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Authors: A. Lindem Y. Qu  
*LabN Consulting, L.L.C. Futurewei Technologies*

# RFC 9403

## A YANG Data Model for RIB Extensions

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### Abstract

A Routing Information Base (RIB) is a list of routes and their corresponding administrative data and operational state.

RFC 8349 defines the basic building blocks for the RIB data model, and this model augments it to support multiple next hops (aka paths) for each route as well as additional attributes.

### Status of This Memo

This is an Internet Standards Track document.

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## Table of Contents

1. Introduction	2
2. Terminology and Notation	3
2.1. Tree Diagrams	3
2.2. Prefixes in Data Node Names	3
3. Design of the Model	4
3.1. Tags and Preferences	4
3.2. Repair Path	5
4. RIB Model Tree	6
5. RIB Extension YANG Module	6
6. Security Considerations	12
7. IANA Considerations	13
8. References	14
8.1. Normative References	14
8.2. Informative References	15
Appendix A. Combined Tree Diagram	15
Appendix B. ietf-rib-extension.yang example	18
Acknowledgments	22
Authors' Addresses	22

## 1. Introduction

This document defines a YANG data model [RFC7950] that extends the RIB data model defined in the ietf-routing YANG module [RFC8349] with more route attributes.

A RIB is a collection of routes with attributes controlled and manipulated by control plane protocols. Each RIB contains only routes of one address family [RFC8349]. Within a protocol, routes are selected based on the metrics in use by that protocol, and the protocol installs the routes to the RIB. The RIB selects the preferred or active route by comparing the route preference (aka administrative distance) of the candidate routes installed by different protocols.

The module defined in this document extends the RIB to support more route attributes, such as multiple next hops, route metrics, and administrative tags.

The YANG modules defined and discussed in this document conform to the Network Management Datastore Architecture (NMDA) [[RFC8342](#)].

## 2. Terminology and Notation

The following terms are defined in [[RFC8342](#)]:

- configuration
- system state
- operational state

The following terms are defined in [[RFC7950](#)]:

- action
- augment
- container
- container with presence
- data model
- data node
- leaf
- list
- mandatory node
- module
- schema tree

The following term is defined in [[RFC8349](#)], [Section 5.2](#):

- RIB

### 2.1. Tree Diagrams

Tree diagrams used in this document follow the notation defined in [[RFC8340](#)].

### 2.2. Prefixes in Data Node Names

In this document, names of data nodes, actions, and other data model objects are often used without a prefix, as long as it is clear from the context in which YANG module each name is defined. Otherwise, names are prefixed using the standard prefix associated with the corresponding YANG module, as shown in [Table 1](#).

---

Prefix	YANG Module	Reference
if	ietf-interfaces	[RFC8343]
rt	ietf-routing	[RFC8349]
v4ur	ietf-ipv4-unicast-routing	[RFC8349]
v6ur	ietf-ipv6-unicast-routing	[RFC8349]
inet	ietf-inet-types	[RFC6991]
ospf	ietf-ospf	[RFC9129]
isis	ietf-isis	[RFC9130]

Table 1: Prefixes and Corresponding YANG Modules

### 3. Design of the Model

The YANG module defined in this document augments the `ietf-routing`, `ietf-ipv4-unicast-routing`, and `ietf-ipv6-unicast-routing` YANG modules defined in [RFC8349], which provide a basis for routing system data model development. Together with the `ietf-routing` YANG module and other YANG modules defined in [RFC8349], a generic RIB YANG data model is defined herein to implement and monitor a RIB.

The modules in [RFC8349] also define the basic configuration and operational state for both IPv4 and IPv6 static routes. This document provides augmentations for static routes to support multiple next hops and more next-hop attributes.

#### 3.1. Tags and Preferences

Individual route tags are supported at both the route and next-hop level. A preference per next hop is also supported for selection of the most preferred reachable static route.

