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Operation of the IP Flow Information Export (IPFIX) Protocol
on IPFIX Mediators

Abstract

This document specifies the operation of the IP Flow Information Export (IPFIX) protocol specific to IPFIX Mediators, including Template and Observation Point management, timing considerations, and other Mediator-specific concerns.

Status of This Memo

This is an Internet Standards Track document.

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1. Introduction

The IPFIX architectural components in [RFC5470] consist of IPFIX Devices and IPFIX Collectors communicating using the IPFIX protocol [RFC7011], which specifies how to export IP Flow information. 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 relevant Information Element is specified in the IPFIX Information Model [RFC7012],

registered with IANA, or specified as an enterprise-specific Information Element. The IPFIX protocol [RFC7011] was not originally written with IPFIX Mediators in mind. Therefore, the IPFIX protocol must be adapted for Intermediate Processes, as defined in the IPFIX Mediation Reference Model as specified in Figure A of [RFC6183], which is based on the IPFIX Mediation Problem Statement [RFC5982].

This document specifies the IP Flow Information Export (IPFIX) protocol in the context of the implementation and deployment of IPFIX Mediators. The use of the IPFIX protocol within an IPFIX Mediator -- a device that contains both a Collecting Process and an Exporting Process -- has an impact on the technical details of the usage of the protocol. An overview of the technical problem is covered in Section 6 of [RFC5982]: loss of original Exporter information, loss of base time information, transport sessions management, loss of Options Template Information, Template Id management, considerations for network topology, IPFIX mediation interpretation, and considerations for aggregation.

The specifications in this document are based on the IPFIX protocol specifications [RFC7011], but they are adapted according to the IPFIX Mediation Framework [RFC6183].

1.1. IPFIX Documents Overview

The IPFIX protocol [RFC7011] 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 the IPFIX Requirements document, [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 [RFC7012]. The IPFIX Information Element registry [IANA-IPFIX] is maintained by IANA. New Information Element definitions can be added to this registry subject to an Expert Review [RFC5226], with additional process considerations described in [RFC7013]; that document also provides guidelines for authors and reviewers of new Information Element definitions. The inline export of the Information Element type information is specified in [RFC5610].

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. IPFIX Mediator Documents Overview

"IP Flow Information Export (IPFIX) Mediation: Problem Statement" [RFC5982] provides an overview of the applicability of IPFIX Mediators and defines requirements for IPFIX Mediators in general terms. This document is of use largely to define the problems to be solved through the deployment of IPFIX Mediators and to provide scope to the role of IPFIX Mediators within an IPFIX collection infrastructure.

"IP Flow Information Export (IPFIX) Mediation: Framework" [RFC6183], which details the IPFIX Mediation reference model and the components of an IPFIX Mediator, provides more architectural details of the arrangement of Intermediate Processes within an IPFIX Mediator.

Documents specifying the operations of specific Intermediate Processes cover the operation of these Processes within the IPFIX Mediator framework and comply with the specifications given in this document; additionally, they may specify the operation of the process independently, outside the context of an IPFIX Mediator, when this is appropriate. The details of specific Intermediate Processes, when they have additional export specifications (e.g., metadata about the intermediate processing conveyed through IPFIX Options Templates), are each addressed in their own document. As of today, these documents are:

1. "IP Flow Anonymization Support", [RFC6235], which describes anonymization techniques for IP flow data and the export of anonymized data using the IPFIX protocol.
2. "Flow Selection Techniques" [RFC7014], which describes the process of selecting a subset of Flows from all Flows observed at an Observation Point, the flow selection motivations, and some specific flow selection techniques.
3. "Flow Aggregation for the IP Flow Information Export (IPFIX) Protocol" [RFC7015], which describes Aggregated Flow export within the framework of IPFIX Mediators and defines an interoperable, implementation-independent method for Aggregated Flow export.

This document specifies the IP Flow Information Export (IPFIX) protocol specific to Mediation, to which all Intermediate Processes must comply. Some extra specifications might be required per Intermediate Process type (in which case, the document specific to the Intermediate Process would apply).

1.3. Relationship with the IPFIX and PSAMP Protocols

The specification in this document is based on the IPFIX protocol specification [RFC7011]. All specifications from [RFC7011] apply unless specified otherwise in this document.

As the Packet Sampling (PSAMP) protocol specifications [RFC5476] are based on the IPFIX protocol specifications, the specifications in this document are also valid for the PSAMP protocol. Therefore, the method specified by this document also applies to PSAMP.

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 [RFC2119].

IPFIX-specific terms, such as Observation Domain, Flow, Flow Key, Metering Process, Exporting Process, Exporter, IPFIX Device, Collecting Process, Collector, Template, IPFIX Message, Message Header, Template Record, Data Record, Options Template Record, Set, Data Set, Information Element, Scope and Transport Session, used in this document are defined in [RFC7011]. The PSAMP-specific terms used in this document, such as Filtering and Sampling, are defined in [RFC5476].

IPFIX Mediation terms related to aggregation, such as the Interval, Aggregated Flow and Aggregated Function, are defined in [RFC7015].

The terminology specific to IPFIX Mediation that is used in this document is defined in "IP Flow Information Export (IPFIX) Mediation: Problem Statement" [RFC5982] and reused in "IP Flow Information Export (IPFIX) Mediation: Framework" [RFC6183]. However, since both of those documents are Informational RFCs, the definitions have been reproduced and elaborated on here.

Similarly, since [RFC6235] is an Experimental RFC, the Anonymization Record, Anonymized Data Record, and Intermediate Anonymization Process terms, specified in [RFC6235], are also reproduced here.

