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Russian Dolls Bandwidth Constraints Model for Diff-Serv-aware MPLS Traffic Engineering

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Abstract

This document provides specification for one Bandwidth Constraints model for Diff-Serv-aware MPLS Traffic Engineering, which is referred to as the Russian Dolls Model.

Summary for Sub-IP related Internet Drafts

RELATED DOCUMENTS:

[draft-ietf-tewg-diff-te-reqts-06.txt](#)
[draft-ietf-tewg-diff-te-proto-02.txt](#)

WHERE DOES IT FIT IN THE PICTURE OF THE SUB-IP WORK

This ID is a Working Group document of the TE Working Group.

WHY IS IT TARGETED AT THIS WG(s)

TEWG is responsible for specifying protocol extensions for support of

JUSTIFICATION

The TEWG charter states that "This will entail verification and review of the Diffserv requirements in the WG Framework document and initial specification of how these requirements can be met through use and potentially expansion of existing protocols."

In line with this, the TEWG is specifying bandwidth constraints model for Diff-Serv-aware MPLS Traffic Engineering. This document describes one particular bandwidth constraints model.

Specification of Requirements

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 [[RFC2119](#)].

1. Introduction

[DSTE-REQ] presents the Service Providers requirements for support of Diff-Serv-aware MPLS Traffic Engineering (DS-TE). This includes the fundamental requirement to be able to enforce different bandwidth constraints for different classes of traffic.

[DSTE-REQ] also defines the concept of Bandwidth Constraint Models for DS-TE and states that "The DS-TE technical solution MUST specify at least one bandwidth constraint model and MAY specify multiple bandwidth constraint."

This document provides a detailed description of one particular Bandwidth Constraint model for DS-TE which is introduced in [DSTE-REQ] and called the Russian Dolls Model (RDM).

[DSTE-PROTO] specifies the IGP and RSVP-TE signaling extensions for support of DS-TE. These extensions support RDM.

2. Contributing Authors

This document was the collective work of several. The text and content of this document was contributed by the editor and the co-authors listed below. (The contact information for the editor appears in [Section 11](#), and is not repeated below.)

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3. Definitions

For readability a number of definitions from [[DSTE-REQ](#)] are repeated here:

Class-Type (CT): the set of Traffic Trunks crossing a link that is governed by a specific set of Bandwidth Constraints. CT is used for the purposes of link bandwidth allocation, constraint based routing

and admission control. A given Traffic Trunk belongs to the same CT on all links.

TE-Class: A pair of:

- i. a Class-Type
- ii. a preemption priority allowed for that Class-Type. This means that an LSP transporting a Traffic Trunk from that Class-Type can use that preemption priority as the set-up priority, as the holding priority or both.

Reserved (CT_c) : For a given Class-Type CT_c ($0 \leq c \leq \text{MaxCT}$), let us define "Reserved(CT_c)" as the sum of the bandwidth reserved by all established LSPs which belong to CT_c.

The following definition from [[DSTE-PROTO](#)] is also repeated here:

Normalised(CT_c) : let us define "Normalised(CT_c)" as "Reserved(CT_c)/LOM(c)", where LOM (c) is the Local Overbooking Multiplier for CT_c defined in [[DSTE-PROTO](#)].

We also introduce the following definitions:

Reserved(CT_b,q) : let us define "Reserved(CT_b,q)" as the sum of the bandwidth reserved by all established LSPs which belong to CT_b and have a holding priority of q. Note that if q and CT_b do not form one of the 8 possible configured TE-Classes, then there can not be any

established LSP which belong to CT_b and have a holding priority of q, so in that case Reserved(CT_b,q)=0.

Normalised(CT_c,q) : let us define "Normalised(CT_c,q)" as "Reserved(CT_c/q) / LOM(c)", where LOM (c) is the Local Overbooking Multiplier for CT_c defined in [[DSTE-PROTO](#)].

