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IETF – MEF Token Bucket Comparison

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Abstract

The two most important algorithms used to perform traffic policing in a packet based telecommunications network were defined by Metro Ethernet Forum (MEF) and Internet Engineering Task Force (IETF) bodies. The two algorithms slightly differ both in the terms used to describe their configuration parameters and in the traffic management. Even if translating MEF set of parameters into IETF one seems trivial at a first glance, this is not the case and strongly depends upon the traffic pattern. This article, after a description of the two algorithms, tries to describe the relationship between the set of parameters.

Keywords: Policing; Packet networks; MEF algorithm

Introduction

Token bucket specification

Before entering in the analysis of the behaviour differences, the two token bucket are compared in terms of their definitions and specifications. IETF two rate Three Color Marker (RFC 2698)

The parameters used to describe the IETF token bucket are:

CIR = Committed Information Rate

> This parameter is used to define the average rate of traffic that respect the guarantees of bandwidth. This traffic is defined as "green traffic": its transmission is guaranteed across the network (overbooking of resources is not considered in this analysis)

CBS = Committed Burst Size

> This parameter defines the amount of traffic that instantaneously can be admitted above the CIR and anyway considered "green" (burst).

PIR = Peak Information Rate

> This parameter is used to define the average rate of traffic that is admitted in the network with the assurance that it won't be discarded directly by the policer; the traffic in excess to the "green" one can be discarded in case of congestion and is considered "yellow".

PBS = Peak Burst Size

> This parameter defines the amount of traffic that instantaneously can be admitted above the PIR (burst) without being discarded directly by the policer (yellow).

The policer behaviour can be described as in the following figure. Two buckets containing a number of "tokens" equal to PBS and CBS are continuously filled in at a rate PIR and CIR respectively. Each time a packet arrives, its length is compared to the tokens present in the PBS: if the tokens are less than the packet length, it is considered red and it is discarded. Then the packet length is compared to the tokens present in the CBS bucket: if the tokens are less than the packet length the packet is considered yellow, otherwise it is considered green (Figure 1).

The algorithm is:

if (packet_size > PBS_tokens)

packet_is_red;

else if (packet_size > CBS)

packet_is_yellow;

else packet_is_green;

The following figure pictorially describes the behaviour of this algorithm with a nearly stationary traffic patterns (Figure 2).

Area 1: In this area the packet arrival rate is not enough to empty the PBS and the CBS bucket: each time the packet arrives, the two bucket is already filled up with tokens. The regime scenario is with CBS and PBS bucket full and the entire packet are considered green and little bursts of packets exceeding CIR (up to CBS) are still considered green.

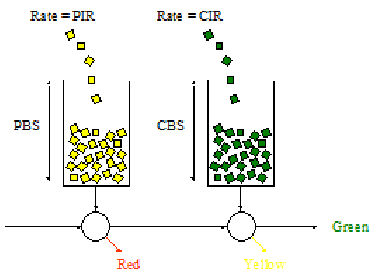

Figure 1: Policer behaviour.

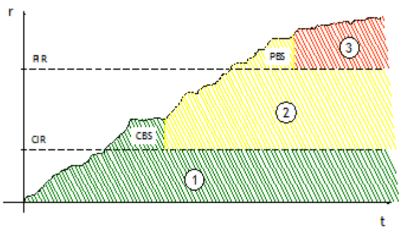

Figure 2: Stationary traffic patterns.

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Area 2: In this area the packet arrival rate is enough to empty the CBS bucket but not enough to empty the PBS bucket: each time a packet arrives the PBS bucket has already been filled up, but the number of tokens thrown in the CBS bucket is not enough to fill it up. The regime scenario is with CBS bucket empty and PBS bucket full and all the packet arrived up to the CIR are considered green and the other ones are yellow.

Area 3: In this area the packet arrival rate is enough to empty both the CBS and the PBS buckets: each time a packet arrives the number of tokens thrown in the CBS and in the PBS buckets are not enough to fill them up. The regime scenario is with PBS and CBS bucket empty and the packets arriving at a CIR rate are considered green while all the other packets are yellow if arriving below PIR and red otherwise (apart from a little burst of packets that even if arrived above PIR are still to be considered yellow)Even if the algorithm is very simple and its behaviour can be, at a first sight, very predictable, there are some traffic patterns that can lead to unforeseeable results.

