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K. Chan
J. Babiarz
Nortel
F. Baker
Cisco Systems

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Aggregation of Diffserv Service Classes

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Abstract

In the core of a high-capacity network, service differentiation may still be needed to support applications' utilization of the network. Applications with similar traffic characteristics and performance requirements are mapped into Diffserv service classes based on end-to-end behavior requirements of the applications. However, some network segments may be configured in such a way that a single forwarding treatment may satisfy the traffic characteristics and performance requirements of two or more service classes. In these cases, it may be desirable to aggregate two or more Diffserv service classes into a single forwarding treatment. This document provides guidelines for the aggregation of Diffserv service classes into forwarding treatments.

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1. Introduction

In the core of a high capacity network, it is common for the network to be engineered in such a way that a major link, switch, or router can fail, and the result will be a routed network that still meets ambient Service Level Agreements (SLAs). The implications are that there is sufficient capacity on any given link such that all SLAs sold can be simultaneously supported at their respective maximum rates, and that this remains true after re-routing (either IP re-routing or Multiprotocol Label Switching (MPLS) protection-mode switching) has occurred.

Over-provisioning is generally considered to meet the requirements of all traffic without further quality of service (QoS) treatment, and in the general case, that is true in high-capacity backbones. However, as the process of network convergence continues, and with the increasing speed of the access networks, certain services may still have issues. Delay, jitter, and occasional loss are perfectly acceptable for elastic applications. However, sub-second surges that occur in the best-designed of networks [12] affect real-time applications. Moreover, denial of service (DoS) loads, worms, and network disruptions such as that of 11 September 2001 affect routing [13]. Our objective is to prevent disruption to routing (which in turn affects all services) and to protect real-time jitter-sensitive services, while minimizing loss and delay of sensitive elastic traffic.

RFC 4594 [3] defines a set of basic Diffserv classes from the points of view of the application requiring specific end-to-end behaviors from the network. The service classes are differentiated based on the application payload’s tolerance to packet loss, delay, and delay variation (jitter). Different degrees of these criteria form the foundation for supporting the needs of real-time and elastic traffic. RFC 4594 [3] also provides recommendations for the treatment method of these service classes. But, at some network segments of the end-to-end path, the number of levels of network treatment differentiation may be less than the number of service classes that the network segment needs to support. In such a situation, that network segment may use the same treatment to support more than one service class. In this document, we provide guidelines on how multiple service classes may be aggregated into a forwarding treatment aggregate. This entails having the IP traffic belonging to service classes, expressed using the DSCP (Differentiated Services Code Point), as described by RFC 4594 [3]. Note that in a given domain, we may recommend that the supported service classes be aggregated into forwarding treatment aggregates; however, this does not mean all service classes need to be supported, and hence not all forwarding treatment aggregates need to be supported. A domain may

support a fewer or greater number of forwarding treatment aggregates than recommended by this document. Which service classes and which forwarding treatment aggregates are supported by a domain is up to the domain administration and may be influenced by business reasons or other reasons (e.g., operational considerations).

In this document, we've provided:

- o definitions for terminology we use in this document,
- o requirements for performing this aggregation,
- o an example of performing the aggregation when four treatment aggregates are used, and
- o an example (in the appendix) of performing this aggregation over MPLS using E-LSP, EXP Inferred PHB Scheduling Class (PSC) Label Switched Path (LSP).

The treatment aggregate recommendations are designed to aggregate the service classes [3] in such a manner as to protect real-time traffic and routing, on the assumption that real-time sessions are protected from each other by admission at the edge. The recommendation given is one possible way of performing the aggregation; there may be other ways of aggregation, for example, into fewer treatment aggregates or more treatment aggregates.

In the appendix, an example of aggregation over MPLS networks using E-LSP to realize the treatment aggregates is provided. Note that the MPLS E-LSP is just an example; this document does not exclude the use of other methods. This example only considers aggregation of IP traffic into E-LSP. The use of E-LSP by non-IP traffic is not discussed.

1.1. Requirements Notation

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 [1].

2. Terminology

This document assumes the reader is familiar with the terms used in differentiated services. This document provides the definitions for new terms introduced by this document and references information defined in RFCs for existing terms not commonly used in differentiated services.

