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J. Heinanen
Telia Finland
F. Baker
Cisco Systems
W. Weiss
Lucent Technologies
J. Wroclawski
MIT LCS

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Assured Forwarding PHB Group

Status of this Memo

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Abstract

This document defines a general use Differentiated Services (DS) [Blake] Per-Hop-Behavior (PHB) Group called Assured Forwarding (AF). The AF PHB group provides delivery of IP packets in four independently forwarded AF classes. Within each AF class, an IP packet can be assigned one of three different levels of drop precedence. A DS node does not reorder IP packets of the same microflow if they belong to the same AF class.

1. Purpose and Overview

There is a demand to provide assured forwarding of IP packets over the Internet. In a typical application, a company uses the Internet to interconnect its geographically distributed sites and wants an assurance that IP packets within this intranet are forwarded with high probability as long as the aggregate traffic from each site does not exceed the subscribed information rate (profile). It is desirable that a site may exceed the subscribed profile with the understanding that the excess traffic is not delivered with as high probability as the traffic that is within the profile. It is also

important that the network does not reorder packets that belong to the same microflow, as defined in [Nichols], no matter if they are in or out of the profile.

Assured Forwarding (AF) PHB group is a means for a provider DS domain to offer different levels of forwarding assurances for IP packets received from a customer DS domain. Four AF classes are defined, where each AF class is in each DS node allocated a certain amount of forwarding resources (buffer space and bandwidth). IP packets that wish to use the services provided by the AF PHB group are assigned by the customer or the provider DS domain into one or more of these AF classes according to the services that the customer has subscribed to. Further background about this capability and some ways to use it may be found in [Clark].

Within each AF class IP packets are marked (again by the customer or the provider DS domain) with one of three possible drop precedence values. In case of congestion, the drop precedence of a packet determines the relative importance of the packet within the AF class. A congested DS node tries to protect packets with a lower drop precedence value from being lost by preferably discarding packets with a higher drop precedence value.

In a DS node, the level of forwarding assurance of an IP packet thus depends on (1) how much forwarding resources has been allocated to the AF class that the packet belongs to, (2) what is the current load of the AF class, and, in case of congestion within the class, (3) what is the drop precedence of the packet.

For example, if traffic conditioning actions at the ingress of the provider DS domain make sure that an AF class in the DS nodes is only moderately loaded by packets with the lowest drop precedence value and is not overloaded by packets with the two lowest drop precedence values, then the AF class can offer a high level of forwarding assurance for packets that are within the subscribed profile (i.e., marked with the lowest drop precedence value) and offer up to two lower levels of forwarding assurance for the excess traffic.

This document describes the AF PHB group. An otherwise DS-compliant node is not required to implement this PHB group in order to be considered DS-compliant, but when a DS-compliant node is said to implement an AF PHB group, it must conform to the specification in this document.

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 [Bradner].

2. The AF PHB Group

Assured Forwarding (AF) PHB group provides forwarding of IP packets in N independent AF classes. Within each AF class, an IP packet is assigned one of M different levels of drop precedence. An IP packet that belongs to an AF class i and has drop precedence j is marked with the AF codepoint AFij, where 1 <= i <= N and 1 <= j <= M. Currently, four classes (N=4) with three levels of drop precedence in each class (M=3) are defined for general use. More AF classes or levels of drop precedence MAY be defined for local use.

A DS node SHOULD implement all four general use AF classes. Packets in one AF class MUST be forwarded independently from packets in another AF class, i.e., a DS node MUST NOT aggregate two or more AF classes together.

A DS node MUST allocate a configurable, minimum amount of forwarding resources (buffer space and bandwidth) to each implemented AF class. Each class SHOULD be serviced in a manner to achieve the configured service rate (bandwidth) over both small and large time scales.

An AF class MAY also be configurable to receive more forwarding resources than the minimum when excess resources are available either from other AF classes or from other PHB groups. This memo does not specify how the excess resources should be allocated, but implementations MUST specify what algorithms are actually supported and how they can be parameterized.

Within an AF class, a DS node MUST NOT forward an IP packet with smaller probability if it contains a drop precedence value p than if it contains a drop precedence value q when p < q. Note that this requirement can be fulfilled without needing to dequeue and discard already-queued packets.

Within each AF class, a DS node MUST accept all three drop precedence codepoints and they MUST yield at least two different levels of loss probability. In some networks, particularly in enterprise networks, where transient congestion is a rare and brief occurrence, it may be reasonable for a DS node to implement only two different levels of loss probability per AF class. While this may suffice for some networks, three different levels of loss probability SHOULD be supported in DS domains where congestion is a common occurrence.