4. Russian Dolls Model Definition

RDM is defined in the following manner (assuming for now that the optional per-CT Local Overbooking Multipliers defined in [[DSTE-PROTO](#)])

are not used - i.e. $LOM[c]=1$, $0 \leq c \leq 7$):

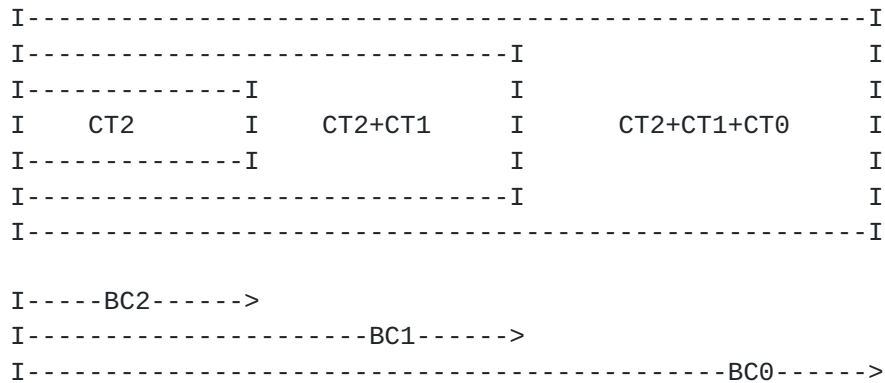
- o Maximum Number of Bandwidth Constraints (MaxBC)= Maximum Number of Class-Types (MaxCT) = 8
- o for each value of b in the range $0 \leq b \leq (MaxCT - 1)$:
SUM (Reserved (CTc)) $\leq BC_b$,
for all "c" in the range $b \leq c \leq (MaxCT - 1)$

A DS-TE LSR implementing RDM MUST support enforcement of bandwidth constraints in compliance with this definition.

Where 8 Class-Types are active, the RDM bandwidth constraints can also be expressed in the following way:

- All LSPs from CT7 use no more than BC7
- All LSPs from CT6 and CT7 use no more than BC6
- All LSPs from CT5, CT6 and CT7 use no more than BC5
- etc.
- All LSPs from CT0, CT1, ... CT7 use no more than BC0

Purely for illustration purposes, the diagram below represents the Russian Doll Bandwidth Constraints model in a pictorial manner when 3 Class-Types are active:



While simpler Bandwidth Constraints models (see [\[MAM\]](#)) or, conversely, more flexible/sophisticated Bandwidth Constraints models can be defined, the Russian Dolls Model is attractive in some DS-TE environments for the following reasons:

- Although less intuitive than MAM, RDM is still a simple model to conceptualize.
- RDM can be used to simultaneously ensure bandwidth efficiency and protection against QoS degradation of all Class-Types, whether preemption is used or not.
- RDM can be used in conjunction with preemption to simultaneously achieve isolation across Class-Types (so that each Class-Type is guaranteed its share of bandwidth no matter the level of contention by other classes), bandwidth efficiency and protection against QoS degradation of all Class-Types.
- RDM only requires limited protocol extensions such as the ones defined in [\[DSTE-PROTO\]](#).

RDM may not be attractive in some DS-TE environments for the following reasons:

- if the usage of preemption is precluded for some administrative reason, while RDM can still ensure bandwidth efficiency and protection against QoS degradation of all CTs, RDM cannot guarantee isolation across Class-Types.

Additional considerations on the properties of RDM can be found in [\[BC-CONS\]](#) and [\[BC-MODEL\]](#).

As a simple example usage of the "Russian Doll" Bandwidth Constraints Model, a network administrator using one CT for Voice (CT1) and one CT for data (CT0) might configure on a given link:

- BC0 = 2.5 Gb/s (i.e. Voice + Data is limited to 2.5 Gb/s)
- BC1= 1.5 Gb/s (i.e. Voice is limited to 1.5 Gb/s).

5. Example Formulas for Computing "Unreserved TE-Class [i]" with Russian Dolls Model

As specified in [[DSTE-PROTO](#)], formulas for computing "Unreserved TE-Class [i]" MUST reflect all of the Bandwidth Constraints relevant to the CT associated with TE-Class[i], and thus, depend on the Bandwidth Constraints Model. Thus, a DS-TE LSR implementing RDM MUST reflect the RDM bandwidth constraints defined in [section 4](#) above when computing "Unreserved TE-Class [i]".

Keeping in mind, as explained in [[DSTE-PROTO](#)], that details of admission control algorithms as well as formulas for computing "Unreserved TE-Class [i]" are outside the scope of the IETF work, we provide in this section, for illustration purposes, an example of how values for the unreserved bandwidth for TE-Class[i] might be computed with RDM, assuming:

- the basic admission control algorithm which simply deducts the exact bandwidth of any established LSP from all of the Bandwidth Constraints relevant to the CT associated with that LSP.
- the optional per-CT Local Overbooking Multipliers are not used (.i.e. LOM[c]=1, $0 \leq c \leq 7$).

