

Internet Engineering Task Force (IETF)
Request for Comments: 9468
Category: Standards Track
ISSN: 2070-1721

E. Chen
Palo Alto Networks
N. Shen
Zededa
R. Raszuk
Arrcus
R. Rahman
Equinix
August 2023

Unsolicited Bidirectional Forwarding Detection (BFD) for Sessionless Applications

Abstract

For operational simplification of "sessionless" applications using Bidirectional Forwarding Detection (BFD), in this document, we present procedures for "unsolicited BFD" that allow a BFD session to be initiated by only one side and established without explicit per-session configuration or registration by the other side (subject to certain per-interface or global policies).

We also introduce a new YANG module to configure and manage "unsolicited BFD". The YANG module in this document is based on YANG 1.1, as defined in RFC 7950, and conforms to the Network Management Datastore Architecture (NMDA), as described in RFC 8342. This document augments RFC 9314.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc9468>.

Copyright Notice

Copyright (c) 2023 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the

in the Revised BSD License.

Table of Contents

- 1. Introduction
 - 1.1. Requirements Language
- 2. Procedures for Unsolicited BFD
- 3. State Variables
- 4. YANG Data Model
 - 4.1. Unsolicited BFD Hierarchy
 - 4.2. Unsolicited BFD Module
 - 4.3. Data Model Example
- 5. IANA Considerations
- 6. Security Considerations
 - 6.1. BFD Protocol Security Considerations
 - 6.2. BFD Protocol Authentication Considerations
 - 6.3. YANG Module Security Considerations
- 7. References
 - 7.1. Normative References
 - 7.2. Informative References
- Acknowledgments
- Authors' Addresses

1. Introduction

The current implementation and deployment practice for BFD ([RFC5880] and [RFC5881]) usually requires that BFD sessions be explicitly configured or registered on both sides. This requirement is not an issue when an application like BGP [RFC4271] has the concept of a "session" that involves both sides for its establishment. However, this requirement can be operationally challenging when the prerequisite "session" does not naturally exist between two endpoints in an application. Simultaneous configuration and coordination may be required on both sides for BFD to take effect. For example:

- * When BFD is used to keep track of the "liveness" of the next hop of static routes. Although only one side may need the BFD functionality, currently, both sides need to be involved in specific configuration and coordination, and in some cases, static routes are created unnecessarily just for BFD.
- * When BFD is used to keep track of the "liveness" of the third-party next hop of BGP routes received from the Route Server [RFC7947] at an Internet Exchange Point (IXP). As the third-party next hop is different from the peering address of the Route Server, for BFD to work, currently, two routers peering with the Route Server need to have routes and next hops from each other (although indirectly via the Route Server).

Clearly, it is beneficial and desirable to reduce or eliminate unnecessary configurations and coordination in these "sessionless" applications using BFD.

In this document, we present procedures for "unsolicited BFD" that allow a BFD session to be initiated by only one side and established without explicit per-session configuration or registration by the

other side (subject to certain per-interface or global policies).

Unsolicited BFD impacts only the initiation of BFD sessions. There is no change to all the other procedures specified in [RFC5880], such as, but not limited to, the Echo function and Demand mode.

With "unsolicited BFD", there is potential risk for excessive resource usage by BFD from "unexpected" remote systems. To mitigate such risks, several mechanisms are recommended in the Security Considerations section.

The procedure described in this document could be applied to BFD for multihop paths [RFC5883]. However, because of security risks, this document applies only to BFD for single IP hops [RFC5881].

Compared to the "Seamless BFD" [RFC7880], this proposal involves only minor procedural enhancements to the widely deployed BFD itself. Thus, we believe that this proposal is inherently simpler in the protocol itself and deployment. As an example, it does not require the exchange of BFD discriminators over an out-of-band channel before BFD session bring-up.

When BGP ADD-PATH [RFC7911] is deployed at an IXP using a Route Server, multiple BGP paths (when they exist) can be made available to the clients of the Route Server, as described in [RFC7947]. Unsolicited BFD can be used by BGP route selection's route resolvability condition (Section 9.1.2.1 of [RFC4271]) to exclude routes where the NEXT_HOP is not reachable using the procedures specified in this document.

