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X. Wei
Huawei Technologies
L.Zhu
Huawei Technologies
L.Deng
China Mobile
May 23, 2017

Tunnel Congestion Feedback
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Abstract

This document describes a method to measure congestion on a tunnel segment based on recommendations from [RFC 6040](#), "Tunneling of Explicit Congestion Notification", and to use IPFIX to communicate the congestion measurements from the tunnel's egress to a controller which can respond by modifying the traffic control policies at the tunnel's ingress.

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1. Introduction

In IP networks, persistent congestion[RFC2914] lowers transport throughput, leading to waste of network resource. Appropriate congestion control mechanisms are therefore critical to prevent the network from falling into the persistent congestion state. Currently, transport protocols such as TCP[RFC793], SCTP[RFC4960], DCCP[RFC4340], have their built-in congestion control mechanisms, and even for certain single transport protocol like TCP there can be a couple of different congestion control mechanisms to choose from. All these congestion control mechanisms are implemented on host side, and there are reasons that only host side congestion control is not sufficient for the whole network to keep away from persistent congestion. For example, (1) some protocol's congestion control scheme may have internal design flaws; (2) improper software implementation of protocol; (3) some transport protocols, e.g. RTP[RFC3550] do not even provide congestion control at all; (4) a heavy load from a much larger than expected number of responsive flows could also lead to persistent congestion.

Tunnels are widely deployed in various networks including public Internet, data center network, and enterprise network etc. A tunnel consists of ingress, egress and a set of intermediate routers. For the tunnel scenario, a tunnel-based mechanism is introduced for network traffic control to keep the network from persistent congestion. Here, tunnel ingress will implement congestion management function to control the traffic entering the tunnel.

This document provides a mechanism of feeding back inner tunnel congestion level to the ingress. Using this mechanism the egress can feed the tunnel congestion level information it collects back to the ingress. After receiving this information the ingress will be able to perform congestion management according to network management policy.

The following subjects are out of scope of current document: it gives no advice on how to select which tunnel endpoints should be used in order to manage traffic over a network criss-crossed by multiple tunnels; if a congested node is part of multiple tunnels, and it causes congestion feedback to multiple traffic management functions at the ingresses of all the tunnels, the draft gives no advice on how all the traffic management functions should respond.

2. Conventions And Terminologies

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](#)]

DP: Decision Point, an logical entity that makes congestion management decision based on the received congestion feedback information.

EP: Enforcement Point, an logical entity that implements congestion management action according to the decision made by Decision Point.

ECT: ECN-Capable Transport code point defined in [RFC3168](#).

3. Congestion Information Feedback Models

The feedback model mainly consists of tunnel egress and tunnel ingress. The tunnel egress composes of meter function and exporter function; tunnel ingress composes EP (Enforcement Point) function, collector function and DP (Decision Point) function.

The Meter function collects network congestion level information, and conveys the information to Exporter which feeds back the information to the collector function.

The feedback message contains CE-marked packet ratio, the traffic volumes of all kinds of ECN marking packets.

The collector collects congestion level information from exporter, after that congestion management Decision Point (DP) function will make congestion management decision based on the information from collector.

The Enforcement Point controls the traffic entering tunnel, and it implements traffic control decision of DP.

