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BGP Monitoring Protocol
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Abstract

This document defines a protocol, BMP, which can be used to monitor BGP sessions. BMP is intended to provide a more convenient interface for obtaining route views for research purpose than the screen-scraping approach in common use today. The design goals are to keep BMP simple, useful, easily implemented, and minimally service-affecting. BMP is not suitable for use as a routing protocol.

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1. Introduction

Many researchers wish to have access to the contents of routers' BGP RIBs as well as a view of protocol updates that the router is receiving. This monitoring task cannot be realized by standard protocol mechanisms. Prior to introduction of BMP, this data could only be obtained through screen-scraping.

The BMP protocol provides access to the Adj-RIB-In of a peer on an ongoing basis and a periodic dump of certain statistics that the monitoring station can use for further analysis. From a high level, BMP can be thought of as the result of multiplexing together the messages received on the various monitored BGP sessions.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

2. Definitions

- o Adj-RIB-In: As defined in [[RFC4271](#)], "The Adj-RIBs-In contains unprocessed routing information that has been advertised to the local BGP speaker by its peers." This is also referred to as the pre-policy Adj-RIB-In in this document.
- o Post-Policy Adj-RIB-In: The result of applying inbound policy to

an Adj-RIB-In, but prior to the application of route selection to form the Loc-RIB.

[3.](#) Overview of BMP Operation

[3.1.](#) BMP Messages

The following are the messages provided by BMP.

- o Route Monitoring (RM): An initial dump of all routes received from a peer as well as an ongoing mechanism that sends the incremental routes advertised and withdrawn by a peer to the monitoring station.
- o Peer Down Notification (PD): A message sent to indicate that a peering session has gone down with information indicating the reason for the session disconnect.

- o Stats Reports (SR): An ongoing dump of statistics that can be used by the monitoring station as a high level indication of the activity going on in the router.
- o Peer Up Notification (PU): A message sent to indicate that a peering session has come up. The message includes information regarding the data exchanged between the peers in their OPEN messages as well as information about the peering TCP session itself. In addition to being sent whenever a peer transitions to ESTABLISHED state, a Peer Up Notification is sent for each peer that is in ESTABLISHED state when the BMP session itself comes up.
- o Initiation: A means for the monitored router to inform the monitoring station of its vendor, software version, and so on.
- o Termination: A means for the monitored router to inform the monitoring station of why it is closing a BMP session.

[3.2.](#) Connection Establishment and Termination

BMP operates over TCP. All options are controlled by configuration on the monitored router. No message is ever sent from the monitoring

station to the monitored router. The monitored router MAY take steps to prevent the monitoring station from sending data (for example by half-closing the TCP session or setting its window size to zero) or it MAY silently discard any data sent by the monitoring station.

The router may be monitored by one or more monitoring stations. With respect to each (router, monitoring station) pair, one party is active with respect to TCP session establishment, and the other party is passive. Which party is active and which is passive is controlled by configuration.

The passive party is configured to listen on a particular TCP port and the active party is configured to establish a connection to that port. If the active party is unable to connect to the passive party, it periodically retries the connection. Retries MUST be subject to some variety of backoff. Exponential backoff with a default initial backoff of 30 seconds and a maximum of 720 seconds is suggested.

The router MAY restrict the set of IP addresses from which it will accept connections. It SHOULD restrict the number of simultaneous connections it will permit from a given IP address. The default value for this restriction SHOULD be 1, though an implementation MAY permit this restriction to be disabled in configuration. The router MUST also restrict the rate at which sessions may be established. A suggested default is an establishment rate of 2 sessions per minute.

A router (or management station) MAY implement logic to detect redundant connections, as might occur if both parties are configured to be active, and MAY elect to terminate redundant connections. A Termination reason code is defined for this purpose.

Once a connection is established, the router sends messages over it. There is no initialization or handshaking phase, messages are simply sent as soon as the connection is established.

If the monitoring station intends to restart BMP processing, it simply drops the connection, optionally with a Termination message.

[3.3.](#) Lifecycle of a BMP Session

A router is configured to speak BMP with one more monitoring

stations. It MAY be configured to send monitoring information for only a subset of its BGP peers. Otherwise, all BGP peers are assumed to be monitored.