If a DS node only implements two different levels of loss probability for an AF class x, the codepoint AFx1 MUST yield the lower loss probability and the codepoints AFx2 and AFx3 MUST yield the higher loss probability.

A DS node MUST NOT reorder AF packets of the same microflow when they belong to the same AF class regardless of their drop precedence. There are no quantifiable timing requirements (delay or delay variation) associated with the forwarding of AF packets.

The relationship between AF classes and other PHBs is described in Section 7 of this memo.

The AF PHB group MAY be used to implement both end-to-end and domain edge-to-domain edge services.

3. Traffic Conditioning Actions

A DS domain MAY at the edge of a domain control the amount of AF traffic that enters or exits the domain at various levels of drop precedence. Such traffic conditioning actions MAY include traffic shaping, discarding of packets, increasing or decreasing the drop precedence of packets, and reassigning of packets to other AF classes. However, the traffic conditioning actions MUST NOT cause reordering of packets of the same microflow.

4. Queueing and Discard Behavior

This section defines the queueing and discard behavior of the AF PHB group. Other aspects of the PHB group's behavior are defined in Section 2.

An AF implementation MUST attempt to minimize long-term congestion within each class, while allowing short-term congestion resulting from bursts. This requires an active queue management algorithm. An example of such an algorithm is Random Early Drop (RED) [Floyd]. This memo does not specify the use of a particular algorithm, but does require that several properties hold.

An AF implementation MUST detect and respond to long-term congestion within each class by dropping packets, while handling short-term congestion (packet bursts) by queueing packets. This implies the presence of a smoothing or filtering function that monitors the instantaneous congestion level and computes a smoothed congestion level. The dropping algorithm uses this smoothed congestion level to determine when packets should be discarded.

The dropping algorithm MUST be insensitive to the short-term traffic characteristics of the microflows using an AF class. That is, flows with different short-term burst shapes but identical longer-term packet rates should have packets discarded with essentially equal probability. One way to achieve this is to use randomness within the dropping function.

The dropping algorithm MUST treat all packets within a single class and precedence level identically. This implies that for any given smoothed congestion level, the discard rate of a particular microflow's packets within a single precedence level will be proportional to that flow's percentage of the total amount of traffic passing through that precedence level.

The congestion indication feedback to the end nodes, and thus the level of packet discard at each drop precedence in relation to congestion, MUST be gradual rather than abrupt, to allow the overall system to reach a stable operating point. One way to do this (RED) uses two (configurable) smoothed congestion level thresholds. When the smoothed congestion level is below the first threshold, no packets of the relevant precedence are discarded. When the smoothed congestion level is between the first and the second threshold, packets are discarded with linearly increasing probability, ranging from zero to a configurable value reached just prior to the second threshold. When the smoothed congestion level is above the second threshold, packets of the relevant precedence are discarded with 100% probability.

To allow the AF PHB to be used in many different operating environments, the dropping algorithm control parameters MUST be independently configurable for each packet drop precedence and for each AF class.

Within the limits above, this specification allows for a range of packet discard behaviors. Inconsistent discard behaviors lead to inconsistent end-to-end service semantics and limit the range of possible uses of the AF PHB in a multi-vendor environment. As experience is gained, future versions of this document may more tightly define specific aspects of the desirable behavior.

5. Tunneling

When AF packets are tunneled, the PHB of the tunneling packet MUST NOT reduce the forwarding assurance of the tunneled AF packet nor cause reordering of AF packets belonging to the same microflow.

6. Recommended Codepoints

Recommended codepoints for the four general use AF classes are given below. These codepoints do not overlap with any other general use PHB groups.

The RECOMMENDED values of the AF codepoints are as follows: AF11 = '001010', AF12 = '001100', AF13 = '001110', AF21 = '010010', AF22 = '010100', AF23 = '010110', AF31 = '011010', AF32 = '011100', AF33 = '011110', AF41 = '100010', AF42 = '100100', and AF43 = '100110'. The table below summarizes the recommended AF codepoint values.

	Class 1	Class 2	Class 3	Class 4
Low Drop Prec	001010	010010	011010	100010
Medium Drop Prec	001100	010100	011100	100100
High Drop Prec	001110	010110	011110	100110

7. Interactions with Other PHB Groups

The AF codepoint mappings recommended above do not interfere with the local use spaces nor the Class Selector codepoints recommended in [Nichols]. The PHBs selected by those Class Selector codepoints may thus coexist with the AF PHB group and retain the forwarding behavior and relationships that was defined for them. In particular, the Default PHB codepoint of '000000' may remain to be used for conventional best effort traffic. Similarly, the codepoints '11x000' may remain to be used for network control traffic.