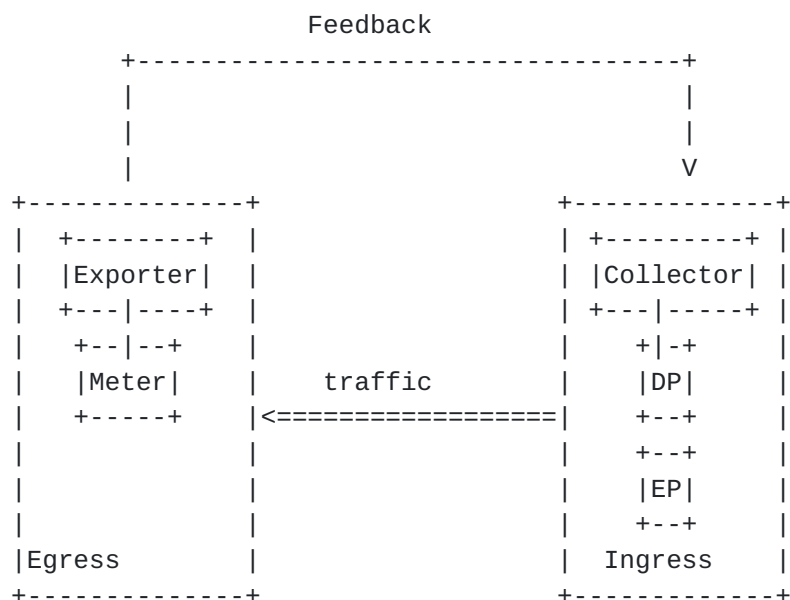


Figure 1: Feedback Model.

4. Congestion Level Measurement

The congestion level measurement is based on ECN (Explicit Congestion Notification) [[RFC3168](#)] and packet drop. The network congestion level could be indicated through the ratio of CE-marked packet and the volumes of packet drop, the relationship between these two kinds of indicator is complementary. If the congestion level in tunnel is not high enough, the packets would be marked as CE instead of being dropped, and then it is easy to calculate congestion level according to the ratio of CE-marked packets. If the congestion level is so high that ECT packet will be dropped, then the packet loss ratio could be calculated by comparing total packets entering ingress and total packets arriving at egress over the same span of packets, if packet loss is detected, it could be assumed that severe congestion has occurred in the tunnel.

Egress calculates CE-marked packet ratio by counting different kinds of ECN-marked packet, the CE-marked packet ratio will be used as an indication of tunnel load level. It's assumed that routers in the tunnel will not drop packets biased towards certain ECN codepoint, so calculating of CE-marked packet ratio is not affect by packet drop.

The calculation of volumes of packet drop is by comparing the traffic volumes between ingress and egress.

Faked ECN-capable transport (ECT) is used at ingress to defer

packet loss to egress. The basic idea of faked ECT is that, when encapsulating packets, ingress first marks tunnel outer header according to [RFC6040](#), and then remarks outer header of Not-ECT packet as ECT, there will be three kinds of combination of outer header ECN field and inner header ECN field: CE|CE, ECT|N-ECT, ECT|ECT (in the form of outer ECN| inner ECN); when decapsulating packets at egress, [RFC6040](#) defined decapsulation behavior is used, and according to [RFC6040](#), the packets marked as CE|N-ECT will be dropped by egress. Faked-ECT is used to shift some drops to the egress in order to calculate CE-marked packet ratio more precisely by egress.

To calculate congestion level, for the same span of packets, the ratio of CE-marked packets will be calculated by egress, and the total bytes count of packets at ingress and egress will be compared to detect the traffic volume loss in tunnel.

The basic procedure of packets loss measurement is as follows:

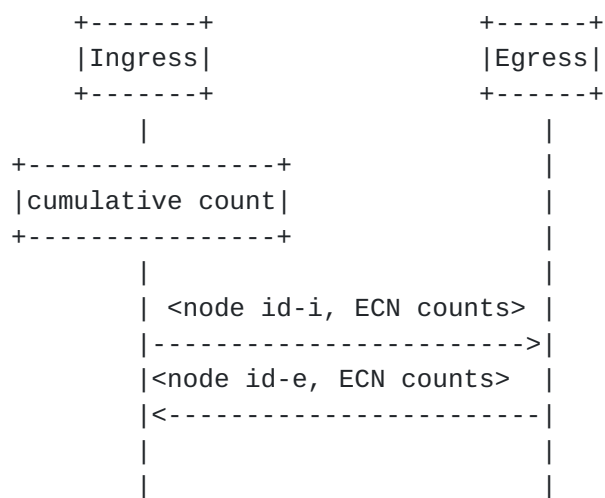


Figure 2: Procedure of Packet Loss Measurement

Ingress encapsulates packets and marks outer header according to faked ECT as described above. Ingress cumulatively counts packet bytes for three types of ECN combination (CE|CE, ECT|N-ECT, ECT|ECT) and then the ingress regularly sends cumulative bytes counts message of each type of ECN combination to the egress.

