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Guidelines for Characterizing "OAM"

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Abstract

As the IETF continues to produce and standardize different

Operations, Administration, and Maintenance (OAM) protocols and

technologies, various qualifiers and modifiers are prepended to the

OAM abbreviation. While, at first glance, the most used appear to be

well understood, the same qualifier may be interpreted differently in

different contexts. A case in point is the qualifiers "in-band" and

"out-of-band" which have their origins in the radio lexicon, and

which have been extrapolated into other communication networks.

This document considers some common qualifiers and modifiers that are

prepended, within the context of packet networks, to the OAM

abbreviation and lays out guidelines for their use in future IETF

work to enable a more precise and consistent understanding of OAM mechanisms

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1. Introduction

It is not uncommon for historical and popular terms to have nuances

in how they are interpreted or understood. This was, for example,

the case with the abbreviation for Operations, Administration, and

Maintenance, "OAM", and [RFC6291] provided guidelines for its use as

well as definitions of its constituent parts.

Characterizations or qualifiers for "OAM" within packet networks

often encounter similar problems of interpretation, such as with the

adjective phrases "in-band" and "out-of-band". This document

considers some common qualifiers and modifiers that are prepended to

the OAM abbreviation, and lays out guidelines for their use in future

IETF work to achieve consistent and unambiguous characterization.

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This document updates [RFC6291] by adding to the guidelines for the

use of the term "OAM". It does not modify any other part of

[RFC6291].

2. In-Band and Out-of-Band OAM

Historically, the terms "in-band" and "out-of-band" were used

extensively in radio communications as well as in telephony signaling

[RFC4733]. In both these cases, there is an actual "Band" (i.e., a

"Channel" or "Frequency") to be within or outside.

While those terms, useful in their simplicity, continued to be

broadly used to mean "within something" and "outside something", a

challenge is presented for IP communications and packet-switched

networks (PSNs) which do not have a "band" per se, and, in fact, have

multiple "somethings" that OAM traffic can be carried within or

outside. A frequently encountered case is the use of "in-band" to

mean either In-Packet or on-path.

Within the IETF, the terms "in-band" and "out-of-band" cannot be

reliably understood consistently and unambiguously. Context-specific

definitions of these terms are inconsistent and therefore cannot be

generalized. More importantly, the terms are not self-defining to

any further extent and cannot be understood by someone exposed to

them for the first time, since there is no "band" in IP.

There are many examples of "in-band OAM" and "out-of-band OAM" in

published RFCs. For instance, the term "in-band" appears in both

Virtual Circuit Connectivity Verification (VCCV) [RFC5085] and OAM

for Deterministic Networking (DetNet) [RFC9551]. While the context

in each of these documents is clear, the term carries different

meanings in each case. These two examples, as well as other examples

of uses of the term "in-band" in previous documents are described

throughout Section 3.

While interpreting existing documents, it is important to understand

the semantics of what "band" is a proxy for, and to be more explicit

if those documents are updated. This document does not change the

meaning of any terms in any prior RFCs.

3. Terminology and Guidance

This document recommends avoiding the terms "in-band" and "out-of-

band" when referring to OAM. Instead, it encourages the use of more

fine-grained and descriptive terminology. The document also presents

alternative terms and definitions for use in future IETF documents

referencing OAM, without precluding the use of other precise,

descriptive terms that do not rely on the "-band" convention.

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The terminology presented in this section classifies OAM according to

three criteria: whether it operates in an active, passive, or hybrid

mode; whether it follows the same path as data traffic; and whether

it receives the same treatment as data traffic.

3.1. Active, Passive, Hybrid, and In-Packet OAM

[RFC7799] provides clear definitions for active and passive

performance assessment, enabling the construction of metrics and

methods to be described as either "Active" or "Passive". Even though

[RFC7799] does not explicitly use these terms as modifiers of "OAM",

they are widely used in practice and are included here for clarity.

