged.";
```

```
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.3.";
  }

  leaf packet-log {
    type inet:uri;
    config false;
    description
      "A reference or url link to a file that contains a
       timestamped log of packets received and sent on
       udp-port on this interface. The [libpcap] file
       format with .pcap file extension SHOULD be supported for
       packet log files. Logging is enabled / disabled by
       packet-log-enable.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.3.";
  }

  container stats {
    config false;

    description
      "Statistics collection object for this interface.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.3.";

    leaf sent-mcast-hello {
      type yt:counter32;
      description
        "A count of the number of multicast Hello packets sent
         on this interface.";
      reference
        "RFC ZZZZ: Babel Information Model, Section 3.4.";
    }

    leaf sent-mcast-update {
      type yt:counter32;
      description
        "A count of the number of multicast update packets sent
         on this interface.";
      reference
        "RFC ZZZZ: Babel Information Model, Section 3.4.";
    }

    leaf sent-ucast-hello {
      type yt:counter32;
      description
        "A count of the number of unicast Hello packets sent
```

```
        to this neighbor.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.6.";
}

leaf sent-ucast-update {
    type yt:counter32;
    description
        "A count of the number of unicast update packets sent
        to this neighbor.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.6.";
}

leaf sent-ihu {
    type yt:counter32;
    description
        "A count of the number of IHU packets sent to this
        neighbor.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.6.";
}

leaf received-packets {
    type yt:counter32;
    description
        "A count of the number of Babel packets received on
        this interface.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.4.";
}

action reset {
    description
        "The information model [RFC ZZZZ] defines reset
        action as a system-wide reset of Babel statistics.
        In YANG the reset action is associated with the
        container where the action is defined. In this case
        the action is associated with the stats container
        inside an interface. The action will therefore
        reset statistics at an interface level.

        Implementations that want to support a system-wide
        reset of Babel statistics need to call this action
        for every instance of the interface.";

    input {
        leaf reset-at {
            type yt:date-and-time;
```

```
        description
          "The time when the reset was issued.";
      }
    }
    output {
      leaf reset-finished-at {
        type yt:date-and-time;
        description
          "The time when the reset finished.";
      }
    }
  }
}

list neighbor-objects {
  key "neighbor-address";
  config false;

  description
    "A set of Babel Neighbor Object.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.5.";

  leaf neighbor-address {
    type inet:ip-address;
    description
      "IPv4 or v6 address the neighbor sends packets from.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.5.";
  }

  leaf hello-mcast-history {
    type string;
    description
      "The multicast Hello history of whether or not the
      multicast Hello packets prior to exp-mcast-
      hello-seqno were received, with a '1' for the most
      recent Hello placed in the most significant bit and
      prior Hellos shifted right (with '0' bits placed
      between prior Hellos and most recent Hello for any
      not-received Hellos); represented as a string using
      utf-8 encoded hex digits where a '1' bit = Hello
      received and a '0' bit = Hello not received.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.5.";
  }

  leaf hello-ucast-history {
```

```
type string;
description
  "The unicast Hello history of whether or not the
  unicast Hello packets prior to exp-ucast-hello-seqno
  were received, with a '1' for the most
  recent Hello placed in the most significant bit and
  prior Hellos shifted right (with '0' bits placed
  between prior Hellos and most recent Hello for any
  not-received Hellos); represented as a string using
  utf-8 encoded hex digits where a '1' bit = Hello
  received and a '0' bit = Hello not received.";
reference
  "RFC ZZZZ: Babel Information Model, Section 3.5.";
}

leaf txcost {
  type int32;
  default "0";
  description
    "Transmission cost value from the last IHU packet
    received from this neighbor, or maximum value
    (infinity) to indicate the IHU hold timer for this
    neighbor has expired description.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.5.";
}

leaf exp-mcast-hello-seqno {
  type uint16;
  default "0";
  description
    "Expected multicast Hello sequence number of next Hello
    to be received from this neighbor; if multicast Hello
    packets are not expected, or processing of multicast
    packets is not enabled, this MUST be NULL.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.5.";
}

leaf exp-ucast-hello-seqno {
  type uint16;
  default "0";
  description
    "Expected unicast Hello sequence number of next Hello to
    be received from this neighbor; if unicast Hello
    packets are not expected, or processing of unicast
    packets is not enabled, this MUST be NULL.";
  reference
```