When each message arrives at egress, (1)egress calculates the ratio of CE-marked packet; (2)the egress cumulatively counts packet bytes coming from the ingress and adds its own bytes counts of each type of ECN combination (CE|CE, ECT|N-ECT, CE|N-ECT, CE|ECT, ECT|ECT) to the

message for ingress to calculate packet loss. Egress feeds back CE-marked packet ratio and bytes counts information to the ingress for evaluating congestion level in the tunnel.

The counting of bytes can be at the granularity of the all traffic from the ingress to the egress to learn about the overall congestion status of the path between the ingress and the egress. The counting can also be at the granularity of individual customer's traffic or a specific set of flows to learn about their congestion contribution.

5. Congestion Information Delivery

As described above, the tunnel ingress needs to convey a message containing cumulative bytes counts of packets of each type of ECN combination to tunnel egress, and the tunnel egress also needs to feed back the message of cumulative bytes counts of packets of each type of ECN combination and CE-marked packet ratio to the ingress. This section describes how the messages should be conveyed.

The message travels along the same path with network data traffic, referred as in-band signal. Because the message is transmitted in band, so the message packet may get lost in case of network congestion. To cope with the situation that the message packet gets lost, the bytes counts values are sent as cumulative counters. Then if a message is lost the next message will recover the missing information. Even though the missing information could be recovered, the message should be transmitted in a much higher priority than users' traffic flows.

IPFIX [[RFC7011](#)] is selected as a candidate information feedback protocol. IPFIX uses preferably SCTP as transport. SCTP allows partially reliable delivery [[RFC3758](#)], which ensures the feedback message will not be blocked in case of packet loss due to network congestion.

Ingress can do congestion management at different granularity which means both the overall aggregated inner tunnel congestion level and congestion level contributed by certain traffic(s) could be measured for different congestion management purpose. For example, if the ingress only wants to limit congestion volume caused by certain traffic(s), e.g UDP-based traffic, then congestion volume for the traffic will be fed back; or if the ingress do overall congestion management, the aggregated congestion volume will be fed back.

When sending message from ingress to egress, the ingress acts as IPFIX exporter and egress acts as IPFIX collector; When feedback congestion level information from egress to ingress, then the egress acts as IPFIX exporter and ingress acts as IPFIX collector.

The combination of congestion level measurement and congestion information delivery procedure should be as following:

The ingress determines IPFIX template record to be used. The template record can be pre-configured or determined at runtime, the content of template record will be determined according to the granularity of congestion management, if the ingress wants to limit congestion volume contributed by specific traffic flow then the elements such as source IP address, destination IP address, flow id and CE-marked packet volume of the flow etc will be included in the template record.

Meter on ingress measures traffic volume according to template record chosen and then the measurement records are sent to egress in band.

Meter on egress measures congestion level information according to template record, the content of template record should be the same as template record of ingress.

Exporter of egress sends measurement record together with the measurement record of ingress back to the ingress.

5.1 IPFIX Extensions

This sub-section defines a list of new IPFIX Information Elements according to [RFC7013](#) [[RFC7013](#)].