For new terms introduced by this document, we provide the definition here:

- Treatment Aggregate. This term is defined as the aggregate of Diffserv service classes [3]. A treatment aggregate is concerned only with the forwarding treatment of the aggregated traffic, which may be marked with multiple DSCPs. A treatment aggregate differs from Behavior Aggregate [2] and Traffic Aggregate [14], each of which indicate the aggregated traffic having a single Diffserv codepoint and utilizing a single Per Hop Behavior (PHB).

For terms from existing RFCs, we provide the reference to the appropriate section of the relevant RFC that contain the definition:

- Real-Time and Elastic Applications and their traffic. Section 3.1 of RFC 1633 [4].

- Diffserv Service Class. Section 1.3 of RFC 4594 [3].

- MPLS E-LSP, EXP Inferred PHB Scheduling Class (PSC) Label Switched Path (LSP). Section 1.2 of RFC 3270 [6].

- MPLS L-LSP, Label Only Inferred PHB Scheduling Class (PSC) Label Switched Path (LSP). Section 1.3 of RFC 3270 [6].

3. Overview of Service Class Aggregation

In Diffserv domains where less fine-grained traffic treatment differentiation is provided, aggregation of the different service classes [3] may be required.

These aggregations have the following requirements:

1. The end-to-end network performance characteristic required by the application MUST be supported. This performance characteristic is represented by the use of Diffserv service classes [3].

2. The treatment aggregate MUST meet the strictest requirements of its member service classes.

3. The treatment aggregate SHOULD only contain member service classes with similar traffic characteristic and performance requirements.

4. The notion of the individual end-to-end service classes MUST NOT be destroyed when aggregation is performed. Each domain along the end-to-end path may perform aggregation differently, based on the original end-to-end service classes. We recommend an easy

way to accomplish this by not altering the DSCP used to indicate the end-to-end service class. But some administrative domains may require the use of their own marking; when this is needed, the original end-to-end service class indication must be restored upon exiting such administrative domains. One possible way of achieving this is with the use of tunnels to encapsulate the end-to-end traffic.

5. Each treatment aggregate has limited resources; hence, traffic conditioning and/or admission control SHOULD be performed for each service class aggregated into the treatment aggregate. Additional admission control and policing may be used on the sum of all traffic aggregated into the treatment aggregate.

In addition to the above requirements, we have the following suggestions:

1. The treatment aggregate and assigned resources may consider historical traffic patterns and the variability of these patterns. For example, a point-point service (e.g., pseudowire) may have a very predictable pattern, while a multipoint service (e.g., VPLS, Virtual Private LAN Service) may have a much less predictable pattern.

2. In addition to Diffserv, other controls are available to influence the traffic level offered to a particular traffic aggregate. These include adjustment of routing metrics, and usage of MPLS-based traffic engineering techniques.

This document only describes the aggregation of IP traffic based on the use of Diffserv service classes [3].

4. Service Classes to Treatment Aggregate Mapping

The service class and DSCP selection in RFC 4594 [3] has been defined to allow, in many instances, mapping of two or possibly more service classes into a single forwarding treatment aggregate. Notice that there is a relationship/trade-off between link speed, queue depth, delay, and jitter. The degree of aggregation and hence the number of treatment aggregates will depend on the aggregation’s impacts on loss, delay, and jitter. This depends on whether the speed of the links and scheduler behavior, being used to implement the aggregation, can minimize the effects of mixing traffic with different packet sizes and transmit rates on queue depth. A general rule-of-thumb is that higher link speeds allow for more aggregation/ smaller number of treatment aggregates, assuming link utilization is within the engineered level.

4.1. Mapping Service Classes into Four Treatment Aggregates

This section provides an example of mapping all the service classes defined in RFC 4594 [3] into four treatment aggregates. The use of four treatment aggregates assumes that the resources allocated to each treatment aggregate are sufficient to honor the required behavior of each service class [3]. We use the performance requirement (tolerance to loss, delay, and jitter) from the application/end-user as a guide on how to map the service classes into treatment aggregates. We have also used section 3.1 of RFC 1633 [4] to provide us with guidance on the definition of Real-Time and Elastic applications. An overview of the mapping between service classes and the four treatment aggregates is provided by Figure 1, with the mapping being based on performance requirements. In Figure 1, the right side columns of "Service Class" and "Tolerance to Loss/ Delay/Jitter" are from Figure 2 of RFC 4594 [3].

