

Export of BGP Community Information in
IP Flow Information Export (IPFIX)

Abstract

By introducing new Information Elements (IEs), this document extends the existing BGP-related IEs to enable IP Flow Information Export (IPFIX) to export BGP community information, including the BGP Standard Communities defined in [RFC 1997](#), BGP Extended Communities defined in [RFC 4360](#), and BGP Large Communities defined in [RFC 8092](#). According to the network operator's BGP community planning, network traffic information can then be accumulated and analyzed at the BGP community granularity, which represents the traffic of different kinds of customers, services, or geographical regions. Network traffic information at the BGP community granularity is useful for network traffic analysis and engineering.

Status of This Memo

This is an Internet Standards Track document.

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Table of Contents

1. Introduction	3
2. Terminology	5
3. Traffic Collection Based on BGP Community	6
4. IEs for BGP Standard Community	7
5. IEs for BGP Extended Community	8
6. IEs for BGP Large Community	8
7. Operational Considerations	9
8. Security Considerations	10
9. IANA Considerations	11
10. References	13
10.1. Normative References	13
10.2. Informative References	14
Appendix A. Encoding Example	16
A.1. Template Record	16
A.2. Data Set	17
Acknowledgements	18
Authors' Addresses	18

1. Introduction

IP Flow Information Export (IPFIX) [RFC7011] provides network administrators with traffic flow information using the Information Elements (IEs) defined in the "IPFIX Information Elements" registry [IANA-IPFIX]. Based on the traffic flow information, network administrators know the amount and direction of the traffic in their network and can then optimize the network when needed. For example, the collected information could be used for traffic monitoring and, optionally, for traffic optimization according to the operator's policy.

The "IPFIX Information Elements" registry [IANA-IPFIX] defines the following IEs for traffic flow information export in different granularities: sourceIPv4Address, sourceIPv4Prefix, destinationIPv4Address, destinationIPv4Prefix, bgpSourceAsNumber, bgpDestinationAsNumber, bgpNextHopIPv4Address, etc. In some circumstances, however, traffic flow information based on these IEs may not be completely suitable or sufficient, especially when traffic engineering and optimization are executed in Tier 1 or Tier 2 operators' backbone networks. For example, flow information based on IP address or IP prefix may provide much too fine granularity for a large network. On the contrary, flow information based on Autonomous System Number (ASN) may be too coarse.

BGP community is a BGP path attribute that includes Standard Communities [RFC1997], Extended Communities [RFC4360], and Large Communities [RFC8092]. The BGP community attribute has a variety of use cases, one of which is to use BGP community with planned specific values to represent groups of customers, services, and geographical or topological regions, as used by operators in their networks. Detailed examples can be found in [RFC4384], [RFC8195], and Section 3 of this document. To understand the traffic generated 1) by different kinds of customers, 2) from different geographical or topological regions, or 3) by different kinds of customers from different regions, we need the community information corresponding to the traffic flow information exported by IPFIX. Network traffic statistics at the BGP community granularity are useful not only for traffic analysis, but also for use by other applications, such as traffic optimization applications located in an IPFIX Collector, Software-Defined Networking (SDN) controller, or PCE. [COMMUNITY-TE] also states that analyzing network traffic information at the BGP community granularity is preferred for inbound traffic engineering. However, the "IPFIX Information Elements" registry [IANA-IPFIX] lacked IEs defined for the BGP community attribute.

