

Babel routing protocol
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Babel Information Model
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Abstract

This Babel Information Model provides structured data elements for a Babel implementation reporting its current state and may allow limited configuration of some such data elements. This information model can be used as a basis for creating data models under various data modeling regimes. This information model only includes parameters and parameter values useful for managing Babel over IPv6.

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1. Introduction

Babel is a loop-avoiding distance-vector routing protocol defined in [RFC8966]. [RFC8967] defines a security mechanism that allows Babel packets to be cryptographically authenticated, and [RFC8968] defines a security mechanism that allows Babel packets to be both authenticated and encrypted. This document describes an information model for Babel (including implementations using one or both of these security mechanisms) that can be used to create management protocol data models (such as a NETCONF [RFC6241] YANG [RFC7950] data model).

Due to the simplicity of the Babel protocol, most of the information model is focused on reporting Babel protocol operational state, and very little of that is considered mandatory to implement for an implementation claiming compliance with this information model. Some parameters may be configurable. However, it is up to the Babel implementation whether to allow any of these to be configured within its implementation. Where the implementation does not allow configuration of these parameters, it MAY still choose to expose them as read-only.

The Information Model is presented using a hierarchical structure. This does not preclude a data model based on this Information Model from using a referential or other structure.

This information model only includes parameters and parameter values useful for managing Babel over IPv6. This model has no parameters or values specific to operating Babel over IPv4, even though [RFC8966] does define a multicast group for sending and listening to multicast announcements on IPv4. There is less likelihood of breakage due to inconsistent configuration and increased implementation simplicity if Babel is operated always and only over IPv6. Running Babel over IPv6 requires IPv6 at the link layer and does not need advertised prefixes, router advertisements or DHCPv6 to be present in the network. Link-local IPv6 is widely supported among devices where Babel is expected to be used. Note that Babel over IPv6 can be used for configuration of both IPv4 and IPv6 routes.

1.1. 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 BCP014 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

1.2. Notation

This document uses a programming language-like notation to define the properties of the objects of the information model. An optional property is enclosed by square brackets, [], and a list property is indicated by two numbers in angle brackets, <m..n>, where m indicates the minimal number of list elements, and n indicates the maximum number of list elements. The symbol * for n means there are no defined limits on the number of list elements. Each parameter and object includes an indication of "ro" or "rw". "ro" means the parameter or object is read-only. "rw" means it is read-write. For an object, read-write means instances of the object can be created or deleted. If an implementation is allowed to choose to implement a

"rw" parameter as read-only, this is noted in the parameter description.

The object definitions use base types that are defined as follows:

binary	A binary string (sequence of octets).
boolean	A type representing a Boolean (true or false) value.
datetime	A type representing a date and time using the Gregorian calendar. The datetime format MUST conform to RFC 3339 [RFC3339] Section 5.6.
ip-address	A type representing an IP address. This type supports both IPv4 and IPv6 addresses.
operation	A type representing a remote procedure call or other action that can be used to manipulate data elements or system behaviors.
reference	A type representing a reference to another information or data model element or to some other device resource.
string	A type representing a human-readable string consisting of a (possibly restricted) subset of Unicode and ISO/IEC 10646 [ISO.10646] characters.
uint	A type representing an unsigned integer number. This information model does not define a precision.

2. Overview

The Information Model is hierarchically structured as follows:

```
+-- babel-information
  +-- babel-implementation-version
  +-- babel-enable
  +-- router-id
  +-- self-seqno
  +-- babel-metric-comp-algorithms
  +-- babel-security-supported
  +-- babel-mac-algorithms
  +-- babel-dtls-cert-types
  +-- babel-stats-enable
  +-- babel-stats-reset
  +-- babel-constants
    | +-- babel-udp-port
    | +-- babel-mcast-group
```

```
+--- babel-interfaces
|   +--- babel-interface-reference
|   +--- babel-interface-enable
|   +--- babel-interface-metric-algorithm
|   +--- babel-interface-split-horizon
|   +--- babel-mcast-hello-seqno
|   +--- babel-mcast-hello-interval
|   +--- babel-update-interval
|   +--- babel-mac-enable
|   +--- babel-if-mac-key-sets
|   +--- babel-mac-verify
|   +--- babel-dtls-enable
|   +--- babel-if-dtls-cert-sets
|   +--- babel-dtls-cached-info
|   +--- babel-dtls-cert-prefer
|   +--- babel-packet-log-enable
|   +--- babel-packet-log
|   +--- babel-if-stats
|       +--- babel-sent-mcast-hello
|       +--- babel-sent-mcast-update
|       +--- babel-sent-ucast-hello
|       +--- babel-sent-ucast-update
|       +--- babel-sent-IHU
|       +--- babel-received-packets
|   +--- babel-neighbors
|       +--- babel-neighbor-address
|       +--- babel-hello-mcast-history
|       +--- babel-hello-ucast-history
|       +--- babel-txcost
|       +--- babel-exp-mcast-hello-seqno
|       +--- babel-exp-ucast-hello-seqno
|       +--- babel-ucast-hello-seqno
|       +--- babel-ucast-hello-interval
|       +--- babel-rxcost
|       +--- babel-cost
+--- babel-routes
|   +--- babel-route-prefix
|   +--- babel-route-prefix-length
|   +--- babel-route-router-id
|   +--- babel-route-neighbor
|   +--- babel-route-received-metric
|   +--- babel-route-calculated-metric
|   +--- babel-route-seqno
|   +--- babel-route-next-hop
|   +--- babel-route-feasible
|   +--- babel-route-selected
+--- babel-mac-key-sets
|   +--- babel-mac-default-apply
```

```
|  +-- babel-mac-keys
|  |  +-- babel-mac-key-name
|  |  +-- babel-mac-key-use-send
|  |  +-- babel-mac-key-use-verify
|  |  +-- babel-mac-key-value
|  |  +-- babel-mac-key-algorithm
|  |  +-- babel-mac-key-test
+-- babel-dtls-cert-sets
  +-- babel-dtls-default-apply
  +-- babel-dtls-certs
    +-- babel-cert-name
    +-- babel-cert-value
    +-- babel-cert-type
    +-- babel-cert-private-key
```

Most parameters are read-only. Following is a descriptive list of the parameters that are not required to be read-only:

- * enable/disable Babel
- * create/delete Babel MAC Key sets
- * create/delete Babel Certificate sets
- * enable/disable statistics collection
- * Constant: UDP port
- * Constant: IPv6 multicast group
- * Interface: enable/disable Babel on this interface
- * Interface: Metric algorithm
- * Interface: Split horizon
- * Interface: sets of MAC keys
- * Interface: verify received MAC packets
- * Interface: set of certificates for use with DTLS
- * Interface: use cached info extensions
- * Interface: preferred order of certificate types
- * Interface: enable/disable packet log

- * MAC-keys: create/delete entries
- * MAC-keys: key used for sent packets
- * MAC-keys: key used to verify packets
- * DTLS-certs: create/delete entries

The following parameters are required to return no value when read:

- * MAC key values
- * DTLS private keys

Note that this overview is intended simply to be informative and is not normative. If there is any discrepancy between this overview and the detailed information model definitions in subsequent sections, the error is in this overview.

