

Workgroup: Babel Working Group
Internet-Draft: draft-ietf-babel-yang-model-13
Published: 22 September 2021
Intended Status: Standards Track
Expires: 26 March 2022
Authors: M. Jethanandani B. Stark
 Kloud Services AT&T

YANG Data Model for Babel

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.

Status of This Memo

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

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

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

This Internet-Draft will expire on 26 March 2022.

Copyright Notice

Copyright (c) 2021 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents

carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

- [1. Introduction](#)
 - [1.1. Note to RFC Editor](#)
 - [1.2. Tree Diagram Annotations](#)
- [2. Babel Module](#)
 - [2.1. Information Model](#)
 - [2.2. Tree Diagram](#)
 - [2.3. YANG Module](#)
- [3. IANA Considerations](#)
 - [3.1. URI Registrations](#)
 - [3.2. YANG Module Name Registration](#)
- [4. Security Considerations](#)
- [5. Acknowledgements](#)
- [6. References](#)
 - [6.1. Normative References](#)
 - [6.2. Informative References](#)
- [Appendix A. Tree Diagram and Example Configurations](#)
 - [A.1. Complete Tree Diagram](#)
 - [A.2. Statistics Gathering Enabled](#)
 - [A.3. Automatic Detection of Properties](#)
 - [A.4. Override Default Properties](#)
 - [A.5. Configuring other Properties](#)
- [Authors' Addresses](#)

1. Introduction

This document defines a data model for [The Babel Routing Protocol](#) [RFC8966]. The data model is defined using [YANG 1.1](#) [RFC7950] and is [Network Management Datastore Architecture \(NDMA\)](#) [RFC8342] compatible. It is based on the [Babel Information Model](#) [RFC9046]. The data model only includes data nodes that are useful for managing Babel over IPv6.

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.

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

*Revision date in model, in the format 2021-09-20 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 \[RFC9046\]](#).

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 the version implemented by this device, the model contains subtrees on 'constants', 'interfaces', 'mac-key-set', 'dtls', and 'routes'.

```

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 statistics-enabled? boolean
    +--rw constants
      |   ...
    +--rw interfaces* [reference]
      |   ...
    +--rw mac-key-set* [name]
      |   ...
    +--rw dtls* [name]
      |   ...
    +--ro routes* [prefix]
      ...

```

The 'interfaces' subtree describes attributes such as the 'interface' object that is being referenced, the type of link, e.g., wired, wireless or tunnel, 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 subtrees are defined to contain MAC keys and DTLS certificates. The 'mac-key-set' 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 sometimes 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 'two-out-of-three' for 'metric-algorithm', and 'split-horizon' set to true. On the other hand, for a wireless interface it will assume 'etx' for '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 with IPsec \[RFC4868\]](#), [The Datagram Transport Layer Security \(DTLS\) Version 1.3 \[I-D.ietf-tls-dtls13\]](#), [The Blake2 Cryptographic Hash and Message Authentication Code \(MAC\) \[RFC7693\]](#), [Babel Information Model \[RFC9046\]](#), [The Babel Routing Protocol \[RFC8966\]](#), [YANG Data Types and Groupings for Cryptography \[I-D.ietf-netconf-crypto-types\]](#), [Network Configuration Access Control Model \[RFC8341\]](#) and [MAC Authentication for Babel \[RFC8967\]](#).

<CODE BEGINS> file "ietf-babel@2021-09-20.yang"

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

  import ietf-yang-types {
    prefix yang;
    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";
  }
  import ietf-crypto-types {
    prefix ct;
    reference
      "I-D.ietf-netconf-crypto-types: YANG Data Types and Groupings
      for Cryptographay.";
  }
  import ietf-netconf-acm {
    prefix nacm;
    reference
      "RFC 8341: Network Configuration Access Control Model";
  }

  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, they appear in all capitals, as shown here.

Copyright (c) 2021 IETF Trust and the persons identified as authors of the code. All rights reserved.

