

Network Working Group
Request for Comments: 5473
Category: Informational

E. Boschi
Hitachi Europe
L. Mark
Fraunhofer IFAM
B. Claise
Cisco Systems, Inc.
March 2009

Reducing Redundancy in IP Flow Information Export (IPFIX)
and Packet Sampling (PSAMP) Reports

Status of This Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

Copyright Notice

Copyright (c) 2009 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents in effect on the date of publication of this document (<http://trustee.ietf.org/license-info>). Please review these documents carefully, as they describe your rights and restrictions with respect to this document.

This document may contain material from IETF Documents or IETF Contributions published or made publicly available before November 10, 2008. The person(s) controlling the copyright in some of this material may not have granted the IETF Trust the right to allow modifications of such material outside the IETF Standards Process. Without obtaining an adequate license from the person(s) controlling the copyright in such materials, this document may not be modified outside the IETF Standards Process, and derivative works of it may not be created outside the IETF Standards Process, except to format it for publication as an RFC or to translate it into languages other than English.

Abstract

This document describes a bandwidth saving method for exporting Flow or packet information using the IP Flow Information eXport (IPFIX) protocol. As the Packet Sampling (PSAMP) protocol is based on IPFIX, these considerations are valid for PSAMP exports as well.

This method works by separating information common to several Flow Records from information specific to an individual Flow Record. Common Flow information is exported only once in a Data Record defined by an Options Template, while the rest of the specific Flow information is associated with the common information via a unique identifier.

Table of Contents

1. Introduction	3
1.1. IPFIX Documents Overview	3
1.2. PSAMP Documents Overview	4
2. Terminology	4
2.1. Terminology Summary Table	5
2.2. IPFIX Flows versus PSAMP Packets	5
3. Specifications for Bandwidth-Saving Information Export	5
3.1. Problem Statement and High-Level Solution	6
3.2. Data Reduction Technique	7
4. Transport Protocol Choice	8
4.1. PR-SCTP	9
4.2. UDP	9
4.3. TCP	9
5. commonPropertiesID Management	9
6. The Collecting Process Side	10
6.1. UDP	11
6.2. TCP	12
7. Advanced Techniques	12
7.1. Multiple Data Reduction	12
7.2. Cascading Common Properties	15
8. Export and Evaluation Considerations	15
8.1. Transport Protocol Choice	16
8.2. Reduced Size Encoding	16
8.3. Efficiency Gain	16
9. Security Considerations	17
10. Acknowledgments	17
11. References	17
11.1. Normative References	17
11.2. Informative References	18
Appendix A. Examples	19
A.1. Per-Flow Data Reduction	19
A.2. Per-Packet Data Reduction	23
A.3. Common Properties Withdrawal Message	26

1. Introduction

The IPFIX working group has specified a protocol to export IP Flow information [RFC5101]. This protocol is designed to export information about IP traffic Flows and related measurement data, where a Flow is defined by a set of key attributes (e.g., source and destination IP address, source and destination port, etc.). However, thanks to its template mechanism, the IPFIX protocol can export any type of information, as long as the Information Element is specified in the IPFIX information model [RFC5101] or registered with IANA.

Regardless of the fields' contents, Flow Records with common properties export the same fields in every single Data Record. These common properties may represent values common to a collection of Flows or packets, or values that are invariant over time. Note that the common properties don't represent the list of Flow Keys, which are used to define a Flow definition; however, the common properties may contain some of the Flow Keys. The reduction of redundant data from the export stream can result in a significant reduction of the transferred data.

This document specifies a way to export these invariant or common properties only once, while the rest of the Flow-specific properties are exported in regular Data Records. Unique common properties identifiers are used to link Data Records and the common attributes.

The proposed method is applicable to IPFIX Flow and to PSAMP per-packet information, without any changes to both the IPFIX and PSAMP protocol specifications.

1.1. IPFIX Documents Overview

The IPFIX protocol [RFC5101] provides network administrators with access to IP Flow information. The architecture for the export of measured IP Flow information out of an IPFIX exporting process to a collecting process is defined in the IPFIX Architecture [RFC5470], per the requirements defined in RFC 3917 [RFC3917]. The IPFIX Architecture [RFC5470] specifies how IPFIX Data Records and templates are carried via a congestion-aware transport protocol from IPFIX exporting processes to IPFIX collecting processes. IPFIX has a formal description of IPFIX Information Elements, their names, types, and additional semantic information, as specified in the IPFIX information model [RFC5102]. Finally, the IPFIX applicability statement [RFC5472] describes what type of applications can use the IPFIX protocol and how they can use the information provided. It furthermore shows how the IPFIX framework relates to other architectures and frameworks.

1.2. PSAMP Documents Overview

The document "A Framework for Packet Selection and Reporting" [RFC5474] describes the PSAMP framework for network elements to select subsets of packets by statistical and other methods, and to export a stream of reports on the selected packets to a collector. The set of packet selection techniques (sampling, filtering, and hashing) supported by PSAMP is described in "Sampling and Filtering Techniques for IP Packet Selection" [RFC5475]. The PSAMP protocol [RFC5476] specifies the export of packet information from a PSAMP exporting process to a PSAMP collecting process. Like IPFIX, PSAMP has a formal description of its Information Elements, their names, types, and additional semantic information. The PSAMP information model is defined in [RFC5477]. Finally, [PSAMP-MIB] describes the PSAMP Management Information Base.

2. Terminology

IPFIX-specific terminology used in this document is defined in Section 2 of the IPFIX protocol specification [RFC5101] and Section 3 of the PSAMP protocol specification [RFC5476]. As in [RFC5101] and [RFC5476], these IPFIX-specific terms have the first letter of a word capitalized when used in this document.

In addition, the following new terms are defined in this document:

commonPropertiesID: The commonPropertiesID is an identifier of a set of common properties that is locally unique per Observation Domain and Transport Session. Typically, this Information Element is used to link to information reported in separate Data Records. See the IPFIX information model [RFC5102] for the Information Element definition.

