

Network Working Group
Internet-Draft
Intended status: Informational
Expires: March 14, 2014

M. Bhatia
Alcatel-Lucent
D. Zhang
Huawei Technologies co., LTD.
M. Jethanandani
Ciena Corporation
September 10, 2013

Analysis of Bidirectional Forwarding Detection (BFD) Security According
to KARP Design Guide
draft-ietf-karp-bfd-analysis-01

Abstract

This document analyzes the Bidirectional Forwarding Detection protocol (BFD) according to the guidelines set forth in section 4.2 of KARP Design Guidelines [RFC6518].

Status of This Memo

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

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

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

This Internet-Draft will expire on March 14, 2014.

Copyright Notice

Copyright (c) 2013 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 (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of

the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

1. Introduction

This document performs a gap analysis of the current state of Bidirectional Forwarding Detection [RFC5880] according to the requirements of KARP Design Guidelines [RFC6518]. Previously, the OPSEC working group has provided an analysis of cryptographic issues with BFD in Issues with Existing Cryptographic Protection Methods for Routing Protocols [RFC6039].

The existing BFD specifications provide a basic security solution. Key ID is provided so that the key used in securing a packet can be changed on demand. Two cryptographic algorithms (MD5 and SHA-1) are supported for integrity protection of the control packets; the algorithms are both demonstrated to be subject to collision attacks. Routing protocols like RIPv2 Cryptographic Authentication [RFC4822], IS-IS Generic Cryptographic Authentication [RFC5310] and OSPFv2 HMAC-SHA Cryptographic Authentication [RFC5709] have started to use BFD for liveness check. Moving the routing protocols to a stronger algorithm while using weaker algorithm for BFD would require the attacker to bring down BFD in order to bring down the routing protocol. BFD therefore needs to match the routing protocols in its strength of algorithm.

While BFD uses a non-decreasing per-packet sequence number to protect itself from intra-connection replay attacks, it still leaves the protocol vulnerable to the inter-session replay attacks.

1.1. Conventions Used in This Document

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 RFC 2119 [RFC2119].

2. Requirements to Meet

There are several requirements described in section 3 of The Threat Analysis and Requirements for Cryptographic Authentication of Routing Protocols' Transports [I-D.ietf-karp-threats-reqs] that BFD does not currently meet:

Replay Protection: BFD provides an incomplete intra-session and no inter-session replay attack protection; this creates significant denial-of-service opportunities.

Strong Algorithms: the cryptographic algorithms adopted for message authentication in BFD are MD5 or SHA-1 based. However, both algorithms are known to be vulnerable to collision attacks. BFD Generic Cryptographic Authentication [I-D.ietf-bfd-generic-crypto-auth] and Authenticating BFD using HMAC-SHA-2 procedures [I-D.ietf-bfd-hmac-sha] together propose a solution to support HMAC with the SHA-2 family of hash functions for BFD.

DoS Attacks: BFD packets can be sent at millisecond intervals (the protocol uses timers at microsecond intervals). When malicious packets are sent at short intervals, with the authentication bit set, it can cause a DoS attack.

The remainder of this document explains the details of how these requirements fail to be met and proposes mechanisms for addressing them.

3. Current State of Security Methods

BFD [RFC5880] describes five authentication mechanisms for the integrity protection of BFD control packets: Simple Password, Keyed MD5 The MD5 Message-Digest Algorithm [RFC1321], Meticulous Keyed MD5, Keyed SHA-1 and Meticulous SHA-1. In the simple password mechanism, every control packet is associated with a password transported in plain text; attacks eavesdropping the network traffic can easily learn the password and compromise the security of the corresponding BFD session. In the Keyed MD5 and the Meticulous Keyed MD5 mechanisms, BFD nodes use share secret keys to generate keyed MD5 digests for control packets. Similarly, in the Keyed SHA-1 and the Meticulous Keyed SHA-1 mechanisms, BFD nodes use shared secret keys to generate keyed SHA-1 digests for control packets. Note that in the keyed authentication mechanisms, every BFD control packet is associated with a non-decreasing 32-bit sequence number to resist replay attacks. In the Keyed MD5 and the Keyed SHA-1 mechanisms, the sequence member is only required to increase occasionally. However, in the Meticulous Keyed MD5 and the Meticulous Keyed SHA-1 mechanisms, the sequence member is required to monotonically increase with each successive packet.