Example: The packets arrive at a rate CIR + ε, with ε very small and the CBS is as large as the packet size; the intuitive result is a stream of green packets with sometimes one yellow packet. The actual result is very different and can be understood only analysing step by step the behaviour of the algorithm in this particular scenario. The first packet arrives and empties the bucket (it is green). The second packet arrives just before the bucket is filled up with the last bit (the packet inter-arrival rate is a little less than 1/CIR), so the first comparison between packet size and the CBS tokens fails and the packet is yellow. A third packet arrives and now the bucket is full, but is emptied by the packet size. The fourth packet arrives just before the bucket is filled up again, so it is yellow again. And so on. The final result is that half of the packets are yellow and half are green.

This simple example gives an important rule to be checked when configuring a token bucket algorithm: do not dimension the bucket size at the packet size (or the MTU in case the packet size varies with time).

MEF 10.1

The parameters used to describe a MEF policer are:

CIR = Committed Information Rate

This parameter is used to define is the average rate of traffic that respect the guarantees of bandwidth. This traffic is considered “green”: its transmission is guaranteed across the network (overbooking of resources is not considered in this analysis).

CBS = Committed Burst Size

This parameter defines the amount of traffic that can be admitted above the CIR and considered “green”.

EIR = Excessive Information Rate

This parameter is used to define how much traffic exceeding the CIR can be admitted in the network with the assurance that it won’t be discarded directly by the policer; this traffic can be discarded in case of congestion and is considered “yellow”.

EBS = Peak Information Rate

This parameter defines the amount of excessive traffic that can be admitted above the EIR without being discarded directly by the policer (yellow).

CF = Coupling Flag

This parameter is used to allow the green tokens to overflow out of the CBS bucket and fall in the EBS bucket (CF = 1).

The policer can be described as in the following figure. Two buckets EBS and CBS are continuously filled in at a rate EIR and CIR respectively. Each time a packet arrives, its length is compared to the tokens present in the CBS: if the tokens are more than the packet length, it is considered green. If no tokens are present in the CBS bucket, then the packet length is compared to the tokens present in the EBS bucket: if the tokens are more than the packet length the packet is considered yellow, otherwise it is considered red (Figure 3).

The algorithm is:

if (packet_size < CBS_tokens)

packet_is_green;

else if (packet_size < EBS)

packet_is_yellow;

else packet_is_red;

The algorithm is very similar to the IETF one (apart from the Coupling Flag), with the following difference: the process is inverted: in the MEF algorithm the packet exits the algorithm when tokens are enough to satisfy the packet size and the CBS bucket is compared at the beginning (Figure 4).

The following figure pictorially describes the behaviour of this algorithm with a nearly stationary traffic patterns.

Area 1: In this area the packet arrival rate is not enough to empty the CBS bucket, so EBS bucket is never used: each time the packet arrives, the two bucket are already filled up with tokens. The regime scenario is with CBS and EBS bucket full and the entire packet are

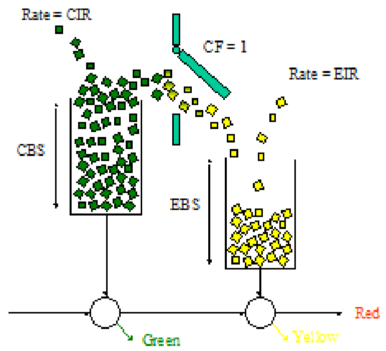


Figure 3: Policer behaviour of two buckets EBS and CBS are continuously filled in at a rate EIR and CIR respectively.

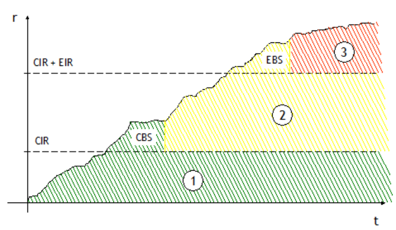


Figure 4: Behaviour of the algorithm with a nearly stationary traffic patterns.

considered green and little bursts of packets exceeding CIR (up to CBS) are still considered green.