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

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

revision 2021-09-20 {

description

"Initial version.";

reference

"RFC XXXX: Babel YANG Data Model.";

}

/*

* Features

*/

feature two-out-of-three-supported {

description

"This implementation supports the '2-out-of-3' computation algorithm.";

}

feature etx-supported {

description

"This implementation supports the Expected Transmission Count (ETX) metric computation algorithm.";

}

```
feature mac-supported {
  description
    "This implementation supports MAC-based security.";
  reference
    "RFC 8967: MAC authentication for Babel Routing
    Protocol.";
}

feature dtls-supported {
  description
    "This implementation supports DTLS based security.";
  reference
    "RFC 8968: Babel Routing Protocol over Datagram
    Transport Layer Security.";
}

feature hmac-sha256-supported {
  description
    "This implementation supports the HMAC-SHA256 MAC algorithm.";
  reference
    "RFC 8967: MAC authentication for Babel Routing
    Protocol.";
}

feature blake2s-supported {
  description
    "This implementation supports BLAKE2s MAC algorithms.";
  reference
    "RFC 8967: MAC authentication for Babel Routing
    Protocol.";
}

feature x-509-supported {
  description
    "This implementation supports the X.509 certificate type.";
  reference
    "RFC 8968: Babel Routing Protocol over Datagram
    Transport Layer Security.";
}

feature raw-public-key-supported {
  description
    "This implementation supports the Raw Public Key certificate
    type.";
  reference
    "RFC 8968: Babel Routing Protocol over Datagram
    Transport Layer Security.";
}
```

```
/*
 * Identities
 */

identity metric-comp-algorithms {
    description
        "Base identity from which all Babel metric computation
        algorithms MUST be derived.";
}

identity two-out-of-three {
    if-feature "two-out-of-three-supported";
    base metric-comp-algorithms;
    description
        "2-out-of-3 algorithm.";
    reference
        "RFC 8966: The Babel Routing Protocol, Section A.2.1.";
}

identity etx {
    if-feature "etx-supported";
    base metric-comp-algorithms;
    description
        "Expected Transmission Count (ETX) metric computation
        algorithm.";
    reference
        "RFC 8966: The Babel Routing Protocol, Section A.2.2.";
}

/*
 * 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 algorithms supported. Specifically, BLAKE2-128 is
    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 certificate 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 9046: Babel Information Model, Section 3.6.";
    }

    leaf router-id {
      type binary {
        length 8;
      }
      description
        "router-id of the source router for which this route is
        advertised.";
      reference
        "RFC 9046: 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 9046: Babel Information Model, Section 3.6.";
    }

    leaf received-metric {
      type union {
        type enumeration {
          enum null {
            description
              "Route was not received from a neighbor.";
          }
        }
      }
      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 NULL if the
    route was not received from a neighbor but instead was
    injected through means external to the Babel routing
    protocol. At least one of calculated-metric or
    received-metric MUST be non-NULL.";
reference
    "RFC 9046: Babel Information Model, Section 3.6,
    RFC 8966: The Babel Routing Protocol, Section 2.1.";
}

leaf calculated-metric {
    type union {
        type enumeration {
            enum null {
                description
                    "Route has not been calculated.";
            }
        }
        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 9046: Babel Information Model, Section 3.6,
        RFC 8966: The Babel Routing Protocol, Section 2.1.";
}

leaf seqno {
    type uint16;
    description
        "The sequence number with which this route was
        advertised.";
    reference
        "RFC 9046: Babel Information Model, Section 3.6.";
}

leaf next-hop {
    type union {
        type enumeration {
            enum null {