The following tree snapshot shows tag and preference entries that augment static IPv4 unicast route and IPv6 unicast route next hops.

```

augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/rt:static-routes/v4ur:ipv4
  /v4ur:route/v4ur:next-hop/v4ur:next-hop-options
  /v4ur:simple-next-hop:
  +--rw preference?   uint32
  +--rw tag?          uint32
augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/rt:static-routes/v4ur:ipv4
  /v4ur:route/v4ur:next-hop/v4ur:next-hop-options
  /v4ur:next-hop-list/v4ur:next-hop-list/v4ur:next-hop:
  +--rw preference?   uint32
  +--rw tag?          uint32
augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/rt:static-routes/v6ur:ipv6
  /v6ur:route/v6ur:next-hop/v6ur:next-hop-options
  /v6ur:simple-next-hop:
  +--rw preference?   uint32
  +--rw tag?          uint32
augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/rt:static-routes/v6ur:ipv6
  /v6ur:route/v6ur:next-hop/v6ur:next-hop-options
  /v6ur:next-hop-list/v6ur:next-hop-list/v6ur:next-hop:
  +--rw preference?   uint32
  +--rw tag?          uint32
augment /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route:
  +--ro metric?       uint32
  +--ro tag*          uint32
  +--ro application-tag? uint32

```

### 3.2. Repair Path

The IP Fast Reroute (IPFRR) calculation by routing protocol precomputes repair paths [RFC5714], and the repair paths are installed in the RIB.

Each route next hop in the RIB is augmented with a repair path and is shown in the following tree snapshot.

```

augment /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route
  /rt:next-hop/rt:next-hop-options/rt:simple-next-hop:
  +--ro repair-path
  +--ro outgoing-interface? if:interface-state-ref
  +--ro next-hop-address?   inet:ip-address-no-zone
  +--ro metric?             uint32
augment /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route
  /rt:next-hop/rt:next-hop-options/rt:next-hop-list
  /rt:next-hop-list/rt:next-hop:
  +--ro repair-path
  +--ro outgoing-interface? if:interface-state-ref
  +--ro next-hop-address?   inet:ip-address-no-zone
  +--ro metric?             uint32

```

## 4. RIB Model Tree

The ietf-routing.yang tree with the augmentations herein is included in [Appendix A](#). The meanings of the symbols can be found in [\[RFC8340\]](#).

## 5. RIB Extension YANG Module

This YANG module references [\[RFC6991\]](#), [\[RFC8343\]](#), [\[RFC8349\]](#), [\[RFC9129\]](#), [\[RFC9130\]](#), and [\[RFC5714\]](#).

```
<CODE BEGINS> file "ietf-rib-extension@2023-11-01.yang"

module ietf-rib-extension {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-rib-extension";
  prefix rib-ext;

  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: A YANG Data Model for Routing
        Management (NMDA Version)";
  }
  import ietf-ipv4-unicast-routing {
    prefix v4ur;
    reference
      "RFC 8349: A YANG Data Model for Routing
        Management (NMDA Version)";
  }
  import ietf-ipv6-unicast-routing {
    prefix v6ur;
    reference
      "RFC 8349: A YANG Data Model for Routing
        Management (NMDA Version)";
  }

  import ietf-ospf {
    prefix ospf;
    reference "RFC 9129: YANG Data Model for the OSPF Protocol";
  }

  import ietf-isis {
```

```
    prefix isis;
    reference "RFC 9130: YANG Data Model for the IS-IS Protocol";
  }

organization
  "IETF RTGWG (Routing Area Working Group)";
contact
  "WG Web: <https://datatracker.ietf.org/wg/rtwgw/>
  WG List: <mailto:rtwgw@ietf.org>

  Author: Acee Lindem
  <mailto:acee.ietf@gmail.com>
  Author: Yingzhen Qu
  <mailto:yingzhen.qu@futurewei.com>";
description
  "This YANG module extends the RIB defined in the ietf-routing
  YANG module with additional route attributes.

  This YANG module conforms to the Network Management
  Datastore Architecture (NMDA) as described in RFC 8342.

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```

```
        "Total number of active routes in the RIB. An active
        route is the route that is preferred over other routes
        to the same destination prefix.";
    }
    leaf total-route-memory {
        type uint64;
        units "bytes";
        description
            "Total memory for all routes in the RIB.";
    }
    list protocol-statistics {
        description
            "RIB statistics for routing protocols installing
            routes in the RIB.";
        leaf protocol {
            type identityref {
                base rt:routing-protocol;
            }
            description
                "Routing protocol installing routes in the RIB.";
        }
        leaf routes {
            type uint32;
            description
                "Total number of routes in the RIB for the routing
                protocol identified by the 'protocol' entry.";
        }
        leaf active-routes {
            type uint32;
            description
                "Total number of active routes in the RIB for the
                routing protocol identified by the 'protocol' entry.
                An active route is preferred over other routes to the
                same destination prefix.";
        }
        leaf route-memory {
            type uint64;
            units "bytes";
            description
                "Total memory for all routes in the RIB for the
                routing protocol identified by the 'protocol'
                entry.";
        }
    }
}

grouping repair-path {
    description
        "Grouping for the IP Fast Reroute (IPFRR) repair path.";
    container repair-path {
        description
            "IPFRR next-hop repair path.";
        leaf outgoing-interface {
            type if:interface-state-ref;
            description
                "Name of the outgoing interface.";
        }
    }
}
```