In this document, as in [RFC7011], [RFC5476], [RFC7015], and [RFC6235], the first letter of each IPFIX-specific and PSAMP-specific term is capitalized along with the IPFIX Mediation-specific term defined here.

In this document, we call a stream of records carrying flow- or packet-based information a "record stream". The records may be encoded as IPFIX Data Records or any other format.

Transport Session: The Transport Session is specified in [RFC7011]. In Stream Control Transmission Protocol (SCTP), the Transport Session information is the SCTP association. In TCP and UDP, the Transport Session information corresponds to a 5-tuple {Exporter IP address, Collector IP address, Exporter transport port, Collector transport port, transport protocol}.

Original Exporter: An Original Exporter is the source from which a Mediator receives its record stream. For simple IPFIX mediation without protocol conversion, this is an IPFIX Device that hosts the Observation Points where the metered IP packets are observed.

Original Observation Point: An Observation Point on a Metering Process associated with the Original Exporter. In the case of the Intermediate Aggregation Process on an IPFIX Mediator, the Original Observation Point can be composed of, but not limited to, a (set of) specific Exporter(s), a (set of) specific interface(s) on an Exporter, a (set of) line card(s) on an Exporter, or any combinations of these.

IPFIX Mediation: IPFIX Mediation is the manipulation and conversion of a record stream for subsequent export using the IPFIX protocol.

Template Mapping: A mapping from Template Records and/or Options Template Records received by an IPFIX Mediator to Template Records and/or Options Template Records sent by that IPFIX Mediator. Each entry in a Template Mapping is scoped by incoming or outgoing Transport Session and Observation Domain, as with Templates and Options Templates in the IPFIX Protocol.

Anonymization Record: A record that defines the properties of the anonymization applied to a single Information Element within a single Template or Options Template, as in [RFC6235].

Anonymized Data Record: A Data Record within a Data Set containing at least one Information Element with anonymized values. The Information Element(s) within the Template or Options Template describing this Data Record SHOULD have a corresponding Anonymization Record, as in [RFC6235].

The following terms are used in this document to describe the architectural entities used by IPFIX Mediation.

Intermediate Process: An Intermediate Process takes a record stream as its input from Collecting Processes, Metering Processes, IPFIX File Readers, other Intermediate Processes, or other record sources; performs some transformations on this stream, based upon the content of each record, states maintained across multiple records, or other data sources; and passes the transformed record stream as its output to Exporting Processes, IPFIX File Writers, or other Intermediate Processes, in order to perform IPFIX Mediation. Typically, an Intermediate Process is hosted by an IPFIX Mediator. Alternatively, an Intermediate Process may be hosted by an Original Exporter.

IPFIX Mediator: An IPFIX Mediator is an IPFIX Device that provides IPFIX Mediation by receiving a record stream from some data sources, hosting one or more Intermediate Processes to transform that stream, and exporting the transformed record stream into IPFIX Messages via an Exporting Process. In the common case, an IPFIX Mediator receives a record stream from a Collecting Process, but it could also receive a record stream from data sources not encoded using IPFIX, e.g., in the case of conversion from the NetFlow V9 protocol [RFC3954] to IPFIX protocol.

Specific Intermediate Processes are described below.

Intermediate Conversion Process (as in [RFC6183]): An Intermediate Conversion Process is an Intermediate Process that transforms non-IPFIX into IPFIX or manages the relation among Templates and states of incoming/outgoing Transport Sessions in the case of transport protocol conversion (e.g., from UDP to SCTP).

Intermediate Aggregation Process (as in [RFC7015]): an Intermediate Process (IAP), as in [RFC6183], that aggregates records, based upon a set of Flow Keys or functions applied to fields from the record.

Intermediate Correlation Process (as in [RFC6183]): An Intermediate Correlation Process is an Intermediate Process that adds information to records, noting correlations among them, or generates new records with correlated data from multiple records (e.g., the production of bidirectional flow records from unidirectional flow records).

Intermediate Anonymization Process (as in [RFC6235]): An intermediate process that takes Data Records and transforms them into Anonymized Data Records.

Intermediate Selection Process (as in [RFC6183]): An Intermediate Selection Process is an Intermediate Process that selects records from a sequence based upon criteria-evaluated record values and passes only those records that match the criteria (e.g., Filtering only records from a given network to a given Collector).

Intermediate Flow Selection Process (as in [RFC7014]: An Intermediate Flow Selection Process is an Intermediate Process, as in [RFC6183] that takes Flow Records as its input and selects a subset of this set as its output. The Intermediate Flow Selection Process is a more general concept than the Intermediate Selection Process as defined in [RFC6183]. While an Intermediate Selection Process selects Flow Records from a sequence based upon criteria-evaluated Flow record values and only passes on those Flow Records that match the criteria, an Intermediate Flow Selection Process selects Flow Records using selection criteria applicable to a larger set of Flow characteristics and information.

Note: for more information on the difference between Intermediate Flow Selection Process and Intermediate Selection Process, see Section 4 in [RFC7014].

3. Handling IPFIX Message Headers

The format of the IPFIX Message Header as exported by an IPFIX Mediator is shown in Figure 1. This is identical to the format defined for IPFIX in [RFC7011], though Export Time and Observation Domain ID may be handled differently at certain Mediators, as noted below.