It is recommended that certain service classes be mapped into specific treatment aggregates. But this does not mean that all the service classes recommended for that treatment aggregate need to be supported. Hence, for a given domain, a treatment aggregate may contain only a subset of the service classes recommended in this document, i.e., the service classes supported by that domain. A domain’s treatment of non-supported service classes should be based on the domain’s local policy. This local policy may be influenced by its agreement with its customers. Such treatment may use the Elastic Treatment Aggregate, dropping the packets, or some other arrangements.

Our example of four treatment aggregates is based on the basic differences in performance requirement from the application/end-user perspective. A domain may choose to support more or fewer treatment aggregates than the four recommended. For example, a domain may support only three treatment aggregates and map any network control traffic into the Assured Elastic treatment aggregate. This is a choice the administrative domain has. Hence, this example of four treatment aggregates does not represent a minimum required set of treatment aggregates one must implement; nor does it represent the maximum set of treatment aggregates one can implement.

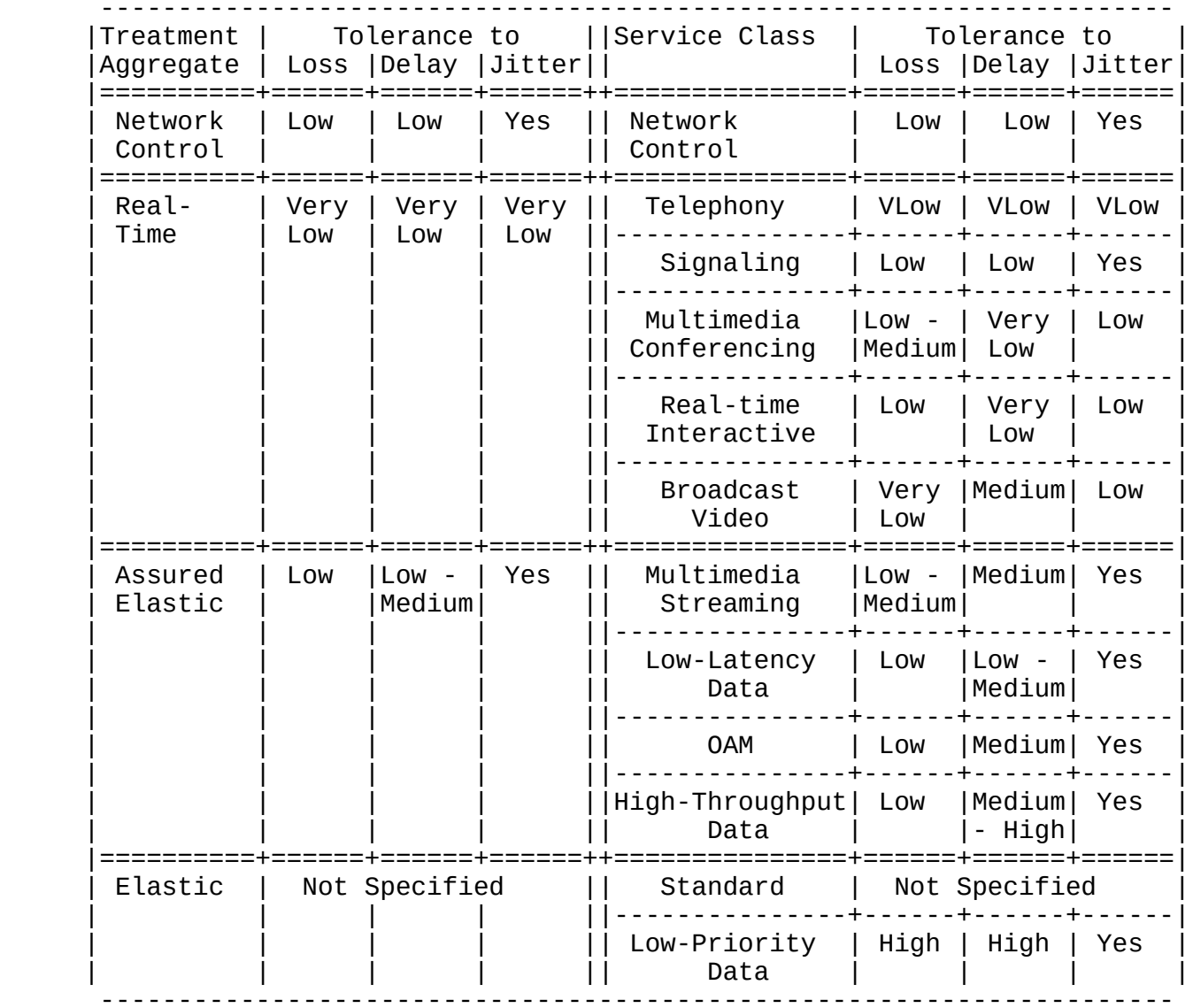

Figure 1: Treatment Aggregate and Service Class Performance Requirements

As we are recommending to preserve the notion of the individual end-to-end service classes, we also recommend that the original DSCP field marking not be changed when treatment aggregates are used. Instead, classifiers that select packets based on the contents of the DSCP field should be used to direct packets from the member Diffserv service classes into the queue that handles each of the treatment aggregates, without remarking the DSCP field of the packets. This is

summarized in Figure 2, which shows the behavior each treatment aggregate should have, and the DSCP field marking of the packets that should be classified into each of the treatment aggregates.

Treatment Aggregate	Treatment Aggregate Behavior	DSCP
Network Control	CS (RFC 2474)	CS6
Real-Time	EF (RFC 3246)	EF, CS5, AF41, AF42, AF43, CS4, CS3
Assured Elastic	AF (RFC 2597)	CS2, AF31, AF21, AF11
		AF32, AF22, AF12
		AF33, AF23, AF13
Elastic	Default (RFC 2474)	Default, (CS0)
		CS1

Figure 2: Treatment Aggregate Behavior

Notes for Figure 2: For Assured Elastic and Elastic Treatment Aggregates, please see sections 4.1.3 and 4.1.4, respectively, for details on additional priority within the treatment aggregate.

