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BMP v4: Extended TLV Support for BGP Monitoring Protocol (BMP)
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Abstract

Most of the BGP Monitoring Protocol (BMP) message types make provision for data in Type, Length, Value (TLV) format. However, Route Monitoring messages (which provide a snapshot of the monitored Routing Information Base) Stats Reports (which supply periodical counters) and Peer Down messages (which indicate that a peering session was terminated) do not. Supporting (optional) data in TLV format across all BMP message types provides consistent and extensible structures that would be useful among the various use-cases where conveying additional data to a monitoring station is required. This document updates RFC 7854 [RFC7854] to support TLV data in all message types and defines some essential TLVs.

Additionally, this document introduces support for enterprise-specific TLVs in the BGP Monitoring Protocol by defining an Enterprise Bit (E-bit) that allows usage of per-vendor Type values.

Status of This Memo

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1. Introduction

The BGP Monitoring Protocol (BMP) version 3 is defined in RFC 7854 [RFC7854].

The Route Monitoring message is defined in Section 4.6 of [RFC7854] and consists of:

- * Common Header
- * Per-Peer Header
- * BGP Update PDU

The Stats Reports message is defined in Section 4.8 of [RFC7854] and consists of:

- * Common Header
- * Per-Peer Header
- * Stats Count
- * Stats in TLV format

The Peer Down Notification message is defined in Section 4.9 of [RFC7854] and consists of:

- * Common Header
- * Per-Peer Header
- * Reason
- * Data (only if Reason code is 1, 2 or 3)
- * TLV (only if Reason code is 6)

This means that Route Monitoring, Stats Reports and Peer Down messages have a non-extensible format (except for the specific case of Peer Down Reason Code 6 as specified in Section 5.3 of [RFC9069]). In the Route Monitoring case, this prevents the transmission of parsing characteristics of transported NLRIs (e.g. ADD-PATH, Multi Labels, etc.), RIB status of a path (e.g. primary, backup, unused, etc.) or of vendor-specific data. In the Stats Reports and Peer Down case, this prevents matching with TLVs previously sent in other messages, including the Peer Up message. This document:

- * Bumps the BMP version for all message types defined in RFC 7854 [RFC7854] for backward compatibility
- * Changes the structure of Route Monitoring message type so that the BGP Update PDU is enclosed in a TLV. The BGP Message PDU TLV is mandatory
- * Allows all defined BMP message types to make provision for optional TLV data.

Also, vendors need the ability to define proprietary Information Elements for reasons such as delivering pre-standard products, this need aligns with Section 4.1 of [RFC8126]. The E-bit allows early development phases to interoperate among vendors by defining enterprise-specific TLVs without conflicting with existing IANA allocations.

The concept of an E-bit is not new. For example, such mechanism is defined in Section 3.2 of [RFC7011] for a very similar purpose.

2. Terminology

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 RFC 2119 [RFC2119] RFC 8174 [RFC8174] when, and only when, they appear in all capitals, as shown here.

The document uses the terms defined in RFC 7854 [RFC7854].

3. Message version

For an exporter to flag a receiver that it does comply with this specification, the Version field of the BMP Common header, documented in Section 4.4 of [RFC7854], MUST be set to 4. This applies to every BMP message type.

If a BMP station does not support the version indicated in the message, it SHOULD close the session and take the procedures described in Error Handling (Section 6)

4. TLV Encoding

The TLV data type (Information TLV) is defined in Section 4.4 of [RFC7854] for the Initiation and Peer Up message types. The definition is updated as described in IANA-registered TLV Encoding (Section 4.1) and further extended by Enterprise-specific TLV Encoding (Section 4.2), IANA-registered Indexed TLV Encoding (Section 4.3) and Enterprise-specific Indexed TLV Encoding (Section 4.4).

4.1. IANA-registered TLV Encoding

- * 1 bit to flag an enterprise-specific TLV, set to 0. The TLV Type value must have been defined in IANA-BMP [IANA-BMP]
- * 15 bits of TLV Type,
- * 2 octets of TLV Length, and
- * 0 or more octets of TLV Value.