Common Properties: Common Properties are a collection of one or more attributes shared by a set of different Flow Records. Each set of Common Properties is uniquely identifiable by means of a commonPropertiesID.

Specific Properties: Specific Properties are a collection of one or more attributes reported in a Flow Record that are not included in the Common Properties defined for that Flow Record.

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].

2.1. Terminology Summary Table

Set	Contents	
	Template	Record
Data Set	/	Data Record(s)
Template Set	Template Record(s)	/
Options Template Set	Options Template Record(s)	/

Terminology Summary Table

A Data Set is composed of Data Record(s). No Template Record is included. A Template Record or an Options Template Record defines the Data Record.

A Template Set contains only Template Record(s).

An Options Template Set contains only Options Template Record(s).

2.2. IPFIX Flows versus PSAMP Packets

As described in the PSAMP protocol specification [RFC5476], the major difference between IPFIX and PSAMP is that the IPFIX protocol exports Flow Records while the PSAMP protocol exports Packet Records. From a pure export point of view, IPFIX will not distinguish a Flow Record composed of several packets aggregated together from a Flow Record composed of a single packet. So, the PSAMP export can be seen as a special IPFIX Flow Record containing information about a single packet.

For this document's clarity, the term Flow Record represents a generic term expressing an IPFIX Flow Record or a PSAMP Packet Record, as foreseen by its definition. However, when appropriate, a clear distinction between Flow Record or Packet Record will be made.

3. Specifications for Bandwidth-Saving Information Export

Several Flow Records often share a set of Common Properties. Repeating the information about these Common Properties for every Flow Record introduces a huge amount of redundancy. This document proposes a method to reduce this redundancy.

The PSAMP specifications are used for the export of per-packet information, exporting the specific observed packet in an IPFIX Flow Record. This can be considered as a special Flow Record case, composed of a single packet. Therefore, the method described in this document is also applicable to per-packet data reduction, e.g., for export of One-Way Delay (OWD) measurements (see Appendix), trajectory sampling, etc.

3.1. Problem Statement and High-Level Solution

Consider a set of properties "A", e.g., common sourceAddressA and sourcePortA, equivalent for each Flow Record exported. Figure 1 shows how this information is repeated with classical IPFIX Flow Records, expressing the waste of bandwidth to export redundant information.

sourceAddressA	sourcePortA	<Flow1 information>
sourceAddressA	sourcePortA	<Flow2 information>
sourceAddressA	sourcePortA	<Flow3 information>
sourceAddressA	sourcePortA	<Flow4 information>
...

Figure 1: Common and Specific Properties Exported Together

Figure 2 shows how this information is exported when applying the specifications of this document. The Common Properties are separated from the Specific Properties for each Flow Record. The Common Properties would be exported only once in a specific Data Record (defined by an Options Template), while each Flow Record contains a pointer to the Common Properties A, along with its Flow-specific information. In order to maintain the relationship between these sets of properties, we introduce indices (in this case, the index for properties A) for the Common Properties that are unique for all Common Properties entries within an Observation Domain. The purpose of the indices is to serve as a "key" identifying "rows" of the Common Properties table. The rows are then referenced by the Specific Properties by using the appropriate value for the Common Properties identifier.

index for properties A	sourceAddressA	sourcePortA
...
index for properties A	<Flow1 information>	
index for properties A	<Flow2 information>	
index for properties A	<Flow3 information>	
index for properties A	<Flow4 information>	

Figure 2: Common and Specific Properties Exported Separately

This unique export of the Common Properties results in a decrease of the bandwidth requirements for the path between the Exporter and the Collector.

3.2. Data Reduction Technique

The IPFIX protocol [RFC5101] is Template based. Templates define how data should be exported, describing data fields together with their type and meaning. IPFIX specifies two types of Templates: the Template Record and the Options Template Record. The difference between the two is that the Options Template Record includes the notion of scope, defining how to scope the applicability of the Data Record. The scope, which is only available in the Options Template Record, gives the context of the reported Information Elements in the Data Records. The Template Records and Options Template Records are necessary to decode the Data Records. Indeed, by only looking at the Data Records themselves, it is impossible to distinguish a Data Record defined by Template Record from a Data Record defined by an Options Template Record. To export information more efficiently, this specification proposes to group Flow Records by their common properties. We define Common Properties as a collection of attributes shared by a set of different Flow Records.

An implementation using the proposed specification MUST follow the IPFIX transport protocol specifications defined in the IPFIX protocol [RFC5101].

As explained in Figure 3, the information is split into two parts, using two different Data Records. Common Properties MUST be exported via Data Records defined by an Options Template Record. Like Template Records, they MUST be sent only once per SCTP association or TCP connection, and MUST be sent reliably via SCTP if SCTP is the transport protocol. These properties represent values common to several Flow Records (e.g., IP source and destination address). The Common Properties Data Records MUST be sent prior to the corresponding Specific Properties Data Records. The Data Records reporting Specific Properties MUST be associated with the Data Records reporting the Common Properties using a unique identifier for the Common Properties, the commonPropertiesID Information Element [RFC5102]. The commonPropertiesID Information Element MUST be included in the scope of the Options Template Record, and also included in the associated Template Record.