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 BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Procedures for Unsolicited BFD

With "unsolicited BFD", one side takes the "Active role" and the other side takes the "Passive role", as described in [RFC5880], Section 6.1.

Passive unsolicited BFD support **MUST** be disabled by default and **MUST** require explicit configuration to be enabled. On the passive side, the following BFD parameters, from [RFC5880], Section 6.8.1, **SHOULD** be configurable:

- * bfd.DesiredMinTxInterval
- * bfd.RequiredMinRxInterval
- * bfd.DetectMult

The passive side **MAY** also choose to use the values of the parameters

listed above that the active side uses in its BFD Control packets. However, the `bfd.LocalDiscr` value **MUST** be selected by the passive side to allow multiple unsolicited BFD sessions.

The active side starts sending the BFD Control packets, as specified in [RFC5880]. The passive side does not send BFD Control packets initially; it sends BFD Control packets only after it has received BFD Control packets from the active side.

When the passive side receives a BFD Control packet from the active side with 0 as "Your Discriminator" and does not find an existing BFD session, the passive side **SHOULD** create a matching BFD session toward the active side, unless not permitted by local configuration or policy.

When the passive side receives an incoming BFD Control packet on a numbered interface, the source address of that packet **MUST** belong to the subnet of the interface on which the BFD packet is received, else the BFD Control packet **MUST NOT** be processed.

The passive side **MUST** then start sending BFD Control packets and perform the necessary procedure for bringing up, maintaining, and tearing down the BFD session. If the BFD session fails to get established within a certain amount of time (which is implementation specific but has to be at least equal to the local failure detection time) or if an established BFD session goes down, the passive side **MUST** stop sending BFD Control packets and **SHOULD** delete the BFD session created until BFD Control packets are initiated by the active side again.

When an unsolicited BFD session goes down, an implementation may retain the session state for a period of time. Retaining this state can be useful for operational purposes.

3. State Variables

This document defines a new state variable called `Role`:

`bfd.Role`

This is the role of the local system during BFD session initialization, as per [RFC5880], Section 6.1. Possible values are `Active` or `Passive`.

4. YANG Data Model

This section extends the YANG data model for BFD [RFC9314] to cover unsolicited BFD. The new module imports the YANG modules described in [RFC8349] since the "bfd" container in [RFC9314] is under "control-plane-protocol". The YANG module in this document conforms to the Network Management Datastore Architecture (NMDA) [RFC8342].

4.1. Unsolicited BFD Hierarchy

Configuration for unsolicited BFD parameters for IP single-hop sessions can be done at 2 levels:

- * globally, i.e., for all interfaces
- * for specific interfaces (this requires support for the "unsolicited-params-per-interface" feature)

If configuration exists at both levels, per-interface configuration takes precedence over global configuration.

For operational data, a new "role" leaf node has been added for BFD IP single-hop sessions.

The tree diagram below uses the graphical representation of data models, as defined in [RFC8340].

```

module: ietf-bfd-unsolicited

augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/bfd:bfd/bfd-ip-sh:ip-sh:
    +--rw unsolicited?
      +--rw local-multiplier?                multiplier
      +--rw (interval-config-type)?
        +--:(tx-rx-intervals)
          +--rw desired-min-tx-interval?    uint32
          +--rw required-min-rx-interval?   uint32
        +--:(single-interval) {single-minimum-interval}?
          +--rw min-interval?               uint32
augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/bfd:bfd/bfd-ip-sh:ip-sh
    /bfd-ip-sh:interfaces:
      +--rw unsolicited
        +--rw enabled?                      boolean
        +--rw local-multiplier?
          bfd-types:multiplier
          {bfd-unsol:unsolicited-params-per-interface}?
        +--rw (interval-config-type)?
          {bfd-unsol:unsolicited-params-per-interface}?
          +--:(tx-rx-intervals)
            +--rw desired-min-tx-interval?  uint32
            +--rw required-min-rx-interval?  uint32
          +--:(single-interval) {bfd-types:single-minimum-interval}?
            +--rw min-interval?              uint32
augment /rt:routing/rt:control-plane-protocols
  /rt:control-plane-protocol/bfd:bfd/bfd-ip-sh:ip-sh
    /bfd-ip-sh:sessions/bfd-ip-sh:session:
      +--ro role?    bfd-unsol:role