A BMP session begins when the active party (either router or management station, as determined by configuration) successfully opens a TCP session (the "BMP session"). Once the session is up, the router begins to send BMP messages. It MUST begin by sending an Initiation message. It subsequently sends a Peer Up message over the BMP session for each of its monitored BGP peers which are in Established state. It follows by sending the contents of its Adj-RIBs-In (pre-policy, post-policy or both, see [Section 5](#)) encapsulated in Route Monitoring messages. Once it has sent all the routes for a given peer, it sends an End-of-RIB message for that peer; when End-of-RIB has been sent for each monitored peer, the initial table dump has completed. (A monitoring station that wishes only to gather a table dump could close the connection once it has gathered an End-of-RIB or Peer Down message corresponding to each Peer Up message.)

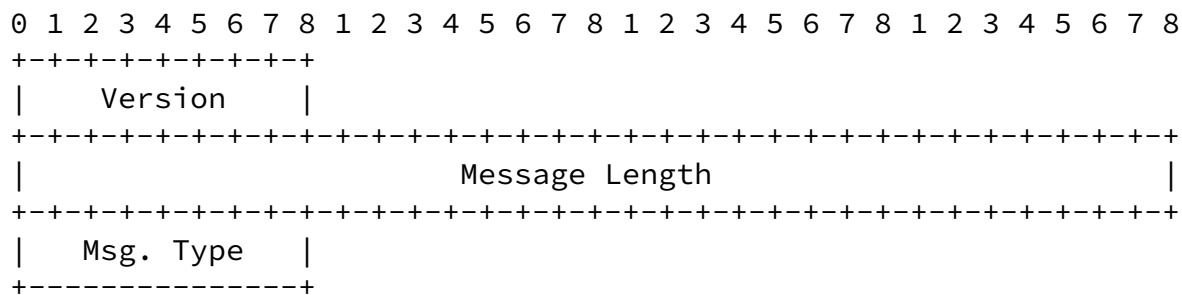
Following the initial table dump, the router sends incremental updates encapsulated in Route Monitoring messages. It MAY periodically send Stats Reports or even new Initiation messages, according to configuration. If any new monitored BGP peers become Established, corresponding Peer Up messages are sent. If any BGP peers for which Peer Up messages were sent transition out of the Established state, corresponding Peer Down messages are sent.

A BMP session ends when the TCP session that carries it is closed for any reason. The router MAY send a Termination message prior to closing the session.

[4.](#) BMP Message Format

[4.1.](#) Common Header

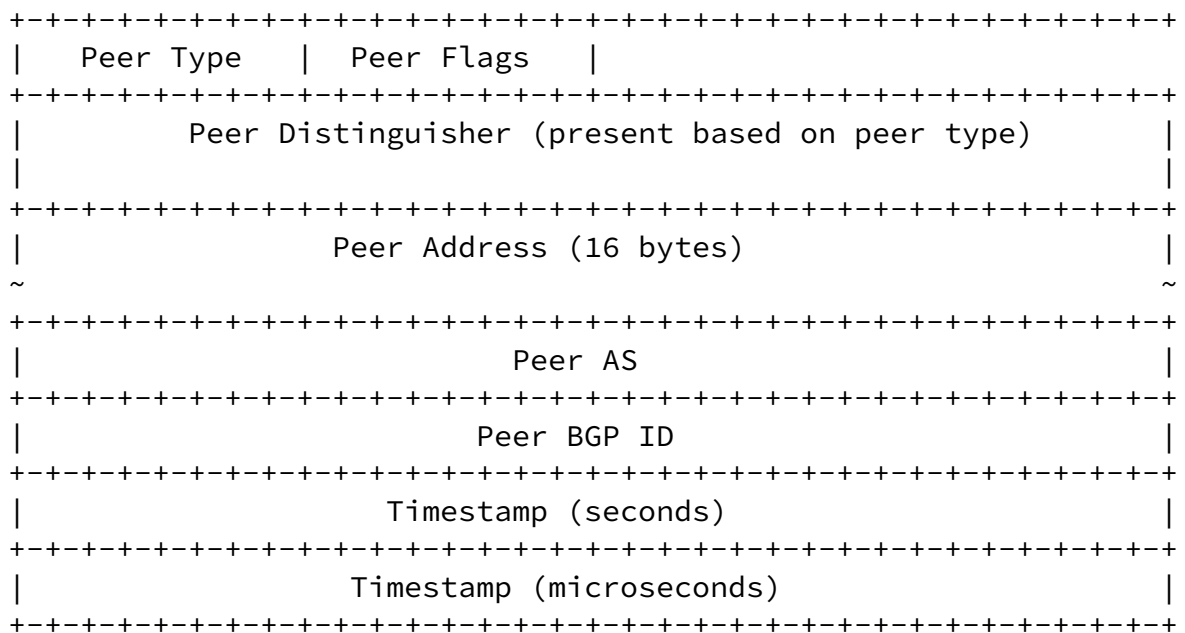
The following common header appears in all BMP messages. The rest of the data in a BMP message is dependent on the "Message Type" field in the common header.