The terms "Active", "Passive" and "Hybrid", as described below, are

consistent with [RFC7799].

Active OAM:

Uses dedicated OAM packets.

Passive OAM:

Relies on the observation of one or more existing data

packet streams and does not use dedicated OAM packets nor does it modify packets.

Hybrid OAM:

Uses augmentation or modification of packet streams. Examples

of protocols classified as "Hybrid OAM" include Alternate Marking

[RFC9341], In situ OAM (IOAM) [RFC9197], and MPLS Loss Measurement

[RFC6374]. Hybrid OAM can be implemented by piggybacking OAM-

related information onto data packets, as described in [RFC9197],

or by utilizing reserved fields in the packet header or specific

values of existing header fields, as proposed in [RFC9341].

Direct loss measurement [RFC6374] is an example of "Hybrid OAM" in

which user packets are not modified by the protocol. Instead, OAM

packets are used to exchange information about user packet

counters, allowing for packet loss and delay computation.

This document defines the term In-Packet OAM as a more specific and

narrowly scoped instance within the broader category of Hybrid OAM.

In-Packet OAM:

The OAM information is carried in the packets that also carry the

data traffic. This is a specific case of Hybrid OAM. It was

sometimes referred to as "in-band".

The MPLS echo request/reply messages [RFC8029] are an example of

"Active OAM", since they are described as "An MPLS echo request/reply

is a (possibly MPLS-labeled) IPv4 or IPv6 UDP packet".

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IOAM [RFC9197] is an example of "Hybrid OAM" that is also "In-Packet

OAM", given that it: '...records OAM information within the packet

while the packet traverses a particular network domain. The term "in

situ" refers to the fact that the OAM data is added to the data

packets rather than being sent within packets specifically dedicated

to OAM.' Another example of In-Packet OAM is Alternate Marking

[RFC9341], in which a small number of bits in the packet header is

used for marking a subset of packets in a flow.

An example of "Hybrid OAM" which is not classified as "In-Packet OAM"

is Direct loss measurement [RFC6374].

Initially, "In situ OAM" [RFC9197] was also referred to as "In-band

OAM", but was renamed due to the overloaded meaning of "In-band OAM".

Further, [RFC9232] also intertwines the terms "in-band" with "in

situ", though [I-D.song-opsawg-ifit-framework] settled on using "in

Situ". Other similar uses, including [P4-INT-2.1] and

[I-D.kumar-ippm-ifa], still use variations of "in-band", "in band",

or "inband".

3.2. Path Followed OAM

Path-Congruent OAM:

The OAM information follows the exact same path as the observed

data traffic. This was sometimes referred to as "in-band".

Non-Path-Congruent OAM:

The OAM information does not follow the exact same path as the

observed data traffic. This can also be called Path-Incongruent

OAM, and was sometimes referred to as "out-of-band".

In this document, the term "path-congruent packets" describes packets

that follow the exact same path (i.e., traverse the same nodes and

links) within a network. Note that this definition does not describe

how the packets are treated in queues within the nodes on the path.

A further concept, "equal-forwarding-treatment" describes how path-

congruent packets receive the same forwarding treatment (e.g.,

Quality of Service (QoS)).

An example of "Path-Congruent OAM" is the Virtual Circuit

Connectivity Verification (VCCV), described is [RFC5085] as "The VCCV

message travels in-band with the Session and follows the exact same

path as the user data for the session". Thus, the term "in-band" in

[RFC5085] refers to using the same path as the user data. This term

is also used in Section 2 of [RFC6669] with the same meaning, and the

word "congruent" is mentioned as synonymous.

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3.3. Packet Forwarding Treatment OAM

Equal-Forwarding-Treatment OAM:

The OAM packets receive the same forwarding (e.g., QoS) treatment

as user data packets. This was sometimes referred to as "in-

band".

Different-Forwarding-Treatment OAM:

The OAM packets receive different forwarding (e.g., QoS) treatment

as user data packets. This was sometimes referred to as "out-of-

band".

