6MAN Working Group
Internet-Draft
Intended status: Standards Track
Expires: 31 March 2023

G. Fioccola
T. Zhou
Huawei
M. Cociglio
Telecom Italia
F. Qin
China Mobile
R. Pang
China Unicom

27 September 2022

IPv6 Application of the Alternate Marking Method
draft-ietf-6man-ipv6-alt-mark-17

Abstract

This document describes how the Alternate Marking Method can be used as a passive performance measurement tool in an IPv6 domain. It defines an Extension Header Option to encode Alternate Marking information in both the Hop-by-Hop Options Header and Destination Options Header.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 31 March 2023.

Table of Contents

1. Introduction

[I-D.ietf-ippm-rfc8321bis] and [I-D.ietf-ippm-rfc8889bis] describe a passive performance measurement method, which can be used to measure packet loss, latency and jitter on live traffic. Since this method is based on marking consecutive batches of packets, the method is often referred to as the Alternate Marking Method.

This document defines how the Alternate Marking Method can be used to measure performance metrics in IPv6. The rationale is to apply the Alternate Marking methodology to IPv6 and therefore allow detailed packet loss, delay and delay variation measurements both hop-by-hop and end-to-end to exactly locate the issues in an IPv6 network.

The Alternate Marking is an on-path telemetry technique and consists of synchronizing the measurements in different points of a network by switching the value of a marking bit and therefore dividing the

packet flow into batches. Each batch represents a measurable entity recognizable by all network nodes along the path. By counting the number of packets in each batch and comparing the values measured by different nodes, it is possible to precisely measure the packet loss. Similarly, the alternation of the values of the marking bits can be used as a time reference to calculate the delay and delay variation. The Alternate Marking operation is further described in Section 5.

This document introduces a TLV (type-length-value) that can be encoded in the Options Headers (Hop-by-Hop or Destination), according to [RFC8200], for the purpose of the Alternate Marking Method application in an IPv6 domain.

The Alternate Marking Method MUST be applied to IPv6 only in a controlled environment, as further described in Section 2.1. [RFC8799] provides further discussion of network behaviors that can be applied only within limited domains.

The threat model for the application of the Alternate Marking Method in an IPv6 domain is reported in Section 6.

1.1. Terminology

This document uses the terms related to the Alternate Marking Method as defined in [I-D.ietf-ippm-rfc8321bis] and [I-D.ietf-ippm-rfc8889bis].

1.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Alternate Marking application to IPv6

The Alternate Marking Method requires a marking field. Several alternatives could be considered such as IPv6 Extension Headers, IPv6 Address and Flow Label. But, it is necessary to analyze the drawbacks for all the available possibilities, more specifically:

- Reusing existing Extension Header for Alternate Marking leads to a non-optimized implementation;

- Using the IPv6 destination address to encode the Alternate Marking processing is very expensive;

Using the IPv6 Flow Label for Alternate Marking conflicts with the utilization of the Flow Label for load distribution purpose ([RFC6438]).

In the end, a Hop-by-Hop or a Destination Option is the best choice.

The approach for the Alternate Marking application to IPv6 specified in this memo is compliant with [RFC8200]. It involves the following operations:

* The source node is the only one that writes the Option Header to mark alternately the flow (for both Hop-by-Hop and Destination Option). The intermediate nodes and destination node MUST only read the marking values of the option without modifying the Option Header.

* In case of Hop-by-Hop Option Header carrying Alternate Marking bits, it is not inserted or deleted, but can be read by any node along the path. The intermediate nodes may be configured to support this Option or not and the measurement can be done only for the nodes configured to read the Option. As further discussed in Section 4, the presence of the hop-by-hop option should not affect the traffic throughput both on nodes that do not recognize this option and on the nodes that support it. However, it is worth mentioning that there is a difference between theory and practice. Indeed, in a real implementation it can happen that packets with hop-by-hop option could also be skipped or processed in the slow path. While some proposals are trying to address this problem and make Hop-by-Hop Options more practical ([I-D.ietf-v6ops-hbh], [I-D.ietf-6man-hbh-processing]), these aspects are out of the scope for this document.

* In case of Destination Option Header carrying Alternate Marking bits, it is not processed, inserted, or deleted by any node along the path until the packet reaches the destination node. Note that, if there is also a Routing Header (RH), any visited destination in the route list can process the Option Header.

Hop-by-Hop Option Header is also useful to signal to routers on the path to process the Alternate Marking. However, as said, routers will only examine this option if properly configured.

The optimization of both implementation and scaling of the Alternate Marking Method is also considered and a way to identify flows is required. The Flow Monitoring Identification field (FlowMonID), as introduced in Section 5.3, goes in this direction and it is used to identify a monitored flow.

The FlowMonID is different from the Flow Label field of the IPv6 Header ([RFC6437]). The Flow Label field in the IPv6 header is used by a source to label sequences of packets to be treated in the network as a single flow and, as reported in [RFC6438], it can be used for load-balancing/equal cost multi-path (LB/ECMP). The reuse of Flow Label field for identifying monitored flows is not considered because it may change the application intent and forwarding behavior. Also, the Flow Label may be changed en route and this may also invalidate the integrity of the measurement. Those reasons make the definition of the FlowMonID necessary for IPv6. Indeed, the FlowMonID is designed and only used to identify the monitored flow. Flow Label and FlowMonID within the same packet are totally disjoint, have different scope, are used to identify flows based on different criteria, and are intended for different use cases.