```

```

        description
            "Route has no next-hop address.";
    }
}
type inet:ip-address;
}
description
    "The next-hop address of this route. This will be NULL
    if this route has no next-hop address.";
reference
    "RFC 9046: Babel Information Model, Section 3.6.";
}

leaf feasible {
    type boolean;
    description
        "A boolean flag indicating whether this route is
        feasible.";
    reference
        "RFC 9046: Babel Information Model, Section 3.6,
        RFC 8966, 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 9046: Babel Information Model, Section 3.6.";
}
description
    "A set of babel-route-obj objects. Contains routes known to
    this node.";
reference
    "RFC 9046: 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 9046: 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 9046: 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 9046: Babel Information Model, Section 3.1.";
  }

  leaf router-id {
    type binary;
    must '../enable = "true"';
    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.

The router-id is valid only if the protocol is enabled, at which time a non-zero value is assigned.";

reference

"RFC 9046: Babel Information Model, Section 3.1,
RFC 8966: 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 9046: Babel Information Model, Section 3.1.";

}

leaf statistics-enabled {

type boolean;

description

"Indicates whether statistics collection is enabled (true) or disabled (false) on all interfaces. On transition to enabled, existing statistics values are not cleared and will be incremented as new packets are counted.";

}

container constants {

description

"Babel Constants object.";

reference

"RFC 9046: 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 9046: 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 9046: Babel Information Model, Section 3.2.";
}
}

list interfaces {
    key "reference";

    description
        "A set of Babel Interface objects.";
    reference
        "RFC 9046: 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 9046: 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 9046: 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 9046: Babel Information Model, Section 3.3.";
    }
}

```

```
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 the split horizon optimization
     is used.";
  reference
    "RFC 9046: Babel Information Model, Section 3.3.";
}

leaf mcast-hello-seqno {
  type uint16;
  config false;
  description
    "The current sequence number in use for multicast hellos
     sent on this interface.";
  reference
    "RFC 9046: 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 9046: 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 9046: 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 9046: Babel Information Model, Section 3.3.";
```

```

}

leaf-list mac-key-sets {
  type leafref {
    path "../..//mac-key-set/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 9046: Babel Information Model, Section 3.3.";
}

leaf mac-verify {
  type boolean;
  description
    "A Boolean flag indicating whether MACs 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.";
  reference
    "RFC 9046: 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 9046: 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 9046: Babel Information Model, Section 3.3.";
}

leaf dtls-cached-info {

```

```

type boolean;
description
  "Indicates whether the cached_info extension is enabled.
  The extension is enabled for inclusion in ClientHello
  and ServerHello messages if the value is 'true'.";
reference
  "RFC 9046: Babel Information Model, Section 3.3.
  RFC 8968: Babel Routing Protocol over
  Datagram Transport Layer Security, Appendix A.";
}

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 the 'type' attribute
    in the list 'certs' of the list 'dtls'
    (../dtls/certs/type). This list is used to populate
    the server_certificate_type extension in a ClientHello.
    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
    ClientHello.";
  reference
    "RFC 9046: Babel Information Model, Section 3.3
    RFC 8968: Babel Routing Protocol over
    Datagram Transport Layer Security, Appendix A.";
}

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 9046: 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 9046: Babel Information Model, Section 3.3.";
}

container statistics {
    config false;
    description
        "Statistics collection object for this interface.";
    reference
        "RFC 9046: Babel Information Model, Section 3.3.";

    leaf discontinuity-time {
        type yang:date-and-time;
        mandatory true;
        description
            "The time on the most recent occasion at which any one
            or more of counters suffered a discontinuity. If no
            such discontinuities have occurred since the last
            re-initialization of the local management subsystem,
            then this node contains the time the local management
            subsystem re-initialized itself.";
    }

    leaf sent-mcast-hello {
        type yang:counter32;
        description
            "A count of the number of multicast Hello packets sent
            on this interface.";
        reference
            "RFC 9046: Babel Information Model, Section 3.4.";
    }

    leaf sent-mcast-update {
        type yang:counter32;
        description
            "A count of the number of multicast update packets sent
            on this interface.";
        reference
            "RFC 9046: Babel Information Model, Section 3.4.";
    }

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