3. The Information Model

3.1. Definition of babel-information-obj

```
object {
  string          ro babel-implementation-version;
  boolean         rw babel-enable;
  binary          ro babel-self-router-id;
  [uint          ro babel-self-seqno;]
  string          ro babel-metric-comp-algorithms<1..*>;
  string          ro babel-security-supported<0..*>;
  [string        ro babel-mac-algorithms<1..*>;]
  [string        ro babel-dtls-cert-types<1..*>;]
  [boolean       rw babel-stats-enable;]
  [operation      babel-stats-reset;]
  babel-constants-obj ro babel-constants;
  babel-interface-obj ro babel-interfaces<0..*>;
  babel-route-obj   ro babel-routes<0..*>;
  [babel-mac-key-set-obj rw babel-mac-key-sets<0..*>;]
  [babel-dtls-cert-set-obj rw babel-dtls-cert-sets<0..*>;]
} babel-information-obj;
```

babel-implementation-version: The name and version of this implementation of the Babel protocol.

babel-enable: When written, it configures whether the protocol should be enabled (true) or disabled (false). A read from the running or intended datastore indicates the configured administrative value of whether the protocol is enabled (true) or

not (false). A read from the operational datastore indicates whether the protocol is actually running (true) or not (i.e., it indicates the operational state of the protocol). A data model that does not replicate parameters for running and operational datastores can implement this as two separate parameters. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-self-router-id: The router-id used by this instance of the Babel protocol to identify itself. [RFC8966] describes this as an arbitrary string of 8 octets.

babel-self-seqno: The current sequence number included in route updates for routes originated by this node. This is a 16-bit unsigned integer.

babel-metric-comp-algorithms: List of supported cost computation algorithms. Possible values include "2-out-of-3", and "ETX". "2-out-of-3" is described in [RFC8966], section A.2.1. "ETX" is described in [RFC8966], section A.2.2.

babel-security-supported: List of supported security mechanisms. Possible values include "MAC" to indicate support of [RFC8967] and "DTLS" to indicate support of [RFC8968].

babel-mac-algorithms: List of supported MAC computation algorithms. Possible values include "HMAC-SHA256", "BLAKE2s-128" to indicate support for algorithms indicated in [RFC8967].

babel-dtls-cert-types: List of supported certificate types. Possible values include "X.509" and "RawPublicKey" to indicate support for types indicated in [RFC8968].

babel-stats-enable: Indicates whether statistics collection is enabled (true) or disabled (false) on all interfaces. When enabled, existing statistics values are not cleared and will be incremented as new packets are counted.

babel-stats-reset: An operation that resets all babel-if-stats parameters to zero. This operation has no input or output parameters.

babel-constants: A babel-constants-obj object.

babel-interfaces: A set of babel-interface-obj objects.

babel-routes: A set of babel-route-obj objects. Contains the routes known to this node.

babel-mac-key-sets: A set of babel-mac-key-set-obj objects. If this object is implemented, it provides access to parameters related to the MAC security mechanism. An implementation MAY choose to expose this object as read-only ("ro").

babel-dtls-cert-sets: A set of babel-dtls-cert-set-obj objects. If this object is implemented, it provides access to parameters related to the DTLS security mechanism. An implementation MAY choose to expose this object as read-only ("ro").

3.2. Definition of babel-constants-obj

```
object {  
    uint          rw babel-udp-port;  
    [ip-address   rw babel-mcast-group;]  
} babel-constants-obj;
```

babel-udp-port: UDP port for sending and listening for Babel packets. Default is 6696. An implementation MAY choose to expose this parameter as read-only ("ro"). This is a 16-bit unsigned integer.

babel-mcast-group: Multicast group for sending and listening to multicast announcements on IPv6. Default is ff02::1:6. An implementation MAY choose to expose this parameter as read-only ("ro").

3.3. Definition of babel-interface-obj

```

object {
  reference          ro babel-interface-reference;
  [boolean           rw babel-interface-enable;]
  string            rw babel-interface-metric-algorithm;
  [boolean           rw babel-interface-split-horizon;]
  [uint             ro babel-mcast-hello-seqno;]
  [uint             ro babel-mcast-hello-interval;]
  [uint             ro babel-update-interval;]
  [boolean           rw babel-mac-enable;]
  [reference         rw babel-if-mac-key-sets<0..*>;]
  [boolean           rw babel-mac-verify;]
  [boolean           rw babel-dtls-enable;]
  [reference         rw babel-if-dtls-cert-sets<0..*>;]
  [boolean           rw babel-dtls-cached-info;]
  [string           rw babel-dtls-cert-prefer<0..*>;]
  [boolean           rw babel-packet-log-enable;]
  [reference         ro babel-packet-log;]
  [babel-if-stats-obj ro babel-if-stats;]
  babel-neighbor-obj ro babel-neighbors<0..*>;
} babel-interface-obj;

```

babel-interface-reference: Reference to an interface object that can be used to send and receive IPv6 packets, as defined by the data model (e.g., YANG [RFC7950], BBF [TR-181]). Referencing syntax will be specific to the data model. If there is no set of interface objects available, this should be a string that indicates the interface name used by the underlying operating system.

babel-interface-enable: When written, it configures whether the protocol should be enabled (true) or disabled (false) on this interface. A read from the running or intended datastore indicates the configured administrative value of whether the protocol is enabled (true) or not (false). A read from the operational datastore indicates whether the protocol is actually running (true) or not (i.e., it indicates the operational state of the protocol). A data model that does not replicate parameters for running and operational datastores can implement this as two separate parameters. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-interface-metric-algorithm: Indicates the metric computation algorithm used on this interface. The value MUST be one of those listed in the babel-information-obj babel-metric-comp-algorithms parameter. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-interface-split-horizon: 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. Split horizon optimization is described in [RFC8966], section 3.7.4. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-mcast-hello-seqno: The current sequence number in use for multicast Hellos sent on this interface. This is a 16-bit unsigned integer.

babel-mcast-hello-interval: The current interval in use for multicast Hellos sent on this interface. Units are centiseconds. This is a 16-bit unsigned integer.