- o Version (1 byte): Indicates the BMP version. This is set to '3' for all messages defined in this specification. Version 0 is reserved and MUST NOT be sent.
- o Message Length (4 bytes): Length of the message in bytes (including headers, data and encapsulated messages, if any).
- o Message Type (1 byte): This identifies the type of the BMP message. A BMP implementation MUST ignore unrecognized message types upon receipt.
 - * Type = 0: Route Monitoring
 - * Type = 1: Statistics Report
 - * Type = 2: Peer Down Notification
 - * Type = 3: Peer Up Notification
 - * Type = 4: Initiation Message
 - * Type = 5: Termination Message

[4.2.](#) Per-Peer Header

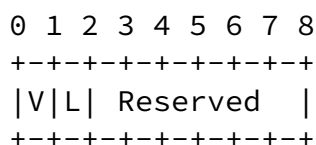
The per-peer header follows the common header for most BMP messages. The rest of the data in a BMP message is dependent on the "Message Type" field in the common header.



o Peer Type (1 byte): These bits identify the type of the peer. Currently only two types of peers are identified,

- * Peer Type = 0: Global Instance Peer
- * Peer Type = 1: L3 VPN Instance Peer

o Peer Flags (1 byte): These flags provide more information about the peer. The flags are defined as follows.



- * The V flag indicates the the Peer address is an IPv6 address. For IPv4 peers this is set to 0.
- * The L flag, if set to 1, indicates that the message reflects the post-policy Adj-RIB-In (i.e., it reflects the application of inbound policy). It is set to 0 if the message reflects the pre-policy Adj-RIB-In. See [Section 5](#) for further detail.
- * The remaining bits are reserved for future use.

o Peer Distinguisher (8 bytes): Routers today can have multiple instances (example L3VPNs). This field is present to distinguish peers that belong to one address domain from the other.

If the peer is a "Global Instance Peer", this field is zero

filled. If the peer is a "L3VPN Instance Peer", it is set to the route distinguisher of the particular L3VPN instance that the peer belongs to.

- o Peer Address: The remote IP address associated with the TCP session over which the encapsulated PDU was received. It is 4 bytes long if an IPv4 address is carried in this field (with most significant bytes zero filled) and 16 bytes long if an IPv6 address is carried in this field.
- o Peer AS: The Autonomous System number of the peer from which the encapsulated PDU was received. If a 16 bit AS number is stored in this field [[RFC4893](#)], it should be padded with zeroes in the most significant bits.
- o Peer BGP ID: The BGP Identifier of the peer from which the encapsulated PDU was received.
- o Timestamp: The time when the encapsulated routes were received (one may also think of this as the time when they were installed in the Adj-RIB-In), expressed in seconds and microseconds since midnight (zero hour), January 1, 1970 (UTC). If zero, the time is unavailable. Precision of the timestamp is implementation-dependent.

[4.3.](#) Initiation Message

The initiation message provides a means for the monitored router to inform the monitoring station of its vendor, software version, and so on. An initiation message **MUST** be sent as the first message after the TCP session comes up. An initiation message **MAY** be sent at any point thereafter, if warranted by a change on the monitored router.

The initiation message consists of the common BMP header followed by two or more TLVs containing information about the monitored router, as follows:

```

0 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Information Type           |           Information Length           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Information (variable)                                     |
~                                                                               ~
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

- o Information Type (2 bytes): Type of information provided. Defined


```

+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     Information (variable)                                     |
~                                                                                             ~
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

- o Information Type (2 bytes): Type of information provided. Defined types are:

- * Type = 0: String. The Information field contains a free-form UTF-8 string whose length is given by the "Information Length" field. Inclusion of this TLV is optional. It MAY be used to provide further detail for any of the defined reasons. Multiple String TLVs MAY be included in the message.
- * Type = 1: Reason. The Information field contains a two-byte code indicating the reason the connection was terminated. Some reasons may have further TLVs associated with them. Inclusion of this TLV is not optional. Defined reasons are:
 - + Reason = 0: Session administratively closed.
 - + Reason = 1: Unspecified reason.
 - + Reason = 2: Out of resources. The router has exhausted resources available for the BMP session.
 - + Reason = 3: Redundant connection. The router has determined that this connection is redundant with another one.
- o Information Length (2 bytes): The length of the following Information field, in bytes.
- o Information (variable): Information about the monitored router, according to the type.

