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Bidirectional Forwarding Detection
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Abstract

This document describes a protocol intended to detect faults in the bidirectional path between two forwarding engines, including interfaces, data link(s), and to the extent possible the forwarding engines themselves, with potentially very low latency. It operates independently of media, data protocols, and routing protocols. Comments on this draft should be directed to rtg-bfd@ietf.org.

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 [KEYWORDS].

1. Introduction

An increasingly important feature of networking equipment is the rapid detection of communication failures between adjacent systems, in order to more quickly establish alternative paths. Currently, detection can come fairly quickly in certain circumstances when data link hardware comes into play (such as SONET alarms.) However, there are media that do not provide this kind of signaling (such as Ethernet), and some media may not detect certain kinds of failures in the path, for example, failing interfaces or forwarding engine components.

Networks use relatively slow "Hello" mechanisms, usually in routing protocols, to detect failures when there is no hardware signaling to help out. The detection times available in the existing protocols are no better than a second, which is far too long for some applications and represents a great deal of lost data at gigabit rates. Furthermore, routing protocol Hellos are of no help when those routing protocols are not in use, and the semantics of detection are subtly different--they detect a failure in the path between the two routing protocol engines.

The goal of BFD is to provide low-overhead, short-duration detection of failures in the path between adjacent forwarding engines, including the interfaces, data link(s), and to the extent possible the forwarding engines themselves.

An additional goal is to provide a single mechanism that can be used for liveness detection over any media, at any protocol layer, with a wide range of detection times and overhead, to avoid a proliferation

of different methods.

This document specifies the details of the base protocol. The use of some mechanisms are application dependent, and will be specified in a separate series of application documents. These issues are so noted.

Note that many of the exact mechanisms are implementation dependent and will not affect interoperability, and are thus outside the scope of this specification. Those issues are so noted.

2. Design

BFD is designed to detect failures in communication with a forwarding plane next hop. It is intended to be implemented in some component of the forwarding engine of a system, in cases where the forwarding and control engines are separated. This not only binds the protocol more to the forwarding plane, but decouples the protocol from the fate of the routing protocol engine (making it useful in concert with various "graceful restart" mechanisms for those protocols.) BFD may also be implemented in the control engine, though doing so may preclude the detection of some kinds of failures.

BFD operates on top of any data protocol being forwarded between two systems. It is always run in a unicast, point-to-point mode. BFD packets are carried as the payload of whatever encapsulating protocol is appropriate for the medium and network. BFD may be running at multiple layers in a system. The context of the operation of any particular BFD session is bound to its encapsulation.

BFD can provide failure detection on any kind of path between systems, including direct physical links, virtual circuits, tunnels, MPLS LSPs, multihop routed paths, and unidirectional links (so long as there is some return path, of course.) Multiple BFD sessions can be established between the same pair of systems when multiple paths between them are present in at least one direction, even if a lesser number of paths are available in the other direction (multiple parallel unidirectional links or MPLS LSPs, for example.)

The BFD state machine implements a three-way handshake, both when establishing a BFD session and when tearing it down for any reason, to ensure that both systems are aware of the state change.

BFD can be abstracted as a simple service. The service primitives provided by BFD are to create, destroy, and modify a session, given the destination address and other parameters. BFD in return provides a signal to its clients indicating when the BFD session goes up or

down.

3. Protocol Overview

BFD is a simple, fixed-field, hello protocol that in many respects is similar to the detection components of well-known routing protocols. A pair of systems transmit BFD packets periodically over each path between the two systems, and if a system stops receiving BFD packets for long enough, some component in that particular bidirectional path to the neighboring system is assumed to have failed. Under some conditions, systems may negotiate to not send periodic BFD packets in order to reduce overhead.

A path is only declared to be operational when two-way communication has been established between systems (though this does not preclude the use of unidirectional links.)

A separate BFD session is created for each communications path and data protocol in use between two systems.

Each system estimates how quickly it can send and receive BFD packets in order to come to an agreement with its neighbor about how rapidly detection of failure will take place. These estimates can be modified in real time in order to adapt to unusual situations. This design also allows for fast systems on a shared medium with a slow system to be able to more rapidly detect failures between the fast systems while allowing the slow system to participate to the best of its ability.

3.1. Addressing and Session Establishment

A BFD session is established based on the needs of the application that will be making use of it. It is up to the application to determine the need for BFD, and the addresses to use--there is no discovery mechanism in BFD. For example, an OSPF implementation may request a BFD session to be established to a neighbor discovered using the OSPF Hello protocol.

3.2. Operating Modes

BFD has two operating modes which may be selected, as well as an additional function that can be used in combination with the two modes.

The primary mode is known as Asynchronous mode. In this mode, the systems periodically send BFD Control packets to one another, and if a number of those packets in a row are not received by the other system, the session is declared to be down.