```
        "RFC ZZZZ: Babel Information Model, Section 3.5.";
    }

    leaf ucast-hello-seqno {
        type uint16;
        description
            "Expected unicast Hello sequence number of next Hello
             to be received from this neighbor. If unicast Hello
             packets are not expected, or processing of unicast
             packets is not enabled, this MUST be 0.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.5.";
    }

    leaf ucast-hello-interval {
        type uint16;
        units centiseconds;
        description
            "The current interval in use for unicast hellos sent to
             this neighbor. Units are centiseconds.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.5.";
    }

    leaf rxcost {
        type int32;
        description
            "Reception cost calculated for this neighbor. This value
             is usually derived from the Hello history, which may be
             combined with other data, such as statistics maintained
             by the link layer. The rxcost is sent to a neighbor in
             each IHU.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.5.";
    }

    leaf cost {
        type int32;
        description
            "Link cost is computed from the values maintained in
             the neighbor table. The statistics kept in the neighbor
             table about the reception of Hellos, and the txcost
             computed from received IHU packets.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.5.";
    }
}
}
```

```
list mac {
  key "name";

  description
    "A mac object. If this object is implemented, it
    provides access to parameters related to the MAC security
    mechanism.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.7.";

  leaf name {
    type string;
    description
      "A string that uniquely identifies the mac object.";
  }

  leaf default-apply {
    type boolean;
    description
      "A Boolean flag indicating whether this mac
      instance is applied to all new interfaces, by default.
      If 'true', this instance is applied to new
      interfaces instances at the time they are created,
      by including it in the mac-key-sets list under
      interfaces. If 'false', this instance is not applied
      to new interfaces instances when they are created.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.7.";
  }
}

list keys {
  key "name";
  min-elements "1";

  description
    "A set of keys objects.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.8.";

  leaf name {
    type string;
    mandatory true;
    description
      "A unique name for this MAC key that can be used to
      identify the key in this object instance, since the key
      value is not allowed to be read. This value can only be
      provided when this instance is created, and is not
      subsequently writable.";
```

```
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.8.";
  }

  leaf use-sign {
    type boolean;
    mandatory true;
    description
      "Indicates whether this key value is used to sign sent
       Babel packets. Sent packets are signed using this key
       if the value is 'true'. If the value is 'false', this
       key is not used to sign sent Babel packets.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.8.";
  }

  leaf use-verify {
    type boolean;
    mandatory true;
    description
      "Indicates whether this key value is used to verify
       incoming Babel packets. This key is used to verify
       incoming packets if the value is 'true'. If the value
       is 'false', no MAC is computed from this key for
       comparing an incoming packet.";
    reference
      "RFC ZZZZ: Babel Information Model, Section 3.8.";
  }

  leaf value {
    type binary;
    mandatory true;
    description
      "The value of the MAC key. An implementation MUST NOT
       allow this parameter to be read. This can be done by
       always providing an empty string, or through
       permissions, or other means. This value MUST be
       provided when this instance is created, and is not
       subsequently writable.

       This value is of a length suitable for the associated
       algorithm. If the algorithm is based on
       the HMAC construction [RFC2104], the length MUST be
       between 0 and the block size of the underlying hash
       inclusive (where 'HMAC-SHA256' block size is 64
       bytes as described in [RFC4868]). If the algorithm
       is 'BLAKE2s', the length MUST be between 0 and 32
       bytes inclusive, as described in [RFC7693].";
```