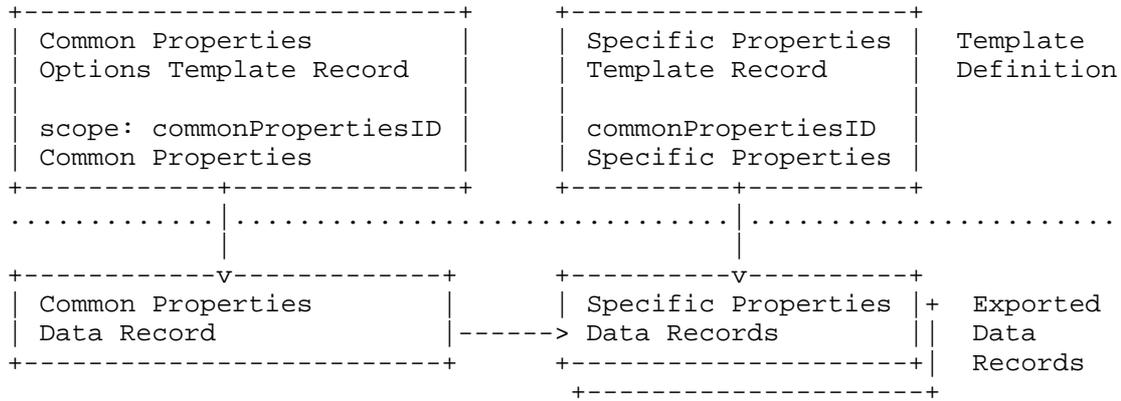


Figure 3: Template Record and Data Record Dependencies

From the IPFIX protocol, there are no differences between the per-Flow or per-packet data reduction, except maybe the terminology where the Specific Properties could be called packet Specific Properties in the previous figure.

4. Transport Protocol Choice

This document follows the IPFIX transport protocol specifications defined in the IPFIX protocol [RFC5101]. However, depending on the transport protocol choice, this document imposes some additional constraints. If Partial Reliable Stream Control Transmission Protocol (PR-SCTP) [RFC3758] is selected as the IPFIX protocol, the following PR-SCTP subsection specifications MUST be respected. If UDP is selected as the IPFIX protocol, the following UDP subsection

specifications MUST be respected. If TCP is selected as the IPFIX protocol, the following TCP subsection specifications MUST be respected.

4.1. PR-SCTP

The active Common Properties MUST be sent after the SCTP association establishment and before the corresponding Specific Properties Data Records. In the case of SCTP association re-establishment, all active Common Properties MUST be resent before the corresponding Specific Properties Data Records.

The Common Properties Data Records MUST be sent reliably.

4.2. UDP

Common Properties Data Records MUST be resent on a regular basis. The periodicity MUST be configurable. The default value for the frequency of Common Properties transmission (refresh timeout) is 10 minutes.

The Exporting Process SHOULD transmit the Common Properties definition in advance of any Data Record that uses these Common Properties to help ensure that the Collector has the Common Properties definition before receiving the first associated Data Record.

If a `commonPropertiesID` is not used anymore, the Exporting Process stops resending the related Common Properties Data Record. The old `commonPropertiesID` MUST NOT be used until its lifetime (see Section 6.1) has expired.

4.3. TCP

Common Properties MUST be sent after the TCP connection establishment, and before the corresponding Specific Properties Data Records. In the case of TCP connection re-establishment, all active Common Properties MUST be resent before the corresponding Specific Properties Data Records.

5. `commonPropertiesID` Management

The `commonPropertiesID` is an identifier of a set of common properties that is locally unique per Observation Domain and Transport Session. The Exporting Process MUST manage the `commonPropertiesIDs` allocations for its Observation Domains and Transport Session. Different

Observation Domains from the same Exporter MAY use the same commonPropertiesID value to refer to different sets of Common Properties.

The commonPropertiesID values MAY be assigned sequentially, but it is NOT REQUIRED. Particular commonPropertiesID ranges or values MAY have explicit meanings for the IPFIX Device. For example, commonPropertiesID values may be assigned based on the result of a hash function, etc.

Using a 64-bit commonPropertiesID Information Element allows the export of 2**64 active sets of Common Properties, per Observation Domain and per Transport Session.

commonPropertiesIDs that are not used anymore SHOULD be withdrawn. The Common Properties Withdrawal message is a Data Record defined by an Options Template consisting of only one scope field -- namely, the commonPropertiesID (with a type of 137 [RFC5102]) and no non-scope fields.

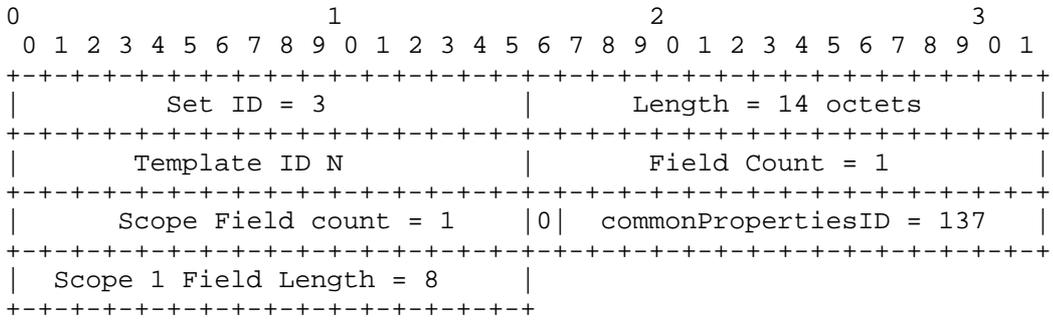


Figure 4: Common Properties Withdrawal Message

If UDP is selected as the transport protocol, the Common Properties Withdrawal messages MUST NOT be used, as this method is inefficient due to the unreliable nature of UDP.

6. The Collecting Process Side

This section describes the Collecting Process when using SCTP and PR-SCTP as the transport protocol. Any necessary changes to the Collecting Process, specifically related to TCP or UDP transport protocols, are specified in the subsections.

The Collecting Process MUST store the commonPropertiesID information for the duration of the association so that it can interpret the corresponding Data Records that are received in subsequent Data Sets.

The Collecting Process can either store the Data Records as they arrive, without reconstructing the initial Flow Record, or reconstruct the initial Flow Record. In the former case, there might be less storage capacity required at the Collector side. In the latter case, the Collector job is more complex and time-consuming due to the higher resource demand for record processing in real time.