The second mode is known as Demand mode. In this mode, it is assumed that each system has an independent way of verifying that it has connectivity to the other system, so once a BFD session is established, the systems stop sending BFD Control packets, except when either system feels the need to verify connectivity explicitly, in which case a short sequence of BFD Control packets is sent, and then the protocol quiesces.

An adjunct to both modes is the Echo function. When the Echo function is active, a stream of BFD Echo packets is transmitted in such a way as to have the other system loop them back through its forwarding path. If a number of packets in a row of the echoed data stream are not received, the session is declared to be down. The Echo function may be used with either Asynchronous or Demand modes. Since the Echo function is handling the task of detection, the rate of periodic transmission of Control packets may be reduced (in the case of Asynchronous mode) or eliminated completely (in the case of Demand mode.)

Pure asynchronous mode is advantageous in that it requires half as many packets to achieve a particular detection time as does the Echo function. It is also used when the Echo function cannot be supported for some reason.

The Echo function has the advantage of truly testing only the forwarding path on the remote system, which may reduce round-trip jitter and thus allow more aggressive detection times, as well as potentially detecting some classes of failure that might not otherwise be detected.

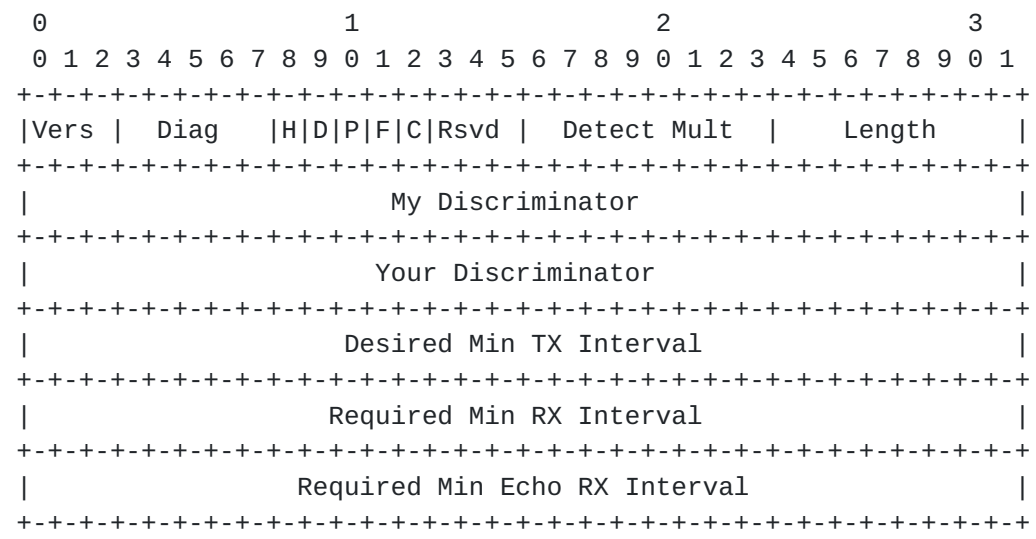
The Echo function may be enabled individually in each direction. It is enabled in a particular direction only when the system that loops the Echo packets back signals that it will allow it, and when the system that sends the Echo packets decides it wishes to.

Demand mode is useful in situations where the overhead of a periodic protocol might prove onerous, such as a system with a very large number of BFD sessions. It is also useful when the Echo function is being used symmetrically. Demand mode has the disadvantage that detection times are essentially driven by the heuristics of the system implementation and are not known to the BFD protocol. Demand mode also may not be used when the path round trip time is greater than the desired detection time. See section 6.4 for more details.

4. BFD Control Packet Format

BFD Control packets are sent in an encapsulation appropriate to the environment, which is outside of the scope of this document. See the appropriate application document for encapsulation details.

The payload of a BFD Control packet has the following format:



Version (Vers)

The version number of the protocol. This document defines protocol version 0.

Diagnostic (Diag)

A diagnostic code specifying the local system's reason for the last transition of the session from Up to some other state. Values are:

- 0 -- No Diagnostic
- 1 -- Control Detection Time Expired
- 2 -- Echo Function Failed
- 3 -- Neighbor Signaled Session Down
- 4 -- Forwarding Plane Reset
- 5 -- Path Down
- 6 -- Concatenated Path Down
- 7 -- Administratively Down
- 8-31 -- Reserved for future use

This field allows remote systems to determine the reason that the

previous session failed, for example.

I Hear You (H)

This bit is set to 0 if the transmitting system either is not receiving BFD packets from the remote system, or is in the process of tearing down the BFD session for some reason. This bit is set to 1 if the transmitting system believes it is communicating with the remote system. See the Elements of Procedure below for more details.

Demand (D)

If set, the transmitting system wishes to operate in Demand Mode. If clear, the transmitting system does not wish to or is not capable of operating in Demand Mode.