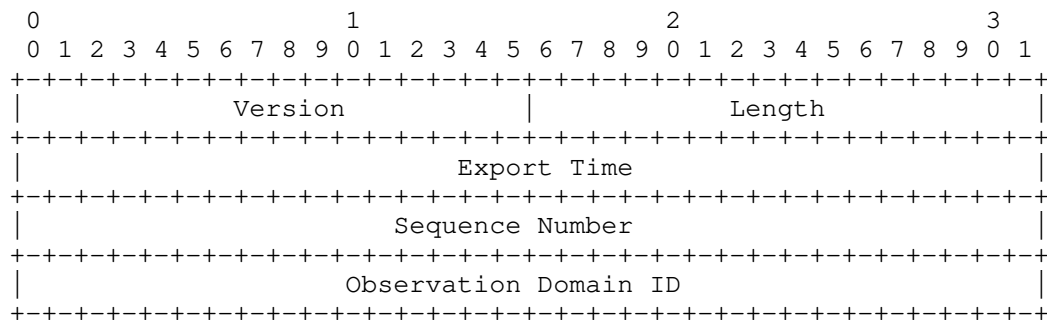


Figure 1: IPFIX Message Header format

The header fields as exported by an IPFIX Mediator are described below.

Version:

Version of IPFIX to which this Message conforms. The value of this field is 0x000a for the current version, incrementing by one the version used in the NetFlow services export version 9 [RFC3954].

Length:

Total length of the IPFIX Message, measured in octets, including Message Header and Set(s).

Export Time:

Time at which the IPFIX Message Header leaves the IPFIX Mediator, expressed in seconds since the UNIX epoch of 1 January 1970 at 00:00 UTC, encoded as an unsigned 32-bit integer.

However, in the specific case of an IPFIX Mediator containing an Intermediate Conversion Process, the IPFIX Mediator MAY use the export time received from the incoming Transport Session.

Sequence Number:

Incremental sequence counter modulo 2^{32} of all IPFIX Data Records sent in the current stream from the current Observation Domain by the Exporting Process. Each SCTP Stream counts sequence numbers separately, while all messages in a TCP connection or UDP Transport Session are considered to be part of the same stream. This value can be used by the Collecting Process to identify whether any IPFIX Data Records have been missed. Template and Options Template Records do not increase the Sequence Number.

Observation Domain ID:

A 32-bit identifier of the Observation Domain that is locally unique to the Exporting Process. The Exporting Process uses the Observation Domain ID to uniquely identify to the Collecting Process the Observation Domain that metered the Flows. It is RECOMMENDED that this identifier also be unique per IPFIX Device. Collecting Processes can use the Transport Session and the Observation Domain ID field to separate different export streams originating from the same Exporter. The Observation Domain ID is set to 0 when no specific Observation Domain ID is relevant for

the entire IPFIX Message, for example, when exporting the Exporting Process Statistics, or in case of a hierarchy of Collectors when aggregated Data Records are exported.

See Section 4.1 for special considerations for Observation Domain management while passing unmodified templates through an IPFIX Mediator, and Section 5 for guidelines for preservation of original Observation Domain information at an IPFIX Mediator.

The following specifications, copied over from [RFC7011] have some implications in this document:

Template Withdrawals MAY appear interleaved with Template Sets, Options Template Sets, and Data Sets within an IPFIX Message. In this case, the Templates and Template Withdrawals shall be interpreted as taking effect in the order in which they appear in the IPFIX Message.

If an IPFIX Mediator receives an IPFIX Message composed of Template Withdrawals and Template Sets, and if the IPFIX Mediator forwards this IPFIX Message, it MUST NOT modify the Set order. If an IPFIX Mediator receives IPFIX Messages composed of Template Withdrawals and Template Sets, and if the IPFIX Mediator forwards these IPFIX Messages, it MUST NOT modify the IPFIX Message order. Note that the Template Mapping (see Section 4.1) is the authoritative source of information on the IPFIX Mediator to decide whether the entire IPFIX Messages can be forwarded as such.

4. Template Management

How an IPFIX Mediator handles the Templates it receives from the Original Exporter depends entirely on the nature of the Intermediate Process running on that IPFIX Mediator. There are two cases here:

1. IPFIX Mediators that pass substantially the same Data Records from the Original Exporter downstream (e.g., an Intermediate Selection Process), pass unmodified Templates as described in Section 4.1; this section describes a Template Mapping required to make this work in the general case, and the correlation between the received and generated IPFIX Message Withdrawals.
2. IPFIX Mediators that export Data Records that are substantially changed from the Data Records received from the Original Exporter follow the guidelines in Section 4.2 instead: in this case, the IPFIX Mediator generates new (Options) Template Records as a result of the Intermediate Process, and no Template Mapping is required.

Subsequent subsections deal with specific issues in Template management that may occur at IPFIX Mediators.

4.1. Passing Unmodified Templates through an IPFIX Mediator

For some Intermediate Processes, the IPFIX Mediator doesn't modify the (Options) Template Record(s) content. A typical example is an Intermediate Flow Selection Process acting as distributor, which collects Flow Records from one or more Exporters, and based on the content of the Information Elements, redirects the Flow Records to the appropriate Collector. This example is a typical case of a single network operation center managing multiple universities: a unique IPFIX Collector collects all Flow Records for the common infrastructure, but might be re-exporting specific university Flow Records to the responsible system administrator.