babel-update-interval: The current interval in use for all updates (multicast and unicast) sent on this interface. Units are centiseconds. This is a 16-bit unsigned integer.

babel-mac-enable: Indicates whether the MAC security mechanism is enabled (true) or disabled (false). An implementation MAY choose to expose this parameter as read-only ("ro").

babel-if-mac-keys-sets: List of references to the babel-mac entries that apply to this interface. When an interface instance is created, all babel-mac-key-sets instances with babel-mac-default-apply "true" will be included in this list. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-mac-verify 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. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-dtls-enable: Indicates whether the DTLS security mechanism is enabled (true) or disabled (false). An implementation MAY choose to expose this parameter as read-only ("ro").

babel-if-dtls-cert-sets: List of references to the babel-dtls-cert-sets entries that apply to this interface. When an interface instance is created, all babel-dtls-cert-sets instances with babel-dtls-default-apply "true" will be included in this list. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-dtls-cached-info: Indicates whether the cached_info extension

(see [RFC8968] Appendix A) is included in ClientHello and ServerHello packets. The extension is included if the value is "true". An implementation MAY choose to expose this parameter as read-only ("ro").

babel-dtls-cert-prefer: List of supported certificate types, in order of preference. The values MUST be among those listed in the babel-dtls-cert-types parameter. This list is used to populate the server_certificate_type extension (see [RFC8968] Appendix A) in a Client Hello. Values that are present in at least one instance in the babel-dtls-certs object of a referenced babel-dtls instance and that have a non-empty babel-cert-private-key will be used to populate the client_certificate_type extension in a Client Hello.

babel-packet-log-enable: Indicates whether packet logging is enabled (true) or disabled (false) on this interface.

babel-packet-log: A reference or url link to a file that contains a timestamped log of packets received and sent on babel-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 babel-packet-log-enable. Implementations will need to carefully manage and limit memory used by packet logs.

babel-if-stats: Statistics collection object for this interface.

babel-neighbors: A set of babel-neighbor-obj objects.

3.4. Definition of babel-if-stats-obj

```
object {  
    uint    ro babel-sent-mcast-hello;  
    uint    ro babel-sent-mcast-update;  
    uint    ro babel-sent-ucast-hello;  
    uint    ro babel-sent-ucast-update;  
    uint    ro babel-sent-IHU;  
    uint    ro babel-received-packets;  
} babel-if-stats-obj;
```

babel-sent-mcast-hello: A count of the number of multicast Hello packets sent on this interface.

babel-sent-mcast-update: A count of the number of multicast update packets sent on this interface.

babel-sent-ucast-hello: A count of the number of unicast Hello

packets sent on this interface.

babel-sent-ucast-update: A count of the number of unicast update packets sent on this interface.

babel-sent-IHU: A count of the number of IHU packets sent on this interface.

babel-received-packets: A count of the number of Babel packets received on this interface.

3.5. Definition of babel-neighbor-obj

```
object {  
    ip-address      ro babel-neighbor-address;  
    [binary         ro babel-hello-mcast-history;]  
    [binary         ro babel-hello-ucast-history;]  
    uint            ro babel-txcost;  
    uint            ro babel-exp-mcast-hello-seqno;  
    uint            ro babel-exp-ucast-hello-seqno;  
    [uint           ro babel-ucast-hello-seqno;]  
    [uint           ro babel-ucast-hello-interval;]  
    [uint           ro babel-rxcost;]  
    [uint           ro babel-cost;]  
} babel-neighbor-obj;
```

babel-neighbor-address: IPv4 or IPv6 address the neighbor sends packets from.

babel-hello-mcast-history: The multicast Hello history of whether or not the multicast Hello packets prior to babel-exp-mcast-hello-seqno were received. A binary sequence where the most recently received Hello is expressed as a "1" placed in the left-most bit, with prior bits shifted right (and "0" bits placed between prior Hello bits and most recent Hello for any not-received Hellos). This value should be displayed using hex digits ([0-9a-fA-F]). See [RFC8966], section A.1.

babel-hello-ucast-history: The unicast Hello history of whether or not the unicast Hello packets prior to babel-exp-ucast-hello-seqno were received. A binary sequence where the most recently received Hello is expressed as a "1" placed in the left-most bit, with prior bits shifted right (and "0" bits placed between prior Hello bits and most recent Hello for any not-received Hellos). This value should be displayed using hex digits ([0-9a-fA-F]). See [RFC8966], section A.1.

babel-txcost: Transmission cost value from the last IHU packet

received from this neighbor, or maximum value to indicate the IHU hold timer for this neighbor has expired. See [RFC8966], section 3.4.2. This is a 16-bit unsigned integer.

babel-exp-mcast-hello-seqno: 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. This is a 16-bit unsigned integer; if the data model uses zero (0) to represent NULL values for unsigned integers, the data model MAY use a different data type that allows differentiation between zero (0) and NULL.

babel-exp-ucast-hello-seqno: 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. This is a 16-bit unsigned integer; if the data model uses zero (0) to represent NULL values for unsigned integers, the data model MAY use a different data type that allows differentiation between zero (0) and NULL.

babel-ucast-hello-seqno: The current sequence number in use for unicast Hellos sent to this neighbor. If unicast Hellos are not being sent, this MUST be NULL. This is a 16-bit unsigned integer; if the data model uses zero (0) to represent NULL values for unsigned integers, the data model MAY use a different data type that allows differentiation between zero (0) and NULL.

babel-ucast-hello-interval: The current interval in use for unicast Hellos sent to this neighbor. Units are centiseconds. This is a 16-bit unsigned integer.

babel-rxcost: 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. See [RFC8966], section 3.4.3. This is a 16-bit unsigned integer.

babel-cost: The link cost, as 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. This is a 16-bit unsigned integer.

3.6. Definition of babel-route-obj

```
object {  
    ip-address    ro babel-route-prefix;  
    uint          ro babel-route-prefix-length;  
    binary        ro babel-route-router-id;  
    reference     ro babel-route-neighbor;  
    uint          ro babel-route-received-metric;  
    uint          ro babel-route-calculated-metric;  
    uint          ro babel-route-seqno;  
    ip-address    ro babel-route-next-hop;  
    boolean       ro babel-route-feasible;  
    boolean       ro babel-route-selected;  
} babel-route-obj;
```

babel-route-prefix: Prefix (expressed in IP address format) for which this route is advertised.

babel-route-prefix-length: Length of the prefix for which this route is advertised.

babel-route-router-id: The router-id of the router that originated this route.

babel-route-neighbor: Reference to the babel-neighbors entry for the neighbor that advertised this route.

babel-route-received-metric: The metric with which this route was advertised by the neighbor, or maximum value to indicate the route was recently retracted and is temporarily unreachable (see Section 3.5.5 of [RFC8966]). This metric will be NULL if the route was not received from a neighbor but was generated through other means. At least one of babel-route-calculated-metric and babel-route-received-metric MUST be non-NULL. Having both be non-NULL is expected for a route that is received and subsequently advertised. This is a 16-bit unsigned integer; if the data model uses zero (0) to represent NULL values for unsigned integers, the data model MAY use a different data type that allows differentiation between zero (0) and NULL.

babel-route-calculated-metric: A calculated metric for this route.