Additionally, limited key updating functionality is provided. There is a Key ID in every authenticated BFD control packet, indicating the key used to hash the packet. However, there is no mechanism described to provide a smooth key rollover that the BFD routers can use when moving from one key to the other.

The BFD session timers are defined with the granularity of microseconds, and it is common in practice to send BFD packets at

millisecond intervals. Since the cryptographic sequence number space is only 32 bits, a sequence number used in a BFD session may reach its maximum value and roll over within limited period. For instance, if a sequence number is increased by one every 3.3 millisecond, then it will reach its maximum value in less than 24 weeks. This can result in potential inter-session replay attacks especially when BFD uses the non-meticulous authentication modes.

Note that when using authentication mechanisms, BFD requests the sequence of a received BFD packets drops with a limited range ($3 \times$ Detection time multiplier). Therefore, when meticulous authentication modes are used, a replayed BFD packet will be rejected if it cannot fit into a relatively short window (3 times of the detect interval of the session). This introduces some difficulties for replaying packets. However, in a non-meticulous authentication mode, such windows can be large as sequence numbers are only increased occasionally, thus making it easier to perform replay attacks.

In a BFD session, each node needs to select a 32-bit discriminator to identify itself. Therefore, a BFD session is identified by two discriminators. If a node will randomly select a new discriminator for a new session and use authentication mechanism to secure the control packets, inter-session replay attacks can be mitigated to some extent. However, in existing BFD demultiplexing mechanisms, the discriminators used in a new BFD session may be predictable. In some deployment scenarios, the discriminators of BFD routers may be decided by the destination and source addresses. So, if the sequence number of a BFD router rolls over for some reasons (e.g., reboot), the discriminators used to identify the new session will be identical to the ones used in the previous session. This makes performing a replay attack relatively simple.

BFD allows a mode called the echo mode. Echo packets are not defined in the BFD specification, though they can keep the BFD session up. The format of the echo packet is local to the sending side and there are no guidelines on the properties of these packets beyond the choice of the source and destination addresses. While the BFD specification recommends applying security mechanisms to prevent spoofing of these packets, there are no guidelines on what type of mechanisms are appropriate.

4. Impacts of BFD Replays

As discussed, BFD cannot meet the requirements of inter-session or intra-session replay protection. This section discusses the impacts of BFD replays.

When cryptographic authentication mechanisms are adopted for BFD, a non-decreasing 32-bit long sequence number is used. In the Keyed MD5 and the Keyed SHA-1 mechanisms, the sequence member is not required to increase for every packet. Therefore an attacker can keep replaying the packets with the latest sequence number until the sequence number is updated. This issue is eliminated in the Meticulous Keyed MD5 and the Meticulous Keyed SHA-1 mechanisms. However, note that a sequence number may reach its maximum and be rolled over in a session. In this case, without the support from an automatic key management mechanism, the BFD session will be vulnerable to replay attacks performed by sending the packets before the roll over of the sequence number. For instance, an attacker can replay a packet with a sequence number which is larger than the current one. If the replayed packet is accepted, the victim will reject the legal packets whose sequence members are less than the one in the replayed packet. Therefore, the attacker can get a good chance to bring down the BFD session.

Additionally, the BFD specification allows for the change of authentication state based on the state of a received packet. For instance, according to BFD [RFC5880], if the state of an accepted packet is down, the receiver of the packet needs to transfer its state to down as well. Therefore, an elaborately selected replayed packet can cause a serious denial-of-service attack.

BFD does not provide any solution to deal with inter-session replay attacks. If two subsequent BFD sessions adopt an identical discriminator pair and use the same cryptographic key to secure the control packets, it is intuitive to use a malicious authenticated packet (stored from the past session) to perform inter-connection replay attacks.

Any security issues in the BFD echo mode will directly affect the BFD protocol and session states, and hence the network stability. For instance, any replay attacks would be indistinguishable from normal forwarding of the tested router. An attack would still cause a faulty link to be believed to be up, but there is little that can be done about it. However, if the echo packets are guessable, it may be possible to spoof from an external source and cause BFD to believe that a one-way link is really bidirectional. As a result, it is important that the echo packets contain random material that is also checked upon reception.

5. Impact of New Authentication Requirements

BFD can be run in software or hardware. Hardware implementations run BFD at a much smaller timeout, typically in the order of few milliseconds. For instance with a timeout of 3.3 milliseconds, a BFD session is required to send or receive 3 packets every 10 milliseconds. Software implementations typically run with a timeout in hundreds of milliseconds.