Flow information based on the BGP community attribute may be collected by an IPFIX Mediator (defined in [RFC6183]). The IPFIX Mediator is responsible for the correlation between flow information and the BGP community attribute. However, no IEs are defined in [RFC6183] for exporting BGP community information in IPFIX. Furthermore, to correlate the BGP community attribute with the flow information, the IPFIX Mediator needs to learn BGP routes and perform lookups in the BGP routing table to get the matching entry for a specific flow. BGP route learning and routing table lookup are not trivial for an IPFIX Mediator. The IPFIX Mediator is mainly introduced to reduce the performance requirement for the Exporter [RFC5982]. In fact, to obtain information for the already-defined BGP-related IEs, such as `bgpSourceAsNumber`, `bgpDestinationAsNumber`, and `bgpNextHopIPv4Address`, etc., the Exporter has to hold the up-to-date BGP routing table and perform lookups in the table. The Exporter can obtain the BGP community information in the same procedure; thus, the additional load added by exporting BGP community information is minimal if the Exporter is already exporting the existing BGP-related IEs. It is RECOMMENDED that the BGP community information be exported by the Exporter directly using IPFIX.

By running BGP [RFC4271] or the BGP Monitoring Protocol (BMP) [RFC7854] and performing lookups in the BGP routing table to correlate the matching entry for a specific flow, IPFIX Collectors and other applications, such as an SDN controller or PCE, can determine the network traffic at the BGP community granularity. However, running BGP or BMP and performing routing table lookup are not trivial for the IPFIX Collectors and other applications. Moreover, correlation between IPFIX flow information and the BGP RIB on the Exporter (such as a router) is more accurate compared to the correlation on a Collector, since the BGP routing table may be updated when the IPFIX Collectors and other applications receive the IPFIX flow information. As stated above, the Exporter can obtain the BGP community information during the same procedure when it obtains other BGP-related information. Therefore, exporting the BGP community information directly by the Exporter to the Collector is both efficient and accurate. If the IPFIX Collectors and other applications only want to determine the network traffic at the BGP community granularity, they do not need to run the full BGP or BMP protocols when the BGP community information can be obtained by IPFIX. However, BMP has its own application scenario, and the mechanism introduced in this document is not meant to replace it.

By introducing new IEs, this document extends the existing BGP-related IEs to enable IPFIX [RFC7011] to export BGP community information, including the BGP Standard Communities [RFC1997], BGP Extended Communities [RFC4360], and BGP Large Communities [RFC8092]. Flow information (including `packetDeltaCount` [RFC7011] [RFC7012],

octetDeltaCount [RFC7011] [RFC7012], etc.) can then be accumulated and analyzed by the Collector or other applications, such as an SDN controller or PCE [RFC4655], at the BGP community granularity. This is useful for measuring the traffic generated 1) by different kinds of customers or 2) from different geographical or topological regions according to the operator's BGP community plan. Flow information can then be used by the traffic engineering or traffic optimization applications, especially in the backbone network.

The IEs introduced in this document are applicable to both IPv4 and IPv6 traffic. Both the Exporter and the IPFIX Mediator can use these IEs to export BGP community information in IPFIX. When needed, the IPFIX Mediator or Collector can use these IEs to report BGP community-related traffic flow information it gets either from Exporters or through local correlation to other IPFIX devices.

As stated above, the method introduced in this document is not the sole, definitive one for obtaining BGP community information related to a specific traffic flow, but it is possible, efficient, and accurate.

No new BGP community attributes are defined in this document.

Note that this document does not update the IPFIX specification [RFC7011] or information model [RFC7012]. Rather, the "IPFIX Information Elements" registry [IANA-IPFIX] contains the current complete reference for IPFIX Information Elements, per Section 1 of [RFC7012].

Please refer to the "IPFIX Information Elements" registry [IANA-IPFIX] for the complete list of BGP-related IEs.

Please refer to Appendix A of this document for the encoding example and Section 3 for a detailed use case.

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

The IPFIX-specific terminology used in this document is defined in Section 2 of [RFC7011] and Section 2 of [RFC6183].

This document uses the term "BGP Standard Community" to refer to the BGP community attribute defined in [RFC1997] in order to distinguish it from BGP Extended Community [RFC4360] and Large Community [RFC8092].