Area 2: In this area the packet arrival rate is enough to empty the CBS bucket but not enough to empty also the EBS bucket: each time a packet arrives the EBS bucket has already been filled up, but the number of tokens thrown in the CBS bucket is not enough to fill it up. The regime scenario is with CBS bucket empty and EBS bucket full and all the packet arrived up to the CIR are considered green and the other ones are yellow.

Area 3: In this area the packet arrival rate is enough to empty both the CBS and the EBS buckets: each time a packet arrives the number of tokens thrown in the CBS and in the PBS buckets are not enough to fill them up. The regime scenario is with PBS and CBS bucket empty and the packets arriving at a CIR rate are considered green while all the other packets are yellow if arriving below PIR and red otherwise (apart from a little burst of packets that even if arrived above PIR are still to be considered yellow).

Also with MEF algorithm the example given in the IETF section applies and then also the general rule to dimension the bucket size at more than the packet size (or the MTU) applies.

The Coupling Flag is a particular option of the MEF algorithm: if the CBS bucket is full but the EBS bucket is not, all the tokens that should go in the CBS bucket are diverted in the EBS one. This applies only in case of "color-aware" mode. One of the consequences is that, in a color aware mode, if the policer is receiving yellow packets, they are admitted up to EIR+CIR rate when CF=1 and up to EIR when CF=0. It is more difficult to predict the behaviour of the algorithm with different traffic patterns.

Algorithms Comparisons

In order to compare the behaviours of the two algorithm, three different traffic patterns are considered: a fixed bandwidth, a bandwidth ramp and a squared scenario.

In order to make the comparison the following tool has been developed (Figure 5). The parameters used in the simulations are:

MEF algorithm parameters

CIR = 150 bytes/sec

CBS = 1000 bytes

EIR = 37.5 bytes/sec

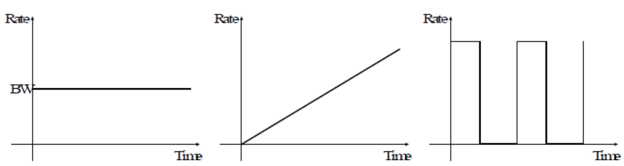
EBS = 1000 bytes

CF = 1

IETF algorithm parameters

CIR = 150 bytes/sec

CBS = 1000 bytes



Fixed BW scenario | Ramp up scenario | Squared scenario

Figure 5: Algorithms comparisons.

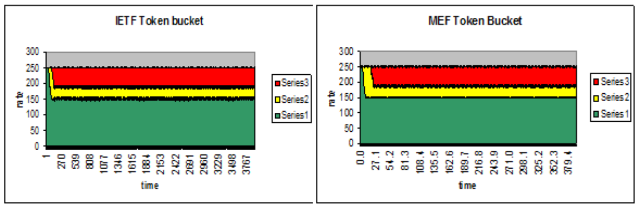


Figure 6: Fixed Band width scenario.

PIR = 187.5 bytes/sec

PBS = 1000 bytes

Fixed bandwidth scenario

This is the simplest scenario, where a fix rate of 250 bytes/sec of traffic is injected in the algorithms. Apart from an initial non stationary regime (not considered in this section), the rate of green, yellow and red packets are constant (Figure 6). The two algorithms in this case behave in exactly the same way, as described by the following figures.

The IETF token bucket shows some degree of waving around the average rates, most probably due to the approximation used in the tool. But for both the algorithms the average rates are: 150 bytes/sec of green packets, 37.5 bytes/sec of yellow packets and 62.5 bytes/sec of red packets.

Ramp up scenario

The rate raises linearly from 0 to 350 byte/sec in 400 seconds, in order to reach a semi-regime scenario in each of the three regions already defined in the previous sections.

Two graphs has been added, to prove the behaviour of the buckets in the three regions described in the previous chapter: in the first phase both the buckets are full; in the second phase the CBS bucket is empty and the PBS (or the EBS) bucket is full; in the third phase both the buckets are empty (Figure 7).

In this scenario the two algorithms behaves exactly in the same way, with PIR=EIR+CIR and PBS = EBS.

Squared scenario

This is the scenario where the difference between the two algorithms is clear.

The traffic pattern is a series of bursts of packets sent at a rate of 312.5 bytes/sec, followed by a period of silence, needed to refill the token buckets (both the CIR and the PIR/EIR) (Figure 8).