The rationale for the FlowMonID is further discussed in Section 5.3. This 20 bit field allows easy and flexible identification of the monitored flow and enables improved measurement correlation and finer granularity since it can be used in combination with the traditional TCP/IP 5-tuple to identify a flow. An important point that will be discussed in Section 5.3 is the uniqueness of the FlowMonID and how to allow disambiguation of the FlowMonID in case of collision.

The following section highlights an important requirement for the application of the Alternate Marking to IPv6. The concept of the controlled domain is explained and it is considered an essential precondition, as also highlighted in Section 6.

2.1. Controlled Domain

IPv6 has much more flexibility than IPv4 and innovative applications have been proposed, but for security and compatibility reasons, some of these applications are limited to a controlled environment. This is also the case of the Alternate Marking application to IPv6 as assumed hereinafter. In this regard, [RFC8799] reports further examples of specific limited domain solutions.

The IPv6 application of the Alternate Marking Method MUST be deployed in a controlled domain. It is not common that the user traffic originates and terminates within the controlled domain, as also noted in Section 2.1.1. For this reason, it will typically only be applicable in an overlay network, where user traffic is encapsulated at one domain border, decapsulated at the other domain border and the encapsulation incorporates the relevant extension header for Alternate Marking. This requirement also implies that an implementation MUST filter packets that carry Alternate Marking data and are entering or leaving the controlled domain.

A controlled domain is a managed network where it is required to select, monitor and control the access to the network by enforcing policies at the domain boundaries in order to discard undesired external packets entering the domain and check the internal packets leaving the domain. It does not necessarily mean that a controlled domain is a single administrative domain or a single organization. A controlled domain can correspond to a single administrative domain or can be composed by multiple administrative domains under a defined network management. Indeed, some scenarios may imply that the Alternate Marking Method involves more than one domain, but in these cases, it is RECOMMENDED that the multiple domains create a whole controlled domain while traversing the external domain by employing IPsec [RFC4301] authentication and encryption or other VPN technology that provides full packet confidentiality and integrity protection. In a few words, it must be possible to control the domain boundaries and eventually use specific precautions if the traffic traverse the Internet.

The security considerations reported in Section 6 also highlight this requirement.

2.1.1. Alternate Marking Measurement Domain

The Alternate Marking measurement domain can overlap with the controlled domain or may be a subset of the controlled domain. The typical scenarios for the application of the Alternate Marking Method depend on the controlled domain boundaries, in particular:

- the user equipment can be the starting or ending node, only in case it is fully managed and if it belongs to the controlled domain. In this case the user generated IPv6 packets contain the Alternate Marking data. But, in practice, this is not common due to the fact that the user equipment cannot be totally secured in the majority of cases.

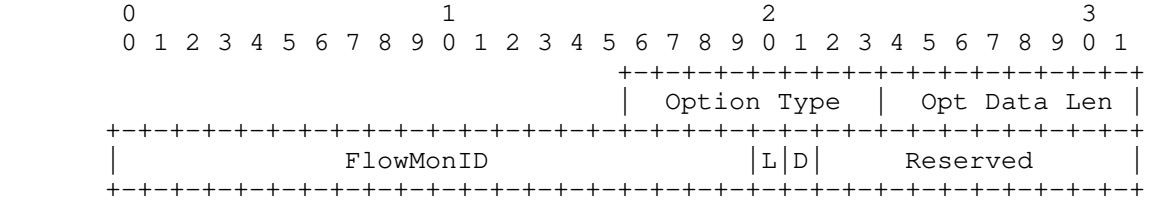
the CPE (Customer Premises Equipment) or the PE (Provider Edge) routers are most likely to be the starting or ending nodes since they can be border routers of the controlled domain. For instance, the CPE, which connects the user's premises with the service provider's network, belongs to a controlled domain only if it is managed by the service provider and if additional security measures are taken to keep it trustworthy. Typically the CPE or the PE can encapsulate a received packet in an outer IPv6 header which contains the Alternate Marking data. They can also be able to filter and drop packets from outside of the domain with inconsistent fields to make effective the relevant security rules at the domain boundaries, for example a simple security check can be to insert the Alternate Marking data if and only if the destination is within the controlled domain.

3. Definition of the AltMark Option

The definition of a TLV for the Options Extension Headers, carrying the data fields dedicated to the Alternate Marking method, is reported below.

3.1. Data Fields Format

The following figure shows the data fields format for enhanced Alternate Marking TLV (AltMark). This AltMark data can be encapsulated in the IPv6 Options Headers (Hop-by-Hop or Destination Option).



where:

* Option Type: 8-bit identifier of the type of Option that needs to be allocated. Unrecognized Types MUST be ignored on processing. For Hop-by-Hop Options Header or Destination Options Header, [RFC8200] defines how to encode the three high-order bits of the Option Type field. The two high-order bits specify the action that must be taken if the processing IPv6 node does not recognize the Option Type; for AltMark these two bits MUST be set to 00 (skip over this Option and continue processing the header). The third-highest-order bit specifies whether the Option Data can change en route to the packet's final destination; for AltMark the

value of this bit MUST be set to 0 (Option Data does not change en route). In this way, since the three high-order bits of the AltMark Option are set to 000, it means that nodes can simply skip this Option if they do not recognize and that the data of this Option do not change en route, indeed the source is the only one that can write it.

* Opt Data Len: 4. It is the length of the Option Data Fields of this Option in bytes.