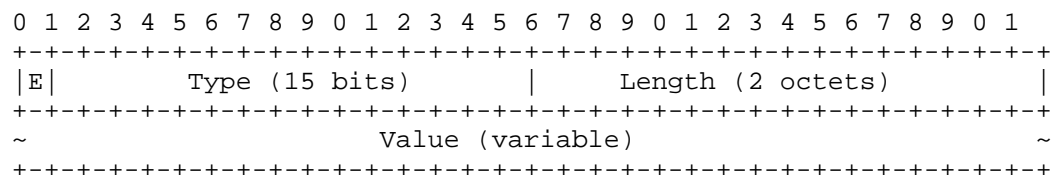


Figure 1

4.2. Enterprise-specific TLV Encoding

Enterprise-specific TLV encoding is defined as follows:

- * 1 bit to flag an enterprise-specific TLV, set to 1
- * 15 bits of TLV Type,
- * 2 octets of TLV length. Comprising length of IANA PEN plus TLV value,
- * 4 octets of IANA Private Enterprise Number IANA-PEN [IANA-PEN]
- * 0 or more octets of TLV Value.

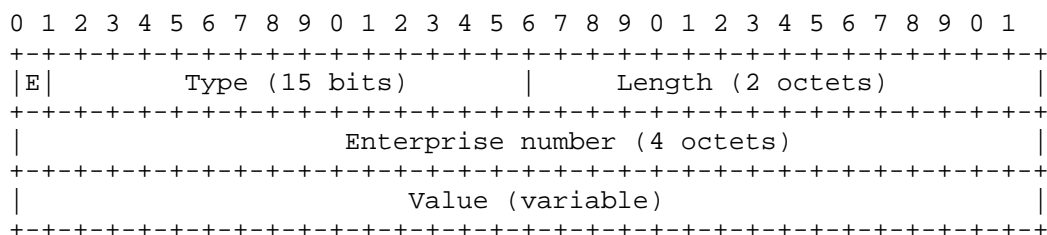


Figure 2

Stats Report messages are also encoded in a TLV-like fashion, as documented in Section 4.8 of [RFC7854]. E-bit does hence similarly apply to these messages too, with the most relevant bit of Stat Type set to 1 in order to flag the presence of a 4-bytes PEN field following Stat Len field and preceding Stat Data field, i.e.:

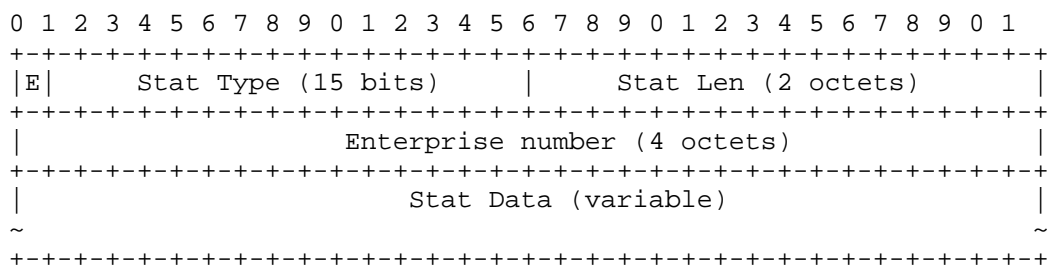


Figure 3

While the encoding is not per-se backward compatible, there is no existing IANA-allocated Type value that makes use of the most significant bit (which is being used in this document to define the E-bit), except the experimental and reserved ones mentioned in Section 10.5 of [RFC7854], Section 10.6 of [RFC7854] and Section 10.9 of [RFC7854]. Of these, the Experimental values are being suppressed in favor of using the E-bit mechanism described in this document; the Reserved value is instead excluded by the E-bit mechanism such that no PEN will be included as part of the TLV.

Future BMP Message Types MUST make use of the TLV encoding defined in this document.