3. Traffic Collection Based on BGP Community

[RFC4384] introduces the mechanism of using BGP Standard Community and Extended Community to collect geographical and topological information in the BGP routing system. [RFC8195] gives some examples of the application of BGP Large Communities to represent the geographical regions. Since the network traffic at the BGP community granularity represents the traffic generated 1) by different kinds of customers or 2) from different geographical regions according to the network operator's BGP community plan, it is useful for network operators to analyze and optimize the network traffic among different customers and regions. This section gives a use case in which the network operator uses traffic information based on BGP community to adjust the network paths for different traffic flows.

Consider the following scenario. Autonomous System (AS) C provides a transit connection between ASes A and B. By tagging different BGP communities, the routes of AS A and B are categorized into several groups in the operator's plan. For example, communities A:X and A:Y are used for routes that originated from different geographical regions in AS A, and communities B:M and B:N are used for routes representing the different kinds of customers in AS B (e.g., B:M is for mobile customers and B:N is for fixed line customers). By default, all traffic originating from AS A and destined for AS B (i.e., traffic A-B) goes through path C1-C2-C3 (i.e., Path-1) in AS C. When the link between C1 and C2 is congested, we cannot simply steer all the traffic A-B from Path-1 to Path C1-C4-C3 (i.e., Path-2) because it will cause congestion in Path-2.

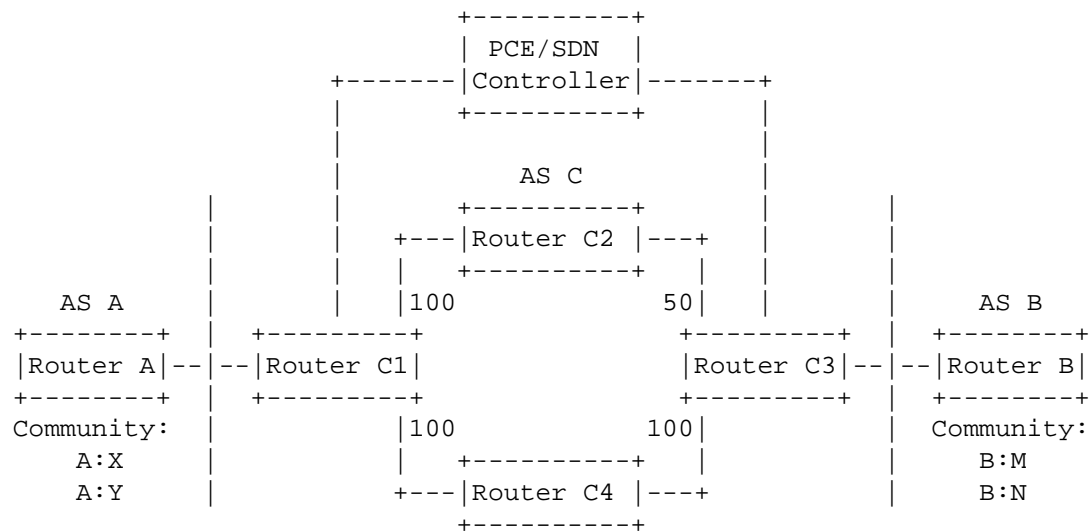


Figure 1: Traffic Collection Based on BGP Community

If the PCE/SDN controller in AS C can obtain network traffic information at the BGP community granularity, it can steer some traffic related to some BGP communities (when we consider only the source or destination of the traffic) or some BGP community pairs (when we consider both the source and the destination of the traffic) from Path-1 to Path-2 according to the utilization of different paths. For instance, it can steer the traffic generated by community A:X from Path-1 to Path-2 by deploying a route policy at Router C1 or steer the traffic from community A:Y to community B:M from Path-1 to Path-2. Using the IEs defined in this document, IPFIX can export the BGP community information related to a specific traffic flow together with other flow information. The traffic information can then be accumulated at the BGP community granularity and used by the PCE/SDN controller to steer the appropriate traffic from Path-1 to Path-2.

4. IEs for BGP Standard Community

[RFC1997] defines the BGP community attribute (referred to as "BGP Standard Community" in this document), which describes a group of routes sharing some common properties. BGP Standard Community is treated as a 32-bit value, as stated in [RFC1997].