```

4.2. Unsolicited BFD Module

```

<CODE BEGINS> file "ietf-bfd-unsolicited@2023-08-31.yang"
module ietf-bfd-unsolicited {

  yang-version 1.1;

```

```

namespace "urn:ietf:params:xml:ns:yang:ietf-bfd-unsolicited";

prefix bfd-unsol;

import ietf-bfd-types {
    prefix bfd-types;
    reference
        "RFC 9314: YANG Data Model for Bidirectional Forwarding
        Detection (BFD)";
}

import ietf-bfd {
    prefix bfd;
    reference
        "RFC 9314: YANG Data Model for Bidirectional Forwarding
        Detection (BFD)";
}

import ietf-bfd-ip-sh {
    prefix bfd-ip-sh;
    reference
        "RFC 9314: YANG Data Model for Bidirectional Forwarding
        Detection (BFD)";
}

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

organization
    "IETF BFD Working Group";

contact
    "WG Web:    <https://datatracker.ietf.org/wg/bfd/>
    WG List:    <rtg-bfd@ietf.org>

    Editors:    Enke Chen (enchen@paloaltonetworks.com),
                Naiming Shen (naiming@zededa.com),
                Robert Raszuk (robert@raszuk.net),
                Reshad Rahman (reshad@yahoo.com);

description
    "This module contains the YANG definition for unsolicited BFD,
    as per RFC 9468.

    Copyright (c) 2023 IETF Trust and the persons
    identified as authors of the code. All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject
    to the license terms contained in, the Revised BSD License
    set forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
  
```

(<http://trustee.ietf.org/license-info>).

This version of this YANG module is part of RFC 9468; see the RFC itself for full legal notices.";

reference

"RFC 9468: Unsolicited Bidirectional Forwarding Detection (BFD) for Sessionless Applications";

revision 2023-08-31 {

description

"Initial revision.";

reference

"RFC 9468: Unsolicited Bidirectional Forwarding Detection (BFD) for Sessionless Applications";

}

/*

* Feature definitions

*/

feature unsolicited-params-per-interface {

description

"This feature indicates that the server supports per-interface parameters for unsolicited sessions.";

reference

"RFC 9468: Unsolicited Bidirectional Forwarding Detection (BFD) for Sessionless Applications";

}

/*

* Type Definitions

*/

identity role {

description

"Base identity from which all roles are derived.
Role of local system during BFD session initialization.";

}

identity active {

base bfd-unsol:role;

description

"Active role.";

reference

"RFC 5880: Bidirectional Forwarding Detection (BFD),
Section 6.1";

}

identity passive {

base bfd-unsol:role;

description

"Passive role.";

reference

"RFC 5880: Bidirectional Forwarding Detection (BFD),
Section 6.1";

}

```

/*
 * Augments
 */

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/bfd:bfd/bfd-ip-sh:ip-sh" {
  description
    "Augmentation for unsolicited BFD parameters.";
  container unsolicited {
    description
      "BFD IP single-hop unsolicited top-level container.";
    uses bfd-types:base-cfg-parms;
  }
}

augment "/rt:routing/rt:control-plane-protocols/"
+ "rt:control-plane-protocol/bfd:bfd/bfd-ip-sh:ip-sh/"
+ "bfd-ip-sh:interfaces" {
  description
    "Augmentation for unsolicited BFD on IP single-hop
    interface.";
  container unsolicited {
    description
      "BFD IP single-hop interface unsolicited top-level
      container.";
    leaf enabled {
      type boolean;
      default "false";
      description
        "Unsolicited BFD is enabled on this interface.";
    }
  }
  /*
   * The following is the same as bfd-types:base-cfg-parms, but
   * without default values (for inheritance)
   */
  leaf local-multiplier {
    if-feature "bfd-unsol:unsolicited-params-per-interface";
    type bfd-types:multiplier;
    description
      "Multiplier transmitted by the local system. Defaults to
      ../../unsolicited/local-multiplier.
      A multiplier configured under an interface takes
      precedence over the multiplier configured at the global
      level.";
  }
  choice interval-config-type {
    if-feature "bfd-unsol:unsolicited-params-per-interface";
    description
      "Two interval values or one value used for both transmit
      and receive. Defaults to
      ../../unsolicited/interval-config-type. An interval
      configured under an interface takes precedence over any
      interval configured at the global level.";
    case tx-rx-intervals {
      leaf desired-min-tx-interval {