4.3. IANA-registered Indexed TLV Encoding

Route Monitoring messages may require per-NLRI TLVs. That is, there may be a need to map TLVs to NLRIs contained in the BGP Update message, for example, to express additional characteristics of a specific NLRI. For this purpose, TLVs enclosed in a Route Monitoring message MUST be indexed, with the index starting at one (1) to refer to the first NLRI. Index zero (0) specifies that a TLV does apply to all NLRIs contained in the BGP Update message. The Index field is 2-byte long of which the top-most bit, G-bit, is used to flag a Group Index (more in Section 5.2.1). TLVs of the same type and with the same index can be repeated as part of the same message, unless specified otherwise by the definition of the specific TLV. Indexed TLVs are encoded as in the following figure:

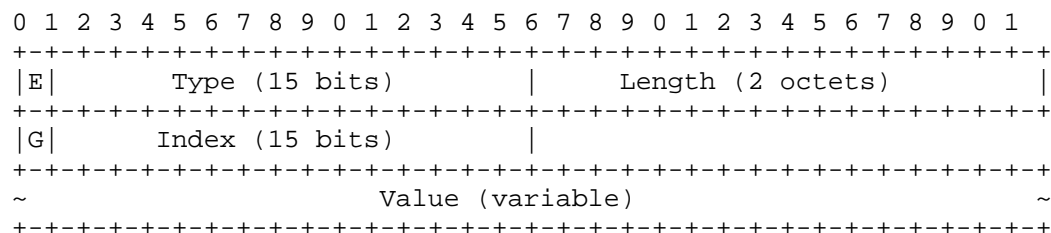


Figure 4

The reported length in indexed TLVs refers to the total encoded TLV value (ie. with the length of the index field excluded).

A monitoring station can properly match indexed TLVs to the corresponding NLRI only if - or as long as - NLRIs are decoded successfully. In case of any parsing or error condition that prevents full decoding of the BGP PDU, the station MUST stop matching indexed TLVs to NLRIs.

Of the BMP message types defined so far, indexed TLVs apply only to Route Monitoring messages. For example, they do not apply to Route Mirroring messages because a sender may not be aware of the payload of the transported BGP Update message.

4.4. Enterprise-specific Indexed TLV encoding

For completeness, following is an illustration of the structure of an Enterprise-specific Indexed TLV.

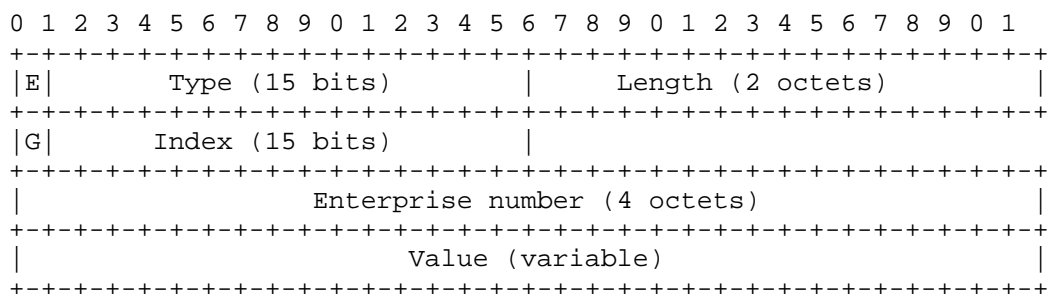


Figure 5

5. BMP Message Format

5.1. Common Header

While the structure of the Common header remains unaltered, the following two definitions are changed compared to Section 4.1 of [RFC7854]:

- * Version: Indicates the BMP version. This is set to '4' for all message types defined in RFC 7854 [RFC7854].
- * Message Length: Total length of the message in bytes (including headers, encapsulated BGP Message PDU TLV and optional TLV data).

5.2. TLV Data in Route Monitoring

For consistency with the Route Mirroring type defined in Section 4.7 of [RFC7854], this document extends the encoding of the Route Monitoring message type where the Per-peer header is followed by mandatory and optional TLVs.

The BGP Update PDU (Section 4.3 of [RFC4271]) is encoded itself as part of a BGP Message TLV with code point 7 and index set to 0. A Route Monitoring message MUST contain one BGP Message TLV which may be preceded or followed by other optional TLV data.

Corollary, the BGP Update PDU is not encoded as part of the message as it was the case for BMPv3 (RFC 7854 [RFC7854]) but it is rather enclosed in a TLV.