```
leaf next-hop-address {
  type inet:ip-address-no-zone;
  description
    "IP address of the next hop.";
}
leaf metric {
  type uint32;
  description
    "The metric for the repair path. While the reroute
    repair is local and the metric is not advertised
    externally, the metric for the repair path is useful
    for troubleshooting purposes.";
}
reference
  "RFC 5714: IP Fast Reroute Framework";
}
}

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/rt:static-routes/v4ur:ipv4/"
+ "v4ur:route/v4ur:next-hop/v4ur:next-hop-options/"
+ "v4ur:simple-next-hop" {
  description
    "Augment 'simple-next-hop' case in IPv4 unicast route.";
  leaf preference {
    type uint32;
    default "1";
    description
      "The preference is used to select among multiple static
      routes. Routes with a lower next-hop preference value
      are preferred, and equal-preference routes result in
      Equal-Cost Multipath (ECMP) static routes.";
  }
  leaf tag {
    type uint32;
    default "0";
    description
      "The tag is a 32-bit opaque value associated with the
      route that can be used for policy decisions such as
      advertisement and filtering of the route.";
  }
}

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/rt:static-routes/v4ur:ipv4/"
+ "v4ur:route/v4ur:next-hop/v4ur:next-hop-options/"
+ "v4ur:next-hop-list/v4ur:next-hop-list/v4ur:next-hop" {
  description
    "Augment static route configuration 'next-hop-list'.";
  leaf preference {
    type uint32;
    default "1";
    description
      "The preference is used to select among multiple static
      routes. Routes with a lower next-hop preference value
      are preferred, and equal-preference routes result in
      ECMP static routes.";
  }
}
```

```
leaf tag {
  type uint32;
  default "0";
  description
    "The tag is a 32-bit opaque value associated with the
    route that can be used for policy decisions such as
    advertisement and filtering of the route.";
}
}

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/rt:static-routes/v6ur:ipv6/"
+ "v6ur:route/v6ur:next-hop/v6ur:next-hop-options/"
+ "v6ur:simple-next-hop" {
  description
    "Augment 'simple-next-hop' case in IPv6 unicast route.";
  leaf preference {
    type uint32;
    default "1";
    description
      "The preference is used to select among multiple static
      routes. Routes with a lower next-hop preference value
      are preferred, and equal-preference routes result in
      ECMP static routes.";
  }
  leaf tag {
    type uint32;
    default "0";
    description
      "The tag is a 32-bit opaque value associated with the
      route that can be used for policy decisions such as
      advertisement and filtering of the route.";
  }
}

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/rt:static-routes/v6ur:ipv6/"
+ "v6ur:route/v6ur:next-hop/v6ur:next-hop-options/"
+ "v6ur:next-hop-list/v6ur:next-hop-list/v6ur:next-hop" {
  description
    "Augment static route configuration 'next-hop-list'.";
  leaf preference {
    type uint32;
    default "1";
    description
      "The preference is used to select among multiple static
      routes. Routes with a lower next-hop preference value
      are preferred, and equal-preference routes result in
      ECMP static routes.";
  }
  leaf tag {
    type uint32;
    default "0";
    description
      "The tag is a 32-bit opaque value associated with the
      route that can be used for policy decisions such as
      advertisement and filtering of the route.";
  }
}
```