We assume that:

TE-Class [i] \leftrightarrow < CT_c , preemption p >
in the configured TE-Class mapping.

For readability, formulas are first shown assuming only 4 CTs are active. The formulas are then extended to cover the cases where more CTs are used.

If CT_c = CT₀, then "Unreserved TE-Class [i]" =
[BC₀ - SUM (Reserved(CT_b,q))] for q ≤ p and 0 ≤ b ≤ 3

If CT_c = CT₁, then "Unreserved TE-Class [i]" =
MIN [

$$\begin{aligned} & [BC1 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 1 \leq b \leq 3, \\ & [BC0 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 0 \leq b \leq 3 \\ &] \end{aligned}$$

If $CT_c = CT_2$, then "Unreserved TE-Class [i]" =

$$\begin{aligned} & \text{MIN} [\\ & [BC2 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 2 \leq b \leq 3, \\ & [BC1 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 1 \leq b \leq 3, \\ & [BC0 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 0 \leq b \leq 3 \\ &] \end{aligned}$$

If $CT_c = CT_3$, then "Unreserved TE-Class [i]" =

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$$\begin{aligned} & \text{MIN} [\\ & [BC3 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 3 \leq b \leq 3, \\ & [BC2 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 2 \leq b \leq 3, \\ & [BC1 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 1 \leq b \leq 3, \\ & [BC0 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 0 \leq b \leq 3 \\ &] \end{aligned}$$

The formula can be generalized to 8 active CTs and expressed in a more compact way in the following:

$$\begin{aligned} & \text{"Unreserved TE-Class [i]" =} \\ & \text{MIN} [\\ & [BCC - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } c \leq b \leq 7, \\ & \dots \\ & [BC0 - \text{SUM} (\text{Reserved}(CTb, q))] \text{ for } q \leq p \text{ and } 0 \leq b \leq 7, \\ &] \end{aligned}$$

where:

TE-Class [i] \leftrightarrow $\langle CT_c, \text{preemption } p \rangle$
in the configured TE-Class mapping.

6. Support of Optional Local Overbooking Method

We remind the reader that, as discussed in [[DSTE-PROTO](#)], the "LSP/link size overbooking" method (which does not use the Local Overbooking Multipliers - LOMs-) is expected to be sufficient in many DS-TE environments. It is expected that the optional Local Overbooking method (and LOMs) would only be used in specific environments, in particular where different overbooking ratios need to be enforced on different links of the DS-TE domain and cross-effect of overbooking across CTs needs to be accounted for very accurately.

This section discusses the impact of the optional local overbooking method on RDM and associated rules and formula. This is only applicable in the cases where the optional local overbooking method is indeed supported by the DS-TE LSRs and actually deployed.

6.1. Russian Dolls Model Definition With Local Overbooking

As specified in [[DSTE-PROTO](#)], when the optional Local Overbooking method is supported, the bandwidth constraints MUST be applied to "Normalised(CTc)" rather than to "Reserved(CTc)". Thus, when the optional Local Overbooking method is supported, the Russian Doll Model definition is extended in the following manner:

- o Maximum Number of Bandwidth Constraints (MaxBC)=
Maximum Number of Class-Types (MaxCT) = 8
- o for each value of b in the range $0 \leq b \leq (\text{MaxCT} - 1)$:
SUM (Normalised (CTc)) \leq BCb,
for all "c" in the range $b \leq c \leq (\text{MaxCT} - 1)$

A DS-TE LSR implementing RDM and implementing the optional Local Overbooking method MUST support enforcement of bandwidth constraints in compliance with this extended definition.

Purely for illustration purposes, the diagram below represents the Russian Doll Bandwidth Constraints model in a pictorial manner when 3 Class-Types are active and the local overbooking method is used:

I-----I

```

I-----I Normalised(CT2) I
I-----I Normalised(CT2) I + I
I Normalised(CT2) I + I Normalised(CT1) I
I-----I Normalised(CT1) I + I
I-----I Normalised(CT0) I
I-----I

I-----BC2----->
I-----BC1----->
I-----BC0----->

```

6.2. Example Formulas for Computing "Unreserved TE-Class [i]" With Local Overbooking

A DS-TE LSR implementing RDM and implementing the optional Local Overbooking method MUST reflect the RDM bandwidth constraints defined in [section 6.1](#) above when computing "Unreserved TE-Class [i]".