```


- * BFD IP single-hop unsolicited is enabled on interface eth1. Since there is no parameter configuration for eth1, it inherits from the global configuration.

```
<?xml version="1.0" encoding="UTF-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
<interfaces xmlns="urn:ietf:params:xml:ns:yang:ietf-interfaces">
  <interface>
    <name>eth0</name>
    <type
      xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
      ianaift:ethernetCsmacd</type>
  </interface>
  <interface>
    <name>eth1</name>
    <type
      xmlns:ianaift="urn:ietf:params:xml:ns:yang:iana-if-type">
      ianaift:ethernetCsmacd</type>
  </interface>
</interfaces>
<routing xmlns="urn:ietf:params:xml:ns:yang:ietf-routing">
  <control-plane-protocols>
    <control-plane-protocol>
      <type xmlns:bfd-types=
        "urn:ietf:params:xml:ns:yang:ietf-bfd-types">
        bfd-types:bfdv1</type>
      <name>name:BFD</name>
      <bfd xmlns="urn:ietf:params:xml:ns:yang:ietf-bfd">
        <ip-sh xmlns="urn:ietf:params:xml:ns:yang:ietf-bfd-ip-sh">
          <unsolicited>
            <local-multiplier>2</local-multiplier>
            <min-interval>50000</min-interval>
          </unsolicited>
          <interfaces>
            <interface>eth0</interface>
            <unsolicited>
              <enabled>true</enabled>
              <local-multiplier>3</local-multiplier>
              <min-interval>250000</min-interval>
            </unsolicited>
          </interfaces>
          <interfaces>
            <interface>eth1</interface>
            <unsolicited>
              <enabled>true</enabled>
            </unsolicited>
          </interfaces>
        </ip-sh>
      </bfd>
    </control-plane-protocol>
  </control-plane-protocols>
</routing>
</config>
```

5. IANA Considerations

IANA has registered the following namespace URI in the "ns" subregistry within the "IETF XML Registry" [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-bfd-unsolicited

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-bfd-unsolicited

Maintained by IANA: N

Namespace: urn:ietf:params:xml:ns:yang:ietf-bfd-unsolicited

Prefix: bfd-unsol

Reference: RFC 9468

6. Security Considerations

6.1. BFD Protocol Security Considerations

The same security considerations and protection measures as those described in [RFC5880] and [RFC5881] apply to this document. In addition, with "unsolicited BFD", there is potential risk for excessive resource usage by BFD from "unexpected" remote systems. To mitigate such risks, implementations of unsolicited BFD MUST:

- * Limit the feature to specific interfaces and to single-hop BFD sessions using the procedures from [RFC5082]. See Section 5 of [RFC5881] for the details of these procedures.
- * Apply policy to process BFD packets only from certain subnets or hosts.
- * Deploy the feature only in an environment that does not offer anonymous participation. Examples include an IXP, where the IXP operator will have a business relationship with all IXP participants, or between a provider and its customers.

6.2. BFD Protocol Authentication Considerations

Implementations of unsolicited BFD are RECOMMENDED to use BFD authentication; see [RFC5880]. If BFD authentication is used, the strongest BFD authentication mechanism that is supported MUST be used.

In some environments, such as IXPs, BFD authentication cannot be used because of the lack of coordination for the operation of the two endpoints of the BFD session.

In other environments, such as when BFD is used to track the next hop of static routes, it is possible to use BFD authentication. This comes with the extra cost of configuring matching key chains between the two endpoints.

6.3. YANG Module 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 Mode (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 this 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:

/routing/control-plane-protocols/control-plane-protocol/bfd/ip-sh
/unsolicited:

- * Data node "enabled" enables creation of unsolicited BFD IP single-hop sessions globally, i.e., on all interfaces. See Section 6.1.
- * Data nodes "local-multiplier", "desired-min-tx-interval", "required-min-rx-interval", and "min-interval" all impact the parameters of the unsolicited BFD IP single-hop sessions. Write operations to these nodes change the rates of BFD packet generation and detection time of the failures of a BFD session.