* FlowMonID: 20-bit unsigned integer. The FlowMon identifier is described in Section 5.3. As further discussed below, it has been picked as 20 bits since it is a reasonable value and a good compromise in relation to the chance of collision. It MUST be set pseudo randomly by the source node or by a centralized controller.

* L: Loss flag for Packet Loss Measurement as described in Section 5.1;

* D: Delay flag for Single Packet Delay Measurement as described in Section 5.2;

* Reserved: is reserved for future use. These bits MUST be set to zero on transmission and ignored on receipt.

4. Use of the AltMark Option

The AltMark Option is the best way to implement the Alternate Marking method and it is carried by the Hop-by-Hop Options header and the Destination Options header. In case of Destination Option, it is processed only by the source and destination nodes: the source node inserts and the destination node processes it. While, in case of Hop-by-Hop Option, it may be examined by any node along the path, if explicitly configured to do so.

It is important to highlight that the Option Layout can be used both as Destination Option and as Hop-by-Hop Option depending on the Use Cases and it is based on the chosen type of performance measurement. In general, it is needed to perform both end to end and hop by hop measurements, and the Alternate Marking methodology allows, by definition, both performance measurements. In many cases the end-to-end measurement is not enough and it is required the hop-by-hop measurement, so the most complete choice can be the Hop-by-Hop Options Header.

IPv6, as specified in [RFC8200], allows nodes to optionally process Hop-by-Hop headers. Specifically the Hop-by-Hop Options header is not inserted or deleted, but may be examined or processed by any node

along a packet's delivery path, until the packet reaches the node (or each of the set of nodes, in the case of multicast) identified in the Destination Address field of the IPv6 header. Also, it is expected that nodes along a packet's delivery path only examine and process the Hop-by-Hop Options header if explicitly configured to do so.

Another scenario that can be mentioned is the presence of a Routing Header. Both Hop-by-Hop Options and Destination Options headers can be used when a Routing Header is present. Depending on where the Destination Options are situated in the header chain (before or after the Routing Header if any), Destination Options headers can be processed by either intermediate routers specified in the Routing Header, or by the destination node. As an example, a type of Routing Header, referred as Segment Routing Header (SRH), has been defined in [RFC8754] for Segment Routing over IPv6 dataplane (SRv6), and more details about the SRv6 application can be found in [I-D.fz-spring-srv6-alt-mark].

In summary, using these tools, it is possible to control on which nodes measurement occurs:

* Destination Option not preceding a Routing Header => measurement only by node in Destination Address.

* Hop-by-Hop Option => every router on the path with feature enabled.

* Destination Option preceding a Routing Header => every destination node in the route list.

In general, Hop-by-Hop and Destination Options are the most suitable ways to implement Alternate Marking.

It is worth mentioning that Hop-by-Hop Options are not strongly recommended in [RFC7045] and [RFC8200], unless there is a clear justification to standardize it, because nodes may be configured to ignore the Options Header, drop or assign packets containing an Options Header to a slow processing path. In case of the AltMark data fields described in this document, the motivation to standardize a Hop-by-Hop Option is that it is needed for OAM (Operations, Administration, and Maintenance). An intermediate node can read it or not, but this does not affect the packet behavior. The source node is the only one that writes the Hop-by-Hop Option to mark alternately the flow, so, the performance measurement can be done for those nodes configured to read this Option, while the others are simply not considered for the metrics.

The Hop-by-Hop Option defined in this document is designed to take advantage of the property of how Hop-by-Hop options are processed. Nodes that do not support this Option would be expected to ignore it if encountered, according to the procedures of [RFC8200]. This can mean that, in this case, the performance measurement does not account for all links and nodes along a path. The definition of the Hop-by-Hop Options in this document is also designed to minimize throughput impact both on nodes that do not recognize the Option and on node that support it. Indeed, the three high-order bits of the Options Header defined in this draft are 000 and, in theory, as per [RFC8200] and [I-D.ietf-6man-hbh-processing], this means "skip if do not recognize and data do not change en route". [RFC8200] also mentions that the nodes only examine and process the Hop-by-Hop Options header if explicitly configured to do so. For these reasons, this Hop-by-Hop Option should not affect the throughput. However, in practice, it is important to be aware that the things may be different in the implementation and it can happen that packets with Hop-by-Hop are forced onto the slow path, but this is a general issue, as also explained in [I-D.ietf-6man-hbh-processing]. It is also worth mentioning that the application to a controlled domain should avoid the risk of arbitrary nodes dropping packets with Hop-by-Hop Options.

5. Alternate Marking Method Operation

This section describes how the method operates. [I-D.ietf-ippm-rfc8321bis] introduces several applicable methods which are reported below, and an additional field is introduced to facilitate the deployment and improve the scalability.

5.1. Packet Loss Measurement

The measurement of the packet loss is really straightforward in comparison to the existing mechanisms, as detailed in [I-D.ietf-ippm-rfc8321bis]. The packets of the flow are grouped into batches, and all the packets within a batch are marked by setting the L bit (Loss flag) to a same value. The source node can switch the value of the L bit between 0 and 1 after a fixed number of packets or according to a fixed timer, and this depends on the implementation. The source node is the only one that marks the packets to create the batches, while the intermediate nodes only read the marking values and identify the packet batches. By counting the number of packets in each batch and comparing the values measured by different network nodes along the path, it is possible to measure the packet loss occurred in any single batch between any two nodes. Each batch represents a measurable entity recognizable by all network nodes along the path.