In order to export BGP Standard Community information along with other flow information defined by IPFIX, this document introduces three new IEs:

- o `bgpCommunity` - used to identify that the value in this IE is a BGP Standard Community.

- o `bgpSourceCommunityList` - a `basicList` [RFC6313] of `bgpCommunity` used to export BGP Standard Community information corresponding to a specific flow's source IP address.
- o `bgpDestinationCommunityList` - a `basicList` [RFC6313] of `bgpCommunity` used to export BGP Standard Community information corresponding to a specific flow's destination IP address.

See [Section 9](#) ("IANA Considerations") for detailed information about these three new IEs.

5. IEs for BGP Extended Community

[RFC4360] defines the BGP Extended Communities attribute, which provides a mechanism for labeling the information carried in BGP. Each Extended Community is encoded as an 8-octet quantity with the format defined in [RFC4360].

In order to export BGP Extended Community information together with other flow information by IPFIX, this document introduces three new IEs:

- o `bgpExtendedCommunity` - used to identify that the value in this IE is a BGP Extended Community.
- o `bgpSourceExtendedCommunityList` - a `basicList` [RFC6313] of `bgpExtendedCommunity` used to export the BGP Extended Community information corresponding to a specific flow's source IP address.
- o `bgpDestinationExtendedCommunityList` - a `basicList` [RFC6313] of `bgpExtendedCommunity` used to export the BGP Extended Community information corresponding to a specific flow's destination IP address.

See [Section 9](#) ("IANA Considerations") for detailed information about these three new IEs.

6. IEs for BGP Large Community

[RFC8092] defines the BGP Large Communities attribute, which is suitable for use with all Autonomous System Numbers (ASNs), including 4-octet ASNs. Each BGP Large Community is encoded as a 12-octet quantity with the format defined in [RFC8092].

In order to export BGP Large Community information together with other flow information by IPFIX, this document introduces three new IEs:

- o `bgpLargeCommunity` - used to identify that the value in this IE is a BGP Large Community.
- o `bgpSourceLargeCommunityList` - a `basicList` [RFC6313] of `bgpLargeCommunity` used to export the BGP Large Community information corresponding to a specific flow's source IP address.
- o `bgpDestinationLargeCommunityList` - a `basicList` [RFC6313] of `bgpLargeCommunity` used to export the BGP Large Community information corresponding to a specific flow's destination IP address.

See [Section 9](#) ("IANA Considerations") for detailed information about these three new IEs.

7. Operational Considerations

The maximum length of an IPFIX message is 65535 bytes as per [RFC7011], and the maximum length of a normal BGP message is 4096 bytes as per [RFC4271]. Since BGP communities, including Standard, Extended, and Large Communities, are BGP path attributes carried in BGP Update messages, the total length of these attributes cannot exceed the length of a BGP message, i.e., 4096 bytes. Therefore, one IPFIX message with a maximum length of 65535 bytes has enough space to fit all the communities relating to a specific flow's source and destination IP address.

[EXT-MSG] extends the maximum size of a BGP Update message to 65535 bytes. In that case, the BGP community information related to a specific flow could theoretically exceed the length of one IPFIX message. However, according to information regarding actual networks in the field, the number of BGP communities in one BGP route is usually no more than ten. Nevertheless, BGP speakers that support the extended message SHOULD only convey as many communities as possible without exceeding the 65535-byte limit of an IPFIX message. The Collector, which receives an IPFIX message with the maximum length and BGP communities contained in its data set, SHOULD generate a warning or log message to indicate that the BGP communities may be truncated due to limited message space. In this case, it is recommended that the export policy of BGP communities be configured to limit the BGP communities by including or excluding specific communities.

If needed, the IPFIX message length can be extended from 16 bits to 32 bits to solve this problem completely. The details about increasing the IPFIX message length is out of scope of this document.