It is evident that the number of yellow packets in the MEF algorithm is higher than in the IETF algorithm. This is due to the fact that while in the IETF algorithm the PBS bucket (that governs the number of yellow packets) is emptied together with the CBS bucket and if the latter is large enough there is no space for yellow traffic, in the MEF algorithm the EBS bucket is not emptied as long as the CBS bucket still have enough token to serve a packet. Hence, in the MEF algorithm the number of yellow packets admitted thanks to the EBS bucket does not depend upon the size of the CBS bucket (Figure 9).

The following figure better describes this difference.

The steps are:

- **t_1**: CBS bucket starts being emptied and the rate it is emptied is R-CIR in both algorithms. In IETF algorithm the PBS bucket starts

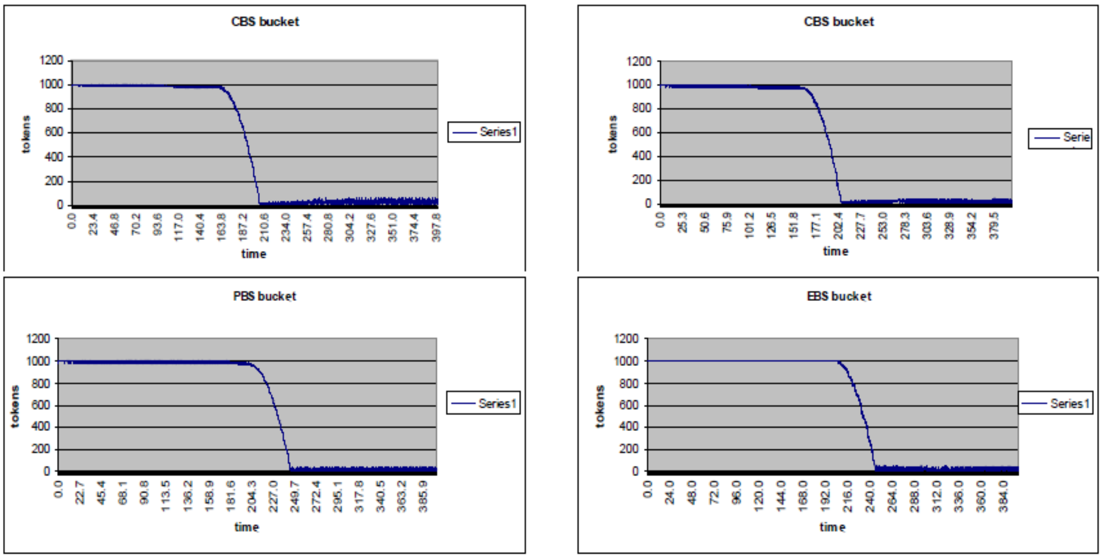


Figure 7: Ramp up scenario.

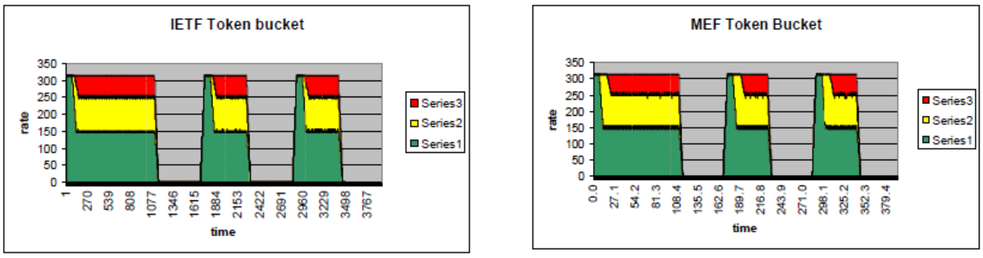


Figure 8: Squaredscenario.

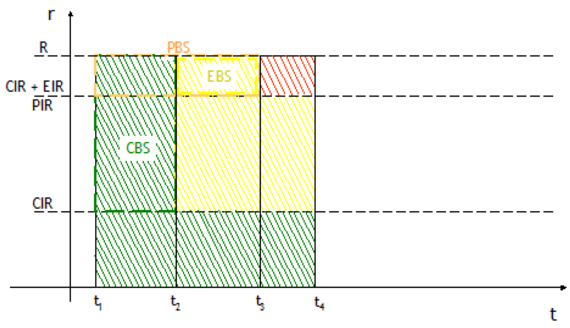


Figure 9: MEF algorithm.

being emptied at a rate R-PIR; in MEF algorithm the EBS is not emptied.