```
reference
  "RFC ZZZZ: Babel Information Model, Section 3.8,
  RFC 2104: HMAC: Keyed-Hashing for Message
  Authentication
  RFC 4868: Using HMAC-SHA-256, HMAC-SHA-384, and
  HMAC-SHA-512 with IPsec,
  RFC 7693: The BLAKE2 Cryptographic Hash and Message
  Authentication Code (MAC).";
}

leaf algorithm {
  type identityref {
    base mac-algorithms;
  }
  description
    "The name of the MAC algorithm used with this key. The
    value MUST be the same as one of the enumerations
    listed in the mac-algorithms parameter.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.8.";
}

action test {
  description
    "An operation that allows the MAC key and hash
    algorithm to be tested to see if they produce an
    expected outcome. Input to this operation is a
    binary string. The implementation is expected to
    create a hash of this string using the value and
    the algorithm. The output of this operation is
    the resulting hash, as a binary string.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.8.";

  input {
    leaf test-string {
      type binary;
      mandatory true;
      description
        "Input to this operation is a binary string.
        The implementation is expected to create
        a hash of this string using the value and
        the algorithm.";
      reference
        "RFC ZZZZ: Babel Information Model, Section 3.8.";
    }
  }
  output {
```

```
        leaf resulting-hash {
            type binary;
            mandatory true;
            description
                "The output of this operation is
                 the resulting hash, as a binary string.";
            reference
                "RFC ZZZZ: Babel Information Model, Section 3.8.";
        }
    }
}

list dtls {
    key "name";

    description
        "A dtls object. If this object is implemented,
         it provides access to parameters related to the DTLS
         security mechanism.";
    reference
        "RFC ZZZZ: Babel Information Model, Section 3.9";

    leaf name {
        type string;
        description
            "A string that uniquely identifies a dtls object.";
    }

    leaf default-apply {
        type boolean;
        mandatory true;
        description
            "A Boolean flag indicating whether this dtls
             instance is applied to all new interfaces, by default. If
             'true', this instance is applied to new interfaces
             instances at the time they are created, by including it
             in the dtls-certs list under interfaces. If 'false',
             this instance is not applied to new interfaces
             instances when they are created.";
        reference
            "RFC ZZZZ: Babel Information Model, Section 3.9.";
    }

    list certs {
        key "name";
        min-elements "1";
```

```
description
  "A set of cert objects. This contains
  both certificates for this implementation to present
  for authentication, and to accept from others.
  Certificates with a non-empty private-key
  can be presented by this implementation for
  authentication.";
reference
  "RFC ZZZZ: Babel Information Model, Section 3.10.";

leaf name {
  type string;
  description
    "A unique name for this DTLS certificate that can be
    used to identify the certificate in this object
    instance, since the value is too long to be useful
    for identification. This value MUST NOT be empty
    and can only be provided when this instance is created
    (i.e., it is not subsequently writable).";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.10.";
}

leaf value {
  type string;
  mandatory true;
  description
    "The DTLS certificate in PEM format [RFC7468]. This
    value can only be provided when this instance is
    created, and is not subsequently writable.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.10.";
}

leaf type {
  type identityref {
    base dtls-cert-types;
  }
  mandatory true;
  description
    "The name of the certificate type of this object
    instance. The value MUST be the same as one of the
    enumerations listed in the dtls-cert-types
    parameter. This value can only be provided when this
    instance is created, and is not subsequently writable.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.10.";
}
```

```
leaf private-key {
  type binary;
  mandatory true;
  description
    "The value of the private key. If this is non-empty,
    this certificate can be used by this implementation to
    provide a certificate during DTLS handshaking. An
    implementation MUST NOT allow this parameter to be
    read. This can be done by always providing an empty
    string, or through permissions, or other means. This
    value can only be provided when this instance is
    created, and is not subsequently writable.";
  reference
    "RFC ZZZZ: Babel Information Model, Section 3.10.";
}

action test {
  input {
    leaf test-string {
      type binary;
      mandatory true;
      description
        "The test string on which this test has to be
        performed.";
    }
  }
  output {
    leaf resulting-hash {
      type binary;
      mandatory true;
      description
        "The output of this operation is a binary string,
        and is the resulting hash computed using the
        certificate public key, and the SHA-256
        hash algorithm.";
    }
  }
}