If the Collecting Process has received the Specific Properties Data Record before the associated Common Properties Data Record, the Collecting Process SHOULD store the Specific Properties Data Record and await the retransmission or out-of-order arrival of the Common Properties Data Record.

commonPropertiesIDs are unique per SCTP association and per Observation Domain. If the Collecting Process receives an Options Template Record with a scope containing a commonPropertiesID that has already been received but that has not previously been withdrawn (i.e., a commonPropertiesID from the same Exporter Observation Domain received on the SCTP association), then the Collecting Process MUST shut down the association.

When an SCTP association is closed, the Collecting Process MUST discard all commonPropertiesIDs received over that association and stop decoding IPFIX Messages that use those commonPropertiesIDs.

If a Collecting Process receives a Common Properties Withdrawal message, the Collecting Process MUST delete the corresponding Common Properties associated with the specific SCTP association and specific Observation Domain, and stop interpreting Data Records referring to those Common Properties. The receipt of Data Records referring to Common Properties that have been withdrawn MUST be ignored and SHOULD be logged by the Collecting Process.

If the Collecting Process receives a Common Properties Withdrawal message for Common Properties that it has not received before on this SCTP association, it MUST reset the SCTP association and discard the IPFIX Message, and it SHOULD log the error as it does for malformed IPFIX Messages.

6.1. UDP

The Collecting Process MUST associate a lifetime with each Common Property received via UDP. Common Properties not refreshed by the Exporting Process within the lifetime are expired at the Collecting Process.

If the Common Properties are not refreshed before that lifetime has expired, the Collecting Process MUST discard the corresponding definition of the commonPropertiesID and any current and future associated Data Records. In this case, an alarm MUST be logged.

The Collecting Process MUST NOT decode any further Data Records that are associated with the expired Common Properties. If a Common Property is refreshed with a definition that differs from the previous definition, the Collecting Process SHOULD log a warning and replace the previously received Common Property with the new one. The Common Property lifetime at the Collecting Process MUST be at least 3 times higher than the refresh timeout of the Template used to export the Common Property definition, configured on the Exporting Process.

The Collecting Process SHOULD accept Data Records without the associated Common Properties required to decode the Data Record. If the Common Properties have not been received at the time Data Records are received, the Collecting Process SHOULD store the Data Records for a short period of time and decode them after the Common Properties definitions are received. The short period of time MUST be lower than the lifetime of definitions associated with identifiers considered unique within the UDP session.

6.2. TCP

When the TCP connection is reset, either gracefully or abnormally, the Collecting Processes MUST delete all commonPropertiesID values and associated Common Properties data corresponding to that connection.

If a Collection Process receives a Common Properties Withdrawal message, the Collection Process MUST expire the related Common Properties data.

7. Advanced Techniques

7.1. Multiple Data Reduction

A Flow Record can refer to one or more Common Properties sets; the use of multiple Common Properties can lead to more efficient exports. When sets of Common Properties are identified in the data, it may be found that there is more than one set of non-overlapping properties.

Note that in the case of multiple Common Properties in one Data Record, the different sets of Common Properties MUST be disjoint (i.e., MUST NOT have Information Elements in common) to avoid potential collisions.

Consider a set of properties "A", e.g., common sourceAddressA and sourcePortA, and another set of properties "B", e.g., destinationAddressB and destinationPortB. Figure 5 shows how this information is repeated with classical IPFIX export in several Flow Records.

```

+-----+-----+-----+-----+-----+
|srcAddrA|srcPortA|destAddrB|destPortB| <Flow1 information> |
+-----+-----+-----+-----+-----+
|srcAddrA|srcPortA|destAddrC|destPortC| <Flow2 information> |
+-----+-----+-----+-----+-----+
|srcAddrD|srcPortD|destAddrB|destPortB| <Flow3 information> |
+-----+-----+-----+-----+-----+
|srcAddrD|srcPortD|destAddrC|destPortC| <Flow4 information> |
+-----+-----+-----+-----+-----+
|  ...  |  ...  |  ...  |  ...  |  ...  |
+-----+-----+-----+-----+-----+

```

Figure 5: Common and Specific Properties Exported Together

Besides A and B, other sets of Properties might be repeated as well (e.g., Properties C and D in the figure above).

We can separate the Common Properties into properties A composed of sourceAddressA and sourcePortA, properties D composed of sourceAddressD and sourcePortD, properties B composed of destinationAddressB and destinationPortB, and properties C composed of destinationAddressC and destinationPortC. These four records can be expanded to four combinations of Data Records to reduce redundancy without the need to define four complete sets of Common Properties (see the figure below). The more Common Properties sets that are defined, the more combinations that are available.

```

+-----+-----+-----+
| index for prop. A | sourceAddressA | sourcePortA |
+-----+-----+-----+
| index for prop. D | sourceAddressD | sourcePortD |
+-----+-----+-----+

+-----+-----+-----+
| index for prop. B | destinationAddressB | destinationPortB |
+-----+-----+-----+
| index for prop. C | destinationAddressC | destinationPortC |
+-----+-----+-----+

+-----+-----+-----+
| index for prop. A | index for prop. B | <Flow1 information> |
+-----+-----+-----+
| index for prop. A | index for prop. C | <Flow2 information> |
+-----+-----+-----+
| index for prop. D | index for prop. B | <Flow3 information> |
+-----+-----+-----+
| index for prop. D | index for prop. C | <Flow4 information> |
+-----+-----+-----+

```

Figure 6: Multiple Common (above) and Specific Properties (below)
Exported Separately

The advantage of the multiple Common Properties is that the objective of reducing the bandwidth is met while the number of indices is kept to a minimum. Defining an extra index for all records would not save bandwidth in the case of Figure 5 and is generally a less efficient solution.

If a set of Flow Records share multiple sets of Common Properties, multiple commonPropertiesID instances MAY be used to increase export efficiency even further, as displayed in Figure 7.

addition, there might be less storage capacity required at the Collector side if the Collector decides to store the Data Records as they arrive, without reconstructing the initial Flow Record.