5.1.1 tunnelEcnCeCeByteTotalCount

Description: The total number of bytes of incoming packets with CE|CE ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD1

Statuses: current

Units: bytes

5.1.2 tunnelEcnEct0NectBytetTotalCount

Description: The total number of bytes of incoming packets with ECT(0)|N-ECT ECN marking combination at the Observation Point since

the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD2

Statues: current

Units: bytes

5.1.3 tunnelEcnEct1NectByteTotalCount

Description: The total number of bytes of incoming packets with ECT(1)|N-ECT ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD3

Statues: current

Units: bytes

5.1.4 tunnelEcnCeNectByteTotalCount

Description: The total number of bytes of incoming packets with CE|N-ECT ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD4

Statues: current

Units: bytes

5.1.5 tunnelEcnCeEct0ByteTotalCount

Description: The total number of bytes of incoming packets with CE|ECT(0) ECN marking combination at the Observation Point since the

Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD5

Statuses: current

Units: bytes

5.1.6 tunnelEcnCeEct1ByteTotalCount

Description: The total number of bytes of incoming packets with CE|ECT(1) ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD6

Statuses: current

Units: bytes

5.1.7 tunnelEcnEct0Ect0ByteTotalCount

Description: The total number of bytes of incoming packets with ECT(0)|ECT(0) ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD7

Statuses: current

Units: bytes

5.1.8 tunnelEcnEct1Ect1PacketTotalCount

Description: The total number of bytes of incoming packets with ECT(1)|ECT(1) ECN marking combination at the Observation Point since

the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

ElementId: TBD8

Statuses: current

Units: bytes

[5.1.9](#) tunnelEcnCEMarkedRatio

Description: The ratio of CE-marked Packet at the Observation Point.

Abstract Data Type: float32

ElementId: TBD8

Statuses: current

[6.](#) Congestion Management

After tunnel ingress receives congestion level information, then congestion management actions could be taken based on the information, e.g. if the congestion level is higher than a predefined threshold, then action could be taken to reduce the congestion level.

The design of network side congestion management SHOULD take host side e2e congestion control mechanism into consideration, which means the congestion management needs to avoid the impacts on e2e congestion control. For instance, congestion management action must be delayed by more than a worst-case global RTT (e.g. 100ms), otherwise tunnel traffic management will not give normal e2e congestion control enough time to do its job, and the system could go unstable.

The detailed description of congestion management is out of scope of this document, as examples, congestion management such as circuit breaker [[RFC8084](#)] could be applied. Circuit breaker is an automatic mechanism to estimate congestion, and to terminate flow(s) when persistent congestion is detected to prevent network congestion collapse.

[6.1](#) Example

This subsection provides an example of how the solution described in this document could work.

First of all, IPFIX template records are exchanged between ingress and egress to negotiate the format of data record, the example here is to measure the congestion level for the overall tunnel (caused by all the traffic in tunnel). After the negotiation is finished, ingress sends in-band message to egress, the message contains the number of each kind of ECN-marked packets (i.e. CE|CE, ECT|N-ECT and ECT|ECT) received until the sending of message.

After egress receives the message, the egress calculates CE-marked packet ratio and counts number of different kinds of ECN-marking packets received until receiving the message, then the egress sends a feedback message containing the counts together with the information in ingress's message to ingress.

Figure 3 to Figure 6 below show the example procedure between ingress and egress.

+-----+-----+	
Set ID=2	Length=40
+-----+-----+	
Template ID=256	Field Count =8
+-----+-----+	
tunnelEcnCeCeByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnEctNectByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnEctEctByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnCeCeByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnEctNectByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnEctEctByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnCeNectByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnCeEctByteTotalCount	Field Length=8
+-----+-----+	
tunnelEcnCEMarkedRatio	Field Length=4
+-----+-----+	