4.1.1. Network Control Treatment Aggregate

The Network Control Treatment Aggregate aggregates all service classes that are functionally necessary for the survival of a network during a DoS attack or other high-traffic load interval. The theory is that whatever else is true, the network must protect itself. This includes the traffic that RFC 4594 [3] characterizes as being included in the Network Control service class.

Traffic in the Network Control Treatment Aggregate should be carried in a common queue or class with a PHB as described in RFC 2474 [2], section 4.2.2.2 for Class Selector (CS). This treatment aggregate should have a lower probability of packet loss and bear a relatively deep target mean queue depth (min-threshold if RED (Random Early Detection) is being used).

Please notice this Network Control Treatment Aggregate is meant to be used for the customer's network control traffic. The provider may choose to treat its own network control traffic differently, perhaps in its own service class that is not aggregated with the customer's network control traffic.

4.1.2. Real-Time Treatment Aggregate

The Real-Time Treatment Aggregate aggregates all real-time (inelastic) service classes. The theory is that real-time traffic is admitted under some model and controlled by an SLA managed at the edge of the network prior to aggregation. As such, there is a predictable and enforceable upper bound on the traffic that can enter such a queue, and to provide predictable variation in delay it must be protected from bursts of elastic traffic. The predictability of traffic level may be based upon admission control for a well-known community of interest (e.g., a point-point service) and/or based upon historical measurements.

This treatment aggregate may include the following service classes from the Diffserv service classes [3], in addition to other locally defined classes: Telephony, Signaling, Multimedia Conferencing, Real-time Interactive, and Broadcast Video.

Traffic in each service class that is going to be aggregated into the treatment aggregate should be conditioned prior to aggregation. It is recommended that per-service-class admission control procedures be used, followed by per-service-class policing so that any individual service class does not generate more than what it is allowed. Furthermore, additional admission control and policing may be used on the sum of all traffic aggregated into this treatment aggregate.

Traffic in the Real-Time Treatment Aggregate should be carried in a common queue or class with a PHB (Per Hop Behavior) as described in RFC 3246 [9] and RFC 3247 [10].