On the other hand, this method requires additional resources on both the Exporter and the Collector. The Exporter has to manage Common Properties information and to assign commonPropertiesID values. The Collector has to process records described by two templates instead of just one. Additional effort is also required when post processing the measurement data, in order to correlate Flow Records with Common Properties information.

8.1. Transport Protocol Choice

The proposed method is most effective using a reliable transport protocol for the transfer of the Common Properties. Therefore, the use of PR-SCTP with full reliability or TCP is recommended for the transmission of IPFIX Messages containing Common Properties. Note that use of UDP is less efficient for the transmission of Common Properties, as they have to be resent regularly.

8.2. Reduced Size Encoding

The transfer of the commonPropertiesIDs originates some overhead and might even increase the amount of exported data if the length of the commonPropertiesID field is not shorter than the length of the replaced fields.

In cases where the range of the commonPropertiesID can be restricted, it is RECOMMENDED to apply reduced size encoding to the commonPropertiesID to achieve a further gain in bandwidth efficiency.

8.3. Efficiency Gain

While the goal of this specification is to reduce the bandwidth, the efficiency might be limited. Indeed, the efficiency gain is based on the abundance of redundant information in Flows and would be directly proportional to the reuse of the defined commonPropertiesID values, with a theoretical limit where all the Data Records would use a single commonPropertiesID. In other words, the more we reuse a commonPropertiesID value, the better the efficiency gain. While the Exporting Process can evaluate the direct gain for the Flow Records to be exported, it cannot predict whether future Flow Records would contain the information specified by active commonPropertiesID values. This implies that the efficiency factor of this specification is higher for specific applications where filtering is involved, such as one-way delay or trajectory sampling.

Note that this technique might even lead to an increase in bandwidth usage under certain conditions. Taking into account the overhead of exporting the commonPropertiesID values, if the commonPropertiesID values are not used in future Data Records, this technique would actually increase the export bandwidth. A typical case would be the assignments of Common Properties based on past observed traffic, hoping that future Flows would contain the same characteristics.

The efficiency gain depends also on the difference between the length of the replaced fields and the length of the commonPropertiesID. The shorter the length of the commonPropertiesID is (with respect to the total length of the Common Properties fields), the bigger the gain is.

The example in Appendix A.2 below uses IPFIX to export measurement data for each received packet. In that case, for a Flow of 1000 packets, the amount of data can be decreased more than 26 percent.

9. Security Considerations

The same security considerations as for the IPFIX protocol [RFC5101] apply.

10. Acknowledgments

The authors would like to thank Guido Pohl for initiating this work and for his contribution to early versions of this document. Thanks also to Andrew Johnson, Gehrard Muenz, Brian Trammell, and Paul Aitken for their comments and feedback.

11. References

11.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC5101] Claise, B., "Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of IP Traffic Flow Information", RFC 5101, January 2008.
- [RFC5102] Quittek, J., Bryant, S., Claise, B., Aitken, P., and J. Meyer, "Information Model for IP Flow Information Export", RFC 5102, January 2008.
- [RFC5476] Claise, B., Ed., "Packet Sampling (PSAMP) Protocol Specifications", RFC 5476, March 2009.

11.2. Informative References

- [PSAMP-MIB] Dietz, T., Ed. and B. Claise, "Definitions of Managed Objects for Packet Sampling", Work in Progress, June 2006.
- [RFC3550] Schulzrinne, H., Casner, S., Frederick, R., and V. Jacobson, "RTP: A Transport Protocol for Real-Time Applications", STD 64, RFC 3550, July 2003.
- [RFC3758] Stewart, R., Ramalho, M., Xie, Q., Tuexen, M., and P. Conrad, "Stream Control Transmission Protocol (SCTP) Partial Reliability Extension", RFC 3758, May 2004.
- [RFC3917] Quittek, J., Zseby, T., Claise, B., and S. Zander, "Requirements for IP Flow Information Export (IPFIX)", RFC 3917, October 2004.
- [RFC4960] Stewart, R., "Stream Control Transmission Protocol", RFC 4960, September 2007.
- [RFC5470] Sadasivan, G., Brownlee, N., Claise, B., and J. Quittek, "Architecture for IP Flow Information Export", RFC 5470, March 2009.
- [RFC5472] Zseby, T., Boschi, E., Brownlee, N., and B. Claise, "IP Flow Information Export (IPFIX) Applicability", RFC 5472, March 2009.
- [RFC5474] Duffield, N., Ed., "A Framework for Packet Selection and Reporting", RFC 5474, March 2009.
- [RFC5475] Zseby, T., Molina, M., Duffield, N., Niccolini, S., and F. Raspall, "Sampling and Filtering Techniques for IP Packet Selection", RFC 5475, March 2009.
- [RFC5477] Dietz, T., Claise, B., Aitken, P., Dressler, F., and G. Carle, "Information Model for Packet Sampling Exports", RFC 5477, March 2009.

Appendix A. Examples

A.1. Per-Flow Data Reduction

In this section, we show how Flow information can be exported efficiently using the method described in this document. Let's suppose we have to periodically export data about two IPv6 Flows.

In this example, we report the following information:

Flow	dstIPv6Address	dst-Port	nPkts	nBytes
A	2001:DB8:80AD:5800:0058:0800:2023:1D71	80	30	6000
A	2001:DB8:80AD:5800:0058:0800:2023:1D71	80	50	9500
B	2001:DB8:80AD:5800:0058:00AA:00B7:AF2B	1932	60	8000
A	2001:DB8:80AD:5800:0058:0800:2023:1D71	80	40	6500
A	2001:DB8:80AD:5800:0058:0800:2023:1D71	80	60	9500
B	2001:DB8:80AD:5800:0058:00AA:00B7:AF2B	1932	54	7600

Figure 8: Flow Information Example

The Common Properties in this case are the destination IPv6 address and the destination port. We first define an Options Template that contains the following Information Elements:

- o Scope: commonPropertiesID in [RFC5102], with a type of 137 and a length of 8 octets.
- o The destination IPv6 address: destinationIPv6Address in [RFC5102], with a type of 28 and a length of 16 octets.
- o The destination port: destinationTransportPort in [RFC5102], with a type of 11, and a length of 2 octets.