Poll (P)

If set, the transmitting system is requesting verification of connectivity, or of a parameter change. If clear, the transmitting system is not requesting verification.

Final (F)

If set, the transmitting system is responding to a received BFD Control packet that had the Poll (P) bit set. If clear, the transmitting system is not responding to a Poll.

Control Plane Independent (C)

If set, the transmitting system's BFD implementation does not share fate with its control plane (in other words, BFD is implemented in the forwarding plane and can continue to function through disruptions in the control plane.) If clear, the transmitting system's BFD implementation shares fate with its control plane.

The use of this bit is application dependent and is outside the scope of this specification. See specific application specifications for details.

Reserved (Rsvd)

These bits must be zero on transmit, and ignored on receipt.

Detect Mult

Detect time multiplier. The negotiated transmit interval, multiplied by this value, provides the detection time for the transmitting system in Asynchronous mode.

Length

Length of the BFD Control packet, in bytes.

My Discriminator

A unique, nonzero discriminator value generated by the transmitting system, used to demultiplex multiple BFD sessions between the same pair of systems.

Your Discriminator

The discriminator received from the corresponding remote system. This field reflects back the received value of My Discriminator, or is zero if that value is unknown.

Desired Min TX Interval

This is the minimum interval, in microseconds, that the local system would like to use when transmitting BFD Control packets.

Required Min RX Interval

This is the minimum interval, in microseconds, between received BFD Control packets that this system is capable of supporting.

Required Min Echo RX Interval

This is the minimum interval, in microseconds, between received BFD Echo packets that this system is capable of supporting. If this value is zero, the transmitting system does not support the

receipt of BFD Echo packets.

5. BFD Echo Packet Format

BFD Echo packets are sent in an encapsulation appropriate to the environment. See the appropriate application document for the specifics of particular environments.

The payload of a BFD Echo packet is a local matter, since only the sending system ever processes the content. The only requirement is that sufficient information is included to demultiplex the received packet to the correct BFD session after it is looped back to the sender. The contents are otherwise outside the scope of this specification.

6. Elements of Procedure

This section discusses the normative requirements of the protocol in order to achieve interoperability. It is important for implementors to enforce only the requirements specified in this section, as misguided pedantry has been proven by experience to adversely affect interoperability.

Remember that all references of the form "bfd.Xx" refer to internal state variables (defined in section 6.5.1), whereas all references to "the Xxx field" refer to fields in the protocol packets themselves (defined in section 6.4).

6.1. Overview

A system may take either an Active role or a Passive role in session initialization. A system taking the Active role MUST send BFD Control packets for a particular session, regardless of whether it has received any BFD packets for that session. A system taking the Passive role MUST NOT begin sending BFD packets for a particular session until it has received a BFD packet for that session, and thus has learned the remote system's discriminator value. At least one system MUST take the Active role (possibly both.) The role that a system takes is specific to the application of BFD, and is outside the scope of this specification.

A session begins with the periodic, slow transmission of BFD Control packets. When bidirectional communication is achieved (by virtue of

the I Hear You field being nonzero in both directions, a three way handshake), the BFD session comes up.

Once the BFD session is Up, a system can choose to start the Echo function if it desires to and the other system signals that it will allow it. The rate of transmission of Control packets is typically kept low when the Echo function is active.

If the Echo function is not active, the transmission rate of Control packets may be increased to a level necessary to achieve the detection time requirements for the session.

If both systems signal that they want to use Demand mode, the transmission of BFD Control packets ceases once the session is Up. Other means of implying connectivity are used to keep the session alive. If one of the systems wishes to verify connectivity, it can initiate a short exchange (a "Poll Sequence") of BFD Control packets to verify this.

If Demand mode is not active, and no Control packets are received in the calculated detection time, the session is declared down, and signalled to the remote end by sending a zero value in the I Hear You field in outgoing packets.

If sufficient Echo packets are lost, the session is declared down in the same manner.

If Demand mode is active and no appropriate Control packets are received in response to a Poll Sequence, the session is declared down in the same manner.

If the session goes down, the transmission of Echo packets (if any) ceases, and the transmission of Control packets goes back to the slow rate.

Once a session has been declared down, it cannot come back up until the remote end first signals that it is down (by setting its outgoing I Hear You field to zero), thus implementing a three-way handshake.

A session may be kept administratively down by always setting its outgoing I Hear You field to zero, and sending an explanatory diagnostic code in the Diagnostic field.

6.2. Demultiplexing and the Discriminator Fields

Since multiple BFD sessions may be running between two systems, there needs to be a mechanism for demultiplexing received BFD packets to the proper session.

Each system MUST choose an opaque discriminator value that identifies each session, and which MUST be unique among all BFD sessions on the system. The local discriminator is sent in the My Discriminator field in the BFD Control packet, and is echoed back in the Your Discriminator field of packets sent from the remote end.