5.2.1. Group TLV

In a Route Monitoring message where a BGP Update PDU carries N NLRIs, indexed TLVs do allow to handle the cases of 1:1 and N:1 relationship among TLVs and NLRIs (ie. one TLV applies to one NLRI, N TLVs apply to one same NLRI). The cases of 1:N and M:N relationships (i.e., one TLV applies to N NLRIs and M TLVs apply to N NLRIs) can benefit by a form of grouping. For that purpose, a Group TLV is defined with the aim to limit both verbosity and repetitions.

The 2-byte index defines a new Group Index and the top-most bit (G-bit) MUST be set to 1. The full 2-byte value, that is including the G-bit, MUST be unique to the message

The value carries two or more 2-byte NLRI indexes whose values MUST be less or equal to the amount of NLRIs packed in the BGP Update PDU.

An NLRI index can be listed as part of multiple Group TLVs within the same message. NLRI indexes within a Group TLV SHOULD be sorted by the sender. A Group Index MUST NOT reference an NLRI index 0. A Group TLV MUST NOT include its own or another Group Index. Multiple non-Group TLVs MAY point to the same Group Index, i.e., a group can be reused within the same Route Monitoring message.

The Group TLV type is 4. It is RECOMMENDED that this TLV is encoded first in order to ease parsing of the Route Monitoring message at the BMP station side.

5.2.2. VRF/Table Name TLV

The Information field contains a UTF-8 string whose value MUST be equal to the value of the VRF or table name (i.e., RD instance name) being conveyed. The string size MUST be within the range of 1 to 255 bytes. This is in line with Section 5.2.1 of [RFC9069].

The VRF/Table Name TLV type is 5

5.2.3. Stateless Parsing TLV

Stateless parsing helps scaling the amount of Route Monitoring messages that can be processed at collection time, avoiding to have to correlate them to BGP capabilities received as part of the Peer Up message, for example.

Some BGP capabilities are not per AFI/SAFI, like 4-byte ASN RFC 6793 [RFC6793], and hence these can potentially be part of the BMP Peer flags [IANA-BPPF] of a Route Monitoring message. Those that are, instead, per AFI/SAFI require finer granularity and hence the need to

use an indexed TLV. To maintain the consistency between BGP Capabilities, they are all carried in Stateless Parsing TLVs, regardless of their type.

The encoding of BGP Capabilities is already generically defined in Section 4 of [RFC5492]. It includes every information needed for its understanding, including AFI/SAFI codes. This encoding can be reused in the Stateless Parsing TLV, leveraging already existing BGP encoders and decoders for implementers.

The Stateless Parsing TLV type is 6 and its Value is the BGP Capability encoded as exactly as it would be in the BGP OPEN of the session. It is thus made of all three Capability Code, Capability Length, and Capability Value fields defined in [RFC5492].

For example, an ADD-PATH capability, as defined by RFC 7911 [RFC7911], for IP/Unicast with value Send/Receive would be encoded in the Capability Value as:

- * Capability Code, 1 byte, value=69
- * Capability Length, 1 byte, value=4
- * AFI, 2 bytes, value=1
- * SAFI, 1 byte, value=1
- * Value, 1 byte, value=3

The index of the Stateless Parsing TLV MUST be set to 0.

If no Stateless Parsing TLV is present in a Route Monitoring message, the receiver MUST fall back to use capabilities present in the BGP Open PDU contained in the relevant BMP Peer Up message in order to properly parse BGP Update PDUs. Each BGP capability is to be encoded in a separate Stateless Parsing TLV.

It is RECOMMENDED that the Stateless Parsing TLV is encoded preceding the BGP Message TLV in order to ease parsing of the Route Monitoring message at the BMP station side.

5.3. TLV Data in Peer Down

The Peer Down Notification message type (Section 4.9 of [RFC7854]) is extended following a consistent approach with the Peer Up type (Section 4.10 of [RFC7854]). That is, the message is extended so that optional TLVs are placed at the end of the message.

This means for Reason codes 1 or 3, a BGP Notification PDU follows; the PDU MAY be further followed by TLV data. For Reason code 2, a 2-byte field follows to provide additional Finite State Machine (FSM) info; this field MAY be followed by TLV data. For all other Reason codes, TLV data MAY follow the Reason field.