Figure 9 shows the Options Template defining the Common Properties with commonPropertiesID as scope:

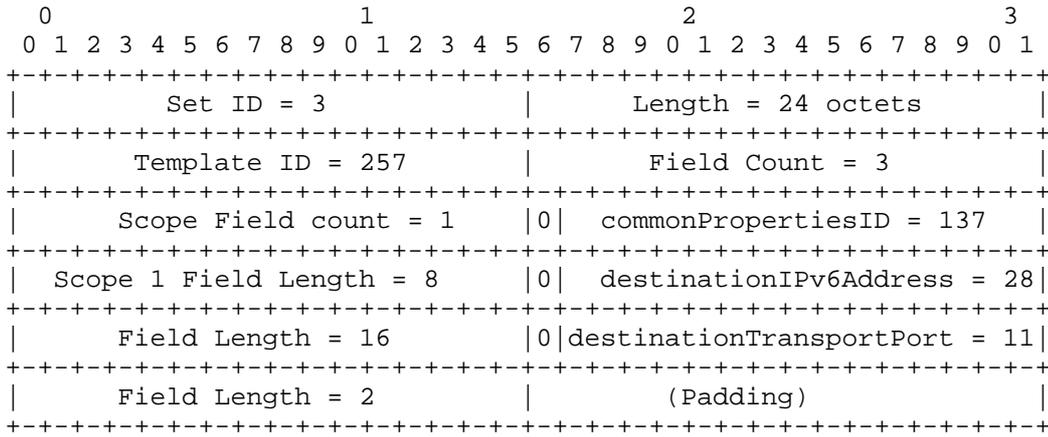


Figure 9: Common Properties Options Template

The Specific Properties Template consists of the information not contained in the Options Templates, i.e., Flow-specific information; in this case, the number of packets and the number of bytes to be reported. Additionally, this Template contains the commonPropertiesID. In Data Records, the value of this field will contain one of the unique indices of the Option Records exported before. It contains the following Information Elements (see also Figure 10):

- o commonPropertiesID with a length of 8 octets.
- o The number of packets of the Flow: inPacketDeltaCount in [RFC5102], with a length of 4 octets.
- o The number of octets of the Flow: inOctetDeltaCount in [RFC5102], with a length of 4 octets.

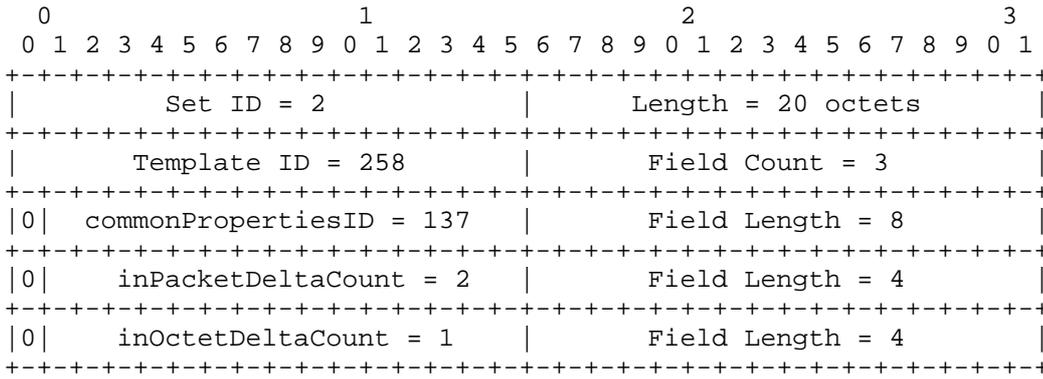


Figure 10: Specific Properties Template

Considering the data shown at the beginning of this example, the following two Data Records will be exported:

Common-PropertiesID	dstAddress	dst-Port
101	2001:DB8:80AD:5800:0058:0800:2023:1D71	80
102	2001:DB8:80AD:5800:0058:00AA:00B7:AF2B	1932

Figure 11

The Data Records reporting the Common Properties will look like:

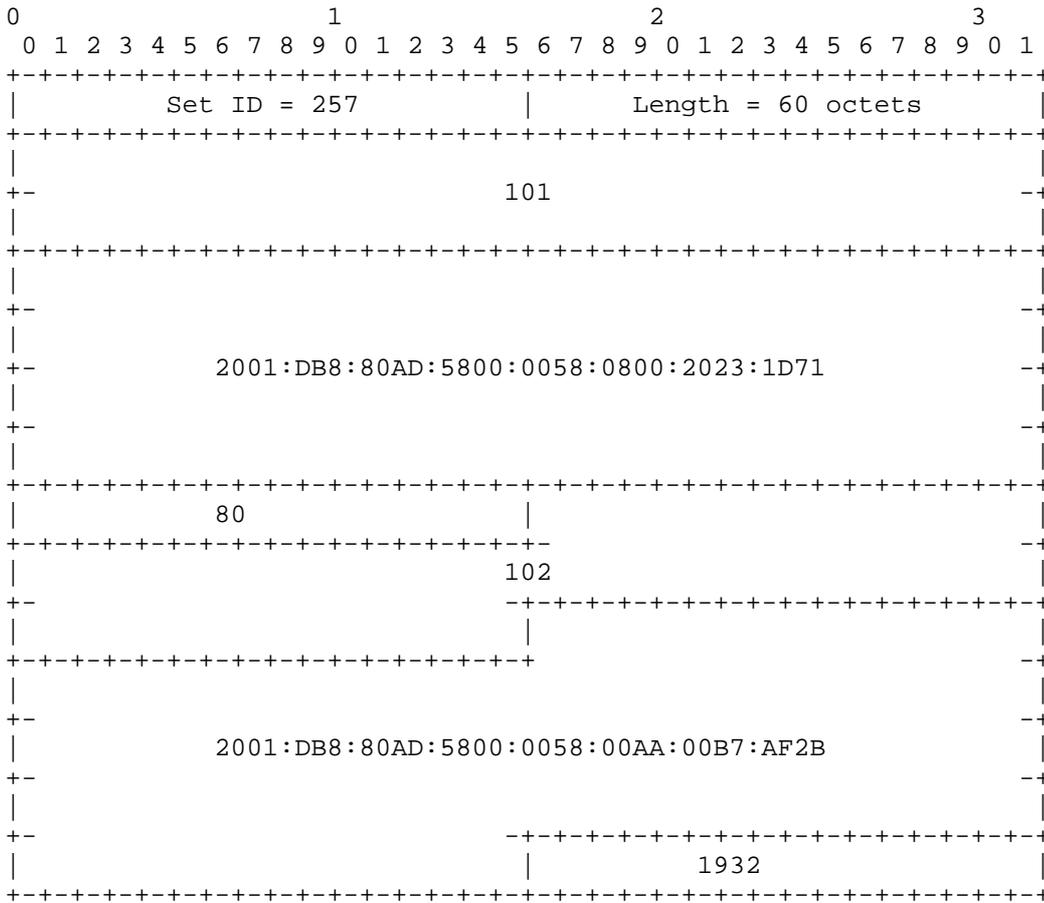


Figure 12: Data Records reporting Common Properties

The Data Records will in turn be:

commonPropertiesID	inPacketDeltaCount	inOctetDeltaCount
101	30	6000
101	50	9500
102	60	8000
101	40	6500
101	60	9500
102	54	7600

Figure 13

Figure 14 shows the first Data Record listed in the table:

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	2	3	4	5	6	7	8	9
Set ID = 258										Length = 16																													
										101																													
30																				6000																			

Figure 14: Data Record reporting Common Properties

A.2. Per-Packet Data Reduction

An example of the per-packet data reduction is the measurement of One-Way Delay (OWD), where the exact same specific packet must be observed at the source and destination of the path to be measured. The OWD is computed by subtracting the time of observation of the same packet at the two end-points with synchronized clocks. As the OWD is measured for a specific application on which a Service Level Agreement (SLA) is bound, this translates into the observation of multiple packets with Specific Properties. In order to match the identical packet at both Observation Points, a series of packets with a set of properties (for example, all the packets of a specific source and destination IP addresses, of a specific Diffserv codepoint (DSCP) value, and of a specific destination transport port) must be observed at both ends of the measurements. This implies that the source and destination must export a series of Flow Records composed of two types of information: some common information for all packets, and some unique information about each packet in order to generate a unique identifier for each packet passing this Observation Point (for example, a hash value on the invariant fields of the packet). So, the source and destination composing the measurement's end-points can individually and independently apply the redundancy technique described in this document in order to save some bandwidth for their respective Flow Records exports.

The Templates required for exporting measurement data of this kind are illustrated in the figures below. Figure 15 shows the Options Template containing the information concerning Flows using the commonPropertiesID as scope. In the Common Properties Template, we export the following Information Elements:

- o The source IPv4 Address: sourceIPv4Address in [RFC5102], with a type of 8 and a length of 4 octets.
- o The destination IPv4 Address: destinationIPv4Address in [RFC5102], with a type of 12 and a length of 4 octets.
- o The Class of Service field: ClassOfServiceIPv4 in [RFC5102], with a type of 5 and a length of 1 octet.
- o The Protocol Identifier: protocolIdentifier in [RFC5102], with a type of 4 and a length of 1 octet.
- o The source port: sourceTransportPort in [RFC5102], with a type of 7 and a length of 2 octets.
- o The destination port: destinationTransportPort in [RFC5102], with a type of 11 and a length of 2 octets.

The commonPropertiesID Information Element is used as the Scope Field.

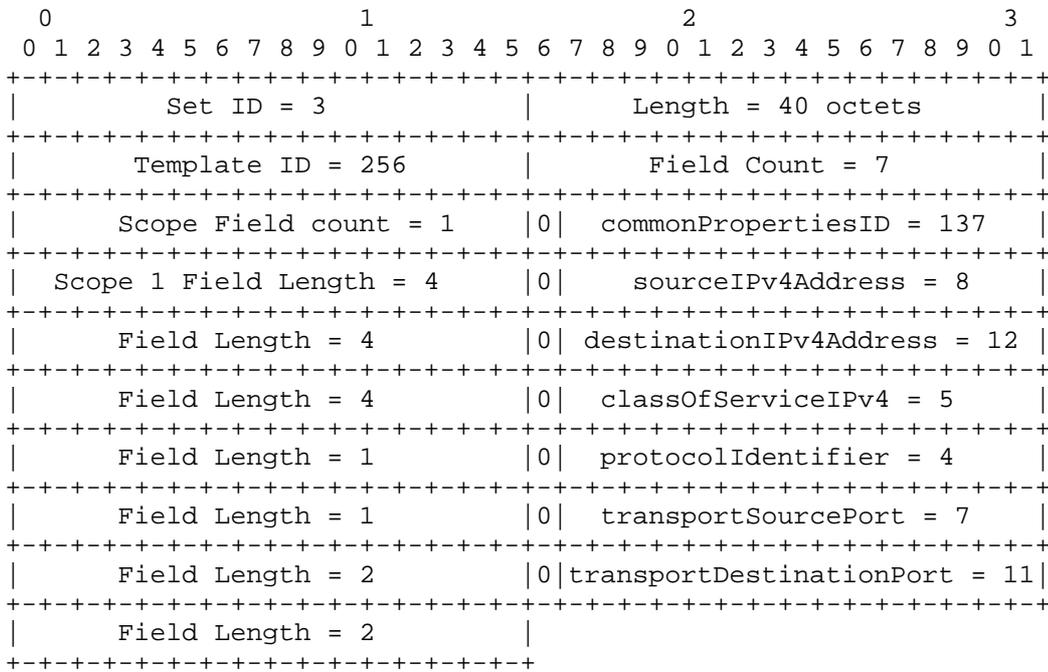


Figure 15: Example Flow Properties Template

For passive OWD measurement, the Packet Properties Template or Specific Properties Template consists of at least the timestamp and packet ID. Additionally, this template contains a commonPropertiesID field to associate the packet with a Flow.