Again, keeping in mind that details of admission control algorithms as well as formulas for computing "Unreserved TE-Class [i]" are outside the scope of the IETF work, we provide in this section, for illustration purposes, an example of how values for the unreserved bandwidth for TE-Class[i] might be computed with the Russian Dolls Model, assuming:

- the basic admission control algorithm which simply deducts the exact bandwidth of any established LSP from all of the Bandwidth Constraints relevant to the CT associated with that LSP.
- the optional per-CT Local Overbooking Multipliers are used.

When the optional local overbooking method is supported, the example generalized formula of [section 5](#) becomes:

$$\begin{aligned}
 &\text{"Unreserved TE-Class [i]" =} \\
 &\text{LOM(c) } \times \text{ MIN } [\\
 &\quad [\text{BCc} - \text{SUM (Normalised(CTb,q)) }] \text{ for } q \leq p \text{ and } c \leq b \leq 7, \\
 &\quad \cdot \cdot \cdot \\
 &\quad [\text{BC0} - \text{SUM (Normalised(CTb,q)) }] \text{ for } q \leq p \text{ and } 0 \leq b \leq 7, \\
 &\quad]
 \end{aligned}$$

where:

- TE-Class [i] <--> < CTc , preemption p>
in the configured TE-Class mapping.

6.3. Example Usage of LOM

To illustrate usage of the local overbooking method with the Russian Dolls model, let's consider a DS-TE deployment where two CTs (CT0 for data and CT1 for voice) and a single preemption priority are used.

The TE-Class mapping is the following:

| TE-Class | <--> | CT, preemption |
|----------|------|----------------|
| 0 | | CT0, 0 |
| 1 | | CT1, 0 |
| rest | | unused |

Let's assume that on a given link, BCs and LOMs are configured in the following way:

```

BC0 = 200
BC1 = 100
LOM(0) = 4 (i.e. = 400%)
LOM(1) = 2 (i.e. = 200%)

```

Let's further assume that the DS-TE LSR uses the example formulas presented above for computing unreserved bandwidth values.

If there is no established LSP on the considered link, the LSR will advertise for that link in IGP :

```

Unreserved TE-Class [0] = 4 x (200 - 0/4 - 0/2 )= 800
Unreserved TE-Class [1] = 2 x (100- 0/2) = 200

```

Note again that these values advertised for Unreserved Bandwidth are larger than BC1 and BC0.

If there is only a single established LSP, with CT=CT0 and BW=100, the LSR will advertise:

```

Unreserved TE-Class [0] = 4 x (200 - 100/4 - 0/2 )=700
Unreserved TE-Class [1] = 2 x (100- 0/2) = 200

```

If there is only a single established LSP, with CT=CT1 and BW=100, the LSR will advertise:

```

Unreserved TE-Class [0] = 4 x (200 - 0/4 - 100/2 )= 600
Unreserved TE-Class [1] = 2 x (100- 100/2) = 100

```

Note that the impact of an LSP on the unreserved bandwidth of a CT does not depend only on the LOM for that CT: it also depends on the LOM for the CT of the LSP. This can be seen in our example. A BW=100 tunnel affects Unreserved

CT0 twice as much if it is a CT1 tunnel, than if it is a CT0 tunnel.
It reduces Unreserved CT0 by 200 (800->600) rather than by 100
(800->700). This is because LOM(1) is half as big as LOM(0). This

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illustrates why the local overbooking method allows very fine accounting of cross-effect of overbooking across CTs, as compared with the LSP/link size overbooking method.