As specified in [RFC7011], the Template IDs are unique per Exporter, per Transport Session, and per Observation Domain. As there is no guarantee that, for similar Template Records, the Template IDs received on the incoming Transport Session and exported to the outgoing Transport Session would be same, the IPFIX Mediator **MUST** maintain a Template Mapping composed of related received and exported (Options) Template Records:

- o for each received (Options) Template Record: Template Record Information Elements, Template ID, Observation Domain ID, and Transport Session information, metadata scoped to the Template (*)
- o for each exported (Options) Template Record: Template Record Information Elements, Template ID, Collector, Observation Domain ID, and Transport Session information metadata scoped to the Template (*)

(*) The "metadata scoped to the Template" encompasses the metadata, that are scoped to the Template, and that help to determine the semantics of the Template Record. Note that these metadata are typically sent in Data Records described by an Options Template. An example is the flowKeyIndicator. An IPFIX Mediator could potentially receive two different Template IDs, from the same Exporter, with the same Information Elements, but with a different set of Flow Keys (indicated by the flowKeyIndicator in an Options Template Record). Another example is the combination of anonymizationFlags and anonymizationTechnique [RFC6235]). This metadata information must be present in the Template Mapping, to stress that the two Template Record semantics are different.

If an IPFIX Mediator receives an IPFIX Withdrawal Message for a (Options) Template Record that is not used anymore in any other Template Mappings, the IPFIX Mediator SHOULD export the appropriate IPFIX Withdrawal Message(s) on the outgoing Transport Session and remove the corresponding entry in the Template Mapping.

If a (Options) Template Record is not used anymore in an outgoing Transport Session, it MUST be withdrawn with an IPFIX Template Withdrawal Message on that specific outgoing Transport Session, and its entry, MUST be removed from the Template Mapping.

If an incoming or outgoing Transport Session is gracefully shut down or reset, the (Options) Template Records corresponding to that Transport Session MUST be removed from the Template Mapping.

For example, Figure 2 displays an example of an Intermediate Flow Selection Process, redistributing Data Records to Collectors on the basis of customer networks, i.e., the Route Distinguisher (RD). In this example, the Template Record received from the Exporter #1 is reused towards Collector #1, Collector #2, and Collector #3, for the customer #1, customer #2, and customer #3, respectively. In this example, the outgoing Template Records exported to the different Collectors are identical. As a reminder that the Template ID uniqueness is local to the Transport Session and Observation Domain that generated the Template ID, a mix of Template ID 256 and 257 has been used.

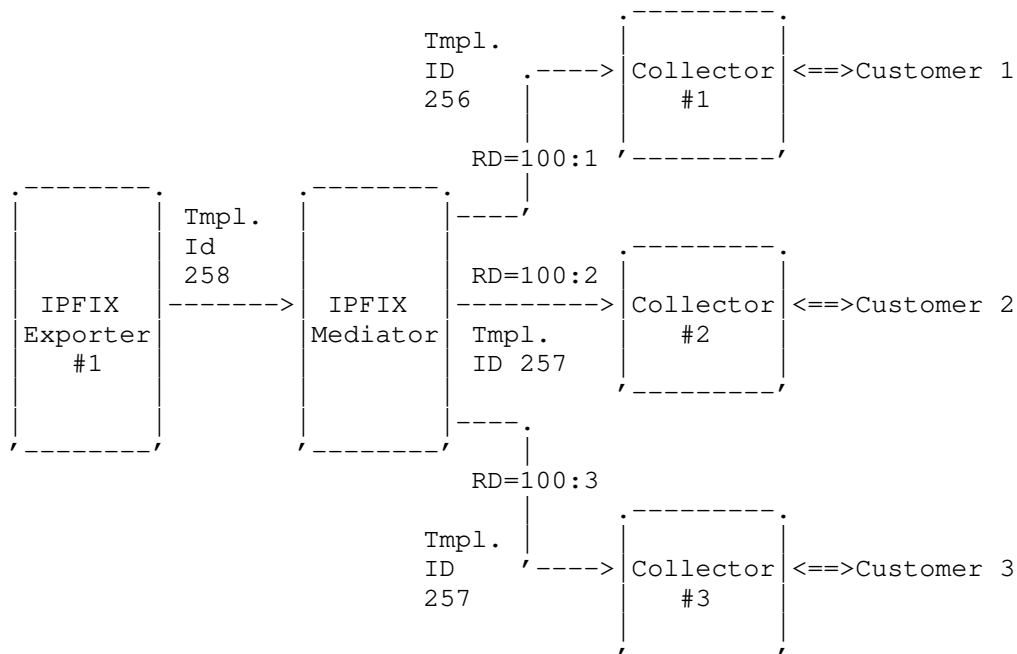


Figure 2: Intermediate Flow Selection Process Example

Figure 3 shows the Template Mapping for the system shown in Figure 2.

<p>Template Entry A: Incoming Transport Session information (from Exporter#1): Source IP: <Exporter#1 export IP address> Destination IP: <IPFIX Mediator IP address> Protocol: SCTP Source Port: <source port> Destination Port: 4739 (IPFIX) Observation Domain ID: <Observation Domain ID> Template ID: 258 Metadata scoped to the Template : <not applicable in this case></p> <p>Template Entry B: Outgoing Transport Session information (to Collector#1): Source IP: <IPFIX Mediator IP address> Destination IP: <IPFIX Collector#1 IP address> Protocol: SCTP Source Port: <source port> Destination Port: 4739 (IPFIX) Observation Domain ID: <Observation Domain ID> Template ID: 256 Metadata scoped to the Template : <not applicable in this case></p> <p>Template Entry C: Outgoing Transport Session information (to Collector#2): Source IP: <IPFIX Mediator IP address> Destination IP: <IPFIX Collector#2 IP address> Protocol: SCTP Source Port: <source port> Destination Port: 4739 (IPFIX) Observation Domain ID: <Observation Domain ID> Template ID: 257 Metadata scoped to the Template : <not applicable in this case></p> <p>Template Entry D: Outgoing Transport Session information (to Collector#3): Source IP: <IPFIX Mediator IP address> Destination IP: <IPFIX Collector#3 IP address> Protocol: SCTP Source Port: <source port> Destination Port: 4739 (IPFIX) Observation Domain ID: <Observation Domain ID> Template ID: 257 Metadata scoped to the Template : <not applicable in this case></p>
--