```
}

augment "/rt:routing/rt:ribs/rt:rib" {
  description
    "Augment a RIB with statistics.";
  uses rib-statistics;
}

augment "/rt:routing/rt:ribs/rt:rib/"
  + "rt:routes/rt:route" {
  description
    "Augment a route in the RIB with common attributes.";
  leaf metric {
    when "not(derived-from("
      + "../rt:source-protocol, 'ospf:ospf')) "
      + "and not(derived-from("
      + "../rt:source-protocol, 'isis:isis'))" {
    description
      "This augmentation is only valid for routes that don't
      have OSPF or IS-IS as the source protocol. The YANG
      data models for OSPF and IS-IS already include a
      'metric' augmentation for routes.";
    }
    type uint32;
    description
      "The metric is a numeric value indicating the cost
      of the route from the perspective of the routing
      protocol installing the route. In general, routes with
      a lower metric installed by the same routing protocol
      are lower cost to reach and are preferable to routes
      with a higher metric. However, metrics from different
      routing protocols are not comparable.";
  }
  leaf-list tag {
    when "not(derived-from("
      + "../rt:source-protocol, 'ospf:ospf')) "
      + "and not(derived-from("
      + "../rt:source-protocol, 'isis:isis'))" {
    description
      "This augmentation is only valid for routes that don't
      have OSPF or IS-IS as the source protocol. The YANG
      data models for OSPF and IS-IS already include a 'tag'
      augmentation for routes.";
    }
    type uint32;
    description
      "A tag is a 32-bit opaque value associated with the
      route that can be used for policy decisions such as
      advertisement and filtering of the route.";
  }
  leaf application-tag {
    type uint32;
    description
      "The application-specific tag is an additional tag that
      can be used by applications that require semantics and/or
      policy different from that of the tag. For example,
      the tag is usually automatically advertised in OSPF
      AS-External Link State Advertisements (LSAs) while this
```

```
        application-specific tag is not advertised implicitly.";
    }
}

augment "/rt:routing/rt:ribs/rt:rib/"
  + "rt:routes/rt:route/rt:next-hop/rt:next-hop-options/"
  + "rt:simple-next-hop" {
  description
    "Augment 'simple-next-hop' with 'repair-path'.";
  uses repair-path;
}

augment "/rt:routing/rt:ribs/rt:rib/"
  + "rt:routes/rt:route/rt:next-hop/rt:next-hop-options/"
  + "rt:next-hop-list/rt:next-hop-list/rt:next-hop" {
  description
    "Augment the next hop with a repair path.";
  uses repair-path;
}
}