- **t_2:** CBS bucket is empty in both algorithms; in IETF algorithm the PBS bucket goes on being emptied; in MEF algorithm the EBS bucket starts being emptied

- **t_3:** In IETF algorithm the PBS bucket is empty; in MEF algorithm the EBS bucket is emptied. From now on the CBS bucket fill rate will provide enough tokens to guarantee a CIR rate of green packets and the PBS or EBS fill rate will provide enough tokens to guarantee a EIR or (PIR-CIR) rate of yellow packets.

- **t_4:** The packets stop arriving: the PBS bucket is filled with a PIR rate, the EBS bucket is filled with an EIR rate; if the CBS bucket is filled before the EBS bucket is filled, the Coupling Flag defines whether the EBS bucket finishes being filled with a PIR (CF=1) or EIR (CF=0) rate.

The differences between the two algorithms on the single burst (or on bursts far enough from each other's such that it is a good approximation of single bursts) vanishes when CBS very small compared to EBS and PBS=EBS (in the figures CBS=30 and EBS=PBS=10.000) (Figure 10).

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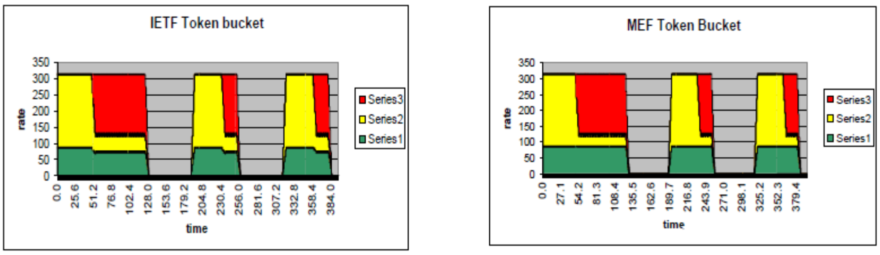

Figure 10: The differences between the two algorithms on the single burst.

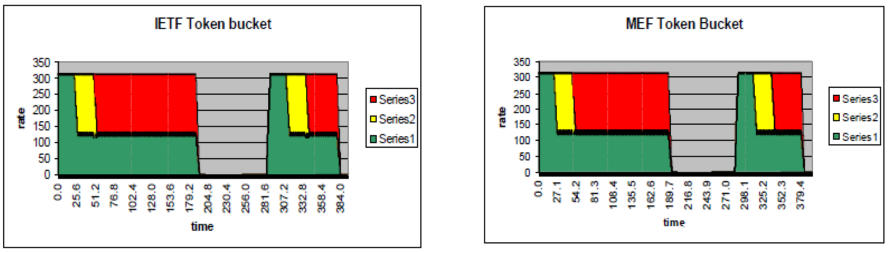

Figure 11: The differences between the two algorithms on the multiplebursts.

or when EIR is small (PIR nearly equal CIR) and PBS = CBS + EBS (in the figures PIR=CIR and EIR=0, CBS=EBS=5.000 and PBS=10.000)

On multiple bursts not so far from each other's such that at the beginning of a burst the buckets are not yet filled up, the relationships between the two algorithms is very complex and depends upon also the distance between the bursts (Figure 11).

Conclusions

The straightforward conclusion is that the relationship between the two algorithms cannot be described simply by a formula, as it strongly depends upon the traffic pattern and the size of the buckets.

The following simple rules apply in particular cases:

- if the traffic pattern is not bursty, the IETF and MEF algorithm behave in the same way, with the relationships: PIR = CIR + EIR and PBS = EBS;
- if the traffic pattern is bursty:
  - if CBS<<EBS and CBS<<PBS, the two algorithms behave in the same way if the bursts rate is not too high and with the following relationships: PIR = CIR + EIR and PBS = EBS;
  - if EIR si very small or PIR is nearly equal to CIR, the two algorithms behave in the same way with the following relationship: PIR = CIR + EIR and PBS = CBS + EBS.