Figure 3: Template Mapping Example: Templates

The Template Mapping corresponding to Figure 3 is displayed in Figure 4:

```

Template Entry A    <----> Template Entry B
Template Entry A    <----> Template Entry C
Template Entry A    <----> Template Entry D
    
```

Figure 4: Template Mapping Example: Mappings

Alternatively, the Template Mapping may be optimized as in Figure 5:

```

      +--> Template Entry B
      |
Template Entry A  <---+---> Template Entry C
      |
      +--> Template Entry D
    
```

Figure 5: Template Mapping Example 2: Mappings

Note that all examples use Transport Sessions based on the SCTP, as simplified use cases. However, the transport protocol would be important in situations such as an Intermediate Conversion Process doing transport protocol conversion.

4.1.1.1. Template Mapping and Information Element Ordering

In the situation where Original Exporters each export an (Options) Template Record to a single IPFIX Mediator, and the (Options) Template Record contains the same Information Elements, but in different order, should the IPFIX Mediator maintain a Template Mapping with a single Export Template Record (see Figure 6) or should the IPFIX Mediator maintain multiple independent Template Records (see Figure 7) before re-exporting to the Collector?

```

Template Entry A    <--+
                  |
Template Entry B    <---+---> Template Entry D
                  |
Template Entry C    <--+
    
```

Figure 6: Template Mapping and Ordering:
A single Export Template Record

```

Template Entry A  <---+---> Template Entry D
Template Entry B  <---+---> Template Entry E
Template Entry C  <---+---> Template Entry F

```

Figure 7: Template Mapping and Ordering:
Multiple Export Template Records

The answer depends on whether the order of the Information Elements implies some specific semantic. One of the guiding principles in IPFIX protocol specifications is that the semantic meaning of one Information Element doesn't depend on the value of any other Information Element. However, there is one noticeable exception, as mentioned in [RFC7011]:

Multiple Scope Fields MAY be present in the Options Template Record, in which case the composite scope is the combination of the scopes. For example, if the two scopes are meteringProcessId and templateId, the combined scope is this Template for this Metering Process. If a different order of Scope Fields would result in a Record having a different semantic meaning, then the order of Scope Fields MUST be preserved by the Exporting Process. For example, in the context of PSAMP [RFC5476], if the first scope defines the filtering function, while the second scope defines the sampling function, the order of the scope is important. Applying the sampling function first, followed by the filtering function, would lead to potentially different Data Records than applying the filtering function first, followed by the sampling function.

If an IPFIX Mediator receives, from multiple Exporters, Template Records with identical Information Elements, but ordered differently, it SHOULD consider those Template Records as identical, subject to metadata information in the associated Options Template (for example, the Flow Key Options Template, see Section 10.2).

If an IPFIX Mediator receives, from multiple Exporters, Options Template Records with identical and ordered Information Elements in the Scope fields, and with identical Information Elements, but ordered differently, in the non-Scope fields, it SHOULD consider those Template Records as identical.

If an IPFIX Mediator receives, from multiple Exporters, Options Template Records with identical Information Elements in the Scope field, but ones that are ordered differently, it MUST consider those Template Records as semantically different.

4.2. Creating New Templates at an IPFIX Mediator

For other Intermediate Processes, the IPFIX Mediator generates new (Options) Template Records as a result of the Intermediate Process.

In these cases, the IPFIX Mediator doesn't need to maintain a Template Mapping, as it generates its own series of (Options) Template Records. However, some special cases might still require a Template Mapping. Consider a situation where the IPFIX Mediator generates new (Options) Template Records based on what it receives from the Exporter(s) based on the Intermediate Process function: for example, an Intermediate Anonymization process that performs black-marker anonymization [RFC6235] on certain Information Elements. In such cases, it's important to keep the correlation between the received (Options) Template Records and derived (Options) Template Records in the Template Mapping. These Template Mappings would be kept as in Section 4.1, except that the exported Template would not be identical to the received Template.

Similar to Exporting Processes in any Exporter, an IPFIX Mediator may use the technique for reducing redundancy in IPFIX described in [RFC5473].

4.3. Handling Unknown Information Elements

Depending on application requirements, Mediators that do not generate new Records SHOULD re-export values for unknown Information Elements, for which the Mediator does not have information about Information Element data type and semantics. However, as there may be presence or ordering dependencies among the unknown Information Elements, the Mediator MUST NOT omit fields from such re-exported Records or reorder any fields within the Records.

Mediators that generate new Records, as in Section 4.2, MUST ignore values of Information Elements they do not understand. If a Mediator passes values of Information Elements it does not understand (for example, when re-exporting Flow Records), it MUST pass them in the order in which they were originally received.

In any case, Mediators handling unknown Information Elements SHOULD log this fact, as it is likely that mediation of records containing unknown values will have unintended consequences.

5. Preserving Original Observation Point Information

Depending on the use case, the Collector in an Exporter/IPFIX Mediator/Collector structure (for example, tiered Mediators) may need to receive information about the Original Observation Point(s);

otherwise, it may wrongly conclude that the IPFIX Device exporting the Flow Records, i.e., the IPFIX Mediator, directly observed the packets that generated the Flow Records. Two new Information Elements are introduced to address this use case: `originalExporterIPv4Address` and `originalExporterIPv6Address`. Practically, the Original Exporters will not be exporting these Information Elements. Therefore, the Intermediate Process will report the Original Observation Point(s) to the best of its knowledge. Note that the Configuration Data Model for IPFIX and PSAMP [RFC6728] may report the Original Exporter information out of band.