To align with the sizes of the BGP Extended Community and Large Community attributes, the sizes of `bgpExtendedCommunity` and `bgpLargeCommunity` are 8 octets and 12 octets, respectively. In the event that the `bgpExtendedCommunity` or `bgpLargeCommunity` IE is not the expected size, the IPFIX Collector SHOULD ignore it. This is intended to protect implementations using BGP logic from calling their parsing routines with invalid lengths.

To properly process the Exporter when it receives the template requesting to report the BGP community information (refer to [Appendix A](#) for an example), the Exporter SHOULD obtain the corresponding BGP community information through a BGP lookup using the corresponding source or destination IP address of the specific traffic flow. When exporting the IPFIX information to the Collector, the Exporter SHOULD include the corresponding BGP communities in the IPFIX message.

8. Security Considerations

This document defines new IEs for IPFIX. The same security considerations as for the IPFIX protocol specification [[RFC7011](#)] and information model [[RFC7012](#)] apply.

Systems processing BGP community information collected by IPFIX Collectors need to be aware of the use of communities as an attack vector [[WEAPONIZING-BGP](#)] and only include BGP community information in decisions where they are confident of its validity. Thus, we cannot assume that all BGP community information collected by IPFIX Collectors is credible and accurate. It is RECOMMENDED to use only the IPFIX-collected BGP community information that the processing system can trust, for example, the BGP communities generated by the consecutive neighboring ASes within the same trust domain as the processing system (i.e., the consecutive neighboring ASes and the processing system are operated by one carrier).

[[RFC7011](#)] notes that the storage of the information collected by IPFIX must be protected and its visibility confined to authorized users via technical as well as policy means to ensure the privacy of the information collected. [[RFC7011](#)] also provides mechanisms to ensure the confidentiality and integrity of IPFIX data transferred from an Exporting Process to a Collecting Process. The mechanism to authenticate IPFIX Collecting and Exporting Processes is also provided in [[RFC7011](#)]. If sensitive information is contained in the

community information, the above recommendations and mechanisms are recommended. No additional privacy risks are introduced by this document.

9. IANA Considerations

This document specifies IPFIX IEs to enable export of BGP community information along with other flow information. IANA has assigned the following ElementIDs for these IEs in the "IPFIX Information Elements" registry [[IANA-IPFIX](#)]:

ElementID	Name	Abstract Data Type	Data Type Semantics
483	bgpCommunity	unsigned32	identifier
484	bgpSourceCommunityList	basicList	list
485	bgpDestinationCommunityList	basicList	list
486	bgpExtendedCommunity	octetArray	default
487	bgpSourceExtendedCommunityList	basicList	list
488	bgpDestinationExtendedCommunityList	basicList	list
489	bgpLargeCommunity	octetArray	default
490	bgpSourceLargeCommunityList	basicList	list
491	bgpDestinationLargeCommunityList	basicList	list

ElementID	Description
483	BGP community as defined in [RFC1997]
484	basicList of zero or more bgpCommunity IEs, containing the BGP communities corresponding with source IP address of a specific flow
485	basicList of zero or more bgpCommunity IEs, containing the BGP communities corresponding with destination IP address of a specific flow
486	BGP Extended Community as defined in RFC 4360; the size of this IE MUST be 8 octets
487	basicList of zero or more bgpExtendedCommunity IEs, containing the BGP Extended Communities corresponding with source IP address of a specific flow
488	basicList of zero or more bgpExtendedCommunity IEs, containing the BGP Extended Communities corresponding with destination IP address of a specific flow
489	BGP Large Community as defined in [RFC8092]; the size of this IE MUST be 12 octets
490	basicList of zero or more bgpLargeCommunity IEs, containing the BGP Large Communities corresponding with source IP address of a specific flow
491	basicList of zero or more bgpLargeCommunity IEs, containing the BGP Large Communities corresponding with destination IP address of a specific flow