<CODE ENDS>
```

## 6. Security Considerations

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

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in the `ietf-rib-extension.yang` module that are writable/creatable/deletable (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:

- `/v4ur:next-hop-options/v4ur:simple-next-hop/rib-ext:preference`
- `/v4ur:next-hop-options/v4ur:simple-next-hop/rib-ext:tag`
- `/v4ur:next-hop-options/v4ur:next-hop-list/v4ur:next-hop-list /v4ur:next-hop/rib-ext:preference`
- `/v4ur:next-hop-options/v4ur:next-hop-list/v4ur:next-hop-list /v4ur:next-hop/rib-ext:tag`
- `/v6ur:next-hop-options/v6ur:simple-next-hop/rib-ext:preference`
- `/v6ur:next-hop-options/v6ur:simple-next-hop/rib-ext:tag`

- /v6ur:next-hop-options/v6ur:next-hop-list/v6ur:next-hop-list /v6ur:next-hop/rib-ext:preference
- /v6ur:next-hop-options/v6ur:next-hop-list/v6ur:next-hop-list /v6ur:next-hop/rib-ext:tag

For these augmentations to ietf-routing.yang, the ability to delete, add, and modify IPv4 and IPv6 static route preferences and tags would allow traffic to be misrouted.

Some of the readable data nodes in the ietf-rib-extension.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:

- /rt:routing/rt:ribs/rt:rib/rib-ext:statistics
- /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route/rib-ext:metric
- /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route/rib-ext:tag
- /rt:routing/rt:ribs/rt:rib/rt:routes/rt:route/rib-ext:application-tag
- /rt:route/rt:next-hop/rt:next-hop-options/rt:simple-next-hop/rib-ext:repair-path
- /rt:routes/rt:route/rt:next-hop/rt:next-hop-options/rt:next-hop-list/rt:next-hop-list/rt:next-hop/rib-ext:repair-path

Exposing the RIB will expose the routing topology of the network. This may be undesirable due to the fact that such exposure may facilitate other attacks. Additionally, network operators may consider their topologies to be sensitive confidential data.

All the security considerations for writable and readable data nodes defined in [\[RFC8349\]](#) apply to the augmentations described herein.

## 7. IANA Considerations

This document registers the following URI in the "IETF XML Registry" [\[RFC3688\]](#).

URI: urn:ietf:params:xml:ns:yang:ietf-rib-extension

Registrant Contact: The IESG.

XML: N/A; the requested URI is an XML namespace.

IANA has registered the following YANG module in the "YANG Module Names" registry [\[RFC6020\]](#).

Name: ietf-rib-extension

Namespace: urn:ietf:params:xml:ns:yang:ietf-rib-extension

Prefix: rib-ext

Reference: RFC 9403

## 8. References

### 8.1. Normative References

- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/info/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.
- [RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <<https://www.rfc-editor.org/info/rfc6991>>.
- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.
- [RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <<https://www.rfc-editor.org/info/rfc8341>>.
- [RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <<https://www.rfc-editor.org/info/rfc8342>>.
- [RFC8343] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 8343, DOI 10.17487/RFC8343, March 2018, <<https://www.rfc-editor.org/info/rfc8343>>.
- [RFC8349] Lhotka, L., Lindem, A., and Y. Qu, "A YANG Data Model for Routing Management (NMDA Version)", RFC 8349, DOI 10.17487/RFC8349, March 2018, <<https://www.rfc-editor.org/info/rfc8349>>.
- [RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/info/rfc8446>>.
- [RFC9129] Yeung, D., Qu, Y., Zhang, Z., Chen, I., and A. Lindem, "YANG Data Model for the OSPF Protocol", RFC 9129, DOI 10.17487/RFC9129, October 2022, <<https://www.rfc-editor.org/info/rfc9129>>.

- [RFC9130] Litkowski, S., Ed., Yeung, D., Lindem, A., Zhang, J., and L. Lhotka, "YANG Data Model for the IS-IS Protocol", RFC 9130, DOI 10.17487/RFC9130, October 2022, <<https://www.rfc-editor.org/info/rfc9130>>.
- [W3C.REC-xml-20081126] Bray, T., Paoli, J., Sperberg-McQueen, M., Maler, E., and F. Yergeau, "Extensible Markup Language (XML) 1.0 (Fifth Edition)", World Wide Web Consortium Recommendation REC-xml-20081126, November 2008, <<https://www.w3.org/TR/2008/REC-xml-20081126>>.

## 8.2. Informative References

- [RFC5714] Shand, M. and S. Bryant, "IP Fast Reroute Framework", RFC 5714, DOI 10.17487/RFC5714, January 2010, <<https://www.rfc-editor.org/info/rfc5714>>.
- [RFC7951] Lhotka, L., "JSON Encoding of Data Modeled with YANG", RFC 7951, DOI 10.17487/RFC7951, August 2016, <<https://www.rfc-editor.org/info/rfc7951>>.
- [RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/info/rfc8340>>.
- [RFC8792] Watsen, K., Auerswald, E., Farrel, A., and Q. Wu, "Handling Long Lines in Content of Internet-Drafts and RFCs", RFC 8792, DOI 10.17487/RFC8792, June 2020, <<https://www.rfc-editor.org/info/rfc8792>>.

## Appendix A. Combined Tree Diagram

This appendix provides the combined ietf-routing.yang, ietf-ipv4-unicast-routing.yang, ietf-ipv6-unicast-routing.yang, and ietf-rib-extension.yang tree diagram.

```

module: ietf-routing
  +--rw routing
  +--rw router-id?                yang:dotted-quad {router-id}?
  +--ro interfaces
  | +--ro interface* if:interface-ref
  +--rw control-plane-protocols
  | +--rw control-plane-protocol* [type name]
  | | +--rw type                identityref
  | | +--rw name                 string
  | | +--rw description?        string
  | | +--rw static-routes
  | | | +--rw v4ur:ipv4
  | | | | +--rw v4ur:route* [destination-prefix]
  | | | | | +--rw v4ur:destination-prefix  inet:ipv4-prefix
  | | | | | +--rw v4ur:description?       string
  | | | | | +--rw v4ur:next-hop
  | | | | | | +--rw (v4ur:next-hop-options)
  | | | | | | | +--:(v4ur:simple-next-hop)
  | | | | | | | | +--rw v4ur:outgoing-interface?
  | | | | | | | | | if:interface-ref
  | | | | | | | | +--rw v4ur:next-hop-address?
  | | | | | | | | | | inet:ipv4-address

```