4.1.3. Assured Elastic Treatment Aggregate

The Assured Elastic Treatment Aggregate aggregates all elastic traffic that uses the Assured Forwarding model as described in RFC 2597 [8]. The premise of such a service is that an SLA that is negotiated includes a "committed rate" and the ability to exceed that rate (and perhaps a second "excess rate") in exchange for a higher probability of loss using Active Queue Management (AQM) [7] or Explicit Congestion Notification (ECN) marking [11] for the portion of traffic deemed to be in excess.

This treatment aggregate may include the following service classes from the Diffserv service classes [3], in addition to other locally defined classes: Multimedia Streaming, Low Latency Data, OAM, and High-Throughput Data.

The DSCP values belonging to the Assured Forwarding (AF) PHB group and class selector of the original service classes remain an important consideration and should be preserved during aggregation. This treatment aggregate should maintain the AF PHB group marking of the original packet. For example, AF3x marked packets should remain AF3x marked within this treatment aggregate. In addition, the class selector DSCP value should not be changed. Traffic bearing these DSCPs is carried in a common queue or class with a PHB as described in RFC 2597 [8]. In effect, appropriate target rate thresholds have been applied at the edge, dividing traffic into AFn1 (committed, for any value of n), AFn2, and AFn3 (excess). The service should be engineered so that AFn1 and CS2 marked packet flows have sufficient bandwidth in the network to provide high assurance of delivery. Since the traffic is elastic and responds dynamically to packet loss, Active Queue Management [7] should be used primarily to reduce the forwarding rate to the minimum assured rate at congestion points. The probability of loss of AFn1 and CS2 traffic must not exceed the probability of loss of AFn2 traffic, which in turn must not exceed the probability of loss of AFn3 traffic.

If RED [7] is used as an AQM algorithm, the min-threshold specifies a target queue depth for each of AFn1+CS2, AFn2, and AFn3, and the max-threshold specifies the queue depth above which all traffic with such a DSCP is dropped or ECN marked. Thus, in this treatment aggregate, the following inequalities SHOULD hold in queue configurations:

- min-threshold AFn3 < max-threshold AFn3
- max-threshold AFn3 <= min-threshold AFn2
- min-threshold AFn2 < max-threshold AFn2
- max-threshold AFn2 <= min-threshold AFn1+CS2
- min-threshold AFn1+CS2 < max-threshold AFn1+CS2
- max-threshold AFn1+CS2 <= memory assigned to the queue

Note: This configuration tends to drop AFn3 traffic before AFn2, and AFn2 before AFn1 and CS2. Many other AQM algorithms exist and are used; they should be configured to achieve a similar result.

4.1.4. Elastic Treatment Aggregate

The Elastic Treatment Aggregate aggregates all remaining elastic traffic. The premise of such a service is that there is no intrinsic SLA differentiation of traffic, but that AQM [7] or ECN flagging [11] is appropriate for such traffic.

This treatment aggregate may include the following service classes from the Diffserv service classes [3], in addition to other locally defined classes: Standard and Low-Priority Data.

Treatment aggregates should be well specified, each indicating the service classes it will handle. But in cases where unspecified or unknown service classes are encountered, they may be dropped or be treated using the Elastic Treatment Aggregate. The choice of how to treat unspecified service classes should be well defined, based on some agreements.

Traffic in the Elastic Treatment Aggregate should be carried in a common queue or class with a PHB as described in RFC 2474 [2], section 4.1, "A Default PHB". The AQM thresholds for Elastic traffic MAY be separately set, so that Low Priority Data traffic is dropped before Standard traffic, but this is not a requirement.

5. Treatment Aggregates and Inter-Provider Relationships

When treatment aggregates are used at provider boundaries, we recommend that the inter-provider relationship be based on Diffserv service classes [3]. This allows the admission control into each treatment aggregate of a provider domain to be based on the admission control of traffic into the supported service classes, as indicated by the discussion in section 4 of this document.

If the inter-provider relationship needs to be based on treatment aggregates specified by this document, then the exact treatment aggregate content and representation must be agreed to by the peering providers.

Some additional work on inter-provider relationships is provided by inter-provider QoS [15], where details on supporting real-time services between service providers are discussed. Some related work in ITU-T provided by Appendix VI of Y.1541 [16] may also help with inter-provider relationships, especially with international providers.