5.4. TLV Data in Stats Reports

The Stats Reports message is extended so that the Stats Count and stats data as defined in Section 4.8 of [RFC7854] are all enclosed inside a Stats TLV with code- point 1. The Stats TLV is mandatory and can be followed by optional TLV data.

While the Stats Count field could be used to discriminate among stats data and trailing optional TLV data, it is felt that enclosing Stats Count and stats data inside a container TLV is cleaner by embracing a fully TLV'd body.

5.5. TLV Data in Other BMP Messages

All other message types defined in RFC7854 [RFC7854] do already provision for TLV data. It is RECOMMENDED that all future defined BMP message types will also provide for optional TLV data following a consistency model for encoding with existing message types.

5.6. New TLVs in all BMP Messages

In this section some TLVs are introduced that apply to all existing BMP message types and as such will need a code point reserved in all TLV registries, namely: BMP Initiation Information TLVs, BMP Termination Message TLVs, BMP Route Mirroring TLVs along with registries defined in this document BMP Route Monitoring TLVs and BMP Peer Up and Peer Down TLVs. We thus request IANA to allocate, for each TLV, the same codepoint value in every TLV codepoint registry of this document, as detailed in their respective sections.

5.6.1. Timestamp TLV

The Timestamp TLV carries one of multiple types of Timestamp for a BMP message. For each TLV registry seeded in this document, the code point of the Timestamp TLV is 3.

The value of the TLV is the Timestamp Type code, defined in Table 1, followed by the timestamp values expressed in seconds and microseconds since midnight (zero hour), January 1, 1970 (UTC).

The encoding of the timestamp is identical to existing BMP documents [RFC7854], [RFC8671], and [RFC9069], except that the timestamp MUST NOT be set to zero to indicate unavailability. The Timestamp TLV is optional, a timestamp MUST NOT be included if it is not available.

The value of the Length field is 9 bytes (1 byte for the Timestamp Type field plus the length of the Timestamp fields which are 4 bytes each). The Index field is not included in the length.

The TLV structure is illustrated in Figure 6.

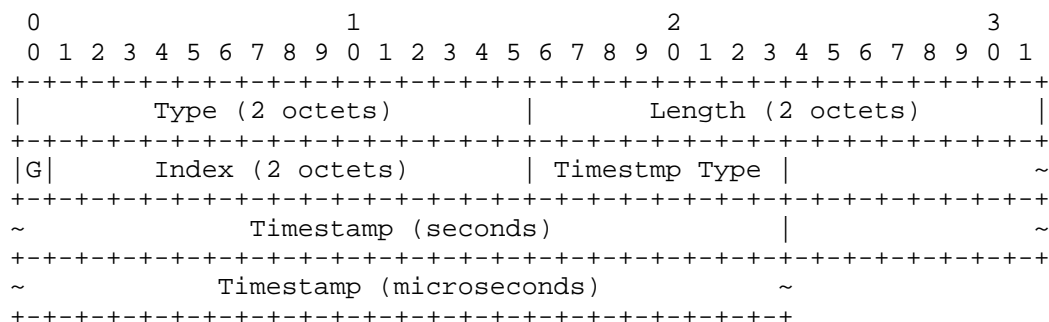


Figure 6: Timestamp TLV

The Section 5.6.1.1 defines the list of currently defined Timestamp Types.

5.6.1.1. Timestamp Types

The Table 1 defines the list of timestamp types that can be carried in the Timestamp TLV. Each timestamp type is described in the section associated with its name and code in the table.

Code	Name	Section
0x00	Trigger Time	Section 5.6.1.1.1
0x01	Message Export Time	Section 5.6.1.1.2
0x02	Adj-RIB-In Time	Section 5.6.1.1.3
0x03	Local-RIB Time	Section 5.6.1.1.4
0x04	Adj-RIB-Out Time	Section 5.6.1.1.5

Table 1

5.6.1.1.1. Trigger Time

The Trigger Time is the timestamp of the event which triggered BMP to report the event. This might be a received message, a BGP peering or a BMP session going down or up, etc.

5.6.1.1.2. Message Export Time

The Message Export Time is the time at which BMP generates the BMP message.

5.6.1.1.3. Adj-RIB-In Time

The Adj-In Time is the time at which the route has been installed in the Adj-RIB-In, as per [RFC7854].