The AF PHB group, in conjunction with edge traffic conditioning actions that limit the amount of traffic in each AF class to a (generally different) percentage of the class's allocated resources, can be used to obtain the overall behavior implied by the Class Selector PHBs. In this case it may be appropriate within a DS domain to use some or all of the Class Selector codepoints as aliases of AF codepoints.

In addition to the Class Selector PHBs, any other PHB groups may co-exist with the AF PHB group within the same DS domain. However, any AF PHB group implementation should document the following:

(a) Which, if any, other PHB groups may preempt the forwarding resources specifically allocated to each AF PHB class. This preemption MUST NOT happen in normal network operation, but may be appropriate in certain unusual situations - for example, the '11x000' codepoint may preempt AF forwarding resources, to give precedence to unexpectedly high levels of network control traffic when required.

(b) How "excess" resources are allocated between the AF PHB group and other implemented PHB groups. For example, once the minimum allocations are given to each AF class, any remaining resources could be allocated evenly between the AF classes and the Default PHB. In an alternative example, any remaining resources could be allocated to forwarding excess AF traffic, with resources devoted to the Default PHB only when all AF demand is met.

This memo does not specify that any particular relationship hold between AF PHB groups and other implemented PHB groups; it requires only that whatever relationship is chosen be documented. Implementations MAY allow either or both of these relationships to be configurable. It is expected that this level of configuration flexibility will prove valuable to many network administrators.

8. Security Implications

In order to protect itself against denial of service attacks, a provider DS domain SHOULD limit the traffic entering the domain to the subscribed profiles. Also, in order to protect a link to a customer DS domain from denial of service attacks, the provider DS domain SHOULD allow the customer DS domain to specify how the resources of the link are allocated to AF packets. If a service offering requires that traffic marked with an AF codepoint be limited by such attributes as source or destination address, it is the responsibility of the ingress node in a network to verify validity of such attributes.

Other security considerations are covered in [Blake] and [Nichols].

9. Intellectual Property Rights

The IETF has been notified of intellectual property rights claimed in regard to some or all of the specification contained in this document. For more information, consult the online list of claimed rights.

10. IANA Considerations

This document allocates twelve codepoints, listed in section 6, in Pool 1 of the code space defined by [Nichols].

Appendix: Example Services

The AF PHB group could be used to implement, for example, the so-called Olympic service, which consists of three service classes: bronze, silver, and gold. Packets are assigned to these three classes so that packets in the gold class experience lighter load (and thus have greater probability for timely forwarding) than packets assigned to the silver class. Same kind of relationship exists between the silver class and the bronze class. If desired, packets within each class may be further separated by giving them either low, medium, or high drop precedence.

The bronze, silver, and gold service classes could in the network be mapped to the AF classes 1, 2, and 3. Similarly, low, medium, and high drop precedence may be mapped to AF drop precedence levels 1, 2, or 3.

The drop precedence level of a packet could be assigned, for example, by using a leaky bucket traffic policer, which has as its parameters a rate and a size, which is the sum of two burst values: a committed burst size and an excess burst size. A packet is assigned low drop precedence if the number of tokens in the bucket is greater than the excess burst size, medium drop precedence if the number of tokens in the bucket is greater than zero, but at most the excess burst size, and high drop precedence if the bucket is empty. It may also be necessary to set an upper limit to the amount of high drop precedence traffic from a customer DS domain in order to avoid the situation where an avalanche of undeliverable high drop precedence packets from one customer DS domain can deny service to possibly deliverable high drop precedence packets from other domains.

Another way to assign the drop precedence level of a packet could be to limit the user traffic of an Olympic service class to a given peak rate and distribute it evenly across each level of drop precedence. This would yield a proportional bandwidth service, which equally apportions available capacity during times of congestion under the assumption that customers with high bandwidth microflows have subscribed to higher peak rates than customers with low bandwidth microflows.

The AF PHB group could also be used to implement a loss and low latency service using an over provisioned AF class, if the maximum arrival rate to that class is known a priori in each DS node. Specification of the required admission control services, however, is beyond the scope of this document. If low loss is not an objective, a low latency service could be implemented without over provisioning by setting a low maximum limit to the buffer space available for an AF class.

References

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Authors' Addresses

Juha Heinanen
Telia Finland
Myyrmaentie 2
01600 Vantaa, Finland

EMail: jh@telia.fi

Fred Baker
Cisco Systems
519 Lado Drive
Santa Barbara, California 93111

EMail: fred@cisco.com

Walter Weiss
Lucent Technologies
300 Baker Avenue, Suite 100,
Concord, MA 01742-2168

EMail: wweiss@lucent.com

John Wroclawski
MIT Laboratory for Computer Science
545 Technology Sq.
Cambridge, MA 02139

EMail: jtw@lcs.mit.edu

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