```

|   |   |   |   |   if:interface-state-ref
|   |   |   |   |   +---ro rib-ext:next-hop-address?
|   |   |   |   |   |   inet:ip-address-no-zone
|   |   |   |   |   |   +---ro rib-ext:metric?                               uint32
+---:(special-next-hop)
|   |   |   |   |   |   +---ro special-next-hop?                               enumeration
+---:(next-hop-list)
|   |   |   |   |   |   +---ro next-hop-list
|   |   |   |   |   |   |   +---ro next-hop* []
|   |   |   |   |   |   |   |   +---ro outgoing-interface?
|   |   |   |   |   |   |   |   |   if:interface-ref
|   |   |   |   |   |   |   |   |   +---ro v4ur:address?
|   |   |   |   |   |   |   |   |   |   inet:ipv4-address
|   |   |   |   |   |   |   |   |   |   +---ro v6ur:address?
|   |   |   |   |   |   |   |   |   |   |   inet:ipv6-address
|   |   |   |   |   |   |   |   |   |   +---ro rib-ext:repair-path
|   |   |   |   |   |   |   |   |   |   |   +---ro rib-ext:outgoing-interface?
|   |   |   |   |   |   |   |   |   |   |   |   if:interface-state-ref
|   |   |   |   |   |   |   |   |   |   |   |   +---ro rib-ext:next-hop-address?
|   |   |   |   |   |   |   |   |   |   |   |   |   inet:ip-address-no-zone
|   |   |   |   |   |   |   |   |   |   |   |   |   +---ro rib-ext:metric?                               uint32
+---ro source-protocol                               identityref
+---ro active?                                       empty
+---ro last-updated?                                  yang:date-and-time
+---ro v4ur:destination-prefix?                       inet:ipv4-prefix
+---ro v6ur:destination-prefix?                       inet:ipv6-prefix
+---ro rib-ext:metric?                               uint32
+---ro rib-ext:tag*                                   uint32
+---ro rib-ext:application-tag?                       uint32
+---x active-route
+---w input
|   |   |   |   |   |   +---w v4ur:destination-address?   inet:ipv4-address
|   |   |   |   |   |   |   +---w v6ur:destination-address?   inet:ipv6-address
+---ro output
|   |   |   |   |   |   +---ro route
|   |   |   |   |   |   |   +---ro next-hop
|   |   |   |   |   |   |   |   +---ro (next-hop-options)
|   |   |   |   |   |   |   |   |   +---:(simple-next-hop)
|   |   |   |   |   |   |   |   |   |   +---ro outgoing-interface?
|   |   |   |   |   |   |   |   |   |   |   if:interface-ref
|   |   |   |   |   |   |   |   |   |   |   |   +---ro v4ur:next-hop-address?
|   |   |   |   |   |   |   |   |   |   |   |   |   inet:ipv4-address
|   |   |   |   |   |   |   |   |   |   |   |   |   +---ro v6ur:next-hop-address?
|   |   |   |   |   |   |   |   |   |   |   |   |   |   inet:ipv6-address
|   |   |   |   |   |   |   |   |   |   |   |   |   +---:(special-next-hop)
|   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro special-next-hop?                               enumeration
|   |   |   |   |   |   |   |   |   |   |   |   |   |   +---:(next-hop-list)
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro next-hop-list
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro next-hop* []
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro outgoing-interface?
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   if:interface-ref
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro v4ur:next-hop-address?
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   inet:ipv4-address
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   +---ro v6ur:next-hop-address?
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   inet:ipv6-address
+---ro source-protocol                               identityref
+---ro active?                                       empty
+---ro last-updated?                                  yang:date-and-time

```

```

|         +--ro v4ur:destination-prefix?  inet:ipv4-prefix
|         +--ro v6ur:destination-prefix?  inet:ipv6-prefix
+--rw description?                        string
+--ro rib-ext:statistics
  +--ro rib-ext:total-routes?              uint32
  +--ro rib-ext:total-active-routes?      uint32
  +--ro rib-ext:total-route-memory?       uint64
  +--ro rib-ext:protocol-statistics* []
    +--ro rib-ext:protocol?                identityref
    +--ro rib-ext:routes?                  uint32
    +--ro rib-ext:active-routes?          uint32
    +--ro rib-ext:route-memory?           uint64

```

## Appendix B. ietf-rib-extension.yang example

The following is an XML example [W3C.REC-xml-20081126] using the RIB extension module and RFC 8349.

Note: '\ ' line wrapping per [RFC8792].