Once the remote end echoes back the local discriminator, all further received packets are demultiplexed based on the Your Discriminator field only (which means that, among other things, the source address field can change or the interface over which the packets are received can change, but the packets will still be associated with the proper session.)

The method of demultiplexing the initial packets (in which Your Discriminator is zero) is application-dependent, and is thus outside the scope of this specification.

Note that it is permissible for a system to change its discriminator during a session (without affecting the session state), since only that system uses its discriminator for demultiplexing purposes (by having the other system reflect it back.) The implications on an implementation for changing the discriminator value is outside the scope of this specification.

6.3. The Echo Function and Asymmetry

The Echo function can be run independently in each direction between a pair of systems. For whatever reason, a system may advertise that it is willing to receive (and loop back) Echo packets, but may not wish to ever send any. The fact that a system is sending Echo packets is not directly signalled to the system looping them back.

When a system is using the Echo function, it is advantageous to choose a sedate transmission rate for Control packets, since liveness detection is being handled by the Echo packets. This can be controlled by manipulating the Desired Min TX Interval field (see section 6.5.3.)

If the Echo function is only being run in one direction, the system not running the Echo function will more likely wish to send fairly rapid Control packets in order to achieve its desired detection time.

Since BFD allows independent transmission rates in each direction, this is easily accomplished.

A system SHOULD always advertise the lowest value of Required Min RX Interval and Required Min Echo RX Interval that it can under the circumstances, to give the other system more freedom in choosing its transmission rate. Note that a system is committing to be able to receive both streams of packets at the rate it advertises, so this should be taken into account when choosing the values to advertise.

6.4. Demand Mode

Demand mode is negotiated by virtue of both systems setting the Demand (D) bit in its BFD Control packets. Both systems must request Demand mode for it to become active.

Demand mode requires that some other mechanism is used to imply continuing connectivity between the two systems. The mechanism used does not have to be the same in both directions, and is outside of the scope of this specification. One possible mechanism is the receipt of traffic from the remote system; another is the use of the Echo function.

Once a BFD session comes up, if Demand mode is active, both systems stop sending periodic BFD Control packets, and depend on the alternative mechanism for maintaining ongoing connectivity.

When a system wishes to verify connectivity, it initiates a Poll Sequence. It starts periodically sending BFD Control packets with the Poll (P) bit set, at the negotiated transmission rate. When a system receives such a packet, it immediately replies with a BFD Control packet of its own, with the Poll (P) bit clear, and the Final (F) bit set. The receipt of a reply to a Poll terminates the Poll Sequence. If no response is received to a Poll, the Poll is repeated until the detection time expires, at which point the session is declared to be down.

The detection time in Demand mode is calculated differently than in Asynchronous mode; it is based on the transmit rate of the local system, rather than the transmit rate of the remote system. This ensures that the Poll Sequence mechanism works properly. See section 6.5.8 for more details.

Note that this mechanism requires that the detection time negotiated is greater than the round trip time between the two systems, or the Poll mechanism will always fail. Enforcement of this requirement is outside the scope of this specification.

Demand mode MAY be enabled or disabled at any time by setting or clearing the Demand (D) bit in the BFD Control packet, without affecting the BFD session state.

Because the underlying detection mechanism is unspecified, and may differ between the two systems, the overall detection time characteristics of the path will not be fully known to either system. The total detection time for a particular system is the sum of the time prior to the initiation of the Poll Sequence, plus the calculated detection time.

6.5. Functional Specifics

The following section of this specification is normative. The means by which this specification is achieved is outside the scope of this specification.

When a system is said to have "the Echo function active," it means that the system is sending BFD Echo packets, implying that the session is Up and the other system has signalled its willingness to loop back Echo packets.

When a system is said to have "Demand mode active," it means that bfd.DemandModeDesired is 1 in the local system (see State Variables below), the remote system is signalling with the Demand (D) bit set, and that the session is Up.

6.5.1. State Variables

A minimum amount of information about a session needs to be tracked in order to achieve the elements of procedure described here. The following is a set of state variables that are helpful in describing the mechanisms of BFD. Any means of tracking this state may be used so long as the protocol behaves as described.