Both fixed number of packets and fixed timer can be used by the source node to create packet batches. But, as also explained in [I-D.ietf-ippm-rfc8321bis], the timer-based batches are preferable because they are more deterministic than the counter-based batches. There is no definitive rule for counter-based batches, differently from timer-based batches. Using a fixed timer for the switching offers better control over the method, indeed the length of the batches can be chosen large enough to simplify the collection and the comparison of the measures taken by different network nodes. In the implementation the counters can be sent out by each node to the controller that is responsible for the calculation. It is also possible to exchange this information by using other on-path techniques. But this is out of scope for this document.

Packets with different L values may get swapped at batch boundaries, and in this case, it is required that each marked packet can be assigned to the right batch by each router. It is important to mention that for the application of this method there are two elements to consider: the clock error between network nodes and the network delay. These can create offsets between the batches and out-of-order of the packets. The mathematical formula on timing aspects, explained in section 5 of [I-D.ietf-ippm-rfc8321bis], must be satisfied and it takes into considerations the different causes of reordering such as clock error and network delay. The assumption is to define the available counting interval where to get stable counters and to avoid these issues. Specifically, if the effects of network delay are ignored, the condition to implement the methodology is that the clocks in different nodes MUST be synchronized to the same clock reference with an accuracy of +/- B/2 time units, where B is the fixed time duration of the batch. In this way each marked packet can be assigned to the right batch by each node. Usually the counters can be taken in the middle of the batch period to be sure to read quiescent counters. In a few words this implies that the length of the batches MUST be chosen large enough so that the method is not affected by those factors. The length of the batches can be determined based on the specific deployment scenario.

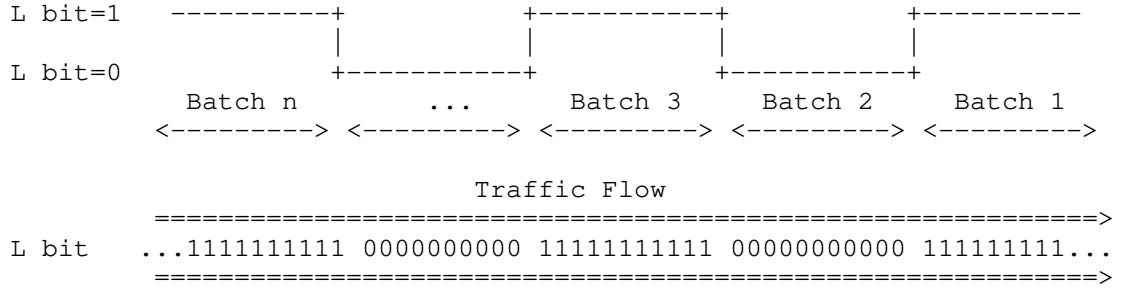


Figure 1: Packet Loss Measurement and Single-Marking Methodology using L bit

It is worth mentioning that the duration of the batches is considered stable over time in the previous figure. In theory, it is possible to change the length of batches over time and among different flows for more flexibility. But, in practice, it could complicate the correlation of the information.

5.2. Packet Delay Measurement

The same principle used to measure packet loss can be applied also to one-way delay measurement. Delay metrics MAY be calculated using the two possibilities:

1. Single-Marking Methodology: This approach uses only the L bit to calculate both packet loss and delay. In this case, the D flag MUST be set to zero on transmit and ignored by the monitoring points. The alternation of the values of the L bit can be used as a time reference to calculate the delay. Whenever the L bit changes and a new batch starts, a network node can store the timestamp of the first packet of the new batch, that timestamp can be compared with the timestamp of the first packet of the same batch on a second node to compute packet delay. But this measurement is accurate only if no packet loss occurs and if there is no packet reordering at the edges of the batches. A different approach can also be considered and it is based on the concept of the mean delay. The mean delay for each batch is calculated by considering the average arrival time of the packets for the relative batch. There are limitations also in this case indeed, each node needs to collect all the timestamps and calculate the average timestamp for each batch. In addition, the information is limited to a mean value.

2. Double-Marking Methodology: This approach is more complete and uses the L bit only to calculate packet loss and the D bit (Delay flag) is fully dedicated to delay measurements. The idea is to use the first marking with the L bit to create the alternate flow and, within the batches identified by the L bit, a second marking is used to select the packets for measuring delay. The D bit creates a new set of marked packets that are fully identified over the network, so that a network node can store the timestamps of these packets; these timestamps can be compared with the timestamps of the same packets on a second node to compute packet delay values for each packet. The most efficient and robust mode is to select a single double-marked packet for each batch, in this way there is no time gap to consider between the double-marked packets to avoid their reorder. Regarding the rule for

the selection of the packet to be double-marked, the same considerations in Section 5.1 apply also here and the double-marked packet can be chosen within the available counting interval that is not affected by factors such as clock errors. If a double-marked packet is lost, the delay measurement for the considered batch is simply discarded, but this is not a big problem because it is easy to recognize the problematic batch and skip the measurement just for that one. So in order to have more information about the delay and to overcome out-of-order issues this method is preferred.

In summary the approach with double marking is better than the approach with single marking. Moreover, the two approaches provide slightly different pieces of information and the data consumer can combine them to have a more robust data set.

Similar to what said in Section 5.1 for the packet counters, in the implementation the timestamps can be sent out to the controller that is responsible for the calculation or could also be exchanged using other on-path techniques. But this is out of scope for this document.