If there are two established LSPs, one with CT=CT1 and BW=100 and one with CT=CT0 and BW=100, the LSR will advertise:

Unreserved TE-Class [0] = $4 \times (200 - 100/4 - 100/2) = 500$

Unreserved TE-Class [1] = $2 \times (100 - 100/2) = 100$

If there are two LSPs established, one with CT=CT1 and BW=100, and one with CT=CT0 and BW=480, the LSR will advertise:

Unreserved TE-Class [0] = $4 \times (200 - 480/4 - 100/2) = 120$

Unreserved TE-Class [1] = $2 \times \text{MIN} [(200 - 480/4 - 100/2), (100 - 100/2)]$

= $2 \times \text{MIN} [30, 50]$

= 60

7. Security Considerations

Security considerations related to the use of DS-TE are discussed in [[DSTE-PROTO](#)]. Those apply independently of the Bandwidth Constraints model, including RDM specified in this document.

8. Acknowledgments

We thank Martin Tatham for his earlier contribution in this work.

9. Normative References

[DSTE-REQ] Le Faucheur et al, Requirements for support of Diff-Serv-aware MPLS Traffic Engineering, [draft-ietf-tewg-diff-te-reqts-07.txt](#), February 2003.

[DSTE-PROTO] Le Faucheur et al, Protocol extensions for support of Diff-Serv-aware MPLS Traffic Engineering, [draft-ietf-tewg-diff-te-proto-03.txt](#), February 2003.

[RFC2119] S. Bradner, Key words for use in RFCs to Indicate Requirement Levels, [RFC2119](#), March 1997.

10. Informative References

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[BC-MODEL] Lai, "Bandwidth Constraints Models for DS-TE", [draft-wlai-tewg-bcmodel-00.txt](#), June 2002.

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[MAM] Le Faucheur, "Maximum Allocation Bandwidth Constraints Model for Diff-Serv-aware MPLS Traffic Engineering", [draft-lefaucheur-diff-tet-mam-00.txt](#), February 2003.

[OSPF-TE] Katz et al., "Traffic Engineering Extensions to OSPF", [draft-katz-yeung-ospf-traffic-09.txt](#), October 2002.

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[RSVP-TE] Awduche et al, "RSVP-TE: Extensions to RSVP for LSP Tunnels", [RFC 3209](#), December 2001.

[DIFF-MPLS] Le Faucheur et al, "MPLS Support of Diff-Serv", [RFC3270](#), May 2002.

11. Intellectual Property Considerations

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protected by one or more patents assigned to Cisco Systems, Cisco Systems intends to disclose those patents and license them on reasonable and non-discriminatory terms.

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Appendix A - Addressing [\[DSTE-REQ\]](#) Scenarios

This Appendix provides examples of how the Russian Dolls Bandwidth Constraints model can be used to support each of the scenarios described in [\[DSTE-REQ\]](#).

1. Scenario 1: Limiting Amount of Voice

By configuring on every link:

- Bandwidth Constraint 1 (for CT1=Voice) = "certain percentage" of link capacity
- BC0 (for CT1=Voice + CT0= Data) = link capacity

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By configuring:

- every CT1/Voice TE-LSP with preemption =0
- every CT0/Data TE-LSP with preemption =1

DS-TE with the Russian Dolls Model will address all the requirements:

- amount of Voice traffic limited to desired percentage on every link
- data traffic capable of using all remaining link capacity
- voice traffic capable of preempting other traffic

2. Scenario 2: Maintain Relative Proportion of Traffic Classes

By configuring on every link:

- BC2 (for CT2) = e.g. 45%
- BC1 (for CT1+CT2) = e.g. 80%
- BC0 (for CT0+CT1+CT2) = e.g. 100%

DS-TE with the Russian Dolls Model will ensure that the amount of traffic of each Class Type established on a link is within acceptable levels as compared to the resources allocated to the corresponding Diff-Serv PHBs regardless of which order the LSPs are routed in, regardless of which preemption priorities are used by which LSPs and regardless of failure situations. Optional automatic adjustment of Diff-Serv scheduling configuration could be used for maintaining very strict relationship between amount of established traffic of each Class Type and corresponding Diff-Serv resources.

3. Scenario 3: Guaranteed Bandwidth Services

By configuring on every link:

- BC1 (for CT1) = "given" percentage of link bandwidth
(appropriate to achieve the Guaranteed Bandwidth service's QoS objectives)
- BC0 (for CT0+CT1) = 100% of link bandwidth

DS-TE with the Russian Dolls Model will ensure that the amount of Guaranteed Bandwidth Traffic established on every link remains below the given percentage so that it will always meet its QoS objectives. At the same time it will allow traffic engineering of the rest of the traffic such that links can be filled up.