Figure 16 displays the template with the packet properties. In this example, we export the following Information Elements:

- o commonPropertiesID. In this case, reduced size encoding is used, and the Information Element is declared with a length of 4 octets instead of 8.
- o The packet timestamp: observationTimeMilliseconds in the PSAMP information model [RFC5477], with a type of 323 and a length of 8 octets.
- o digestHashValue in the PSAMP information model [RFC5477], with a type of 326 and a length of 8 octets.
- o The packet length: ipTotalLength in the IPFIX information model [RFC5102], with a type of 224 and a length of 8 octets.

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	2	3	4	5	6	7	8	9
Set ID = 2										Length = 36 octets																													
Template ID = 257										Field Count = 4																													
0 commonPropertiesID = 137										Field Length = 4																													
0 observationTimeMillis.= 323										Field Length = 8																													
0 digestHashValue = 326										Field Length = 8																													
0 ipTotalLength = 224										Field Length = 8																													

Figure 16: Example Packet Properties Template

At the collection point, packet records from the two measurement points are gathered and correlated by means of the packet ID. The resulting delay Data Records are exported in a similar manner as the packet data. One-Way Delay data is associated with Flow information by the commonPropertiesID field. The OWD properties contain the Packet Pair ID (which is the packet ID of the two contributing packet

records), the timestamp of the packet passing the reference monitor point in order to reconstruct a time series, the calculated delay value, and the commonPropertiesID.

In this example, using IPFIX to export the measurement data for each received packet, 38 bytes have to be transferred (sourceAddressV4=4, destinationAddressV4=4, classOfServiceV4=1, protocolIdentifier=1, sourceTransportPort=2, destinationTransportPort=2, observationTimeMilliseconds=8, digestHashValue=8, ipTotalLength=8). Without considering the IPFIX protocol overhead, a Flow of 1000 packets produces 38000 bytes of measurement data. Using the proposed optimization, each packet produces an export of only 28 bytes (observationTimeMilliseconds=8, digestHashValue=8, ipTotalLength=8, commonPropertiesID=4). The export of the Flow information produces 18 bytes (sourceAddressV4=4, destinationAddressV4=4, classOfServiceV4=1, protocolIdentifier=1, sourceTransportPort=2, destinationTransportPort=2, commonPropertiesID=4). For a Flow of 1000 packets, this sums to 28018 bytes. This is a decrease of more than 26 percent.

A.3. Common Properties Withdrawal Message

This section shows an example commonPropertiesID Withdrawal message. Figure 17 depicts the Options Template Record with the commonPropertiesID as unique scope field, and no non-scope fields.

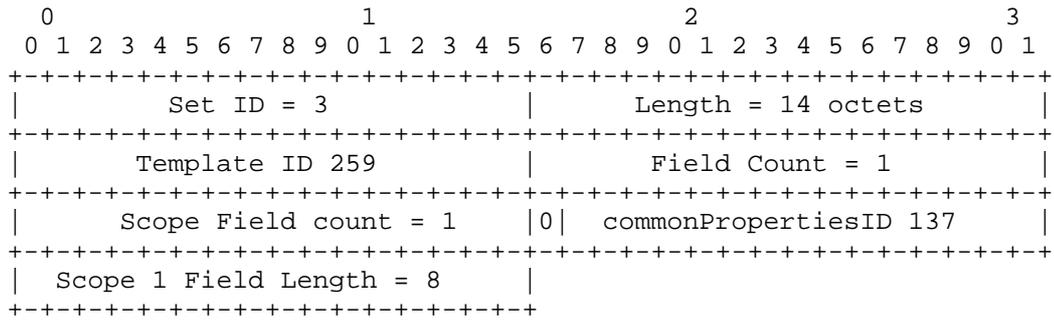


Figure 17: Example Common Properties Withdrawal Template

Figure 18 shows the Option Data Record withdrawing commonPropertiesID N:

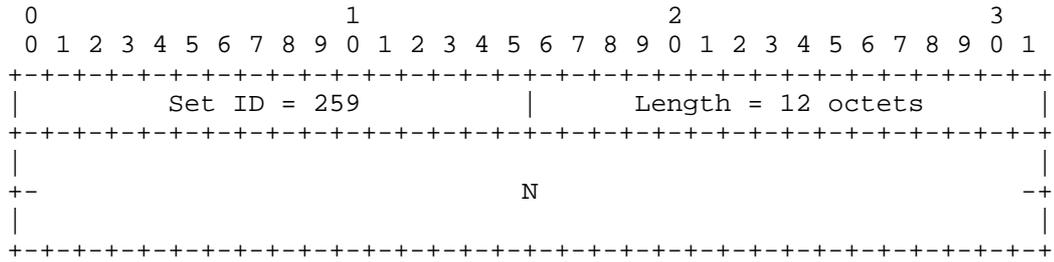


Figure 18: Record Withdrawing commonPropertiesID N

Authors' Addresses

Elisa Boschi
Hitachi Europe
c/o ETH Zurich
Gloriastrasse 35
8092 Zurich
Switzerland

Phone: +41 44 6327057
EMail: elisa.boschi@hitachi-eu.com

Lutz Mark
Fraunhofer IFAM
Wiener Str. 12
28359 Bremen
Germany

Phone: +49 421 2246206
EMail: lutz.mark@ifam.fraunhofer.de

Benoit Claise
Cisco Systems, Inc.
De Kleetlaan 6a b1
Diegem 1813
Belgium

Phone: +32 2 704 5622
EMail: bclaise@cisco.com