How the metric is calculated is implementation-specific. Maximum value indicates the route was recently retracted and is temporarily unreachable (see Section 3.5.5 of [RFC8966]). At least one of `babel-route-calculated-metric` and `babel-route-received-metric` MUST be non-NULL. Having both be non-NULL is expected for a route that is received and subsequently advertised. This is a 16-bit unsigned integer; if the data model uses zero (0) to represent NULL values for unsigned integers, the data model MAY use a different data type that allows differentiation between zero (0) and NULL.

`babel-route-seqno`: The sequence number with which this route was advertised. This is a 16-bit unsigned integer.

`babel-route-next-hop`: The next-hop address of this route. This will be empty if this route has no next-hop address.

`babel-route-feasible`: A Boolean flag indicating whether this route is feasible, as defined in Section 3.5.1 of [RFC8966]).

`babel-route-selected`: A Boolean flag indicating whether this route is selected (i.e., whether it is currently being used for forwarding and is being advertised).

3.7. Definition of `babel-mac-key-set-obj`

```
object {  
    boolean          rw babel-mac-default-apply;  
    babel-mac-key-obj rw babel-mac-keys<0..*>;  
} babel-mac-key-set-obj;
```

`babel-mac-default-apply`: A Boolean flag indicating whether this object instance is applied to all new `babel-interface` instances, by default. If "true", this instance is applied to new `babel-interfaces` instances at the time they are created, by including it in the `babel-if-mac-key-sets` list. If "false", this instance is not applied to new `babel-interfaces` instances when they are created. An implementation MAY choose to expose this parameter as read-only ("ro").

`babel-mac-keys`: A set of `babel-mac-key-obj` objects.

3.8. Definition of `babel-mac-key-obj`


```
object {  
    string      rw babel-mac-key-name;  
    boolean     rw babel-mac-key-use-send;  
    boolean     rw babel-mac-key-use-verify;  
    binary      -- babel-mac-key-value;  
    string      rw babel-mac-key-algorithm;  
    [operation   babel-mac-key-test;]  
} babel-mac-key-obj;
```

babel-mac-key-name: 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 **MUST NOT** be empty and can only be provided when this instance is created (i.e., it is not subsequently writable). The value **MAY** be auto-generated if not explicitly supplied when the instance is created.

babel-mac-key-use-send: 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. An implementation **MAY** choose to expose this parameter as read-only ("ro").

babel-mac-key-use-verify: 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 with the MAC in an incoming packet. An implementation **MAY** choose to expose this parameter as read-only ("ro").

babel-mac-key-value: 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 when read, 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 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].

babel-mac-key-algorithm The name of the MAC algorithm used with this

key. The value MUST be the same as one of the enumerations listed in the babel-mac-algorithms parameter. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-mac-key-test: 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 babel-mac-key-value and the babel-mac-key-algorithm. The output of this operation is a Boolean indication that the calculated MAC matched the input MAC (true) or the MACs did not match (false).

3.9. Definition of babel-dtls-cert-set-obj

```
object {  
    boolean          rw babel-dtls-default-apply;  
    babel-dtls-cert-obj  rw babel-dtls-certs<0..*>;  
} babel-dtls-cert-set-obj;
```

babel-dtls-default-apply: A Boolean flag indicating whether this object instance is applied to all new babel-interface instances, by default. If "true", this instance is applied to new babel-interfaces instances at the time they are created, by including it in the babel-interface-dtls-certs list. If "false", this instance is not applied to new babel-interfaces instances when they are created. An implementation MAY choose to expose this parameter as read-only ("ro").

babel-dtls-certs: A set of babel-dtls-cert-obj objects. This contains both certificates for this implementation to present for authentication, and to accept from others. Certificates with a non-empty babel-cert-private-key can be presented by this implementation for authentication.

3.10. Definition of babel-dtls-cert-obj

```
object {  
    string          rw babel-cert-name;  
    string          rw babel-cert-value;  
    string          rw babel-cert-type;  
    binary          -- babel-cert-private-key;  
} babel-dtls-cert-obj;
```

babel-cert-name: 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). The value MAY be auto-generated if not explicitly supplied when the instance is created.

babel-cert-value: The certificate in PEM format [RFC7468]. This value MUST be provided when this instance is created, and is not subsequently writable.

babel-cert-type: The name of the certificate type of this object instance. The value MUST be the same as one of the enumerations listed in the `babel-dtls-cert-types` parameter. This value can only be provided when this instance is created, and is not subsequently writable.

babel-cert-private-key: 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 when read, or through permissions, or other means. This value can only be provided when this instance is created, and is not subsequently writable.

4. Extending the Information Model

Implementations MAY extend this information model with other parameters or objects. For example, an implementation MAY choose to expose Babel route filtering rules by adding a route filtering object with parameters appropriate to how route filtering is done in that implementation. The precise means used to extend the information model would be specific to the data model the implementation uses to expose this information.

5. Security Considerations

This document defines a set of information model objects and parameters that may be exposed to be visible from other devices, and some of which may be configured. Securing access to and ensuring the integrity of this data is in scope of and the responsibility of any data model derived from this information model. Specifically, any YANG [RFC7950] data model is expected to define security exposure of the various parameters, and a [TR-181] data model will be secured by the mechanisms defined for the management protocol used to transport it.

Misconfiguration (whether unintentional or malicious) can prevent reachability or cause poor network performance (increased latency, jitter, etc.). Misconfiguration of security credentials can cause a denial of service condition for the Babel routing protocol. The information in this model discloses network topology, which can be used to mount subsequent attacks on traffic traversing the network.

This information model defines objects that can allow credentials (for this device, for trusted devices, and for trusted certificate authorities) to be added and deleted. Public keys may be exposed through this model. This model requires that private keys and MAC keys never be exposed. Certificates used by [RFC8968] implementations use separate parameters to model the public parts (including the public key) and the private key.