uses routes;
}
```

<CODE ENDS>

### 3. IANA Considerations

This document registers one URIs and one YANG module.

#### 3.1. URI Registrations

URI: urn:ietf:params:xml:ns:yang:ietf-babel

#### 3.2. YANG Module Name Registration

This document registers one YANG module in the YANG Module Names registry YANG [RFC6020].

Name:ietf-babel

Namespace: urn:ietf:params:xml:ns:yang:ietf-babel

prefix: babel

reference: RFC XXXX

### 4. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocol such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer and the mandatory-to-implement secure transport is SSH [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The NETCONF Access Control Model (NACM [RFC8341]) provides the means to restrict access for particular NETCONF users to a pre-configured subset of all available NETCONF protocol operations and content.

There are a number of data nodes defined in the YANG module which are writable/created/deleted (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., <edit-config>) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability from a config true perspective:

babel: This container includes an "enable" parameter that can be used to enable or disable use of Babel on a router

babel/constants: This container includes configuration parameters that can prevent reachability if misconfigured.

babel/interfaces: This leaf-list has configuration parameters that can enable/disable security mechanisms and change performance characteristics of the Babel protocol.

babel/hmac and babel/dtls: These contain security credentials that influence whether packets are trusted.

Some of the readable data or config false nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability from a config false perspective:

babel: Access to the information in the various nodes can disclose the network topology. Additionally, the routes used by a network device may be used to mount a subsequent attack on traffic traversing the network device.

babel/hmac and babel/dtls: These contain security credentials, include private credentials of the router.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability from a RPC operation perspective:

babel/hmac/hmac/keys/test and babel/dtls/certs/test: These can be used in a brute force attack to identify the credentials being used to secure the Babel protocol.

## 5. Acknowledgements

Juliusz Chroboczek provided most of the example configurations for babel that are shown in the Appendix.

## 6. References

### 6.1. Normative References

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## Appendix A. An Appendix

This section is devoted to examples that demonstrate how Babel can be configured.

### A.1. Statistics Gathering Enabled

In this example, interface eth0 is being configured for routing protocol Babel, and statistics gathering is enabled. For security, HMAC-SHA256 is supported. Every sent Babel packets is signed with the key value provided, and every received Babel packet is verified with the same key value.

```
<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces"
    xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
    <interface>
      <name>eth0</name>
      <type>ianaift:ethernetCsmacd</type>
      <enabled>true</enabled>
    </interface>
  </interfaces>
  <routing
    xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
    <control-plane-protocols>
      <control-plane-protocol>
        <type
          xmlns:babel=
            "urn:ietf:params:xml:ns:yang:ietf-babel">babel:babel
        </type>
        <name>name:babel</name>
        <babel
          xmlns="urn:ietf:params:xml:ns:yang:ietf-babel">
          <enable>true</enable>
          <stats-enable>true</stats-enable>
          <interfaces>
            <reference>eth0</reference>
            <metric-algorithm>two-out-of-three</metric-algorithm>
            <split-horizon>true</split-horizon>
          </interfaces>
          <mac>
            <name>hmac-sha256</name>
            <keys>
              <name>hmac-sha256-keys</name>
              <use-sign>true</use-sign>
              <use-verify>true</use-verify>
              <value>base64encodedvalue==</value>
              <algorithm>hmac-sha256</algorithm>
            </keys>
          </mac>
        </babel>
      </control-plane-protocol>
    </control-plane-protocols>
  </routing>
</config>
```

## A.2. Automatic Detection of Properties

<!-- In this example, babeld is configured on two interfaces

```
interface eth0
interface wlan0
```

This says to run Babel on interfaces eth0 and wlan0. Babeld will automatically detect that eth0 is wired and wlan0 is wireless, and will configure the right parameters automatically.

-->

```
<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces"
    xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
    <interface>
      <name>eth0</name>
      <type>ianaift:ethernetCsmacd</type>
      <enabled>true</enabled>
    </interface>
    <interface>
      <name>wlan0</name>
      <type>ianaift:ieee80211</type>
      <enabled>true</enabled>
    </interface>
  </interfaces>
  <routing
    xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
    <control-plane-protocols>
      <control-plane-protocol>
        <type
          xmlns:babel=
            "urn:ietf:params:xml:ns:yang:ietf-babel">babel:babel
        </type>
        <name>name:babel</name>
        <babel
          xmlns="urn:ietf:params:xml:ns:yang:ietf-babel">
          <enable>true</enable>
          <interfaces>
            <reference>eth0</reference>
            <enable>true</enable>
            <metric-algorithm>two-out-of-three</metric-algorithm>
            <split-horizon>true</split-horizon>
          </interfaces>
          <interfaces>
            <reference>wlan0</reference>
            <enable>true</enable>
```