Figure 3: Template Record Sent From Egress to Ingress

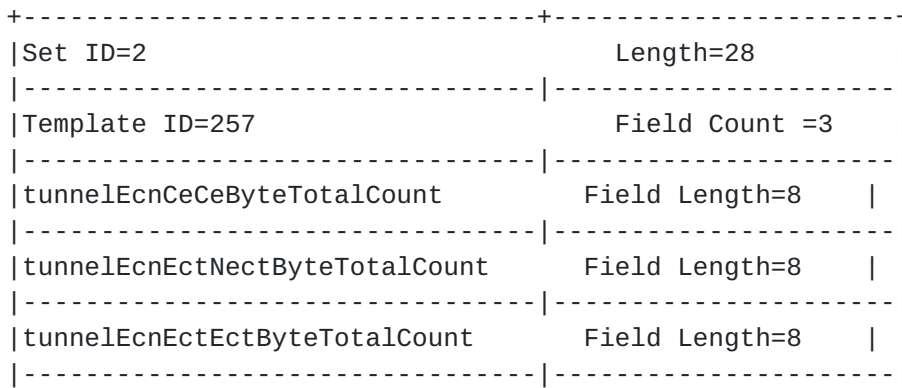
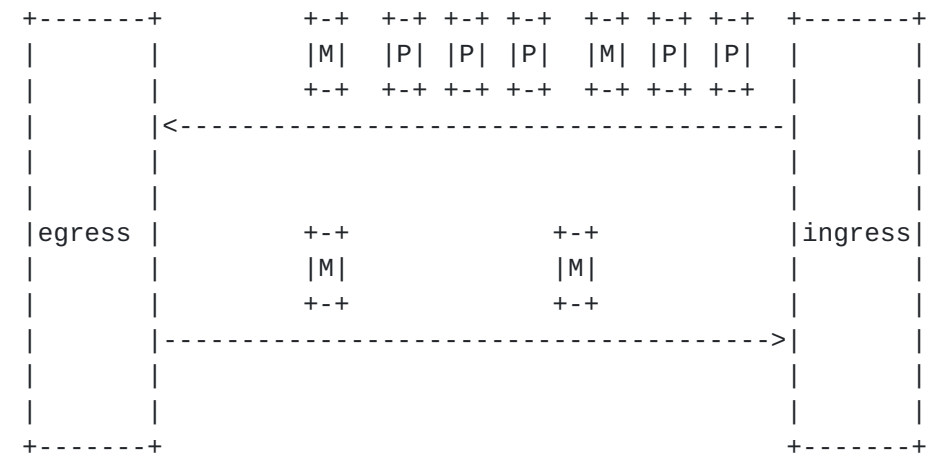


Figure 4: Template Record Sent From Ingress to Egress



```

+-+
|M| : Message Packet
+-+

```

```

+-+
|P| : User Packet
+-+

```

Figure 5 Traffic flow Between Ingress and Egress

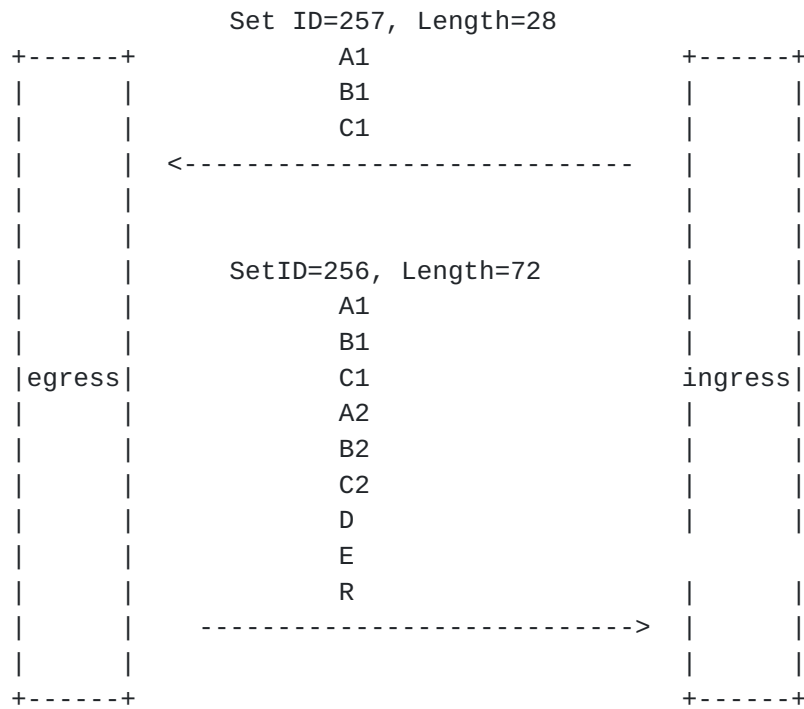


Figure 6: Message Between Ingress and Egress

The following provides an example of how tunnel congestion level could be calculated:

Congestion Level could be divided into two categories: (1) slight congestion (no packets dropped); (2) serious congestion (packet dropping happen).