Additionally, it is not common to find hardware support for computing the authentication data for the BFD session in hardware or software. In the keyed MD5 and Keyed SHA-1 implementation where the sequence number does not increase with every packet, software can be used to compute the authentication data. This is true if the time between increasing sequence number is long enough to compute the data in software. The ability to compute the hash in software is difficult with Meticulous Keyed MD5 and Meticulous Keyed SHA-1 if the time interval between transmits or between receives is small.

Implementors should assess the impact of authenticating BFD sessions on their platform.

6. Considerations for improvement

This section suggests changes that can be adopted to improve the protection of BFD.

As mentioned in section 3, a 32 bit sequence number space can wrap around in less than 24 weeks when set for the minimum time interval of 3.3 milliseconds. To prevent a replay attack the sequence number can be tied to notion of real time where part of the sequence number reflects say the UTC time. A replay attack therefore can easily be detected. However, it does require that the two stations exchanging BFD packets are synchornized with respect to time. Alternatively, the sequence number can be a nonce number generated using the shared key. But nonce numbers will also run out in 24 weeks.

Increasing the sequence number space to 64 bits makes the wrap around time be a little less than 2 million years. Combined with nonce or part of the number reflecting real time would make replay attacks difficult if not impossible.

The security risks brought by SHA-1 and MD5 have been well understood. However, when using stronger digest algorithm, e.g., SHA-2, the imposed computing overhead will seriously affect the performance of BFD implementation. In order to make the trade-off between the strong algorithm requirement and the imposed overhead, Galois Message Authentication Code (GMAC) can be a candidate option.

This algorithm is relative effective and has been supported by IPsec for data origin authentication. More detailed information can be found in [RFC4543].

7. IANA Considerations

This document makes no request of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

8. Security Considerations

9. Acknowledgements

We would like to thank Alexander Vainshtein for his comments on this document.

10. References

10.1. Normative References

- [RFC1321] Rivest, R., "The MD5 Message-Digest Algorithm", RFC 1321, April 1992.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, June 2010.
- [RFC6039] Manral, V., Bhatia, M., Jaeggli, J., and R. White, "Issues with Existing Cryptographic Protection Methods for Routing Protocols", RFC 6039, October 2010.

10.2. Informative References

- [I-D.ietf-bfd-generic-crypto-auth]
Bhatia, M., Manral, V., and D. Zhang, "BFD Generic Cryptographic Authentication", draft-ietf-bfd-generic-crypto-auth-04 (work in progress), April 2013.
- [I-D.ietf-bfd-hmac-sha]
Zhang, D., Bhatia, M., and V. Manral, "Authenticating BFD using HMAC-SHA-2 procedures", draft-ietf-bfd-hmac-sha-03 (work in progress), April 2013.
- [I-D.ietf-karp-threats-reqs]

Lebovitz, G., Bhatia, M., and B. Weis, "Keying and Authentication for Routing Protocols (KARP) Overview, Threats, and Requirements", draft-ietf-karp-threats-reqs-07 (work in progress), December 2012.

[RFC4543] McGrew, D. and J. Viega, "The Use of Galois Message Authentication Code (GMAC) in IPsec ESP and AH", RFC 4543, May 2006.

[RFC4822] Atkinson, R. and M. Fanto, "RIPv2 Cryptographic Authentication", RFC 4822, February 2007.

[RFC5310] Bhatia, M., Manral, V., Li, T., Atkinson, R., White, R., and M. Fanto, "IS-IS Generic Cryptographic Authentication", RFC 5310, February 2009.

[RFC5709] Bhatia, M., Manral, V., Fanto, M., White, R., Barnes, M., Li, T., and R. Atkinson, "OSPFv2 HMAC-SHA Cryptographic Authentication", RFC 5709, October 2009.

[RFC6518] Lebovitz, G. and M. Bhatia, "Keying and Authentication for Routing Protocols (KARP) Design Guidelines", RFC 6518, February 2012.

Authors' Addresses

Manav Bhatia
Alcatel-Lucent
Bangalore
India

Email: manav.bhatia@alcatel-lucent.com

Dacheng Zhang
Huawei Technologies co., LTD.
Beijing
China

Email: zhangdacheng@huawei.com

Mahesh Jethanandani
Ciena Corporation
1741 Technology Drive, #400
San Jose, CA 95110
USA

Phone: 408.436.3313
Fax: 408.436.5582
Email: mjethanandani@gmail.com