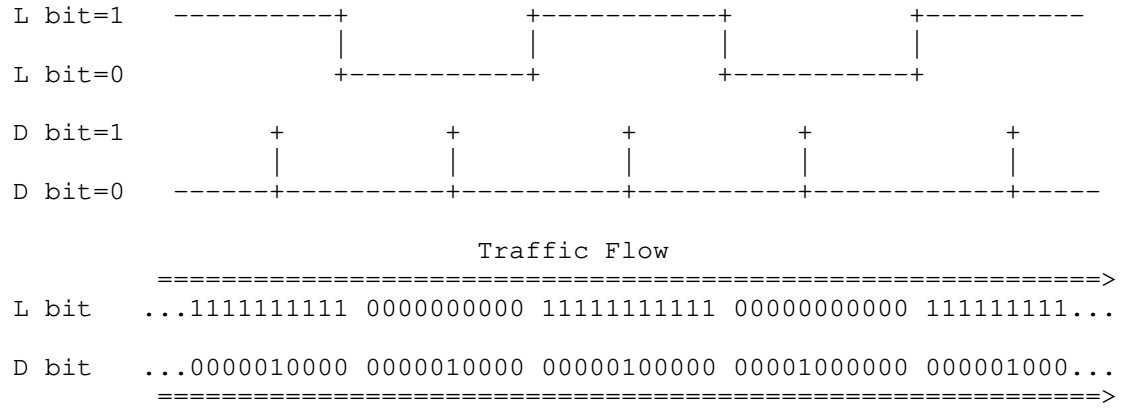


Figure 2: Double-Marking Methodology using L bit and D bit

Likewise to packet delay measurement (both for Single Marking and Double Marking), the method can also be used to measure the inter-arrival jitter.

5.3. Flow Monitoring Identification

The Flow Monitoring Identification (FlowMonID) identifies the flow to be measured and is required for some general reasons:

First, it helps to reduce the per node configuration. Otherwise, each node needs to configure an access-control list (ACL) for each of the monitored flows. Moreover, using a flow identifier allows a flexible granularity for the flow definition, indeed, it can be used together with other identifiers (e.g. 5-tuple).

Second, it simplifies the counters handling. Hardware processing of flow tuples (and ACL matching) is challenging and often incurs into performance issues, especially in tunnel interfaces.

Third, it eases the data export encapsulation and correlation for the collectors.

The FlowMonID MUST only be used as a monitored flow identifier in order to determine a monitored flow within the measurement domain. This entails not only an easy identification but improved correlation as well.

The FlowMonID allocation procedure can be stateful or stateless. In case of a stateful approach, it is required that the FlowMonID historic information can be stored and tracked in order to assign unique values within the domain. This may imply a complex procedure and it is considered out of scope for this document. The stateless approach is described hereinafter where FlowMonID values are pseudo randomly generated.

The value of 20 bits has been selected for the FlowMonID since it is a good compromise and implies a low rate of ambiguous FlowMonIDs that can be considered acceptable in most of the applications. The disambiguation issue can be solved by tagging the pseudo randomly generated FlowMonID with additional flow information. In particular, it is RECOMMENDED to consider the 3-tuple FlowMonID, source and destination addresses:

* If the 20 bit FlowMonID is set independently and pseudo randomly in a distributed way there is a chance of collision. Indeed, by using the well-known birthday problem in probability theory, if the 20 bit FlowMonID is set independently and pseudo randomly without any additional input entropy, there is a 50% chance of collision for 1206 flows. So, for more entropy, FlowMonID is combined with source and destination addresses. Since there is a 1% chance of collision for 145 flows, it is possible to monitor 145 concurrent flows per host pairs with a 1% chance of collision.

* If the 20 bits FlowMonID is set pseudo randomly but in a centralized way, the controller can instruct the nodes properly in order to guarantee the uniqueness of the FlowMonID. With 20 bits, the number of combinations is 1048576, and the controller should

ensure that all the FlowMonID values are used without any collision. Therefore, by considering source and destination addresses together with the FlowMonID, it can be possible to monitor 1048576 concurrent flows per host pairs.

A consistent approach MUST be used in the Alternate Marking deployment to avoid the mixture of different ways of identifying. All the nodes along the path and involved into the measurement SHOULD use the same mode for identification. As mentioned, it is RECOMMENDED to use the FlowMonID for identification purpose in combination with source and destination addresses to identify a flow. By considering source and destination addresses together with the FlowMonID it can be possible to monitor 145 concurrent flows per host pairs with a 1% chance of collision in case of pseudo randomly generated FlowMonID, or 1048576 concurrent flows per host pairs in case of centralized controller. It is worth mentioning that the solution with the centralized control allows finer granularity and therefore adds even more flexibility to the flow identification.

The FlowMonID field is set at the source node, which is the ingress point of the measurement domain, and can be set in two ways:

a. It can be algorithmically generated by the source node, that can set it pseudo-randomly with some chance of collision. This approach cannot guarantee the uniqueness of FlowMonID since conflicts and collisions are possible. But, considering the recommendation to use FlowMonID with source and destination addresses the conflict probability is reduced due to the FlowMonID space available for each endpoint pair (i.e. 145 flows with 1% chance of collision).

b. It can be assigned by the central controller. Since the controller knows the network topology, it can allocate the value properly to avoid or minimize ambiguity and guarantee the uniqueness. In this regard, the controller can verify that there is no ambiguity between different pseudo-randomly generated FlowMonIDs on the same path. The conflict probability is really small given that the FlowMonID is coupled with source and destination addresses and up to 1048576 flows can be monitored for each endpoint pair. When all values in the FlowMonID space are consumed, the centralized controller can keep track and reassign the values that are not used any more by old flows.