All state variables in this specification are of the form "bfd.Xx" and should not be confused with fields carried in the protocol packets, which are always spelled out to match the names in section 4.

bfd.SessionState

The perceived state of the session (Init, Up, Failing, Down, or AdminDown.) The exact action taken when the session state changes is outside the scope of this specification, though it

is expected that this state change (particularly to and from Up state) is reported to other components of the system. This variable MUST be initialized to Failing.

bfd.LocalDiscr

The local discriminator for this BFD session, used to uniquely identify it. It MUST be unique on this system, and nonzero. The value is otherwise outside the scope of this specification.

bfd.RemoteDiscr

The remote discriminator for this BFD session. This is the discriminator chosen by the remote system, and is totally opaque to the local system. This MUST be initialized to zero.

bfd.RemoteHeard

This variable is set to 1 if the local system is actively receiving BFD packets from the remote system, and is set to 0 if the local system has not received BFD packets recently (within the detection time) or if the local system is attempting to tear down the BFD session. This MUST be initialized to zero.

bfd.LocalDiag

The diagnostic code specifying the reason the local session state most recently transitioned from Up to some other state. This MUST be initialized to zero (No Diagnostic.)

bfd.DesiredMinTxInterval

The minimum interval, in microseconds, between transmitted BFD Control packets that this system would like to use at the current time. The actual interval is negotiated between the two systems. This MUST be initialized to a value of at least one second (1,000,000 microseconds) according to the rules described in section 6.5.3. The setting of this variable is otherwise outside the scope of this specification.

bfd.RequiredMinRxInterval

The minimum interval, in microseconds, between received BFD Control packets that this system requires. The setting of this variable is outside the scope of this specification.

bfd.DemandModeDesired

Set to 1 if the local system wishes to use Demand mode, or 0 if not.

bfd.DetectMult

The desired detect time multiplier for BFD Control packets. The negotiated Control packet transmission interval, multiplied by this variable, will be the detection time for this session (as seen by the remote system.) This variable MUST be a nonzero integer, and is otherwise outside the scope of this specification. See section 6.5.4 for further information.

6.5.2. Timer Negotiation

The time values used to determine BFD packet transmission intervals and the session detection time are continuously negotiated, and thus may be changed at any time. The negotiation and time values are independent in each direction for each session. Packets are always periodically transmitted in Asynchronous mode, and are periodically transmitted during Poll Sequences when in Demand mode.

Each system reports in the BFD Control packet how rapidly it would like to transmit BFD packets, as well as how rapidly it is prepared to receive them. With the exceptions listed in the remainder of this section, a system MUST NOT transmit BFD Control packets with an interval less than the larger of bfd.DesiredMinTxInterval and the received Required Min RX Interval field. In other words, the system reporting the slower rate determines the transmission rate.

The periodic transmission of BFD Control packets SHOULD be jittered by up to 25%, that is, the interval SHOULD be reduced by a random value of 0 to 25%, in order to avoid self-synchronization. Thus, the average interval between packets may be up to 12.5% less than that negotiated.

If bfd.DetectMult is equal to 1, the interval between transmitted BFD Control packets MUST be no more than 90% of the negotiated

transmission interval, and MUST be no less than 75% of the negotiated transmission interval. This is to ensure that, on the remote system, the calculated DetectTime does not pass prior to the receipt of the next BFD Control packet.

An extra, single BFD Control packet SHOULD be transmitted during the interval between periodic Control packet transmissions if there is a state change that needs to be communicated, in order to more rapidly converge. (For example, if the local system determines that the BFD session has gone down, it SHOULD communicate this without waiting for the next periodic transmission.) With the exception listed in the next paragraph, once such an extra packet has been transmitted, a system MUST NOT send another BFD Control packet until the next scheduled transmission.

If a BFD Control packet is received with the Poll (P) bit set to 1, the receiving system MUST transmit a BFD Control packet with the Poll (P) bit clear and the Final (F) bit set as soon as practicable, without respect to the transmission timer or any other transmission limitations, and without respect to whether Demand mode is active.

6.5.3. Timer Manipulation

The time values used to determine BFD packet transmission intervals and the session detection time may be modified at any time without affecting the state of the session. When the timer parameters are changed for any reason, the requirements of this section apply.

If Demand mode is active, and either bfd.DesiredMinTxInterval is changed or bfd.RequiredMinRxInterval is changed, a Poll Sequence MUST be initiated (see section 6.5.8).

If Demand mode is not active, and either bfd.DesiredMinTxInterval is changed or bfd.RequiredMinRxInterval is changed, all subsequent transmitted Control packets MUST be sent with the Poll (P) bit set until a packet is received with the Final (F) bit set.

If bfd.DesiredMinTxInterval is increased, the actual transmission interval used MUST NOT change until a Control packet is received with the Final (F) bit set. This is to ensure that the remote system updates its Detect Time before the transmission interval increases.

If bfd.RequiredMinRxInterval is reduced, the calculated detection time for the remote system MUST NOT change until a Control packet is received with the Final (F) bit set. This is to ensure that the remote system is transmitting packets at the higher rate (and those packets are being received) prior to the detection time being

reduced.

When bfd.SessionState is not Up, the system MUST set bfd.DesiredMinTxInterval to a value of not less than one second (1,000,000 microseconds.) This is intended to ensure that the bandwidth consumed by BFD sessions that are not Up is negligible, particularly in the case where a neighbor may not be running BFD.