In the IPFIX Mediator, the Observation Point(s) may be represented by:

- o A single Original Exporter (represented by the `originalExporterIPv4Address` or `originalExporterIPv6Address` Information Elements).
- o A list of Original Exporters (represented by a list of `originalExporterIPv4Address` or `originalExporterIPv6Address` Information Elements).
- o Any combination or list of Information Elements representing Observation Points. For example:
 - * A list of Original Exporter interfaces (represented by the `originalExporterIPv4Address` or `originalExporterIPv6Address`, the `ingressInterface`, and/or `egressInterface` Information Elements, respectively).
 - * A list of Original Exporter line card (represented by the `originalExporterIPv4Address`, `originalExporterIPv6Address`, or `lineCardId` Information Elements, respectively).

Some Information Elements characterizing the Observation Point may be added. For example, the `flowDirection` Information Element specifies the direction of the observation, and, as such, characterizes the Observation Point.

Any combination of the above representations is possible. An example of an Original Observation Point for an Intermediate Aggregation Process is displayed in Figure 8.

```
exporterIPv4Address 192.0.2.1
exporterIPv4Address 192.0.2.2,
  interface ethernet 0, direction ingress
  interface ethernet 1, direction ingress
  interface serial 1, direction egress
  interface serial 2, direction egress
exporterIPv4Address 192.0.2.3,
  lineCardId 1, direction ingress
```

Figure 8: Complex Observation Point Definition Example

A Mediator MAY export such complex Original Observation Point information, depending on application requirements. If such information is exported, the Mediator MUST use [RFC6313] to do so, as described below.

The most generic way to export the Original Observation Point is to use a subTemplateMultiList, with the semantic "exactlyOneOf". Taking the previous example, the encoding in Figure 9 can be used.

```
Template Record 257: exporterIPv4Address
Template Record 258: exporterIPv4Address,
  basicList of ingressInterface, flowDirection
Template Record 259: exporterIPv4Address, lineCardId, flowDirection
```

Figure 9: Complex Observation Point Definition Example: Templates

The Original Observation Point is modeled with the Data Records corresponding to either Template Record 1, Template Record 2, or Template Record 3 but not more than one of these ("exactlyOneOf" semantic). This implies that the Flow was observed at exactly one of the Observation Points reported.

When an IPFIX Mediator receives Flow Records containing the Original Observation Point Information Element, i.e., originalExporterIPv4Address or originalExporterIPv6Address, the IPFIX Mediator SHOULD NOT modify its value(s) when composing new Flow Records in the general case. Known exceptions include anonymization per Section 7.2.4 of [RFC6235] and an Intermediate Correlation Process rewriting addresses across NAT. In other words, the Original Observation Point should not be replaced with the IPFIX Mediator Observation Point. The daisy chain of (Exporter, Observation Point) representing the path the Flow Records took from the Exporter to the top Collector in the Exporter/IPFIX Mediator(s)/Collector structure model is out of the scope of this specification.

The following subsections describe Information Elements for reporting Original Exporter addresses as seen by the Collecting Process; note they may be subject to network address translation upstream; see [NAT-LOGGING] for more on logging in this situation.

5.1. originalExporterIPv4Address Information Element

Name: originalExporterIPv4Address

Description: The IPv4 address used by the Exporting Process on an Original Exporter, as seen by the Collecting Process on an IPFIX Mediator. Used to provide information about the Original Observation Points to a downstream Collector.

Data Type: ipv4Address

ElementId: 403

5.2. originalExporterIPv6Address Information Element

Name: originalExporterIPv6Address

Description: The IPv6 address used by the Exporting Process on an Original Exporter, as seen by the Collecting Process on an IPFIX Mediator. Used to provide information about the Original Observation Points to a downstream Collector.

Data Type: ipv6Address

ElementId: 404

6. Managing Observation Domain IDs

The Observation Domain ID of any IPFIX Message containing Flow Records relevant to no particular Observation Domain, or to multiple Observation Domains, MUST have an Observation Domain ID of 0.

IPFIX Mediators that do not change (Options) Template Records MUST maintain a Template Mapping, as detailed in Section 4.1, to ensure that the combination of Observation Domain IDs and Template IDs do not collide on export.

For IPFIX Mediators that export New (Options) Template Records, as in Section 4.2, there are two options for Observation Domain ID management. The first and simplest of these is to completely decouple exported Observation Domain IDs from received Observation

Domain IDs; the IPFIX Mediator, in this case, comprises its own set of Observation Domain(s) independent of the Observation Domain(s) of the Original Exporters.

The second option is to provide or maintain a Template Mapping for received (Options) Template Records and exported inferred (Options) Template Records, along with the appropriate Observation Domain IDs per Transport Session, which ensures that the combination of Observation Domain IDs and Template IDs do not collide on export.

In some cases where the IPFIX Message Header can't contain a consistent Observation Domain for the entire IPFIX Message, but the Flow Records exported from the IPFIX Mediator should contain the Observation Domain of the Original Exporter anyway, the (Options) Template Record must contain the originalObservationDomainId Information Element, specified in Section 6.1. When an IPFIX Mediator receives Flow Records containing the originalObservationDomainId Information Element, the IPFIX Mediator MUST NOT modify its value(s) when composing new Flow Records with the originalObservationDomainId Information Element.