The motivation for Equal-Forwarding-Treatment OAM lies in the desire

to ensure that OAM packets experience the same network conditions as

the user data they are intended to monitor. This includes not only

traversing the same topological path but also receiving identical

Quality of Service (QoS) treatment, such as queuing, scheduling, and

traffic shaping. When both topological and forwarding treatment

equivalence is achieved, the OAM packets are said to exhibit fate-

sharing [RFC7276] with the data traffic. Fate-sharing ensures that

any impairments or anomalies affecting the user traffic are also

reflected in the behavior of the OAM packets, thereby making the

results of the OAM observations more operationally meaningful and

actionable. Without such equivalence, discrepancies in treatment

could lead to misleading measurements or diagnostics, and even

inadequate corrective actions, reducing the utility of the OAM

mechanism for performance monitoring and fault detection.

An example of "Equal-Forwarding-Treatment OAM" is presented in

[RFC9551] in the context of DetNet OAM: "it traverses the same set of

links and interfaces receiving the same QoS and Packet Replication,

Elimination, and Ordering Functions (PREOF) treatment as the

monitored DetNet flow". This is classified in [RFC9551] as "In-band

OAM". Similarly, the property of "Different-Forwarding-Treatment

OAM" can be found in the following definition in [RFC9551]: "Out-of-

band OAM: an active OAM method whose path through the DetNet domain

may not be topologically identical to the path of the monitored

DetNet flow, its test packets may receive different QoS and/or PREOF

treatment, or both." [I-D.ietf-raw-architecture] uses similar text.

3.4. Using Multiple Criteria

OAM protocols and tools can be classified according to the three

criteria that were described in the previous sections. However, not

all criteria are applicable to all OAM protocols, and not all

combinations are necessarily possible.

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When defining a new OAM protocol or analyzing an existing one, it is

recommended to explicitly consider which of these criterias are

applicable and to describe the protocol accordingly. As a first

step, all OAM mechanisms can be classified according to the first

criterion, as Active, Passive, or Hybrid/In-Packet. Further

classification according to the other two criteria should be

considered on a case-by-case basis.

In some cases, certain criteria are not relevant, or not all

combinations are possible. For example:

\* Passive OAM relies solely on observing existing data packet streams and

does not generate dedicated OAM packets. As such, the path

congruence and forwarding treatment criteria are not relevant,

since no dedicated OAM packets are exchanged between the

measurement points.

\* Non-Path-Congruent OAM, by nature, cannot be Equal-Forwarding-

Treatment.

A few examples of OAM classification according to the three criteria

are presented below:

\* IP Ping, which uses ICMP Echo messages, can be classified as

Active OAM. Since it is not guaranteed to follow the same path or

receive the same treatment as user data packets, it is classified

as Non-Path-Congruent and, consequently, as Different-Forwarding-

Treatment.

\* When IOAM [RFC9197] is incorporated in data packets it can be

classified as In-Packet, Path-Congruent and Equal-Forwarding-

Treatment.

\* VCCV [RFC5085], as discussed above, is classified as Active, Path-

Congruent and Different-Forwarding-Treatment.

\* MPLS inferred loss measurement [RFC6374] uses specially generated

test messages, and therefore can be classified as Active. It is

also Path-Congruent, and can be deployed either as Equal- or

Different-Forwarding-Treatment OAM. MPLS direct loss measurement

[RFC6374] uses OAM messages that exchange counters that count user

data traffic. Hence, it is classified as Hybrid OAM, and as in

the inferred mode, it is Path-Congruent, and can be either Equal-

or Different-Forwarding-Treatment OAM.

This multi-dimensional classification enables a more precise and

consistent understanding of OAM mechanisms.

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4. Security Considerations

Security is improved when terms are used with precision, and their

definitions are unambiguous.

5. IANA Considerations

This document has no IANA actions.

6. Acknowledgements

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