/routing/control-plane-protocols/control-plane-protocol/bfd/ip-sh
/interfaces/interface/unsolicited:

- * Data node "enabled" enables the creation of unsolicited BFD IP single-hop sessions on a specific interface. See Section 6.1.
- * Data nodes "local-multiplier", "desired-min-tx-interval", "required-min-rx-interval", and "min-interval" all impact the parameters of the unsolicited BFD IP single-hop sessions on the interface.

Some of the readable data 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:

/routing/control-plane-protocols/control-plane-protocol/bfd/ip-sh
/sessions/session/role:

Access to this information discloses the role of the local system in the creation of the unsolicited BFD session.

7. References

7.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.
- [RFC5082] Gill, V., Heasley, J., Meyer, D., Savola, P., Ed., and C. Pignataro, "The Generalized TTL Security Mechanism (GTSM)", RFC 5082, DOI 10.17487/RFC5082, October 2007, <<https://www.rfc-editor.org/info/rfc5082>>.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, DOI 10.17487/RFC5880, June 2010, <<https://www.rfc-editor.org/info/rfc5880>>.
- [RFC5881] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD) for IPv4 and IPv6 (Single Hop)", RFC 5881, DOI 10.17487/RFC5881, June 2010, <<https://www.rfc-editor.org/info/rfc5881>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/info/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [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>>.
- [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>>.

- [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>>.
- [RFC9314] Jethanandani, M., Ed., Rahman, R., Ed., Zheng, L., Ed., Pallagatti, S., and G. Mirsky, "YANG Data Model for Bidirectional Forwarding Detection (BFD)", RFC 9314, DOI 10.17487/RFC9314, September 2022, <<https://www.rfc-editor.org/info/rfc9314>>.

7.2. Informative References

- [RFC4271] Rekhter, Y., Ed., Li, T., Ed., and S. Hares, Ed., "A Border Gateway Protocol 4 (BGP-4)", RFC 4271, DOI 10.17487/RFC4271, January 2006, <<https://www.rfc-editor.org/info/rfc4271>>.
- [RFC5883] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD) for Multihop Paths", RFC 5883, DOI 10.17487/RFC5883, June 2010, <<https://www.rfc-editor.org/info/rfc5883>>.
- [RFC7880] Pignataro, C., Ward, D., Akiya, N., Bhatia, M., and S. Pallagatti, "Seamless Bidirectional Forwarding Detection (S-BFD)", RFC 7880, DOI 10.17487/RFC7880, July 2016, <<https://www.rfc-editor.org/info/rfc7880>>.
- [RFC7911] Walton, D., Retana, A., Chen, E., and J. Scudder, "Advertisement of Multiple Paths in BGP", RFC 7911, DOI 10.17487/RFC7911, July 2016, <<https://www.rfc-editor.org/info/rfc7911>>.
- [RFC7947] Jasinska, E., Hilliard, N., Raszuk, R., and N. Bakker, "Internet Exchange BGP Route Server", RFC 7947, DOI 10.17487/RFC7947, September 2016, <<https://www.rfc-editor.org/info/rfc7947>>.
- [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>>.

Acknowledgments

The authors would like to thank Acee Lindem, Alvaro Retana, Dan Romascanu, Derek Atkins, Greg Mirsky, Gyan Mishra, Henning Rogge, Jeffrey Haas, John Scudder, Lars Eggert, Magnus Westerlund, Mahesh Jethanandani, Murray Kucherawy, Raj Chetan, Robert Wilton, Roman Danyliw, Tom Petch, and Zaheduzzaman Sarker for their reviews and valuable input.

Authors' Addresses

Enke Chen
Palo Alto Networks
3000 Tannery Way
Santa Clara, CA 95054
United States of America
Email: enchen@paloaltonetworks.com

Naiming Shen
Zededa
160 W Santa Clara Street
San Jose, CA 95113
United States of America
Email: naiming@zededa.com

Robert Raszuk
Arrcus
2077 Gateway Place
San Jose, CA 95110
United States of America
Email: robert@raszuk.net

Reshad Rahman
Equinix
Canada
Email: reshad@yahoo.com