```

```

        on this interface.";
    reference
        "RFC 9046: Babel Information Model, Section 3.6.";
}

leaf sent-ucast-update {
    type yang:counter32;
    description
        "A count of the number of unicast update packets sent
        on this interface.";
    reference
        "RFC 9046: Babel Information Model, Section 3.6.";
}

leaf sent-ihu {
    type yang:counter32;
    description
        "A count of the number of IHU packets sent on this
        interface.";
    reference
        "RFC 9046: Babel Information Model, Section 3.6.";
}

leaf received-packets {
    type yang:counter32;
    description
        "A count of the number of Babel packets received on
        this interface.";
    reference
        "RFC 9046: Babel Information Model, Section 3.4.";
}

action reset {
    description
        "The information model [RFC 9046] 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 statistics 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 yang:date-and-time;

```

```

        description
            "The time when the reset was issued.";
    }
}

output {
    leaf reset-finished-at {
        type yang: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 9046: 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 9046: 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 of
            utf-8 encoded hex digits. A bit that is set indicates
            that the corresponding Hello was received, and a bit
            that is cleared indicates that the corresponding Hello
            was not received.";
        reference
            "RFC 9046: 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 9046: 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 9046: Babel Information Model, Section 3.5.";
}

leaf exp-mcast-hello-seqno {
    type union {
        type enumeration {
            enum null {
                description
                    "Multicast Hello packets are not expected, or
                    processing of multicast packets is not
                    enabled.";
            }
        }
        type uint16;
    }
    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 9046: Babel Information Model, Section 3.5.";
}

```

```
leaf exp-ucast-hello-seqno {
  type union {
    type enumeration {
      enum null {
        description
          "Unicast Hello packets are not expected, or
           processing of unicast packets is not enabled.";
      }
    }
    type uint16;
  }
  default null;
  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 9046: Babel Information Model, Section 3.5.";
}
```

```
leaf ucast-hello-seqno {
  type union {
    type enumeration {
      enum null {
        description
          "Unicast Hello packets are not being sent.";
      }
    }
    type uint16;
  }
  default null;
  description
    "The current sequence number in use for unicast Hellos
     sent to this neighbor. If unicast Hellos are not being
     sent, this MUST be NULL.";
  reference
    "RFC 9046: 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 9046: Babel Information Model, Section 3.5.";
}
```

```

leaf rxcost {
    type uint16;
    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 9046: 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 9046: Babel Information Model, Section 3.5.";
}
}
}

list mac-key-set {
    key "name";

    description
        "A MAC key set object. If this object is implemented, it
        provides access to parameters related to the MAC security
        mechanism.";
    reference
        "RFC 9046: 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 object
            instance is applied to all new interfaces, by default.
            If 'true', this instance is applied to new babel-
            interfaces instances at the time they are created,

```

```

        by including it in the mac-key-sets list under
        the interface. If 'false', this instance is not applied
        to new interface instances when they are created.";
reference
    "RFC 9046: Babel Information Model, Section 3.7.";
}

list keys {
    key "name";
    min-elements 1;
    description
        "A set of keys objects.";
    reference
        "RFC 9046: Babel Information Model, Section 3.8.";

    leaf name {
        type string;
        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 9046: Babel Information Model, Section 3.8.";
    }

    leaf use-send {
        type boolean;
        mandatory true;
        description
            "Indicates whether this key value is used to compute a
            MAC and include that MAC in the sent Babel packet. A
            MAC for sent packets is computed using this key if the
            value is 'true'. If the value is 'false', this key is
            not used to compute a MAC to include in sent Babel
            packets.";
        reference
            "RFC 9046: 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 9046: Babel Information Model, Section 3.8.";
}

leaf value {
    nacm:default-deny-all;
    type binary;
    mandatory true;
    description
        "The value of the MAC key.

        This value is of a length suitable for the associated
        babel-mac-key-algorithm. If the algorithm is based on
        the HMAC construction [RFC2104], the length MUST be
        between 0 and an upper limit that is at least the size
        of the output length (where 'HMAC-SHA256' output
        length is 32 octets as described in [RFC4868]). Longer
        lengths MAY be supported but are not necessary if the
        management system has the ability to generate a
        suitably random value (e.g., by randomly generating a
        value or by using a key derivation technique as
        recommended in [RFC8967] Security Considerations). If
        the algorithm is 'BLAKE2s-128', the length MUST be
        between 0 and 32 bytes inclusive as specified by
        [RFC7693].";
reference
    "RFC 9046: 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).
    RFC 8967: MAC Authentication for Babel.";
}

leaf algorithm {
    type identityref {
        base mac-algorithms;
    }
    mandatory true;
    description
        "The MAC algorithm used with this key. The
        value MUST be one of the identities
        listed with the base of 'mac-algorithms.'";
reference
    "RFC 9046: Babel Information Model, Section 3.8.";
}