6.1. originalObservationDomainId Information Element

Name: originalObservationDomainId

Description: The Observation Domain ID reported by the Exporting Process on an Original Exporter, as seen by the Collecting Process on an IPFIX Mediator. Used to provide information about the Original Observation Domain to a downstream Collector. When cascading through multiple Mediators, this identifies the initial Observation Domain in the cascade.

Data Type: unsigned32

Data Type Semantics: identifier

ElementId: 405

7. Timing Considerations

The IPFIX Message Header "Export Time" field is the time in seconds since 0000 UTC Jan 1, 1970, at which the IPFIX Message leaves the IPFIX Mediator. However, in the specific case of an IPFIX Mediator containing an Intermediate Conversion Process, the IPFIX Mediator MAY use the export time received from the incoming Transport Session.

It is RECOMMENDED that IPFIX Mediators handle time using absolute timestamps (e.g., flowStartSeconds, flowStartMilliseconds, or flowStartNanoseconds), which are specified relative to the UNIX epoch (00:00 UTC 1 Jan 1970) [POSIX.1], where possible rather than relative timestamps (e.g., flowStartSysUpTime or flowStartDeltaMicroseconds), which are specified relative to protocol structures such as system initialization or message export time.

The latter are difficult to manage for two reasons. First, they require constant translation, as the system initialization time of an intermediate system and the export time of an intermediate message will change across mediation operations. Further, relative timestamps introduce range problems. For example, when using the flowStartDeltaMicroseconds and flowEndDeltaMicroseconds Information Elements [IANA-IPFIX], the Data Record must be exported within a maximum of 71 minutes after its creation. Otherwise, the 32-bit counter would not be sufficient to contain the flow start time offset. Those time constraints might be incompatible with some of the application requirements of some Intermediate Processes.

Intermediate Processes MUST NOT assume that received records appear in flowStartTime, flowEndTime, or observationTime order. An Intermediate Process processing timing information (e.g., an Intermediate Aggregation Process) MAY ignore records that are significantly out of order, in order to meet application-specific state and latency requirements, but SHOULD report that records were dropped.

When an Intermediate Process aggregates information from different Flow Records, the timestamps on exported records SHOULD be the minimum of the start times and the maximum of the end times in the general case. However, if the Flow Records do not overlap, i.e., if there is a time gap between the times in the Flow Records, then the report may be inaccurate. The IPFIX Mediator is only reporting what it knows, on the basis of the information made available to it, and there may not have been any data to observe during the gap. Then again, if there is an overlap in timestamps, there's the potential of double-accounting: different Observation Points may have observed the same traffic simultaneously. The specification of the precise rules for applying Flow Record timestamps at IPFIX Mediators for all the different situations is out of the scope of this document.

Note that [RFC7015] provides additional specifications for handling of timestamps at an Intermediate Aggregation Process.

8. Transport Considerations

SCTP [RFC4960] using the Partially Reliable SCTP (PR-SCTP) extension specified in [RFC3758] MUST be implemented by all compliant IPFIX Mediator implementations. TCP [RFC0793] MAY also be implemented by implementations compliant with the IPFIX Mediator. UDP [RFC0768] MAY also be implemented by compliant IPFIX Mediator implementations. Transport-specific considerations for IPFIX Exporters as specified in Sections 8.3, 8.4, 9.1, 9.2, and 10 of [RFC7011] apply to IPFIX Mediators as well.

SCTP SHOULD be used in deployments where IPFIX Mediators and Collectors are communicating over links that are susceptible to congestion. SCTP is capable of providing any required degree of reliability. TCP MAY be used in deployments where IPFIX Mediators and Collectors communicate over links that are susceptible to congestion, but SCTP is preferred due to its ability to limit back pressure on Exporters and its message versus stream orientation. UDP MAY be used, although it is not a congestion-aware protocol. However, in this case, the IPFIX traffic between IPFIX Mediator and Collector MUST run in an environment where IPFIX traffic has been provisioned for and/or separated from non-IPFIX traffic, whether physically or virtually.

9. Collecting Process Considerations

Any Collecting Process compliant with [RFC7011] can receive IPFIX Messages from an IPFIX Mediator. If the IPFIX Mediator uses IPFIX Structured Data [RFC6313] to export Original Exporter Information, as in Section 5, the Collecting Process MUST support [RFC6313].

10. Specific Reporting Requirements

IPFIX provides Options Templates for the reporting the reliability of processes within the IPFIX Architecture. As each Mediator includes at least one IPFIX Exporting Process, they MAY use the Exporting Process Reliability Statistics Options Template, as specified in [RFC7011].

Analogous to the Metering Process Reliability Statistics Options Template, also specified in [RFC7011], Mediators MAY implement the Intermediate Process Reliability Statistics Options Template, specified in Sections 10.1, 10.3, and 10.4 define Information Elements used by this Options Template.

The Flow Keys Options Template, as specified in [RFC7011], may require special handling at an IPFIX Mediator, as described in Section 10.2.

In addition, each Intermediate Process may have its own specific reporting requirements (e.g., Anonymization Records as in [RFC6235], or the Aggregation Counter Distribution Options Template as in [RFC7015]); these SHOULD be implemented as necessary, as described in the specification for each Intermediate Process.