```

<routing xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
  <control-plane-protocols>
    <control-plane-protocol>
      <type>static</type>
      <name>static-routing-protocol</name>
      <static-routes>
        <ipv4 xmlns="urn:ietf:params:xml:ns:yang:\
          ietf-ipv4-unicast-routing">
          <route>
            <destination-prefix>0.0.0.0/0</destination-prefix>
            <next-hop>
              <next-hop-address>192.0.2.2</next-hop-address>
              <preference xmlns="urn:ietf:params:xml:ns:yang:\
                ietf-rib-extension">30</preference>
              <tag xmlns="urn:ietf:params:xml:ns:yang:\
                ietf-rib-extension">99</tag>
            </next-hop>
          </route>
        </ipv4>
        <ipv6 xmlns="urn:ietf:params:xml:ns:yang:\
          ietf-ipv6-unicast-routing">
          <route>
            <destination-prefix>::/0</destination-prefix>
            <next-hop>
              <next-hop-address>2001:db8:aaaa::1111</next-hop-address>
              <preference xmlns="urn:ietf:params:xml:ns:yang:\
                ietf-rib-extension">30</preference>
              <tag xmlns="urn:ietf:params:xml:ns:yang:\
                ietf-rib-extension">66</tag>
            </next-hop>
          </route>
        </ipv6>
      </static-routes>
    </control-plane-protocol>

```

```

</control-plane-protocols>
<ribs>
  <rib>
    <name>ipv4-primary</name>
    <address-family xmlns:v4ur="urn:ietf:params:xml:ns:yang:\
      ietf-ipv4-unicast-routing">v4ur:ipv4-unicast</address-family>
    <default-rib>true</default-rib>
    <routes>
      <route>
        <destination-prefix xmlns="urn:ietf:params:xml:ns:yang:\
          ietf-ipv4-unicast-routing">0.0.0.0/0</destination-prefix>
        <next-hop>
          <next-hop-address xmlns="urn:ietf:params:xml:ns:yang:\
            ietf-ipv4-unicast-routing">192.0.2.2</next-hop-address>
          </next-hop>
        <route-preference>5</route-preference>
        <source-protocol>static</source-protocol>
        <last-updated>2015-10-24T18:02:45+02:00</last-updated>
      </route>
      <route>
        <destination-prefix xmlns="urn:ietf:params:xml:ns:yang:\
          ietf-ipv4-unicast-routing">198.51.100.0/24\
        </destination-prefix>
        <next-hop>
          <next-hop-address xmlns="urn:ietf:params:xml:ns:yang:\
            ietf-ipv4-unicast-routing">192.0.2.2</next-hop-address>
          <repair-path xmlns="urn:ietf:params:xml:ns:yang:\
            ietf-rib-extension">
            <next-hop-address>203.0.113.1</next-hop-address>
            <metric>200</metric>
          </repair-path>
          </next-hop>
        <route-preference>120</route-preference>
        <source-protocol xmlns:rip="urn:ietf:params:xml:ns:yang:\
          ietf-rip">rip:rip</source-protocol>
        <last-updated>2015-10-24T18:02:45+02:00</last-updated>
      </route>
    </routes>
  </rib>
  <rib>
    <name>ipv6-primary</name>
    <address-family xmlns:v6ur="urn:ietf:params:xml:ns:yang:\
      ietf-ipv6-unicast-routing">v6ur:ipv6-unicast</address-family>
    <default-rib>true</default-rib>
    <routes>
      <route>
        <destination-prefix xmlns="urn:ietf:params:xml:ns:yang:\
          ietf-ipv6-unicast-routing">0::/0</destination-prefix>
        <next-hop>
          <next-hop-address xmlns="urn:ietf:params:xml:ns:yang:\
            ietf-ipv6-unicast-routing">2001:db8:aaaa::1111\
          </next-hop-address>
          </next-hop>
        <route-preference>5</route-preference>
        <source-protocol>static</source-protocol>
        <last-updated>2015-10-24T18:02:45+02:00</last-updated>
      </route>
      <route>

```

```

<destination-prefix xmlns="urn:ietf:params:xml:ns:yang:\
  ietf-ipv6-unicast-routing">2001:db8:bbbb::/64\
</destination-prefix>
<next-hop>
  <next-hop-address xmlns="urn:ietf:params:xml:ns:yang:\
    ietf-ipv6-unicast-routing">2001:db8:aaaa::1111\
  </next-hop-address>
  <repair-path xmlns="urn:ietf:params:xml:ns:yang:\
    ietf-rib-extension">
    <next-hop-address>2001:db8:cccc::2222</next-hop-address>
    <metric>200</metric>
  </repair-path>
</next-hop>
<route-preference>120</route-preference>
<source-protocol xmlns:rip="urn:ietf:params:xml:ns:yang:\
  ietf-rip">rip:rip</source-protocol>
<last-updated>2015-10-24T18:02:45+02:00</last-updated>
</route>
</routes>
</rib>
</ribs>
</routing>

```

The following is the same example using JSON format [RFC7951].