5.6.1.1.4. Local-RIB Time

The Local-RIB Time is the time at which the route has been installed in the Local-RIB, as per [RFC9069].

5.6.1.1.5. Adj-RIB-Out Time

The Adj-Out Time is the time at which the route has been installed in the Adj-RIB-Out, as per [RFC8671].

5.6.2. Sequence Number TLV

The Sequence Number TLV carries the sequence number of a message in a BMP session. For each TLV registry seeded in this document, the code point of the Sequence Number TLV is 1.

Ordering of BMP messages based on timestamp becomes complicated when timestamps have conflicting meanings or when they are simply unavailable. A Sequence Number on a per BMP session basis allows the operator to easily and uniquely identify BMP messages on a BMP session.

The value of the TLV is the sequence number of the BMP message in the BMP session, starting at 0, and encoded on 8 bytes. If the sequence number would overflow, the BMP session MUST be reset.

The value of the Length field is 8. The Index field is not included in the length.

The TLV structure is illustrated in Figure 7.

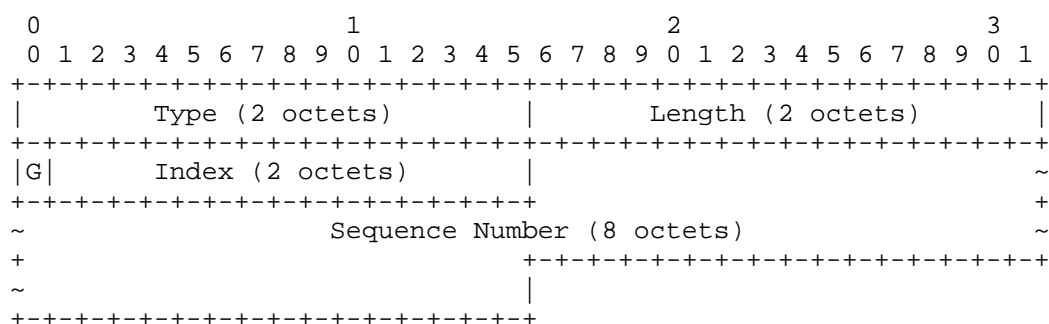


Figure 7: Sequence Number TLV

5.6.3. Extended Flags TLV

The Extended Flags TLV carries the Flags field usually present in the Per-Peer Header, while extending the length of the field. This allows for a larger range of flags to be allocated in the future. For each TLV registry seeded in this document, the code point of the Extended Flags TLV is 2.

The value of the TLV is a sequence of bytes of variable size. The minimum size of the sequence is one, to fit at least the already existing flags. The flags carried in this TLV are defined in the BMP Extended Peer Flags IANA registry defined by this document. The first byte of the sequence carries all flags defined previous to this document, that is Flags V, L, A, O, and F. Newly allocated bits will be carried in the following byte of the sequence.

The value of the Length field is the number of bytes in the sequence. The Index field is not included in the length.

The Index field is set to 0 to indicate the global scope of the TLV.

The TLV structure is illustrated in Figure 8.

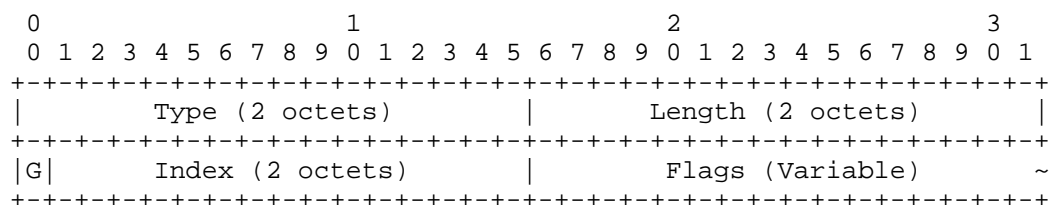


Figure 8: Extended Flags TLV

When this TLV is included in a BMP message, the rightmost bit (X Flag) of the Per-Peer Header Flags MUST be set to 1 to indicate that the flags to consider are carried in this TLV. The flags in the Per-Peer Header are still set according to the current specification, allowing collectors that do not understand the X Flag and Extended Flags TLV to still function.