10.1. Intermediate Process Reliability Statistics Options Template

The Intermediate Process Statistics Options Template specifies the structure of a Data Record for reporting Intermediate Process statistics. It SHOULD contain the following Information Elements; the intermediateProcessId Information Element is defined in Section 10.3 and the ignoredDataRecordTotalCount Information Element is defined in Section 10.4:

IE	Description
observationDomainId [scope]	An identifier of the Observation Domain (of messages exported by this Mediator), locally unique to the Intermediate Process, to which this statistics record applies.
intermediateProcessId [scope]	An identifier for the Intermediate Process to which this statistics record applies.
ignoredDataRecordTotalCount	The total number of Data Records received but not processed by the Intermediate Process.
time first record ignored	The timestamp of the first record that was ignored by the Intermediate Process. For Data Records containing timestamp ranges, this SHOULD be taken from the start timestamp of the range; for data records containing no timing information, this SHOULD be taken from the Export Time in the message header of the IPFIX Message that contains it. For this timestamp, any of the following timestamp can be used: observationTimeSeconds, observationTimeMilliseconds, observationTimeMicroseconds, or observationTimeNanoseconds.

IE	Description
time last record ignored	The timestamp of the last record that was ignored by the Intermediate Process. For Data Records containing timestamp ranges, this SHOULD be taken from the end timestamp of the range; for data records containing no timing information, this SHOULD be taken from the Export Time in the message header of the containing IPFIX Message. For this timestamp, any of the following timestamp can be used: observationTimeSeconds, observationTimeMilliseconds, observationTimeMicroseconds, or observationTimeNanoseconds.

10.2. Flow Key Options Template

The Flow Keys Options Template specifies the structure of a Data Record for reporting the Flow Keys of reported Flows. A Flow Keys Data Record extends a particular Template Record that is referenced by its templateId identifier. The Template Record is extended by specifying which of the Information Elements contained in the corresponding Data Records describe Flow properties that serve as Flow Keys of the reported Flow. This Options Template is defined in Section 4.4 of [RFC7011] and SHOULD be used by Mediators for export as defined there.

When an Intermediate Process exports Data Records containing different Flow Keys from those received from the Original Exporter, and the Original Exporter sent a Flow Keys Options record to the IPFIX Mediator, the IPFIX Mediator MUST export a Flow Keys Options record defining the new set of Flow Keys.

10.3. intermediateProcessId Information Element

Name: intermediateProcessId

Description: An identifier of an Intermediate Process that is unique per IPFIX Device. Typically, this Information Element is used for limiting the scope of other Information Elements. Note that process identifiers may be assigned dynamically; that is, an Intermediate Process may be restarted with a different ID.

Data Type: unsigned32

Data Type Semantics: identifier

ElementId: 406

10.4. ignoredDataRecordTotalCount Information Element

Name: ignoredDataRecordTotalCount

Description: The total number of received Data Records that the Intermediate Process did not process since the (re-)initialization of the Intermediate Process; includes only Data Records not examined or otherwise handled by the Intermediate Process due to resource constraints, not Data Records that were examined or otherwise handled by the Intermediate Process but those that merely do not contribute to any exported Data Record due to the operations performed by the Intermediate Process.

Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: 407

11. Operations and Management Considerations

In general, using IPFIX Mediators to combine information from multiple Original Exporters requires a consistent configuration of the Metering Processes behind these Original Exporters. The details of this consistency are specific to each Intermediate Process. Consistency of configuration should be verified out of band, with the MIB modules ([RFC6615] and [RFC6727]) or with the Configuration Data Model for IPFIX and PSAMP [RFC6728].

From an operational perspective, this specification provides all the information required to set up IPFIX Mediators and Collectors behind IPFIX Mediators. While configuring the IPFIX Mediators, care must be taken to include all the relevant information so that the Collectors deduce the Data Records precise semantic. This is covered by the Template Mapping specifications in Section 4.1. Also, caution must be taken that if something is not carefully configured in the processing chain, this can lead to the wrong interpretation of collected IPFIX data, and the associated applications can produce results that are not operationally meaningful.

12. Security Considerations

As they act as both IPFIX Collecting Processes and Exporting Processes, the Security Considerations for the IPFIX Protocol [RFC7011] also apply to IPFIX Mediators. The Security Considerations for IPFIX Files [RFC5655] also apply to IPFIX Mediators that write IPFIX Files or use them for internal storage. However, there are a few specific considerations that IPFIX Mediator implementations must also take into account.

By design, IPFIX Mediators are "men in the middle": they intercede in the communication between an Original Exporter (or another upstream IPFIX Mediator) and a downstream Collecting Process. This has two important implications for the level of confidentiality provided across an IPFIX Mediator and the ability to protect data integrity and Original Exporter authenticity across an IPFIX Mediator. These are addressed in more detail in the Security Considerations for IPFIX Mediators in [RFC6183].

Note that while IPFIX Mediators can use the exporterCertificate and collectorCertificate Information Elements defined in [RFC5655] as described in Section 9.3 of [RFC6183] to export information about X.509 identities in upstream TLS-protected Transport Sessions, this mechanism cannot be used to provide true end-to-end assertions about a chain of IPFIX Mediators: any IPFIX Mediator in the chain can simply falsify the information about upstream Transport Sessions. In situations where information about the chain of mediation is important, it must be determined out of band. Note as well that an Exporting Process has no in-band way to determine whether or not a given Collecting Process will act as a Mediator. Trust placed in Collecting Processes is absolute, so care should be taken when exporting IPFIX Messages between Exporting Processes and Collecting Processes controlled by different entities.

13. IANA Considerations

This document specifies new IPFIX Information Elements, originalExporterIPv4Address in Section 5.1, originalExporterIPv6Address in Section 5.2, originalObservationDomainId in Section 6.1, intermediateProcessId in Section 10.3, and ignoredDataRecordTotalCount in Section 10.4, which have been added to the IPFIX Information Element registry [IANA-IPFIX].

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