For slight congestion, the congestion level is indicated as the ratio of CE-marked packet:

$ce_marked = R;$

For serious congestion, the congestion level is indicated as the number of volume loss:

$total_ingress = (A1 + B1 + C1)$

$total_egress = (A2 + B2 + C2 + D + E)$

$volume_loss = (total_ingress - total_egress)$

7. Security Considerations

This document describes the tunnel congestion calculation and feedback.

The tunnel endpoints are assumed to be deployed in the same administrative domain, so the ingress and egress will trust each other, the signaling traffic between ingress and egress will be protected utilizing security mechanism provided IPFIX (see [section 11 in RFC7011](#)).

From the consideration of privacy point of view, in case of fine grained congestion management, ingress is aware of the amount of traffic for specific application flows inside the tunnel which seems to be an invasion of privacy. But in any way, the ingress could The solution doesn't introduce more privacy problem.

8. IANA Considerations

This document defines a set of new IPFIX Information Elements (IE), which need to be registered at IANA IPFIX Information Element Registry.

ElementID: TBD1

Name: tunnelEcnCeCePacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description: The total number of bytes of incoming packets with CE|CE ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD2

Name: tunnelEcnEct0NectPacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description: The total number of bytes of incoming packets with ECT(0)|N-ECT ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD3

Name: tunnelEcnEct1NectPacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description: The total number of bytes of incoming packets with

ECT(1)|N-ECT ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.
Units: octets

ElementID: TBD4

Name:tunnelEcnCeNectPacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description:The total number of bytes of incoming packets with CE|N-ECT ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD5

Name:tunnelEcnCeEct0PacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description:The total number of bytes of incoming packets with CE|ECT(0) ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD6

Name:tunnelEcnCeEct1PacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description:The total number of bytes of incoming packets with CE|ECT(1) ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD7

Name:tunnelEcnEct0Ect0PacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description:The total number of bytes of incoming packets with ECT(0)|ECT(0) ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD8

Name:tunnelEcnEct1Ect1PacketTotalCount

Data Type: unsigned64

Data Type Semantics: totalCounter

Status: current

Description: The total number of bytes of incoming packets with ECT(1)|ECT(1)ECN marking combination at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Units: octets

ElementID: TBD9

Name: tunnelEcnCEMarkedRatio

Data Type: float32

Status: current

Description: The ratio of CE-marked Packet at the Observation Point.

[TO BE REMOVED: This registration should take place at the following location: <http://www.iana.org/assignments/ipfix/ipfix.xhtml#ipfix-information-elements>]

9. References

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[9.2](#) Informative References

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[10](#). Acknowledgements

Thanks Bob Briscoe for his insightful suggestions on the basic mechanisms of congestion information collection and many other useful comments. Thanks David Black for his useful technical suggestions. Also, thanks Anthony Chan, Jake Holland, John Kaippallimalil and Vincent Roca for their careful reviews.

Authors' Addresses

Xinpeng Wei
Beiqing Rd. Z-park No.156, Haidian District,
Beijing, 100095, P. R. China
E-mail: weixinpeng@huawei.com

Zhu Lei
Beiqing Rd. Z-park No.156, Haidian District,
Beijing, 100095, P. R. China
E-mail: lei.zhu@huawei.com

Lingli Deng
Beijing, 100095, P. R. China
E-mail: denglingli@gmail.com