6. Security Considerations

This document discusses the policy of using Differentiated Services and its service classes. If implemented as described, it should require that the network do nothing that the network has not already allowed. If that is the case, no new security issues should arise from the use of such a policy.

As this document is based on RFC 4594 [3], the Security Consideration discussion of no new security issues indicated by RFC 4594 [3] also applies to treatment aggregates of this document.

7. Acknowledgements

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Appendix A. Using MPLS for Treatment Aggregates

RFC 2983 on Diffserv and Tunnels [5] and RFC 3270 on MPLS Support of Diffserv [6] provide a very good background on this topic. This document provides an example of using the E-LSP, EXP Inferred PHB Scheduled Class (PSC) Label Switched Path (LSP), defined by MPLS Support of Diffserv [6] for realizing the Treatment Aggregates.

When treatment aggregates are represented in MPLS using EXP Inferred PSC LSP, we recommend the following usage of the MPLS EXP field for treatment aggregates.

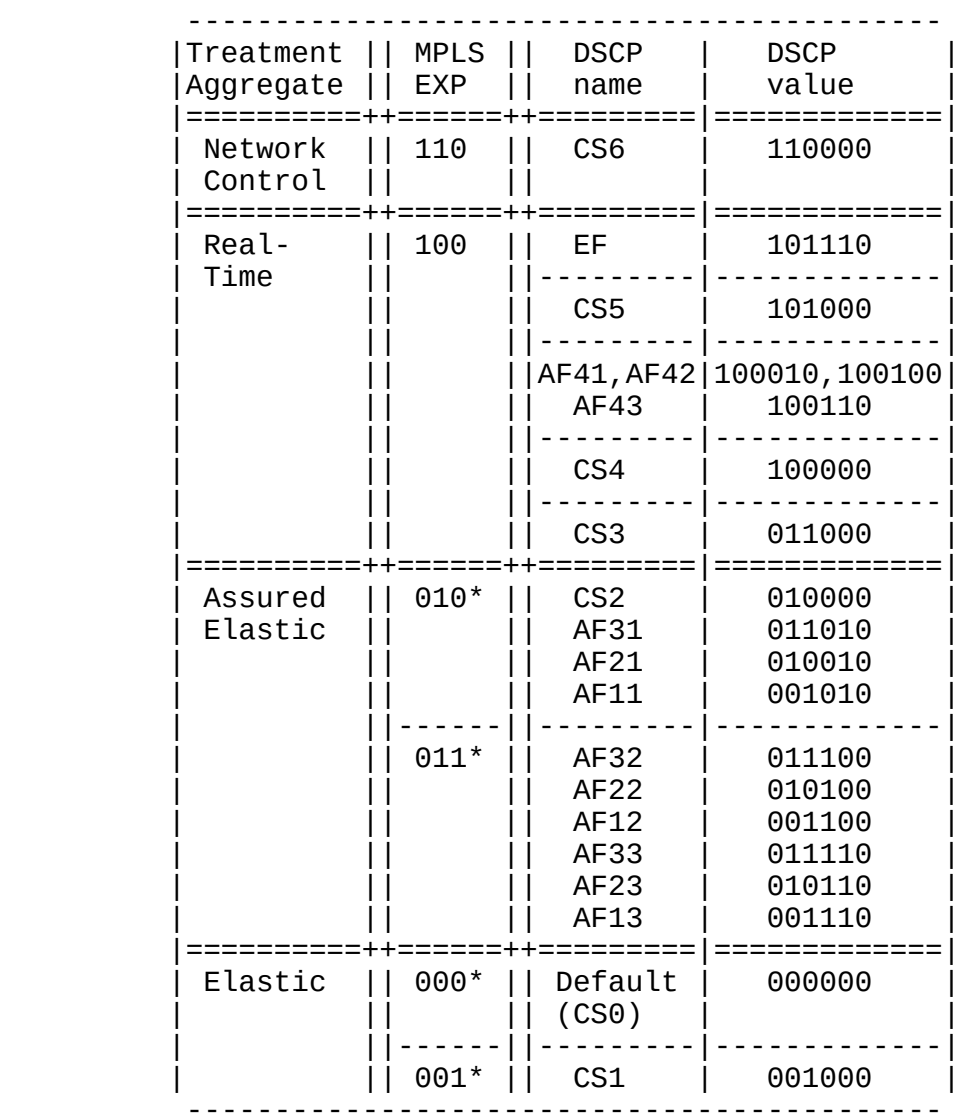

Figure 3: Treatment Aggregate and MPLS EXP Field Usage

* Note: For Assured Elastic (and Elastic) Treatment Aggregate, the usage of 010 or 011 (000 or 001) as EXP field value depends on the drop probability. Packets in the LSP with EXP field of 011 (001) have a higher probability of being dropped than packets with an EXP field of 010 (000).

The above table indicates the recommended usage of EXP fields for treatment aggregates. Because many deployments of MPLS are on a per-domain basis, each domain has total control of its EXP usage and each domain may use a different EXP field allocation for the domain's supported treatment aggregates.

A.1. Network Control Treatment Aggregate with E-LSP

The usage of E-LSP for Network Control Treatment Aggregate needs to adhere to the recommendations indicated in section 4.1.1 of this document and section 3.2 of RFC 4594 [3]. Reinforcing these recommendations, there should be no drop precedence associated with the MPLS PSC used for Network Control Treatment Aggregate because dropping of Network Control Treatment Aggregate traffic should be prevented.

A.2. Real-Time Treatment Aggregate with E-LSP