[4.5.](#) Route Monitoring

Route Monitoring messages are used for initial synchronization of ADJ-RIBs-In. They are also used for ongoing monitoring of received advertisements and withdraws. This is discussed in more detail in

[Section 5.](#)

Following the common BMP header and per-peer header is a BGP Update PDU.

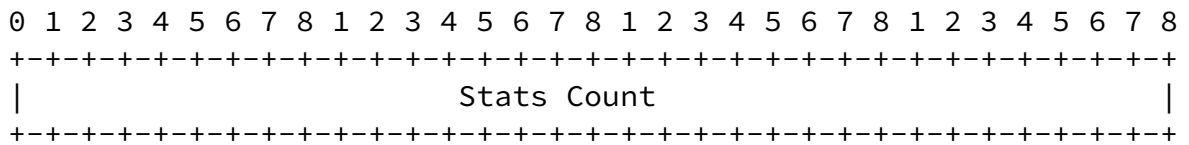
[4.6.](#) Stats Reports

These messages contain information that could be used by the monitoring station to observe interesting events that occur on the router.

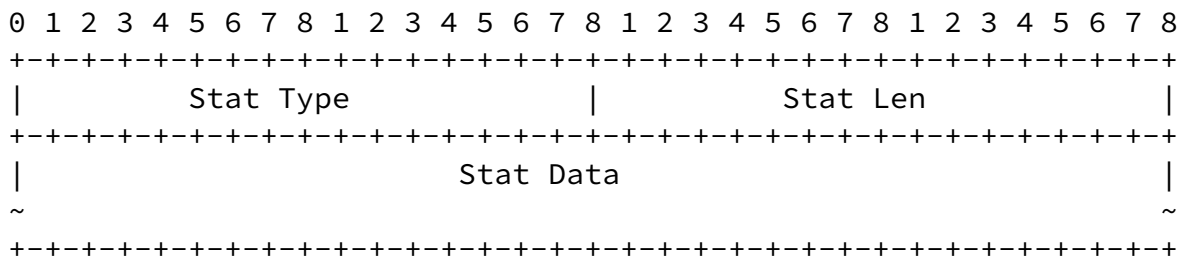
Transmission of SR messages could be timer triggered or event driven (for example, when a significant event occurs or a threshold is reached). This specification does not impose any timing restrictions on when and on what event these reports have to be transmitted. It is left to the implementation to determine transmission timings --

however, configuration control should be provided of the timer and/or threshold values. This document only specifies the form and content of SR messages.

Following the common BMP header and per-peer header is a 4-byte field that indicates the number of counters in the stats message where each counter is encoded as a TLV.



Each counter is encoded as follows,



- o Stat Type (2 bytes): Defines the type of the statistic carried in the "Stat Data" field.
- o Stat Len (2 bytes): Defines the length of the "Stat Data" Field.

This specification defines the following statistics. A BMP implementation MUST ignore unrecognized stat types on receipt, and likewise MUST ignore unexpected data in the Stat Data field.

Stats are either counters or gauges, defined as follows after the examples of [\[RFC1155\] Section 3.2.3.3](#) and [\[RFC2856\] Section 4](#) respectively:

32-bit Counter: A non-negative integer which monotonically increases until it reaches a maximum value, when it wraps around and starts increasing again from zero. It has a maximum value of $2^{32}-1$ (4294967295 decimal).

64-bit Gauge: non-negative integer, which may increase or decrease, but shall never exceed a maximum value, nor fall below a minimum value. The maximum value can not be greater than $2^{64}-1$ (18446744073709551615 decimal), and the minimum value can not be smaller than 0. The value has its maximum value whenever the

information being modeled is greater than or equal to its maximum value, and has its minimum value whenever the information being modeled is smaller than or equal to its minimum value. If the information being modeled subsequently decreases below (increases above) the maximum (minimum) value, the 64-bit Gauge also decreases (increases).