6. Error Handling

RFC8654 [RFC8654] permits BGP Update and other messages to grow to a length of 65535 octets. This may cause a BMP PDU that attempts to encapsulate such long messages to overflow.

A BMP exporter and a BMP station may not support the same version of the protocol; being BMP uni-directional, with data flowing only from the exporter to the station, the station SHOULD close the BMP session and log the condition as a warning; the exporter SHOULD retry to connect with a non-aggressive timer.

A BMP station may not support some of the TLVs encoded by the exporter; the station MUST ignore unsupported TLV types; additionally, in case of indexed TLVs, if the index is invalid (i.e. out of bounds), the TLV MUST be ignored. The station SHOULD log the condition as a warning.

7. Security Considerations

It is not believed that this document adds any additional security considerations compared to RFC7854 [RFC7854].

8. Operational Considerations

In Route Monitoring messages, the number of TLVs can be bound to the amount of NLRIs carried in the BGP Update message. This may degrade the packing of information in such messages and have specific impacts on the memory and CPU used in a BMP implementation. As a result of that it should always be possible to disable such features to mitigate their impact.

TLVs SHOULD be sorted by the sender by their type. Multiple TLVs of the same type can be repeated as part of the same message; it is left to the specific use-cases whether all, any, the first or the last TLV should be considered as well as whether ordering matters and repeating is allowed.

It is recommended that implementors making use of the Enterprise Bit extension have a well-defined internal registry for privately assigned code points that is also exposed to the public.

9. IANA Considerations

This document requests IANA to rename of the "BMP Peer Up Message TLVs" registry defined by BMP Peer Up Message Namespace [RFC9736] into "BMP Peer Up and Peer Down TLVs" and the definition of one new registry "BMP Route Monitoring TLVs". The new "BMP Route Monitoring TLVs" registry is seeded with the following new TLV types (Section 5.2):

- * Type = 1: Support for Sequence TLV. The value field is defined in Section 5.6.2.
- * Type = 2: Support for Extended Flags TLV. The value field is defined in Section 5.6.3.
- * Type = 3: Support for Timestamp TLV. The value field is defined in Section 5.6.1.
- * Type = 4: Support for grouping of TLVs. The value field is defined in Section 5.2.1.
- * Type = 5: Support for VRF/Table Name TLV. The value field is defined in Section 5.2.2.
- * Type = 6: Support for Stateless Parsing TLV. The value field is defined in Section 5.2.3.
- * Type = 7: Support for BGP Message TLV. The value field is defined in Section 5.2.

It is requested the definition of a new "BMP Stats Reports TLVs" registry seeded with the following new TLV types (Section 5.4):

- * Type = 1: Support for Stats TLV to enclose Stats Count and stats data.
- * Type = 1: Support for Sequence TLV. The value field is defined in Section 5.6.2.
- * Type = 2: Support for Extended Flags TLV. The value field is defined in Section 5.6.3.
- * Type = 3: Support for Timestamp TLV. The value field is defined in Section 5.6.1.

Values 0 through 16383 of the "BMP Route Monitoring TLVs" and BMP Stats Reports TLVs" registries MUST be assigned using the Standards Action policy as defined in Section 4.9 of [RFC8126]; values 16384 through 32767 MUST be assigned using the First Come First Served policy as defined in Section 4.4 of [RFC8126]. The upper bound of the registry is 65535. Value 65535 is Reserved.

The TLV Type values used by BMP are managed by IANA as are the Private Enterprise Numbers used by enterprise-specific Type values IANA-PEN [IANA-PEN].

For BMP Initiation Information TLVs, BMP Termination Message TLVs, BMP Peer Up and Peer Down TLVs and BMP Route Mirroring TLVs registries it is requested to make the range 0-16383 as Standards Action (down from current 0-32767); it also asks to make the range 16384-32767 as First Come First Served (in place of current 32768-65530).

This document also requests to remove the Experimental allocation from the same registries, the code points now flagged Experimental will become Unassigned. The top most bit of each registry will be reserved to the E-bit, reducing the Unassigned pool: the maximum available value for assignment for the registries will be 32767 (ie. as opposed to current 65530).