ElementID	References	Requester	Revision
483	RFC 1997	RFC 8549	0
484	RFC 6313 , RFC 1997	RFC 8549	0
485	RFC 6313 , RFC 1997	RFC 8549	0
486	RFC 4360	RFC 8549	0
487	RFC 6313 , RFC 4360	RFC 8549	0
488	RFC 6313 , RFC 4360	RFC 8549	0
489	RFC 8092	RFC 8549	0
490	RFC 6313 , RFC 8092	RFC 8549	0
491	RFC 6313 , RFC 8092	RFC 8549	0

Figure 2: Updates to "IPFIX Information Elements" Registry

10. References

10.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC6313] Claise, B., Dhandapani, G., Aitken, P., and S. Yates, "Export of Structured Data in IP Flow Information Export (IPFIX)", [RFC 6313](#), DOI 10.17487/RFC6313, July 2011, <<https://www.rfc-editor.org/info/rfc6313>>.
- [RFC7011] Claise, B., Ed., Trammell, B., Ed., and P. Aitken, "Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information", STD 77, [RFC 7011](#), DOI 10.17487/RFC7011, September 2013, <<https://www.rfc-editor.org/info/rfc7011>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

10.2. Informative References

[COMMUNITY-TE]

Shao, W., Devienne, F., Iannone, L., and J. Rougier, "On the use of BGP communities for fine-grained inbound traffic engineering", Computer Science: Networking and Internet Architecture, November 2015, <<https://arxiv.org/abs/1511.08336>>.

[EXT-MSG] Bush, R., Patel, K., and D. Ward, "Extended Message support for BGP", Work in Progress, [draft-ietf-idr-bgp-extended-messages-30](#), March 2019.

[IANA-IPFIX]

IANA, "IP Flow Information Export (IPFIX) Entities", <<http://www.iana.org/assignments/ipfix/>>.

[RFC1997] Chandra, R., Traina, P., and T. Li, "BGP Communities Attribute", [RFC 1997](#), DOI 10.17487/RFC1997, August 1996, <<https://www.rfc-editor.org/info/rfc1997>>.

[RFC4271] Rekhter, Y., Ed., Li, T., Ed., and S. Hares, Ed., "A Border Gateway Protocol 4 (BGP-4)", [RFC 4271](#), DOI 10.17487/RFC4271, January 2006, <<https://www.rfc-editor.org/info/rfc4271>>.

[RFC4360] Sangli, S., Tappan, D., and Y. Rekhter, "BGP Extended Communities Attribute", [RFC 4360](#), DOI 10.17487/RFC4360, February 2006, <<https://www.rfc-editor.org/info/rfc4360>>.

[RFC4384] Meyer, D., "BGP Communities for Data Collection", [BCP 114](#), [RFC 4384](#), DOI 10.17487/RFC4384, February 2006, <<https://www.rfc-editor.org/info/rfc4384>>.

[RFC4655] Farrel, A., Vasseur, J., and J. Ash, "A Path Computation Element (PCE)-Based Architecture", [RFC 4655](#), DOI 10.17487/RFC4655, August 2006, <<https://www.rfc-editor.org/info/rfc4655>>.

[RFC5982] Kobayashi, A., Ed. and B. Claise, Ed., "IP Flow Information Export (IPFIX) Mediation: Problem Statement", [RFC 5982](#), DOI 10.17487/RFC5982, August 2010, <<https://www.rfc-editor.org/info/rfc5982>>.

[RFC6183] Kobayashi, A., Claise, B., Muenz, G., and K. Ishibashi, "IP Flow Information Export (IPFIX) Mediation: Framework", [RFC 6183](#), DOI 10.17487/RFC6183, April 2011, <<https://www.rfc-editor.org/info/rfc6183>>.