MAC keys are allowed to be as short as zero-length. This is useful for testing. Network operators are RECOMMENDED to follow current best practices for key length and generation of keys related to the MAC algorithm associated with the key. Short (and zero-length) keys are highly susceptible to brute force attacks and therefore SHOULD NOT be used. See the Security Considerations section of [RFC8967] for additional considerations related to MAC keys. The fifth paragraph of [RFC8967] Security Considerations makes some specific key value recommendations that should be noted. It says that if it is necessary to derive keys from a human-readable passphrase, "only the derived keys should be communicated to the routers" and "the original passphrase itself should be kept on the host used to perform the key generation" (which would be the management system in the case of a remote management protocol). It also recommends that keys "should have a length of 32 octets (both for HMAC-SHA256 and BLAKE2s), and be chosen randomly".

This information model uses key sets and certification sets to provide a means of grouping keys and certificates. This makes it easy to use a different set per interface, the same set for one or more interfaces, have a default set in case a new interface is instantiated and to change keys and certificates as needed.

6. IANA Considerations

This document has no IANA actions.

7. Acknowledgements

Juliusz Chroboczek, Toke Hoeiland-Joergensen, David Schinazi, Antonin Decimo, Acee Lindem, and Carsten Bormann have been very helpful in refining this information model.

The language in the Notation section was mostly taken from [RFC8193].

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April 26, 2019

Delay-based Metric Extension for the Babel Routing Protocol
draft-ietf-babel-rtt-extension-00

Abstract

This document defines an extension to the Babel routing protocol that uses symmetric delay in metric computation and therefore makes it possible to prefer lower latency links to higher latency ones.

Status of This Memo

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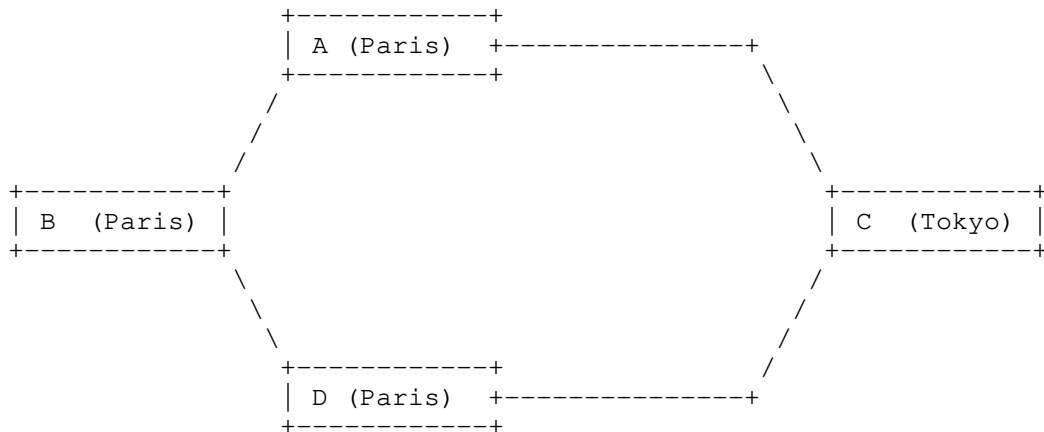
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1. Introduction

The Babel routing protocol [BABEL] does not mandate a specific algorithm for computing metrics; existing implementations use a packet-loss based metric on wireless links and a simple hop-count metric on all other types of links. While this strategy works reasonably well in many networks, it fails to select reasonable routes in some topologies involving tunnels or VPNs.

Consider for example the following topology, with three routers A, B and D located in Paris and a fourth router located in Tokyo, connected through tunnels in a diamond topology.



When routing traffic from A to D, it is obviously preferable to use the local route through B, as this is likely to provide better service quality and lower monetary cost than the distant route through C. However, the existing implementations of Babel consider both routes as having the same metric, and will therefore route the traffic through C in roughly half the cases.

In this document, we specify an extension to the Babel routing protocol that enables precise measurement of the round-trip time (RTT) of a link, and allows its usage in metric computation. Since this causes a negative feedback loop, special care is needed to ensure that the resulting network is reasonably stable (Section 2.3).

We believe that this protocol may be useful in other situations than the one described above, such as when running Babel in a congested wireless mesh network or over a complex link layer that performs its own routing; the high granularity of the timestamps used (1ms) should make it easier to experiment with RTT-based metrics on this kind of link layers.

2. Protocol operation

The protocol estimates the RTT to each neighbour (Section 2.1) which it then uses for metric computation (Section 2.2).

2.1. Delay estimation

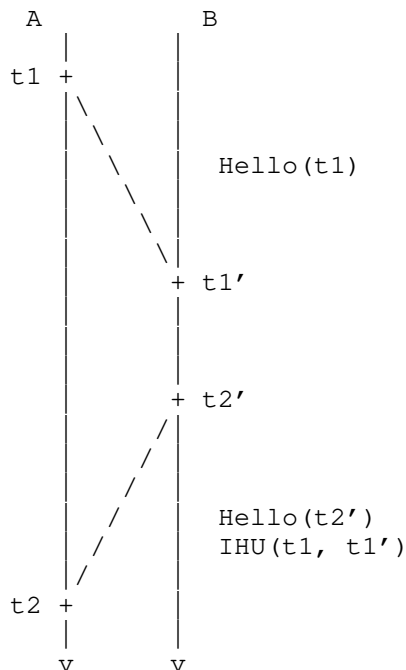
The RTT to a neighbour is estimated using an algorithm due to Mills [MILLS], originally developed for the HELLO routing protocol and later used in NTP [NTP].

A Babel speaker periodically sends a multicast Hello message over all of its interfaces (Section 3.4.1 of [BABEL]). This Hello is usually accompanied with a set of IHU messages, one per neighbour (Section 3.4.2 of [BABEL]).

In order to enable the computation of RTTs, a node A SHOULD include in every Hello that it sends a timestamp t_1 (according to A's clock). When a node B receives A's Hello, it records in its neighbour table the timestamp t_1 as well as the time t_1' according to its own (B's) clock at which it received the packet.

When B later sends an IHU to A, it SHOULD attach to the IHU the timestamps t_1 and t_1' which it has stored in its neighbour table. Additionally, it SHOULD ensure that the packet within which the IHU is sent contains a Hello TLV with an associated timestamp t_2' (according to B's clock). Symmetrically, A will record in its neighbour table the timestamp t_2' as well as the time t_2 (according

to A's clock) at which it has received the Hello. This is illustrated in the following sequence diagram:



A then estimates the RTT between A and B as $(t2 - t1) - (t2' - t1')$.

This algorithm has a number of desirable properties. First, since there is no requirement that $t1'$ and $t2'$ be equal, the protocol remains asynchronous -- the only change to Babel's message scheduling is the requirement that a packet containing an IHU also contains a Hello. Second, since only differences of timestamps according to a single clock are computed, it does not require synchronised clocks. Third, it requires very little additional state -- a node only needs to store the two timestamps associated with the last hello received from each neighbour. Finally, since it only requires piggybacking one or two timestamps on each Hello and IHU packet, it makes efficient use of network resources.