In addition to the recommendations provided in section 4.1.2 of this document and in member service classes' sections of RFC 4594 [3], we want to indicate that Real-Time Treatment Aggregate traffic should not be dropped, as some of the applications whose traffic is carried in the Real-Time Treatment Aggregate do not react well to dropped packets. As indicated in section 4.1.2 of this document, admission control should be performed on each service class contributing to the Real-Time Treatment Aggregate to prevent packet loss due to insufficient resources allocated to Real-Time Treatment Aggregate. Further, admission control and policing may also be applied on the sum of all traffic aggregated into this treatment aggregate.

A.3. Assured Elastic Treatment Aggregate with E-LSP

EXP field markings of 010 and 011 are used for the Assured Elastic Treatment Aggregate. The two encodings are used to provide two levels of drop precedence indications, with 010 encoded traffic having a lower probability of being dropped than 011 encoded traffic. This provides for the mapping of CS2, AF31, AF21, and AF11 into EXP 010; and AF32, AF22, AF12 and AF33, AF23, AF13 into EXP 011. If the domain chooses to support only one drop precedence for this treatment aggregate, we recommend the use of 010 for EXP field marking.

A.4. Elastic Treatment Aggregate with E-LSP

EXP field markings of 000 and 001 are used for the Elastic Treatment Aggregate. The two encodings are used to provide two levels of drop precedence indications, with 000 encoded traffic having a lower probability of being dropped than 001 encoded traffic. This provides for the mapping of Default/CS0 into 000; and CS1 into 001. Notice

that with this mapping, during congestion, CS1-marked traffic may be starved. If the domain chooses to support only one drop precedence for this treatment aggregate, we recommend the use of 000 for EXP field marking.

A.5. Treatment Aggregates and L-LSP

Because L-LSP (Label Only Inferred PSC LSP) supports a single PSC per LSP, the support of each treatment aggregate is on a per-LSP basis. This document does not further specify any additional recommendation (beyond what has been indicated in section 4 of this document) for treatment aggregate to L-LSP mapping, leaving this to each individual MPLS domain administration.

Authors' Addresses

Kwok Ho Chan
Nortel
600 Technology Park Drive
Billerica, MA 01821
US

Phone: +1-978-288-8175
Fax: +1-978-288-8700
EMail: khchan@nortel.com

Jozef Z. Babiarz
Nortel
3500 Carling Avenue
Ottawa, Ont. K2H 8E9
Canada

Phone: +1-613-763-6098
Fax: +1-613-768-2231
EMail: babiarz@nortel.com

Fred Baker
Cisco Systems
1121 Via Del Rey
Santa Barbara, CA 93117
US

Phone: +1-408-526-4257
Fax: +1-413-473-2403
EMail: fred@cisco.com

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