If the FlowMonID is set by the source node, the intermediate nodes can read the FlowMonIDs from the packets in flight and act accordingly. While, if the FlowMonID is set by the controller, both possibilities are feasible for the intermediate nodes which can learn by reading the packets or can be instructed by the controller.

The FlowMonID setting by the source node may seem faster and more scalable than the FlowMonID setting by the controller. But, it is supposed that the controller does not slow the process since it can enable Alternate Marking method and its parameters (like FlowMonID) together with the flow instantiation, as further described in [I-D.ietf-idr-sr-policy-ifit] and [I-D.chen-pce-pcep-ifit].

5.4. Multipoint and Clustered Alternate Marking

The Alternate Marking method can be extended to any kind of multipoint to multipoint paths. [I-D.ietf-ippm-rfc8321bis] only applies to point-to-point unicast flows, while the Multipoint Alternate Marking Clustered method, introduced in [I-D.ietf-ippm-rfc8889bis], is valid for multipoint-to-multipoint unicast flows, anycast and ECMP flows.

[I-D.ietf-ippm-rfc8889bis] describes the network clustering approach which allows a flexible and optimized performance measurement. A Cluster is the smallest identifiable non-trivial subnetwork of the entire Network graph that still satisfies the condition that the number of packets that goes in is the same that goes out. With network clustering, it is possible to use the partition of the network into clusters at different levels in order to perform the needed degree of detail.

For Multipoint Alternate Marking, FlowMonID can identify in general a multipoint-to-multipoint flow and not only a point-to-point flow.

5.5. Data Collection and Calculation

The nodes enabled to perform performance monitoring collect the value of the packet counters and timestamps. There are several alternatives to implement Data Collection and Calculation, but this is not specified in this document.

There are documents on the control plane mechanisms of Alternate Marking, e.g. [I-D.ietf-idr-sr-policy-ifit], [I-D.chen-pce-pcep-ifit].

6. Security Considerations

This document aims to apply a method to perform measurements that does not directly affect Internet security nor applications that run on the Internet. However, implementation of this method must be mindful of security and privacy concerns.

There are two types of security concerns: potential harm caused by the measurements and potential harm to the measurements.

Harm caused by the measurement: Alternate Marking implies the insertion of an Option Header to the IPv6 packets by the source node, but this must be performed in a way that does not alter the quality of service experienced by the packets and that preserves stability and performance of routers doing the measurements. As already discussed in Section 4, the design of the AltMark Option has been chosen with throughput in mind, such that it can be implemented without affecting the user experience.

Harm to the measurement: Alternate Marking measurements could be harmed by routers altering the fields of the AltMark Option (e.g. marking of the packets, FlowMonID) or by a malicious attacker adding AltMark Option to the packets in order to consume the resources of network devices and entities involved. As described above, the source node is the only one that writes the Option Header while the intermediate nodes and destination node only read it without modifying the Option Header. But, for example, an on-path attacker can modify the flags, whether intentionally or accidentally, or deliberately insert an option to the packet flow or delete the option from the packet flow. The consequent effect could be to give the appearance of loss or delay or invalidate the measurement by modifying option identifiers, such as FlowMonID. The malicious implication can be to cause actions from the network administrator where an intervention is not necessary or to hide real issues in the network. Since the measurement itself may be affected by network nodes intentionally altering the bits of the AltMark Option or injecting Options headers as a means for Denial of Service (DoS), the Alternate Marking MUST be applied in the context of a controlled domain, where the network nodes are locally administered and this type of attack can be avoided. For this reason, the implementation of the method is not done on the end node if it is not fully managed and does not belong to the controlled domain. Packets generated outside the controlled domain may consume router resources by maliciously using the HbH Option, but this can be mitigated by filtering these packets at the controlled domain boundary. This can be done because, if the end node does not belong to the controlled domain, it is not supposed to add the AltMark HbH Option, and it can be easily recognized.

An attacker that does not belong to the controlled domain can maliciously send packets with AltMark Option. But if Alternate Marking is not supported in the controlled domain, no problem happens because the AltMark Option is treated as any other unrecognized option and will not be considered by the nodes since they are not configured to deal with it, so the only effect is the increased packet size (by 48 bits). While if Alternate Marking is supported in the controlled domain, it is also necessary to avoid that the measurements are affected and external packets with AltMark Option

MUST be filtered. As any other Hop-by-Hop Options or Destination Options, it is possible to filter AltMark Options entering or leaving the domain e.g. by using ACL extensions for filtering.

The flow identifier (FlowMonID), together with the two marking bit (L and D), comprises the AltMark Option. As explained in Section 5.3, there is a chance of collision if the FlowMonID is set pseudo randomly but that there is a solution for this issue. In general this may not be a problem and a low rate of ambiguous FlowMonIDs can be acceptable, since this does not cause significant harm to the operators or their clients and this harm may not justify the complications of avoiding it. But, for large scale measurements, a big number of flows could be monitored and the probability of a collision is higher, thus the disambiguation of the FlowMonID field can be considered.