```

{
  "ietf-routing:routing": {
    "control-plane-protocols": {
      "control-plane-protocol": [
        {
          "type": "static",
          "name": "static-routing-protocol",
          "static-routes": {
            "ietf-ipv4-unicast-routing:ipv4": {
              "route": [
                {
                  "destination-prefix": "0.0.0.0/0",
                  "next-hop": {
                    "next-hop-address": "192.0.2.2",
                    "ietf-rib-extension:preference": 30,
                    "ietf-rib-extension:tag": 99
                  }
                }
              ]
            },
            "ietf-ipv6-unicast-routing:ipv6": {
              "route": [
                {
                  "destination-prefix": "::/0",
                  "next-hop": {
                    "next-hop-address": "2001:db8:aaaa::1111",
                    "ietf-rib-extension:preference": 30,
                    "ietf-rib-extension:tag": 66
                  }
                }
              ]
            }
          }
        }
      ]
    }
  }
}

```

```

    }
  }
]
},
"ribs": {
  "rib": [
    {
      "name": "ipv4-primary",
      "address-family": "ietf-ipv4-unicast-routing:ipv4-unicast",
      "default-rib": true,
      "routes": {
        "route": [
          {
            "next-hop": {
              "ietf-ipv4-unicast-routing:next-hop-address": \
                "192.0.2.2"
            },
            "route-preference": 5,
            "source-protocol": "static",
            "last-updated": "2015-10-24T18:02:45+02:00",
            "ietf-ipv4-unicast-routing:destination-prefix": \
              "0.0.0.0/0"
          },
          {
            "next-hop": {
              "ietf-rib-extension:repair-path": {
                "next-hop-address": "203.0.113.1",
                "metric": 200
              },
              "ietf-ipv4-unicast-routing:next-hop-address": \
                "192.0.2.2"
            },
            "route-preference": 120,
            "source-protocol": "ietf-rip:rip",
            "last-updated": "2015-10-24T18:02:45+02:00",
            "ietf-ipv4-unicast-routing:destination-prefix": \
              "198.51.100.0/24"
          }
        ]
      }
    }
  ],
  {
    "name": "ipv6-primary",
    "address-family": "ietf-ipv6-unicast-routing:ipv6-unicast",
    "default-rib": true,
    "routes": {
      "route": [
        {
          "next-hop": {
            "ietf-ipv6-unicast-routing:next-hop-address": \
              "2001:db8:aaaa::1111"
          },
          "route-preference": 5,
          "source-protocol": "static",
          "last-updated": "2015-10-24T18:02:45+02:00",
          "ietf-ipv6-unicast-routing:destination-prefix": "::/0"
        }
      ]
    }
  }
}

```

```
    {
      "next-hop": {
        "ietf-rib-extension:repair-path": {
          "next-hop-address": "2001:db8:cccc::2222",
          "metric": 200
        },
        "ietf-ipv6-unicast-routing:next-hop-address": \
          "2001:db8:aaaa::1111"
      },
      "route-preference": 120,
      "source-protocol": "ietf-rip:rip",
      "last-updated": "2015-10-24T18:02:45+02:00",
      "ietf-ipv6-unicast-routing:destination-prefix": \
        "2001:db8:bbbb::/64"
    }
  ]
}
}
```

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## Authors' Addresses

### Acee Lindem

LabN Consulting, L.L.C.  
301 Midenhall Way  
Cary, NC 27513  
United States of America  
Email: [acee.ietf@gmail.com](mailto:acee.ietf@gmail.com)

### Yingzhen Qu

Futurewei Technologies  
2330 Central Expressway  
Santa Clara, CA 95050  
United States of America  
Email: [yingzhen.qu@futurewei.com](mailto:yingzhen.qu@futurewei.com)