- [RFC7012] Claise, B., Ed. and B. Trammell, Ed., "Information Model for IP Flow Information Export (IPFIX)", [RFC 7012](#), DOI 10.17487/RFC7012, September 2013, <<https://www.rfc-editor.org/info/rfc7012>>.
- [RFC7854] Scudder, J., Ed., Fernando, R., and S. Stuart, "BGP Monitoring Protocol (BMP)", [RFC 7854](#), DOI 10.17487/RFC7854, June 2016, <<https://www.rfc-editor.org/info/rfc7854>>.
- [RFC8092] Heitz, J., Ed., Snijders, J., Ed., Patel, K., Bagdonas, I., and N. Hilliard, "BGP Large Communities Attribute", [RFC 8092](#), DOI 10.17487/RFC8092, February 2017, <<https://www.rfc-editor.org/info/rfc8092>>.
- [RFC8195] Snijders, J., Heasley, J., and M. Schmidt, "Use of BGP Large Communities", [RFC 8195](#), DOI 10.17487/RFC8195, June 2017, <<https://www.rfc-editor.org/info/rfc8195>>.
- [WEAPONIZING-BGP]
Streibelt, F., Lichtblau, F., Beverly, R., Pelsser, C., Smaragdakis, G., Bush, R., and A. Feldmann, "Weaponizing BGP Using Communities", November 2018, <<https://datatracker.ietf.org/meeting/103/materials/slides-103-grow-bgp-communities-spread-their-wings-01>>.

Appendix A. Encoding Example

In this section, we provide an example to show the encoding format for the newly introduced IEs.

Flow information, including BGP communities, is shown in the following table. In this example, all the fields are reported by IPFIX.

Source IP	Destination IP	BGP community corresponding with Source IP	BGP community corresponding with Destination IP
1.1.1.1	2.2.2.2	1:1001, 1:1002, 8:1001	2:1002, 8:1001
3.3.3.3	4.4.4.4	3:1001, 3:1002, 8:1001	4:1001, 8:1001

Figure 3: Flow Information Including BGP Communities

A.1. Template Record

0										1										2										3																													
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																												
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
										SET ID = 2																				Length = 24																													
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
										Template ID = 256																				Field Count = 4																													
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
0										SourceIPv4Address = 8																				Field Length = 4																													
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
0										DestinationIPv4Address = 12																				Field Length = 4																													
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
0										bgpSourceCommunityList=484																				Field Length = 0xFFFF																													
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												
0										bgpDestinationCommunityList																				Field Length = 0xFFFF																													
																				= 485																																							
+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-																												

Figure 4: Template Record Encoding Format

In this example, the Template ID is 256, which will be used in the Data Record. The field length for `bgpSourceCommunityList` and `bgpDestinationCommunityList` is 0xFFFF, which means the length of this IE is variable, and the actual length of this IE is indicated by the List Length field in the basicList format as per [RFC6313].

A.2. Data Set

The data set is represented as follows:

```

0                               1                               2                               3
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
+-----+-----+-----+-----+-----+-----+-----+-----+
|          SET ID = 256          |          Length = 92          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          SourceIPv4Address = 1.1.1.1          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          DestinationIPv4Address = 2.2.2.2          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          255          |          List Length = 17          |semantic=allof |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          bgpCommunity = 483          |          Field Length = 4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 1 = 1:1001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 2 = 1:1002          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 3 = 8:1001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          255          |          List Length = 13          |semantic=allof |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          bgpCommunity = 483          |          Field Length = 4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Destination Community Value 1 = 2:1002          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Destination Community Value 2 = 8:1001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          SourceIPv4Address = 3.3.3.3          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          DestinationIPv4Address = 4.4.4.4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          255          |          List Length = 17          | semantic=allof |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          bgpCommunity = 483          |          Field Length = 4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 1 = 3:1001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 2 = 3:1002          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          BGP Source Community Value 3 = 8:1001          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          255          |          List Length = 13          | semantic=allof |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          bgpCommunity = 483          |          Field Length = 4          |

```

```

+-----+
|           BGP Destination Community Value 1 = 4:1001           |
+-----+
|           BGP Destination Community Value 2 = 8:1001           |
+-----+

```

Figure 5: Data Set Encoding Format

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