```

```

action test {
  description
    "An operation that allows the MAC key and MAC
    algorithm to be tested to see if they produce an
    expected outcome. Input to this operation are a
    binary string and a calculated MAC (also in the
    format of a binary string) for the binary string.
    The implementation is expected to create a MAC over
    the binary string using the value and algorithm.
    The output of this operation is a binary indication
    that the calculated MAC matched the input MAC (true)
    or the MACs did not match (false).";
  reference
    "RFC 9046: 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 MAC over this string using the value and
        the algorithm defined as part of the
        mac-key-set.";
      reference
        "RFC 9046: Babel Information Model, Section 3.8.";
    }

    leaf mac {
      type binary;
      mandatory true;
      description
        "Input to this operation includes a MAC.
        The implementation is expected to calculate a MAC
        over the string using the value and algorithm of
        this key object and compare its calculated MAC to
        this input MAC.";
      reference
        "RFC 9046: Babel Information Model, Section 3.8.";
    }
  }

  output {
    leaf indication {
      type boolean;
      mandatory true;
      description

```



```

    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 9046: Babel Information Model, Section 3.10.";

leaf name {
    type string;
    description
        "A unique name for this 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 9046: Babel Information Model, Section 3.10.";
}

leaf value {
    nacm:default-deny-write;
    type string;
    mandatory true;
    description
        "The certificate in PEM format [RFC7468]. This
        value can only be provided when this instance is
        created, and is not subsequently writable.";
    reference
        "RFC 9046: Babel Information Model, Section 3.10.";
}

leaf type {
    nacm:default-deny-write;
    type identityref {
        base dtls-cert-types;
    }
    mandatory true;
    description
        "The certificate type of this object instance.
        The value MUST be the same as one of the
        identities listed with the base 'dtls-cert-types'.
        This value can only be provided when this
        instance is created, and is not subsequently
        writable.";
    reference
        "RFC 9046: Babel Information Model, Section 3.10.";
}

```


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.

The security considerations outlined here are specific to the YANG data model, and do not cover security considerations of the Babel protocol or its security mechanisms in [The Babel Routing Protocol \[RFC8966\]](#), [MAC Authentication for the Babel Routing Protocol \[RFC8967\]](#), and [Babel Routing Protocol over Data Transport Layer Security \[RFC8968\]](#). Each of these has its own Security Considerations section for considerations that are specific to it.

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. For example, enabling logging of packets and giving unintended access to the log files gives an attacker detailed knowledge of the network, and allows it to launch an attack on the traffic traversing the network device.

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

outgoing packets are produced in a way such that the receiver will treat them as 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, including private credentials of the router; however it is required that these values not be readable.

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:

This model defines two actions. Resetting the statistics within an interface container would be visible to any monitoring processes, which should be designed to account for the possibility of such a reset. The "test" action allows for validation that a MAC key and MAC algorithm have been properly configured. The MAC key is a sensitive piece of information, and it is important to prevent an attacker that does not know the MAC key from being able to determine the MAC value by trying different input parameters. The "test" action has been designed to not reveal such information directly. Such information might also be revealed indirectly, due to side channels such as the time it takes to produce a response to the action. Implementations SHOULD use a constant-time comparison between the input mac and the locally generated MAC value for comparison, in order to avoid such side channel leakage.