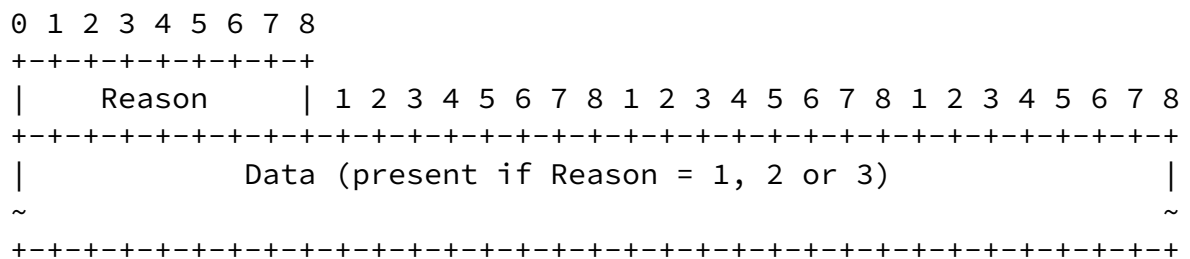
- o Stat Type = 0: (32-bit Counter) Number of prefixes rejected by inbound policy.
- o Stat Type = 1: (32-bit Counter) Number of (known) duplicate prefix advertisements.
- o Stat Type = 2: (32-bit Counter) Number of (known) duplicate withdraws.
- o Stat Type = 3: (32-bit Counter) Number of updates invalidated due to CLUSTER_LIST loop.

- o Stat Type = 4: (32-bit Counter) Number of updates invalidated due to AS_PATH loop.
- o Stat Type = 5: (32-bit Counter) Number of updates invalidated due to ORIGINATOR_ID.
- o Stat Type = 6: (32-bit Counter) Number of updates invalidated due to AS_CONFED loop.
- o Stat Type = 7: (64-bit Gauge) Number of routes in Adj-RIBs-In.
- o Stat Type = 8: (64-bit Gauge) Number of routes in Loc-RIB.

Note that although the current specification only specifies 4-byte counters and 8-byte gauges as "Stat Data", this does not preclude future versions from incorporating more complex TLV-type "Stat Data" (for example, one which can carry prefix specific data). SR messages are optional. However if an SR message is transmitted, at least one statistic MUST be carried in it.

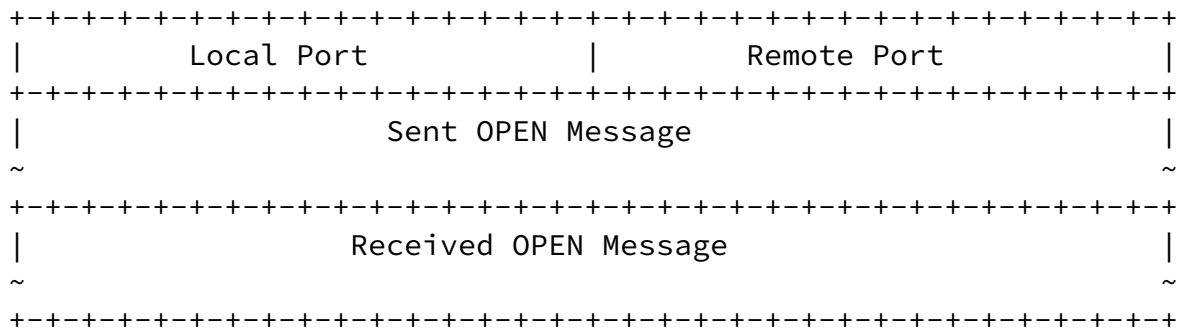
[4.7.](#) Peer Down Notification

This message is used to indicate that a peering session was terminated.



Reason indicates why the session was closed. Defined values are:

- o Reason 1: The local system closed the session. Following the



- o Local Address: The local IP address associated with the peering TCP session. It is 4 bytes long if an IPv4 address is carried in this field, as determined by the V flag (with most significant bytes zero filled) and 16 bytes long if an IPv6 address is carried in this field.
- o Local Port: The local port number associated with the peering TCP session.
- o Remote Port: The remote port number associated with the peering TCP session. (Note that the remote address can be found in the Peer Address field of the fixed header.)
- o Sent OPEN Message: The full OPEN message transmitted by the monitored router to its peer.
- o Received OPEN Message: The full OPEN message received by the monitored router from its peer.