Finally, for the same registries, this document requests IANA to allocate the codepoints for Timestamp TLV (TBD1), Sequence Number TLV (TBD2) and Extended Flags TLV (TBD3). It is recommended that the code points are assigned consistently to the registry seeded in this document (ie. Timestamp TLV = 3 , etc.).

This document requests that IANA assigns the following new parameters to the BMP Peer Flags for Peer Types 0 through 2; registry and to the BMP Peer Flags for Loc-RIB Instance Peer Type registry:

- * Flag = 7: X Flag (Extended Flags). Set if the Flags are carried in the Extended Flags TLV instead of the Per-Peer Header.

This document also requests the definition of a BMP Extended Peer Flags; registry which contains flags contained in the Extended Flags TLV. The size of this registry is TBD. The registration policy for this registry is Standards Action as defined in [RFC8126].

The registry is seeded as follows:

- * Flag 0: V flag [RFC7854]
- * Flag 1: L flag [RFC7854]
- * Flag 2: A flag [RFC7854]
- * Flag 3: O flag [RFC8671]
- * Flag 4: F flag [RFC9069]

This document also requests the definition of a BMP Timestamp Types registry. This registry contains type codes for the kinds of timestamps carried by the Timestamp TLV. The size of the registry matches the size of the Timestamp Type field defined in Figure 6 which is 1 byte.

The registration policy for this registry is Expert Review as defined in [RFC8126].

The registry is seeded as follows:

- * Type = 0x00: Trigger Time. Set to 0x00 if the timestamp corresponds to the event that triggered BMP to report the route or state, such as receiving a message or a session transition.
- * Type = 0x01: Message Export Time. Set to 0x01 if the timestamp corresponds to the time when the BMP message was generated for export.
- * Type = 0x02: Adj-In Time. Set to 0x02 if the timestamp corresponds to when the route was installed in the Adj-RIB-In, as per [RFC7854].
- * Type = 0x03: Local-RIB Time. Set to 0x03 if the timestamp corresponds to when the route was installed in the Local-RIB, as per [RFC9069].
- * Type = 0x04: Adj-Out Time. Set to 0x04 if the timestamp corresponds to when the route was installed in the Adj-RIB-Out, as per [RFC8671].

10. References

10.1. Normative References

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Appendix A. Wire-format Example

The diagram in Figure 9 shows an example of a Route Monitoring message carrying a BGP UPDATE containing 10 NLRI's. The TLVs are comprised of:

1. a Group TLV with index 0x000b, pointing to NLRI 1, 2, 3 and 10
2. a Group TLV with index 0x000c, pointing to NLRI 4, 5 and 6

3. a Stateless Parsing TLV with index 0x0000, stating that the Add-Path Capability is set to Both (Snd/Rcv) for the IPv4 Unicast address family in the BGP UPDATE.
4. a TLV pertaining to NLRI 7
5. a TLV pertaining to the NLRIs listed in the Group TLV defined in 1
6. a TLV pertaining to the NLRIs listed in the Group TLV defined in 2

```

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
|          Common Header + Per-Peer Header (6 + 42 bytes)          ~
~                                                                    |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=2          |          length=0x0008          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|1|          index=0x0001    |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          value={0x0001,   0x0002,
|                      0x0003,   0x000a}
|
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=2          |          length=0x0006          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|1|          index=0x0002    |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          value={0x0004,   0x0005,
|                      0x0006}
|
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=4          |          length=0x0005          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          index=0          |          code=69          |          len=4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          afi=1          |          safi=1          |          value=3          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=1          |          length=X          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          index=0          |          value=$BGP_UPDATE_PDU{          ~
+-----+-----+-----+-----+-----+-----+-----+-----+
~                                                                    ~
~                                                                    ~
~          NLRI_1 .. NLRI_10          ~
~                                                                    ~
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=SomeTlvX          |          length=0x0004          |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

```

|1|          index=0x0001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          value={4 bytes}          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=SomeTlvY          |          length=0x0008          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|1|          index=0x0002          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          value={8 bytes}          |
~                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          type=SomeTlvZ          |          length=0x0008          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0|          index=0x0007          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          value={8 bytes}          |
~                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Figure 9

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