When the Echo function is active, a system SHOULD set bfd.DesiredMinTxInterval to a value of not less than one second (1,000,000 microseconds.) This is intended to keep BFD Control traffic at a negligible level, since the actual detection function is being performed using BFD Echo packets.

6.5.4. Calculating the Detection Time

The Detection Time (the period of time without receiving BFD packets after which the session is determined to have failed) is not carried explicitly in the protocol. Rather, it is calculated independently in each direction by the receiving system based on the negotiated transmit interval and the detection multiplier. Note that, in Asynchronous mode, there may be different detection times in each direction.

The calculation of the Detection Time is slightly different when in Demand mode versus Asynchronous mode.

In Asynchronous mode, the Detection Time calculated in the local system is equal to the value of Detect Mult received from the remote system, multiplied by the agreed transmit interval (the greater of bfd.RequiredMinRxInterval and the last received Desired Min TX Interval.) The Detect Mult value is (roughly speaking, due to jitter) the number of packets that have to be missed in a row to declare the session to be down.

If Demand mode is not active, and a period of time equal to the Detection Time passes without receiving a BFD Control packet from the remote system, and bfd.SessionState is Init or Up, the session has gone down--the local system MUST set bfd.SessionState to Failing, bfd.RemoteHeard to zero, and bfd.LocalDiag to 1 (Control Detection Time Expired.) The timeout in Init state is to avoid a potential deadlock in which one system is in Failing state and the other is in Init state (which could happen if a packet were lost at the right time.)

In Demand mode, the Detection Time calculated in the local system is equal to bfd.DetectMult, multiplied by the agreed transmit interval

(the greater of bfd.RequiredMinRxInterval and the last received Desired Min TX Interval.) bfd.DetectMult is (roughly speaking, due to jitter) the number of packets that have to be missed in a row to declare the session to be down.

If Demand mode is active, and a period of time equal to the Detection Time passes after the initiation of a Poll Sequence (the transmission of the first BFD Control packet with the Poll bit set), the session has gone down--the local system MUST set bfd.SessionState to Failing, bfd.RemoteHeard to zero, and bfd.LocalDiag to 1 (Control Detection Time Expired.)

(Note that a packet is considered to have been received, for the purposes of Detection Time expiration, only if it has not been "discarded" according to the rules of section 6.5.6.)

6.5.5. Detecting Failures with the Echo Function

When the Echo function is active and a sufficient number of Echo packets have not arrived as they should, the session has gone down--the local system MUST set bfd.SessionState to Failing, bfd.RemoteHeard to zero, and bfd.LocalDiag to 2 (The Echo Function Failed.)

The means by which the Echo function failures are detected is outside of the scope of this specification. Any means which will detect a communication failure is acceptable.

6.5.6. Reception of BFD Control Packets

When a BFD Control packet is received, the following procedure MUST be followed, in the order specified:

If the version number is not correct (0), the packet MUST be discarded.

If the Length field is less than the correct value (24), the packet MUST be discarded.

If the Length field is greater than the payload of the encapsulating protocol, the packet MUST be discarded.

If the Detect Mult field is zero, the packet MUST be discarded.

If the My Discriminator field is zero, the packet MUST be discarded.

If the Your Discriminator field is nonzero, it MUST be used to select the session with which this BFD packet is associated. If no session is found, the packet MUST be discarded.

If the Your Discriminator field is zero and the I Hear You field is nonzero, the packet MUST be discarded.

If the Your Discriminator field is zero, the session MUST be selected based on some combination of other fields, possibly including source addressing information, the My Discriminator field, and the interface over which the packet was received. The exact method of selection is application-specific and is thus outside the scope of this specification. If a matching session is not found, a new session may be created, or the packet may be discarded. This choice is outside the scope of this specification.

Set bfd.RemoteDiscr to the value of My Discriminator.

If the Required Min Echo RX Interval field is zero, the transmission of Echo packets, if any, MUST cease.

If Demand mode is active, a Poll Sequence is being transmitted by the local system, and the Final (F) bit in the received packet is set, the Poll Sequence MUST be terminated.

If Demand mode is not active, the Final (F) bit in the received packet is set, and the local system has been transmitting packets with the Poll (P) bit set, the Poll (P) bit MUST be set to zero in subsequent transmitted packets.

Update the Detection Time as described in section 6.5.4.

```
If bfd.SessionState is Down
    Set bfd.RemoteHeard to 1
    If I Hear You is zero
        Set bfd.SessionState to Init
    Else
        Set bfd.SessionState to Up

Else if bfd.SessionState is AdminDown
    Discard the packet

Else if bfd.SessionState is Init
    If I Hear You is nonzero
        Set bfd.SessionState to Up
    Else
        Discard the packet
```

```
Else if bfd.SessionState is Up
    If I Hear You is zero
        Set bfd.LocalDiag to 3 (Neighbor signaled session down)
        Set bfd.SessionState to Failing
        Set bfd.RemoteHeard to 0

Else if bfd.SessionState is Failing
    If I Hear You is zero, set bfd.SessionState to Down
```

Update the transmit interval as described in section 6.5.2.