In principle, this algorithm is inaccurate in the presence of clock drift (i.e. when A's and B's clocks are running at different frequencies). However, $t2' - t1'$ is usually on the order of seconds, and significant clock drift is unlikely to happen at that time scale.

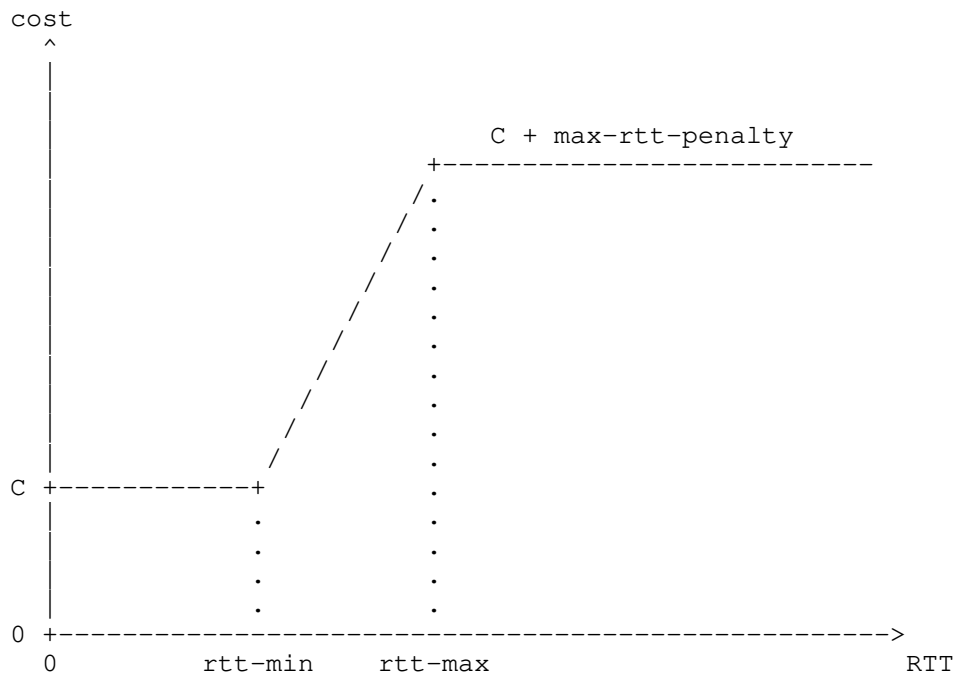
2.2. Metric computation

The algorithm described in the previous section allows computing an RTT to every neighbour. How to map this value to a link cost is a local implementation matter.

Obviously, the mapping should be monotonic (larger RTTs imply larger costs). In addition, in order to enhance stability (Section 2.3), the mapping should be bounded -- above a certain RTT, all links are equally bad.

2.2.1. Example metric computation

The current implementation of Babel uses the following function for mapping RTTs to link costs, parameterised by three parameters `rtt-min`, `rtt-max` and `max-rtt-penalty`:



For RTTs below `rtt-min`, the link cost is just the nominal cost of a single hop, `C`. Between `rtt-min` and `rtt-max`, the cost increases linearly; above `rtt-max`, the constant value `max-rtt-penalty` is added to the nominal cost.

2.3. Stability issues

Using delay as an input to the routing metric in congested networks gives rise to a negative feedback loop: low RTT encourages traffic, which in turn causes the RTT to increase. In a congested network, such a feedback loop can cause persistent oscillations.

The current implementation of Babel uses three techniques that collaborate to limit the frequency of oscillations:

- o the measured RTT is smoothed, which limits Babel's response to short-term RTT variations;
- o the mapping function is bounded, which avoids switching between congested routes;
- o a hysteresis algorithm is applied to the metric before route selection, which limits the worst-case frequency of route oscillations.

These techniques are discussed in more detail in [DELAY-BASED].

2.4. Backwards and forwards compatibility

This protocol extension stores the data that it requires within sub-TLVs of Babel's Hello and IHU TLVs. As discussed in Section 4 of [BABEL-EXT], implementations that do not understand this extension will silently ignore the sub-TLVs while parsing the rest of the TLVs that they contain. In effect, this extension supports building hybrid networks consisting of extended and unextended routers, and while such networks might suffer from sub-optimal routing, they will not suffer from blackholes or routing loops.

If a sub-TLV defined in this extension is longer than expected, the additional data is silently ignored. This provision is made in order to allow a future version of this document to extend the packet format with additional data.

3. Packet format

This extension defines the Timestamp sub-TLV [BABEL-EXT], whose Type field has value 3. This sub-TLV can be contained within a Hello sub-TLV, in which case it carries a single timestamp, or within an IHU sub-TLV, in which case it carries two timestamps.

Timestamps are encoded as 32-bit unsigned integers, expressed in units of one microsecond, counting from an arbitrary origin.

Timestamps wrap around every 4295 seconds, or slightly more than one hour.

3.1. Timestamp sub-TLV in Hello TLVs

When contained within a Hello TLV, the Timestamp sub-TLV has the following format:

```

0      1      2      3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Type = 3   |   Length   |   Transmit timestamp   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Fields :

Type Set to 3 to indicate a Timestamp sub-TLV.

Length	The length of the body, exclusive of the Type and Length fields.
--------	--

Transmit timestamp The time at which the packet containing this sub-TLV was sent, according to the sender's clock.

If the Length field is larger than the expected 4 octets, the sub-TLV MUST be processed normally and any extra data contained in this sub-TLV MUST be silently ignored.

3.2. Timestamp sub-TLV in IHU TLVs

When contained in an IHU TLV destined for node A, the Timestamp sub-TLV has the following format:

0										1										2										3									
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1								
Type = 3										Length										Origin timestamp																			
																				Receive timestamp																			

Fields :

Type Set to 3 to indicate a Timestamp sub-TLV.

Length The length of the body, exclusive of the Type and Length fields.

Origin timestamp A copy of the transmit timestamp of the last Timestamp sub-TLV contained in a Hello TLV received from node A.

Receive timestamp The time at which the last Hello with a Timestamp sub-TLV was received from node A according to the sender's clock.

If the Length field is larger than the expected 8 octets, the sub-TLV MUST be processed normally and any extra data contained in this sub-TLV MUST be silently ignored.

4. IANA Considerations

IANA is instructed to add the following entry to the "Babel Sub-TLV Types" registry:

Type	Name	Reference
3	Timestamp	(this document)

5. Security Considerations

This extension merely adds additional timestamping data to two of the TLVs sent by a Babel router, and does not significantly change the security properties of the Babel protocol.

6. References

6.1. Normative References

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Babel Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 23, 2020

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July 22, 2019

YANG Data Model for Babel
draft-ietf-babel-yang-model-02

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", "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
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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 2019-07-22 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. Definitions and Acronyms

1.3. 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 a 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 link-properties*        identityref
        +--ro sequence-number?        uint16
        +--ro metric-comp-algorithms* identityref
        +--ro security-supported*     identityref
        +--ro hmac-algorithms*        identityref
        +--ro dtls-cert-types*        identityref
        +--rw stats-enable?           boolean
        +--rw constants
          |
          | ...
        +--rw interfaces* [reference]
          |
          | ...
        +--rw hmac* [name]
          |
          | ...
        +--rw dtls* [name]
          |
          | ...
      augment /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route:
        +--ro routes* [prefix]
          +--ro prefix                inet:ip-prefix
          +--ro router-id?            binary
          +--ro neighbor?             leafref
          +--ro received-metric?      uint16
          +--ro calculated-metric?    uint16
          +--ro seqno?                uint16
          +--ro next-hop?             inet:ip-address
          +--ro feasible?             boolean
          +--ro selected?             boolean