```

        <metric-algorithm>etx</metric-algorithm>
        <split-horizon>false</split-horizon>
    </interfaces>
</babel>
</control-plane-protocol>
</control-plane-protocols>
</routing>
</config>

```

### A.3. Override Default Properties

<!-- In this example, babeld is configured on three interfaces

```

interface eth0
interface eth1 type wireless
interface tun0 type tunnel

```

Here, interface eth1 is an Ethernet bridged to a wireless radio, so babeld's autodetection fails, and the interface type needs to be configured manually. Tunnels are not detected automatically, so this needs to be specified.

This is equivalent to the following:

```

interface eth0 metric-algorithm 2-out-of-3 split-horizon true
interface eth1 metric-algorithm etx split-horizon false
interface tun0 metric-algorithm 2-out-of-3 split-horizon true
-->

<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces"
    xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
    <interface>
      <name>eth0</name>
      <type>ianaift:ethernetCsmacd</type>
      <enabled>true</enabled>
    </interface>
    <interface>
      <name>eth1</name>
      <type>ianaift:ethernetCsmacd</type>
      <enabled>true</enabled>
    </interface>
    <interface>
      <name>tun0</name>
      <type>ianaift:tunnel</type>
      <enabled>true</enabled>
    </interface>
  </interfaces>
</config>

```

```

</interfaces>
<routing
  xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
  <control-plane-protocols>
    <control-plane-protocol>
      <type
        xmlns:babel=
          "urn:ietf:params:xml:ns:yang:ietf-babel">babel:babel
      </type>
      <name>name:babel</name>
      <babel
        xmlns="urn:ietf:params:xml:ns:yang:ietf-babel">
        <enable>true</enable>
        <interfaces>
          <reference>eth0</reference>
          <enable>true</enable>
          <metric-algorithm>two-out-of-three</metric-algorithm>
          <split-horizon>true</split-horizon>
        </interfaces>
        <interfaces>
          <reference>eth1</reference>
          <enable>true</enable>
          <metric-algorithm>etx</metric-algorithm>
          <split-horizon>false</split-horizon>
        </interfaces>
        <interfaces>
          <reference>tun0</reference>
          <enable>true</enable>
          <metric-algorithm>two-out-of-three</metric-algorithm>
          <split-horizon>true</split-horizon>
        </interfaces>
      </babel>
    </control-plane-protocol>
  </control-plane-protocols>
</routing>
</config>

```

#### A.4. Configuring other Properties

<!-- In this example, two interfaces are configured for babeld

```

interface eth0
interface ppp0 hello-interval 30 update-interval 120

```

Here, ppp0 is a metered 3G link used for fallback connectivity. It runs with much higher than default time constants in order to avoid control traffic as much as possible.

-->

```
<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces"
    xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
    <interface>
      <name>eth0</name>
      <type>ianaift:ethernetCsmacd</type>
      <enabled>true</enabled>
    </interface>
    <interface>
      <name>ppp0</name>
      <type>ianaift:ppp</type>
      <enabled>true</enabled>
    </interface>
  </interfaces>
  <routing
    xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
    <control-plane-protocols>
      <control-plane-protocol>
        <type
          xmlns:babel=
            "urn:ietf:params:xml:ns:yang:ietf-babel">babel:babel
        </type>
        <name>name:babel</name>
        <babel
          xmlns="urn:ietf:params:xml:ns:yang:ietf-babel">
          <enable>true</enable>
          <interfaces>
            <reference>eth0</reference>
            <enable>true</enable>
            <metric-algorithm>two-out-of-three</metric-algorithm>
            <split-horizon>true</split-horizon>
          </interfaces>
          <interfaces>
            <reference>ppp0</reference>
            <enable>true</enable>
            <mcast-hello-interval>30</mcast-hello-interval>
            <update-interval>120</update-interval>
            <metric-algorithm>two-out-of-three</metric-algorithm>
          </interfaces>
        </babel>
      </control-plane-protocol>
    </control-plane-protocols>
  </routing>
</config>
```

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