5. Acknowledgements

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

6. References

6.1. Normative References

[I-D.ietf-netconf-crypto-types]

Watsen, K., "YANG Data Types and Groupings for Cryptography", Work in Progress, Internet-Draft, draft-ietf-netconf-crypto-types-20, 18 May 2021, <<https://www.ietf.org/archive/id/draft-ietf-netconf-crypto-types-20.txt>>.

[I-D.ietf-tls-dtls13] Rescorla, E., Tschofenig, H., and N. Modadugu, "The Datagram Transport Layer Security (DTLS) Protocol Version 1.3", Work in Progress, Internet-Draft, draft-ietf-tls-dtls13-43, 30 April 2021, <<https://www.ietf.org/internet-drafts/draft-ietf-tls-dtls13-43.txt>>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.

[RFC4868] Kelly, S. and S. Frankel, "Using HMAC-SHA-256, HMAC-SHA-384, and HMAC-SHA-512 with IPsec", RFC 4868, DOI 10.17487/RFC4868, May 2007, <<https://www.rfc-editor.org/info/rfc4868>>.

[RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <<https://www.rfc-editor.org/info/rfc6991>>.

[RFC7693] Saarinen, M-J., Ed. and J-P. Aumasson, "The BLAKE2 Cryptographic Hash and Message Authentication Code (MAC)", RFC 7693, DOI 10.17487/RFC7693, November 2015, <<https://www.rfc-editor.org/info/rfc7693>>.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <<https://www.rfc-editor.org/info/rfc8341>>.

[RFC8343] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 8343, DOI 10.17487/RFC8343, March 2018, <<https://www.rfc-editor.org/info/rfc8343>>.

[RFC8349] Lhotka, L., Lindem, A., and Y. Qu, "A YANG Data Model for Routing Management (NMDA Version)", RFC 8349, DOI

10.17487/RFC8349, March 2018, <<https://www.rfc-editor.org/info/rfc8349>>.

- [RFC8966] Chroboczek, J. and D. Schinazi, "The Babel Routing Protocol", RFC 8966, DOI 10.17487/RFC8966, January 2021, <<https://www.rfc-editor.org/info/rfc8966>>.
- [RFC8967] Dô, C., Kolodziejak, W., and J. Chroboczek, "MAC Authentication for the Babel Routing Protocol", RFC 8967, DOI 10.17487/RFC8967, January 2021, <<https://www.rfc-editor.org/info/rfc8967>>.
- [RFC8968] Décimo, A., Schinazi, D., and J. Chroboczek, "Babel Routing Protocol over Datagram Transport Layer Security", RFC 8968, DOI 10.17487/RFC8968, January 2021, <<https://www.rfc-editor.org/info/rfc8968>>.
- [RFC9046] Stark, B. and M. Jethanandani, "Babel Information Model", RFC 9046, DOI 10.17487/RFC9046, June 2021, <<https://www.rfc-editor.org/info/rfc9046>>.

6.2. Informative References

- [RFC2104] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, DOI 10.17487/RFC2104, February 1997, <<https://www.rfc-editor.org/info/rfc2104>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/info/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.
- [RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/info/rfc8340>>.

[RFC8342]

Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <<https://www.rfc-editor.org/info/rfc8342>>.

[RFC8446]

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

Appendix A. Tree Diagram and Example Configurations

This section is devoted to including a complete tree diagram and examples that demonstrate how Babel can be configured.

A.1. Complete Tree Diagram

This section includes the complete tree diagram for the Babel YANG module.