5. Route Monitoring

After the BMP session is up, Route Monitoring messages are used to provide a snapshot of the Adj-RIB-In of each monitored peer. This is done by sending all routes stored in the Adj-RIB-In of those peers using standard BGP Update messages, encapsulated in Route Monitoring messages. There is no requirement on the ordering of messages in the peer dumps. When the initial dump is completed for a given peer, this MUST be indicated by sending an End-of-RIB marker for that peer (as specified in [Section 2 of \[RFC4724\]](#), plus the BMP encapsulation header). See also [Section 8](#).

A BMP speaker may send pre-policy routes, post-policy routes, or both. The selection may be due to implementation constraints (it is

possible that a BGP implementation may not store, for example, routes which have been filtered out by policy). Pre-policy routes MUST have their L flag clear in the BMP header (see [Section 4](#)), post-policy routes MUST have their L flag set. When an implementation chooses to send both pre- and post-policy routes, it is effectively multiplexing two update streams onto the BMP session. The streams are distinguished by their L flags.

If the implementation is able to provide information about when routes were received, it MAY provide such information in the BMP timestamp field. Otherwise, the BMP timestamp field MUST be set to zero, indicating that time is not available.

AS Numbers in the BMP UPDATE message MUST be sent as 4-octet quantities, as described in [[RFC4893](#)]. This affects the AS_PATH and AGGREGATOR path attributes. AS4_PATH or AS4_AGGREGATOR path attributes MUST NOT be sent in a BMP UPDATE message, as it makes no sense to do so.

Ongoing monitoring is accomplished by propagating route changes in BGP Update PDUs and forwarding those PDUs to the monitoring station, again using RM messages. When a change occurs to a route, such as an attribute change, the router must update the monitor with the new attribute. As discussed above, it MAY generate either an update with the L flag clear, with it set, or two updates, one with the L flag clear and the other with the L flag set. When a route is withdrawn by a peer, a corresponding withdraw is sent to the monitor. The withdraw MUST have its L flag set to correspond to that of any previous announcement; if the route in question was previously announced with L flag both clear and set, the withdraw MUST similarly be sent twice, with L flag clear and set. Multiple changed routes MAY be grouped into a single BGP UPDATE PDU when feasible, exactly as in the standard BGP protocol.

It's important to note that RM messages are not real time replicated messages received from a peer. While the router should attempt to generate updates as soon as they are received there is a finite time that could elapse between reception of an update and the generation an RM message and its transmission to the monitoring station. If there are state changes in the interim for that prefix, it is acceptable that the router generate the final state of that prefix to the monitoring station. The actual PDU generated and transmitted to the station might also differ from the exact PDU received from the peer, for example due to differences between how different implementations format path attributes.

[6.](#) Stat Reports

As outlined above, SR messages are used to monitor specific events and counters on the monitored router. One type of monitoring could be to find out if there are an undue number of route advertisements and withdraws happening (churn) on the monitored router. Another metric is to evaluate the number of looped AS-Paths on the router.

While this document proposes a small set of counters to begin with, the authors envision this list may grow in the future with new applications that require BMP style monitoring.

[7.](#) Other Considerations

Some routers may support multiple instances of the BGP protocol, for example as "logical routers" or through some other facility. The BMP protocol relates to a single instance of BGP; thus, if a router supports multiple BGP instances it should also support multiple BMP instances (one per BGP instance).

[8.](#) Using BMP

Once the BMP session is established route monitoring starts dumping the current snapshot as well as incremental changes simultaneously.

It is fine to have these operations occur concurrently. If the initial dump visits a route and subsequently a withdraw is received, this will be forwarded to the monitoring station which would have to correlate and reflect the deletion of that route in its internal state. This is an operation a monitoring station would need to support regardless.

If the router receives a withdraw for a prefix even before the peer dump procedure visits that prefix, then the router would clean up that route from its internal state and will not forward it to the monitoring station. In this case, the monitoring station may receive a bogus withdraw which it can safely ignore.

9. IANA Considerations

IANA is requested to create the following registries.