```

The interfaces subtree describes attributes such as interface object that is being referenced, the type of link as enumerated by Babel Link Properties, 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 HMAC keys and DTLS certificates. The hmac subtree contains keys used with the

HMAC security mechanism. The boolean flag `babel-hmac-default-apply` indicates whether the set of HMAC keys is automatically applied to new interfaces. The `dtls` subtree contains certificates used with DTLS security mechanism. Similar to the HMAC mechanism, the boolean flag `babel-dtls-default-apply` indicates whether the set of DTLS certificates is automatically applied to new interfaces.

2.3. YANG Module

This module augments A YANG Data Model for Interface Management [RFC8343], YANG Routing Management [RFC8349], and imports definitions from Common YANG Data Types [RFC6991].

<CODE BEGINS> file "ietf-babel@2019-07-22.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.

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

revision 2019-07-22 {

description

"Initial version.";

reference

"RFC XXX: Babel YANG Data Model.";

}

/*

* Identities

*/

identity link-property {

description

"Base identity from which all Babel Link Types are derived.";

}

identity other {

base "link-property";

description

"No link property information available.";

}

identity tunnel {

base "link-property";

description

"A tunneled interface over unknown physical link.";

}

```
identity wired {
  base "link-property";
  description
    "A wired link with fixed physical properties.";
}

identity wireless {
  base "link-property";
  description
    "Wireless link type for Babel Routing Protocol.";
}

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

identity k-out-of-j {
  base "metric-comp-algorithms";
  description
    "k-out-of-j algorithm.";
}

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

/*
 * Babel security type identities
 */
identity security-supported {
  description
    "Base identity from which all Babel security types are
    derived.";
}

identity hmac {
  base security-supported;
  description
    "HMAC supported.";
}

identity dtls {
  base security-supported;
  description
    "Datagram Transport Layer Security (DTLS) supported.";
  reference
```

```
    "RFC 6347, Datagram Transport Layer Security Version 1.2.";
}

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

identity hmac-sha256 {
    base hmac-algorithms;
    description
        "HMAC-SHA256 algorithm supported.";
}

identity blake2s {
    base hmac-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 {
    base dtls-cert-types;
    description
        "X.509 certificate type.";
}

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

/*
 * Babel routing protocol identity.
```



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

/*
 * Features
 */

/*
 * Features supported
 */

/*
 * Typedefs
 */

/*
 * 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 babel-neighbors 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 a 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. Either babel-route-calculated-metric
        or babel-route-received-metric MUST be provided.";
    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. Either
        babel-route-calculated-metric or
        babel-route-received-metric MUST be provided.";
    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 augmentation.";
}

/*
 * 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 features such as VRF.";
reference
  "YANG Routing Management, RFC 8349, Lhotka & Lindem, March
  2018.";

container babel {
  presence "A Babel container.";

  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;
    mandatory "true";
    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,
      rfc6126bis, The Babel Routing Protocol. Section 3.";
  }
}
```

```
leaf-list link-properties {
  type identityref {
    base link-property;
  }
  config false;
  min-elements 1;
  description
    "Lists the collections of link properties supported by this
    instance of Babel. Valid enumeration values are defined
    in the Babel Link Properties registry.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}

leaf sequence-number {
  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-list metric-comp-algorithms {
  type identityref {
    base "metric-comp-algorithms";
  }
  config false;
  min-elements 1;
  description
    "List of cost compute algorithms supported by this
    implementation of Babel.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}

leaf-list security-supported {
  type identityref {
    base "security-supported";
  }
  config false;
  min-elements 1;
  description
    "Babel security mechanism used by this implementation or
    per interface.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}
```

```
}

leaf-list hmac-algorithms {
  type identityref {
    base hmac-algorithms;
  }
  config false;
  description
    "List of supported HMAC computation algorithms. Possible
    values include 'HMAC-SHA256', 'BLAKE2s'.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}

leaf-list dtls-cert-types {
  type identityref {
    base dtls-cert-types;
  }
  config false;
  description
    "List of supported DTLS certificate types. Possible values
    include 'X.509' and 'RawPublicKey'.";
  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, including
    neighbor-specific statistics (babel-nbr-stats).";
}

container constants {
  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 "ff02:0:0:0:0:0:1:6";
  }
}
```

```
    description
      "Multicast group for sending and receiving multicast
       announcements on IPv6.";
    reference
      "RFC ZZZZ, Babel Information Model, Section 3.2.";
  }
  description
    "Babel Constants object.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}

list interfaces {
  key "reference";

  leaf reference {
    type if:interface-ref;
    description
      "Reference to an interface object as defined by the data
       model (e.g., YANG, BBF TR-181); data model is assumed to
       allow for referencing of interface objects which may be at
       any layer (physical, Ethernet MAC, IP, tunneled IP, etc.).
       Referencing syntax will be specific to the data model. If
       there is no set of interface objects available, this should
       be a string that indicates the interface name used by the
       underlying operating system.";
    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 link-properties {
    type identityref {
      base link-property;
    }
    default "wired";
    description
      "Indicates the properties of the link. The value MUST be
```

```
        one of those listed in the babel-supported-link-
        properties parameter. Valid enumeration values are
        identity-refs derived from properties identified in
        Babel Link Properties registry.";
    reference
        "RFC ZZZZ, Babel Information Model, Section 3.3.";
}

leaf metric-algorithm {
    type identityref {
        base metric-comp-algorithms;
    }
    default "k-out-of-j";
    description
        "Indicates the metric computation algorithm used on this
        interface. The value MUST be one of those listed in the
        babel-information-obj babel-metric-comp-algorithms
        parameter.";
}