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 statistics-enabled? boolean
    +--rw constants
      | +--rw udp-port?     inet:port-number
      | +--rw mcast-group?  inet:ip-address
    +--rw interfaces* [reference]
      | +--rw reference     if:interface-ref
      | +--rw enable?       boolean
      | +--rw metric-algorithm identityref
      | +--rw split-horizon? boolean
      | +--ro mcast-hello-seqno? uint16
      | +--rw mcast-hello-interval? uint16
      | +--rw update-interval? uint16
      | +--rw mac-enable?   boolean
      | +--rw mac-key-sets* -> ../../mac-key-set/name
      | +--rw mac-verify?   boolean
      | +--rw dtls-enable?  boolean
      | +--rw dtls-certs*   -> ../../dtls/name
      | +--rw dtls-cached-info? boolean
      | +--rw dtls-cert-prefer* -> ../../dtls/certs/type
      | +--rw packet-log-enable? boolean
      | +--ro packet-log?   inet:uri
      | +--ro statistics
        | | +--ro discontinuity-time yang:date-and-time
        | | +--ro sent-mcast-hello?  yang:counter32
        | | +--ro sent-mcast-update? yang:counter32
        | | +--ro sent-ucast-hello?  yang:counter32
        | | +--ro sent-ucast-update? yang:counter32
        | | +--ro sent-ihu?          yang:counter32
        | | +--ro received-packets?  yang:counter32
        | | +---x reset
        | |   +---w input
        | |     | +---w reset-at?    yang:date-and-time
        | |     +--ro output
        | |       +--ro reset-finished-at? yang:date-and-time
    +--ro neighbor-objects* [neighbor-address]
      | +--ro neighbor-address      inet:ip-address
      | +--ro hello-mcast-history?  string
      | +--ro hello-ucast-history?  string
      | +--ro txcost?               int32
      | +--ro exp-mcast-hello-seqno? union
```

```

|   +--ro exp-ucast-hello-seqno?  union
|   +--ro ucast-hello-seqno?     union
|   +--ro ucast-hello-interval?  uint16
|   +--ro rxcost?                 uint16
|   +--ro cost?                   int32
+--rw mac-key-set* [name]
|   +--rw name                     string
|   +--rw default-apply?          boolean
|   +--rw keys* [name]
|       +--rw name                 string
|       +--rw use-send             boolean
|       +--rw use-verify           boolean
|       +--rw value                binary
|       +--rw algorithm            identityref
|       +---x test
|           +---w input
|               | +---w test-string  binary
|               | +---w mac          binary
|           +--ro output
|               +--ro indication    boolean
+--rw dtls* [name]
|   +--rw name                     string
|   +--rw default-apply            boolean
|   +--rw certs* [name]
|       +--rw name                 string
|       +--rw value                string
|       +--rw type                 identityref
|       +--rw private-key          binary
|       +--rw algorithm            identityref
+--ro routes* [prefix]
    +--ro prefix                    inet:ip-prefix
    +--ro router-id?                binary
    +--ro neighbor?                 leafref
    +--ro received-metric?          union
    +--ro calculated-metric?        union
    +--ro seqno?                    uint16
    +--ro next-hop?                 union
    +--ro feasible?                 boolean
    +--ro selected?                 boolean

```

A.2. 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"?>
<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>
        <statistics-enabled>true</statistics-enabled>
        <interfaces>
          <reference>eth0</reference>
          <metric-algorithm>two-out-of-three</metric-algorithm>
          <split-horizon>true</split-horizon>
        </interfaces>
        <mac-key-set>
          <name>hmac-sha256</name>
          <keys>
            <name>hmac-sha256-keys</name>
            <use-send>true</use-send>
            <use-verify>true</use-verify>
            <value>base64encodedvalue==</value>
            <algorithm>hmac-sha256</algorithm>
          </keys>
        </mac-key-set>
      </babel>
    </control-plane-protocol>
  </control-plane-protocols>
</routing>
```

A.3. 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"?>
<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>
```

A.4. 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"?>
<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>
<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>
      </babel>
    </control-plane-protocol>
  </control-plane-protocols>
</routing>
</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>
```

A.5. 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"?>
<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>
```

Authors' Addresses

Mahesh Jethanandani
Kloud Services
California
United States of America

Email: mjethanandani@gmail.com

Barbara Stark
AT&T
Atlanta, GA
United States of America

Email: barbara.stark@att.com