If the Demand (D) bit is set and bfd.DemandModeDesired is 1, and bfd.SessionState is Up, Demand mode is active.

If the Demand (D) bit is clear or bfd.DemandModeDesired is 0, or bfd.SessionState is not Up, Demand mode is not active.

If the Poll (P) bit is set, send a BFD Control packet to the remote system with the Poll (P) bit clear, and the Final (F) bit set.

If the packet was not discarded, it has been received for purposes of the Detection Time expiration rules in section 6.5.4.

6.5.7. Transmitting BFD Control Packets

BFD Control packets MUST be transmitted periodically at the rate determined according to section 6.5.2, except as specified in this section.

The transmit interval MUST be recalculated whenever bfd.DesiredMinTxInterval changes, or whenever the received Required Min RX Interval changes, and is equal to the greater of those two values. See sections 6.5.2 and 6.5.3 for details on transmit timers.

A system MUST NOT transmit BFD Control packets if bfd.RemoteDiscr is zero and the system is taking the Passive role.

A system MUST NOT periodically transmit BFD Control packets if Demand mode is active and a Poll Sequence is not being transmitted.

A system MUST send a BFD Control packet in response to a received BFD Control Packet with the Poll (P) bit set. The packet sent in response MUST NOT have the Poll (P) bit set, and MUST have the Final (F) bit set.

A single BFD Control packet SHOULD be transmitted between normally scheduled transmissions when the contents of that packet would differ from those in the previously transmitted packet (other than the Poll and Final bits) in order to more rapidly communicate a change in state.

The contents of transmitted BFD Control packets MUST be set as follows:

Version

Set to the current version number (0).

Diagnostic (Diag)

Set to bfd.LocalDiag.

I Hear You (H)

Set to bfd.RemoteHeard.

Demand (D)

Set to bfd.DemandModeDesired.

Poll (P)

Set to 1 if the local system is sending a Poll Sequence or is required to do so according to the requirements of section 6.5.3, or 0 if not.

Final (F)

Set to 1 if the local system is responding to a Control packet received with the Poll (P) bit set, or 0 if not.

Control Plane Independent (C)

Set to 1 if the local system's BFD implementation is independent of the control plane (it can continue to function through a disruption of the control plane.)

Reserved (Rsvd)

Set to 0.

Detect Mult

Set to bfd.DetectMult.

Length

Set to 24.

My Discriminator

Set to bfd.LocalDiscr.

Your Discriminator

Set to bfd.RemoteDiscr.

Desired Min TX Interval

Set to bfd.DesiredMinTxInterval.

Required Min RX Interval

Set to bfd.RequiredMinRxInterval.

Required Min Echo RX Interval

Set to the minimum required Echo packet receive interval for this session. If this field is set to zero, the local system is unwilling or unable to loop back BFD Echo packets to the remote system, and the remote system will not send Echo packets.

6.5.8. Initiation of a Poll Sequence

If Demand mode is active, a Poll Sequence MUST be initiated whenever the contents of the next BFD Control packet to be sent would be different than the contents of the previous packet, with the exception of the Poll (P) and Final (F) bits. This ensures that parameter changes are transmitted to the remote system. Note that if the I Hear You (H) bit is changing to zero, the session is going down and Demand mode will no longer be active.

If Demand mode is active, a Poll Sequence SHOULD be initiated whenever the system feels the need to verify connectivity with the remote system. The conditions under which this is desirable are outside the scope of this specification.

If a Poll Sequence is being sent, and a new Poll Sequence is initiated due to one of the above conditions, the detection interval MUST be restarted in order to ensure that a full Poll Sequence is transmitted under the new conditions.

6.5.9. Reception of BFD Echo Packets

A received BFD Echo packet MUST be demultiplexed to the appropriate session for processing. A means of detecting missing Echo packets MUST be implemented, which most likely involves processing of the Echo packets that are received. The processing of received Echo packets is otherwise outside the scope of this specification.

6.5.10. Transmission of BFD Echo Packets

BFD Echo packets MUST NOT be transmitted when bfd.SessionState is not Up. BFD Echo packets MUST NOT be transmitted unless the last BFD Control packet received from the remote system contains a nonzero value in Required Min Echo RX Interval.

BFD Echo packets MAY be transmitted when bfd.SessionState is Up. The interval between transmitted BFD Echo packets MUST NOT be less than the value advertised by the remote system in Required Min Echo RX Interval, except as follows:

- A 25% jitter MAY be applied to the rate of transmission, such that the actual interval MAY be between 75% and 100% of the advertised value. A single BFD Echo packet MAY be transmitted between normally scheduled Echo transmission intervals.