The privacy concerns also need to be analyzed even if the method only relies on information contained in the Option Header without any release of user data. Indeed, from a confidentiality perspective, although AltMark Option does not contain user data, the metadata can be used for network reconnaissance to compromise the privacy of users by allowing attackers to collect information about network performance and network paths. AltMark Option contains two kinds of metadata: the marking bits (L and D bits) and the flow identifier (FlowMonID).

The marking bits are the small information that is exchanged between the network nodes. Therefore, due to this intrinsic characteristic, network reconnaissance through passive eavesdropping on data-plane traffic is difficult. Indeed, an attacker cannot gain information about network performance from a single monitoring point. The only way for an attacker can be to eavesdrop on multiple monitoring points at the same time, because they have to do the same kind of calculation and aggregation as Alternate Marking requires.

The FlowMonID field is used in the AltMark Option as the identifier of the monitored flow. It represents a more sensitive information for network reconnaissance and may allow a flow tracking type of attack because an attacker could collect information about network paths.

Furthermore, in a pervasive surveillance attack, the information that can be derived over time is more. But, as further described hereinafter, the application of the Alternate Marking to a controlled domain helps to mitigate all the above aspects of privacy concerns.

At the management plane, attacks can be set up by misconfiguring or by maliciously configuring AltMark Option. Thus, AltMark Option configuration MUST be secured in a way that authenticates authorized users and verifies the integrity of configuration procedures. Solutions to ensure the integrity of AltMark Option are outside the scope of this document. Also, attacks on the reporting of the statistics between the monitoring points and the network management system (e.g. centralized controller) can interfere with the proper functioning of the system. Hence, the channels used to report back flow statistics MUST be secured.

As stated above, the precondition for the application of the Alternate Marking is that it MUST be applied in specific controlled domains, thus confining the potential attack vectors within the network domain. A limited administrative domain provides the network administrator with the means to select, monitor and control the access to the network, making it a trusted domain. In this regard it is expected to enforce policies at the domain boundaries to filter both external packets with AltMark Option entering the domain and internal packets with AltMark Option leaving the domain. Therefore, the trusted domain is unlikely subject to hijacking of packets since packets with AltMark Option are processed and used only within the controlled domain.

As stated, the application to a controlled domain ensures the control over the packets entering and leaving the domain, but despite that, leakages may happen for different reasons, such as a failure or a fault. In this case, nodes outside the domain are expected to ignore packets with AltMark Option since they are not configured to handle it and should not process it.

Additionally, it is to be noted that the AltMark Option is carried by the Options Header and it will have some impact on the packet sizes for the monitored flow and on the path MTU, since some packets might exceed the MTU. However, the relative small size (48 bit in total) of these Option Headers and its application to a controlled domain help to mitigate the problem.

It is worth mentioning that the security concerns may change based on the specific deployment scenario and related threat analysis, which can lead to specific security solutions that are beyond the scope of this document. As an example, the AltMark Option can be used as Hop-by-Hop or Destination Option and, in case of Destination Option, multiple administrative domains may be traversed by the AltMark Option that is not confined to a single administrative domain. In this case, the user, aware of the kind of risks, may still want to use Alternate Marking for telemetry and test purposes but the controlled domain must be composed by more than one administrative

domains. To this end, the inter-domain links need to be secured (e.g., by IPsec, VPNs) in order to avoid external threats and realize the whole controlled domain.

It might be theoretically possible to modulate the marking or the other fields of the AltMark Option to serve as a covert channel to be used by an on-path observer. This may affect both the data and management plane, but, here too, the application to a controlled domain helps to reduce the effects.

The Alternate Marking application described in this document relies on a time synchronization protocol. Thus, by attacking the time protocol, an attacker can potentially compromise the integrity of the measurement. A detailed discussion about the threats against time protocols and how to mitigate them is presented in [RFC7384]. Network Time Security (NTS), described in [RFC8915], is a mechanism that can be employed. Also, the time, which is distributed to the network nodes through the time protocol, is centrally taken from an external accurate time source, such as an atomic clock or a GPS clock. By attacking the time source it can be possible to compromise the integrity of the measurement as well. There are security measures that can be taken to mitigate the GPS spoofing attacks and a network administrator should certainly employ solutions to secure the network domain.

7. IANA Considerations

The Option Type should be assigned in IANA's "Destination Options and Hop-by-Hop Options" registry.

This draft requests the following IPv6 Option Type assignment from the Destination Options and Hop-by-Hop Options sub-registry of Internet Protocol Version 6 (IPv6) Parameters (https://www.iana.org/assignments/ipv6-parameters/).

Hex Value	Binary Value act chg rest	Description	Reference
TBD	00 0 tbd	AltMark	[This draft]

8. Acknowledgements

The authors would like to thank Bob Hinden, Ole Troan, Martin Duke, Lars Eggert, Roman Danyliw, Alvaro Retana, Eric Vyncke, Warren Kumari, Benjamin Kaduk, Stewart Bryant, Christopher Wood, Yoshifumi Nishida, Tom Herbert, Stefano Previdi, Brian Carpenter, Greg Mirsky, Ron Bonica for the precious comments and suggestions.

9. References

9.1. Normative References

[I-D.ietf-ippm-rfc8321bis]
Fioccola, G., Cociglio, M., Mirsky, G., Mizrahi, T., and T. Zhou, "Alternate-Marking Method", Work in Progress, Internet-Draft, draft-ietf-ippm-rfc8321bis-03, 25 July 2022, <https://www.ietf.org/archive/id/draft-ietf-ippm-rfc8321bis-03.txt>.