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9.1. BMP Message Types

This document defines five message types for transferring BGP messages between cooperating systems ([Section 4](#)):

- o Type 0: Route Monitor
- o Type 1: Statistics Report
- o Type 2: Peer Down Notification
- o Type 3: Peer Up Notification
- o Type 4: Initiation
- o Type 5: Termination

Type values 6 through 128 MUST be assigned using the "Standards Action" policy, and values 129 through 255 using the "Specification Required" policy defined in [[RFC5226](#)].

9.2. BMP Statistics Types

This document defines nine statistics types for statistics reporting ([Section 4.6](#)):

- o Stat Type = 0: Number of prefixes rejected by inbound policy.
- o Stat Type = 1: Number of (known) duplicate prefix advertisements.
- o Stat Type = 2: Number of (known) duplicate withdraws.
- o Stat Type = 3: Number of updates invalidated due to CLUSTER_LIST loop.
- o Stat Type = 4: Number of updates invalidated due to AS_PATH loop.
- o Stat Type = 5: Number of updates invalidated due to ORIGINATOR_ID.
- o Stat Type = 6: Number of updates invalidated due to a loop found in AS_CONFED_SEQUENCE or AS_CONFED_SET.
- o Stat Type = 7: Number of routes in Adj-RIBs-In.
- o Stat Type = 8: Number of routes in Loc-RIB.

Stat Type values 9 through 32767 MUST be assigned using the "Standards Action" policy, and values 32768 through 65535 using the "Specification Required" policy, defined in [[RFC5226](#)].

[9.3.](#) BMP Initiation Message TLVs

This document defines three types for information carried in the Initiation message ([Section 4.3](#)):

- o Type = 0: String.
- o Type = 1: sysDescr.
- o Type = 2: sysName.

Information type values 3 through 32767 MUST be assigned using the "Standards Action" policy, and values 32768 through 65535 using the

"Specification Required" policy, defined in [[RFC5226](#)].

[9.4.](#) BMP Termination Message TLVs

This document defines two types for information carried in the Termination message ([Section 4.4](#)):

- o Type = 0: String.
- o Type = 1: Reason.

Information type values 2 through 32767 MUST be assigned using the "Standards Action" policy, and values 32768 through 65535 using the "Specification Required" policy, defined in [[RFC5226](#)].

[9.5.](#) BMP Termination Message Reason Codes

This document defines four types for information carried in the Termination message ([Section 4.4](#)) Reason code,:

- o Type = 0: Administratively closed.
- o Type = 1: Unspecified reason.
- o Type = 2: Out of resources.
- o Type = 3: Redundant connection.

Information type values 4 through 32767 MUST be assigned using the "Standards Action" policy, and values 32768 through 65535 using the

"Specification Required" policy, defined in [[RFC5226](#)].

10. Security Considerations

This document defines a mechanism to obtain a full dump or provide continuous monitoring of a BGP speaker's local BGP table, including received BGP messages. This capability could allow an outside party to obtain information not otherwise obtainable.

Implementations of this protocol MUST require manual configuration of the monitored and monitoring devices.

Users of this protocol MAY use some type of secure transport mechanism, such as IPSec [[RFC4303](#)] or TCP-AO [[RFC5925](#)], in order to provide mutual authentication, data integrity and transport protection.

Unless a transport that provides mutual authentication is used, an attacker could masquerade as the monitored router and trick a monitoring station into accepting false information.

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11. Acknowledgements

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Appendix A. Changes Between BMP Versions 1 and 2

- o Added Peer Up Message
- o Added L flag
- o Editorial changes

Appendix B. Changes Between BMP Versions 2 and 3

- o Added a 32-bit length field to the fixed header.
- o Clarified error handling.
- o Added new stat types: 5 (number of updates invalidated due to

- ORIGINATOR_ID), 6 (number of updates invalidated due to AS_CONFED_SEQUENCE/AS_CONFED_SET), 7 (number of routes in Adj-RIB-In) and 8 (number of routes in Loc-RIB).
- o Defined counters and gauges for use with stat types.
 - o For peer down messages, the relevant FSM event is to be sent in type 2 messages.
 - o Added local address and local and remote ports to the peer up message.
 - o Require End-of-RIB marker after initial dump.
 - o Added Initiation message with string content.
 - o Permit multiplexing pre- and post-policy feeds onto a single BMP session.
 - o Changed assignment policy for IANA registries.
 - o Changed "Loc-RIB" references to refer to "Post-Policy Adj-RIB-In", plus other editorial changes.
 - o Introduced option for monitoring station to be active party in initiating connection.
 - o Introduced Termination message.

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