The transmission of BFD Echo packets is otherwise outside the scope

of this specification.

6.5.11. Min Rx Interval Change

When it is desired to change the rate at which BFD Control packets arrive from the remote system, bfd.RequiredMinRxInterval can be changed at any time to any value. The new value will be transmitted in the next outgoing Control packet, and the remote system will adjust accordingly. See sections 6.5.3 and 6.5.8 for further requirements.

6.5.12. Min Tx Interval Change

When it is desired to change the rate at which BFD Control packets are transmitted to the remote system (subject to the requirements of the neighboring system), bfd.DesiredMinTxInterval can be changed at any time to any value. The rules in sections 6.5.3 and 6.5.8 apply.

6.5.13. Detect Multiplier Change

When it is desired to change the detect multiplier, the value of bfd.DetectMult can be changed to any nonzero value. The new value will be transmitted with the next BFD Control packet. See section 6.5.8 for additional requirements.

6.5.14. Enabling or Disabling The Echo Function

If it is desired to start or stop the transmission of BFD Echo packets, this MAY be done at any time (subject to the transmission requirements detailed in section 6.5.10.)

If it is desired to enable or disable the looping back of received BFD Echo packets, this MAY be done at any time by changing the value of Required Min RX Interval to zero or nonzero in outgoing BFD Control packets.

6.5.15. Enabling or Disabling Demand Mode

If it is desired to start or stop Demand mode, this MAY be done at any time by setting bfd.DemandModeDesired to the proper value. If Demand mode is no longer active, the system MUST begin transmitting periodic BFD Control packets as described in section 6.5.7.

6.5.16. Forwarding Plane Reset

When the forwarding plane in the local system is reset for some reason, such that the remote system can no longer rely on the local forwarding state, the local system MUST set bfd.LocalDiag to 4 (Forwarding Plane Reset), set bfd.SessionState to Failing, and set bfd.RemoteHeard to zero.

6.5.17. Administrative Control

There may be circumstances where it is desirable to administratively enable or disable a BFD session. When this is desired, the following procedure MUST be followed:

```
If enabling session
   Set bfd.SessionState to Failing
   Set bfd.RemoteHeard to zero

Else
   Set bfd.SessionState to AdminDown
   Set bfd.RemoteHeard to zero
   Set bfd.LocalDiag to an appropriate value
   Cease the transmission of BFD Echo packets
```

Specific diagnostic codes are provided for two scenarios.

If signalling is received from outside BFD that the underlying path has failed, an implementation MAY adminstratively disable the session with the diagnostic Path Down.

If the path being monitored by BFD is concatenated with other paths, it may be desirable to administratively bring down the BFD session when a concatenated path fails (as a way of propagating the failure indication.) In this case, an implementation MAY administratively disable the BFD session with the diagnostic Concatenated Path Down.

Other scenarios MAY use the diagnostic Administratively Down.

Contributors

Kireeti Kompella and Yakov Rekhter of Juniper Networks were also significant contributors to this document.

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This document was inspired by (and is intended to replace) the Protocol Liveness Protocol draft, written by Kireeti Kompella.

Demand Mode was inspired by draft-ietf-ipsec-dpd-03.txt, by G. Huang et al.

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Changes from the previous draft

The primary technical change in this draft from the previous version is to allow a system to change its discriminator, by eliminating the sanity check in the packet reception rules. This has the side effect of also allowing the removal of the requirement to clear the remote discriminator after a session goes down. Although this change is not backward compatible, it is small enough to not warrant a change in the version number (since systems will interoperate properly so long as they do not change their discriminator, and if they do this will result in only a session flap.

The Control Plane Independent (C) bit was added in this draft to facilitate interactions with OSPF and IS-IS Graceful Restart functions in the accompanying application draft.

Otherwise, the changes in this draft from the previous version are cosmetic and/or editorial.

Normative References

[KEYWORD] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", RFC 2119, March 1997.

Security Considerations

When BFD is run over network layer protocols, a significant denial-of-service risk is created, as BFD packets may be trivial to spoof. When the session is directly connected across a single link (physical, or a tunnel such as GRE or IPsec), the TTL or Hop Count MUST be set to the maximum on transmit, and checked to be equal to the maximum value on reception (and the packet dropped if this is not the case.) If BFD is run across multiple hops, some alternative mechanism MUST be used. One option would be to ensure that the network addresses used for BFD are not routable outside of the infrastructure in which BFD is running (and assuming there are no users connected within that network.) Another option would be to filter all packets carrying BFD's UDP ports at the edges of the network. Still another option would be to use cryptographic methods, though this is not likely to allow for very short detection times. Securing BFD in a routed, multiple hop environment is for further study.

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