[I-D.ietf-ippm-rfc8889bis]
Fioccola, G., Cociglio, M., Sapio, A., Sisto, R., and T. Zhou, "Clustered Alternate-Marking Method", Work in Progress, Internet-Draft, draft-ietf-ippm-rfc8889bis-04, 26 September 2022, <https://www.ietf.org/archive/id/draft-ietf-ippm-rfc8889bis-04.txt>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8200] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", STD 86, RFC 8200, DOI 10.17487/RFC8200, July 2017, <https://www.rfc-editor.org/info/rfc8200>.

9.2. Informative References

[I-D.chen-pce-pcep-ifit]
Yuan, H., Zhou, T., Li, W., Fioccola, G., and Y. Wang, "Path Computation Element Communication Protocol (PCEP) Extensions to Enable IFIT", Work in Progress, Internet-Draft, draft-chen-pce-pcep-ifit-06, 4 February 2022, <https://www.ietf.org/archive/id/draft-chen-pce-pcep-ifit-06.txt>.

[I-D.fz-spring-srv6-alt-mark]
Fioccola, G., Zhou, T., and M. Cociglio, "Segment Routing Header encapsulation for Alternate Marking Method", Work in Progress, Internet-Draft, draft-fz-spring-srv6-alt-mark-03, 5 August 2022, <https://www.ietf.org/archive/id/draft-fz-spring-srv6-alt-mark-03.txt>.

[I-D.ietf-6man-hbh-processing]
Hinden, R. M. and G. Fairhurst, "IPv6 Hop-by-Hop Options Processing Procedures", Work in Progress, Internet-Draft, draft-ietf-6man-hbh-processing-02, 23 August 2022, <https://www.ietf.org/archive/id/draft-ietf-6man-hbh-processing-02.txt>.

[I-D.ietf-idr-sr-policy-ifit]
Qin, F., Yuan, H., Yang, S., Zhou, T., and G. Fioccola, "BGP SR Policy Extensions to Enable IFIT", Work in Progress, Internet-Draft, draft-ietf-idr-sr-policy-ifit-04, 7 July 2022, <https://www.ietf.org/archive/id/draft-ietf-idr-sr-policy-ifit-04.txt>.

[I-D.ietf-v6ops-hbh]
Peng, S., Li, Z., Xie, C., Qin, Z., and G. Mishra, "Operational Issues with Processing of the Hop-by-Hop Options Header", Work in Progress, Internet-Draft, draft-ietf-v6ops-hbh-01, 18 April 2022, <https://www.ietf.org/archive/id/draft-ietf-v6ops-hbh-01.txt>.

[RFC4301] Kent, S. and K. Seo, "Security Architecture for the Internet Protocol", RFC 4301, DOI 10.17487/RFC4301, December 2005, <https://www.rfc-editor.org/info/rfc4301>.

[RFC6437] Amante, S., Carpenter, B., Jiang, S., and J. Rajahalme, "IPv6 Flow Label Specification", RFC 6437, DOI 10.17487/RFC6437, November 2011, <https://www.rfc-editor.org/info/rfc6437>.

[RFC6438] Carpenter, B. and S. Amante, "Using the IPv6 Flow Label for Equal Cost Multipath Routing and Link Aggregation in Tunnels", RFC 6438, DOI 10.17487/RFC6438, November 2011, <https://www.rfc-editor.org/info/rfc6438>.

[RFC7045] Carpenter, B. and S. Jiang, "Transmission and Processing of IPv6 Extension Headers", RFC 7045, DOI 10.17487/RFC7045, December 2013, <https://www.rfc-editor.org/info/rfc7045>.

[RFC7384] Mizrahi, T., "Security Requirements of Time Protocols in Packet Switched Networks", RFC 7384, DOI 10.17487/RFC7384, October 2014, <https://www.rfc-editor.org/info/rfc7384>.

[RFC8754] Filsfils, C., Ed., Dukes, D., Ed., Previdi, S., Leddy, J., Matsushima, S., and D. Voyer, "IPv6 Segment Routing Header (SRH)", RFC 8754, DOI 10.17487/RFC8754, March 2020, <https://www.rfc-editor.org/info/rfc8754>.

[RFC8799] Carpenter, B. and B. Liu, "Limited Domains and Internet Protocols", RFC 8799, DOI 10.17487/RFC8799, July 2020, <https://www.rfc-editor.org/info/rfc8799>.

[RFC8915] Franke, D., Sibold, D., Teichel, K., Dansarie, M., and R. Sundblad, "Network Time Security for the Network Time Protocol", RFC 8915, DOI 10.17487/RFC8915, September 2020, <https://www.rfc-editor.org/info/rfc8915>.

Authors' Addresses

Giuseppe Fioccola
Huawei
Riesstrasse, 25
80992 Munich
Germany
Email: giuseppe.fioccola@huawei.com

Tianran Zhou
Huawei
156 Beiqing Rd.
Beijing
100095
China
Email: zhoutianran@huawei.com

Mauro Cociglio
Telecom Italia
Email: mauro.cociglio@outlook.com

Fengwei Qin
China Mobile
32 Xuanwumenxi Ave.
Beijing
100032
China
Email: qinfengwei@chinamobile.com

Ran Pang
China Unicom
9 Shouti South Rd.
Beijing
100089
China
Email: pangran@chinaunicom.cn