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;
    config false;
    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;
    config false;
    description
        "The current update interval in use for this interface.
        Units are centiseconds.";
    reference
```



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

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

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

leaf hmac-algorithm {
  type identityref {
    base hmac-algorithms;
  }
  description
    "The name of the HMAC algorithm used on this interface.
    The value is one of the identities listed as part of
    babel-hmac-algorithms at a global level.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.3.";
}

leaf hmac-verify {
  type boolean;
  description
    "A Boolean flag indicating whether HMAC 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 HMAC 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 babel-dtls-cert-sets entries
    that apply to this interface. When an interface instance
    is created, all babel-dtls instances with
    babel-dtls-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 the
    babel-dtls-cert-types parameter. 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 babel-dtls-certs object of a referenced
    babel-dtls instance and that have a non-empty
    babel-cert-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
       babel-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;
    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 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 {
  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.";
    }
  }
}
description
  "Statistics collection object for this interface.";
reference
  "RFC ZZZZ, Babel Information Model, Section 3.3.";
}

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

  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 babel-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 babel-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 indicates 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 0.";
    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 0.";
  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.";
}

container stats {
    config false;
    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-hello {
        type yt:counter32;
        description
            "A count of the number of Hello packets received from
            this neighbor.";
        reference
            "RFC ZZZZ, Babel Information Model, Section 3.6.";
    }
}
```

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

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

action reset {
  input {
    leaf reset-at {
      type yt:date-and-time;
      description
        "The time the reset was issued.";
    }
  }
  output {
    leaf reset-finished-at {
      type yt:date-and-time;
      description
        "The time when the reset operation finished.";
    }
  }
  description
    "Statistics collection object for this neighbor.";
  reference
    "RFC ZZZZ, Babel Information Model, Section 3.6.";
}

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

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



```
}

list hmac {
  key "name";

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

  leaf default-apply {
    type boolean;
    description
      "A Boolean flag indicating whether this babel-hmac
      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 babel-interface-hmac-keys list.
      If 'false', this instance is not applied to new
      babel-interfaces instances when they are created.";
    reference
      "RFC ZZZZ, Babel Information Model, Section 3.8.";
  }
}

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

  leaf name {
    type string;
    mandatory "true";
    description
      "A unique name for this HMAC 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 3.9.";
  }

  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 3.9.";
}

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 HMAC is computed from this key for
        comparing an incoming packet.";
    reference
        "RFC ZZZZ, Babel Information Model, Section 3.9.";
}

leaf value {
    type binary;
    mandatory "true";
    description
        "The value of the HMAC 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.";
    reference
        "RFC ZZZZ, Babel Information Model, Section 3.9.";
}

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
```

```
        "An operation that allows the HMAC 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
        babel-hmac-key-value and the babel-hmac-algorithm.
        The output of this operation is the resulting hash,
        as a binary string.";
    reference
        "RFC ZZZZ, Babel Information Model, Section 3.9.";
    }
}
description
    "A set of babel-hmac-keys-obj objects.";
reference
    "RFC ZZZZ, Babel Information Model, Section 3.8.";
}
description
    "A babel-hmac-obj object. If this object is implemented, it
    provides access to parameters related to the HMAC security
    mechanism.";
reference
    "RFC ZZZZ, Babel Information Model, Section 3.1.";
}

list dtls {
    key "name";

    leaf name {
        type string;
        description
            "TODO: This attribute does not exist in the model, but is
            needed for this model to work.";
    }

    leaf default-apply {
        type boolean;
        mandatory "true";
        description
            "A Boolean flag indicating whether this babel-dtls
            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 babel-interface-dtls-certs list. If 'false',
            this instance is not applied to new babel-interfaces
            instances when they are created.";
        reference
    }
}
```

```
    "RFC ZZZZ, Babel Information Model, Section 3.10.";
}

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

  leaf name {
    type string;
    description
      "A unique name that identifies the cert in the list.";
  }

  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 3.11.";
  }

  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 babel-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 3.11.";
  }

  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 3.11.";
}

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.";
        }
    }
}
description
    "A set of babel-dtls-keys-obj objects. This contains
    both certificates for this implementation to present
    for authentication, and to accept from others.
    Certificates with a non-empty babel-cert-private-key
    can be presented by this implementation for
    authentication.";
reference
    "RFC ZZZZ, Babel Information Model, Section 3.10.";
}
description
    "A babel-dtls-obj object. If this object is implemented,
    it provides access to parameters related to the DTLS
    security mechanism.";
reference
    "RFC ZZZZ, Babel Information Model, Section 3.1";
}
description
    "Babel Information Objects.";
```

```
        reference
          "RFC ZZZZ, Babel Information Model, Section 3.";
      }
    }
  augment "/rt:routing/rt:ribs/rt:rib/rt:routes/rt:route" {
    when "derived-from(rt:source-protocol, 'babel')" {
      description
        "Augmentation is valid for a routes whose source protocol
        is Babel.";
    }
    description
      "Babel specific route attributes.";
    uses routes;
  }
}
```

<CODE ENDS>

2.4. Example

The following snippet demonstrates how this data module can be configured. In this example, the routing protocol being configured is Babel, and statistics gathering is enabled.

```
<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <routing
    xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
    <control-plane-protocols>
      <control-plane-protocol>
        <type
          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>
        </babel>
      </control-plane-protocol>
    </control-plane-protocols>
  </routing>
</config>
```

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:

5. Acknowledgements

6. References

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Appendix A. An Appendix

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Babel Working Group
Internet-Draft
Intended status: Standards Track
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22 September 2021

YANG Data Model for Babel
draft-ietf-babel-yang-model-13

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 [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.

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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
            "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.";
    }
}

}

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 9046: 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 object
            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 the interface. If 'false',
        this instance is not applied to new interface
        instances when they are created.";
    reference
        "RFC 9046: Babel Information Model, Section 3.9.";
}

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 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.";
  }

  leaf private-key {
    nacm:default-deny-all;
    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.";
    reference
      "RFC 9046: Babel Information Model, Section 3.10.";
  }

  leaf algorithm {
    nacm:default-deny-write;
    type identityref {
      base ct:private-key-format;
    }
    mandatory true;
    description
      "Identifies the algorithm identity with which the
       private-key has been encoded. This value can only be
       provided when this instance is created, and is not
       subsequently writable.";
  }
}
}
uses routes;
}
}
}
<CODE ENDS>
```

3. IANA Considerations

This document registers a URI and a YANG module.

3.1. URI Registrations

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

3.2. YANG Module Name Registration

This document registers a 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.

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.

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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>
    <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>
```

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