A Comparison of token-bucket based Multi-Color Marking Techniques

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During the last two decades three important architectural models were designed and standardized: the ATM reference model, the Differentiated Services (DiffServ) architecture and recently the Metro-Ethernet (MEF), the evolving Ethernet-based access network. Although the three architectures provide a substantially different networking model, they all assume inter-AS service level agreements (SLAs), where edge routers perform traffic metering or policing according to the SLA traffic parameters over an aggregate stream (An aggregate is a group of connections, for example all the connections of a small company, and the agreement controls an aggregate) and labels each packet as it arrives according to its conformance. The core routers, using e.g., active queue management mechanisms, identify the packet and react, accordingly. The different packet marking differentiates between service aggregate. All the above standards suggest multiple SLA parameters, using an average committed rate and an average peak rate, each with its own allowed amount of burstiness.

The existing networking marking devices follow the ATM, DiffServ and MEF standards and support only two or three-color marking. Whenever two or three colors are used for packet marking the differentiation process can be achieved mainly among the committed rates of the aggregates. Though, it still lacks the differentiation capabilities within the excess rates of each aggregate. Current industrial trends examine multi-color marking that can improve the differentiation capabilities among the SLAs within the excess bandwidth without the need to quantify explicitly the demands. Due to the simplicity of the token bucket algorithm and its inexpensive hardware implementation cost, most of the vendors of marking mechanisms utilize this mechanism for rate estimation, which translate to packet tagging. Thus, it will be natural to examine the multi-coloring effect in the context of an extended platform that uses multiple token buckets for multi-color marking.

This research aims to test the effectiveness of various multi-color algorithms, comparing them to the three-color marking scheme according to several criteria. Each algorithm in this framework is implemented with a combination of token buckets, each with different parameters. We aim to determine which algorithm achieves good traffic performance, and at the same time, per-aggregate service differentiation.

In addition, we devote some of this research to study different token buckets implementations in the context of their role as rate estimators and color markers. Surprisingly, we found that some of the design issues in multi-color marking using token buckets, which are relevant also to the common three color marking, were never studied before. Our simulations show that, even when using two or three colors, certain parameters tuning or different token-bucket implementation mechanisms can lead to ill-behaved results. Specifically, the fact that the TB mechanism prefers shorter packets and colors them with preferred colors. For this purpose we developed a credit-based algorithm that eliminates this preference and reduces the complexity of current TB implementation. Despite the many efforts that are done in the industry in this direction, we are not aware of simulation studies that examine the various token based multi-coloring techniques.

A coloring method slices the traffic to layers, each is represented by a color and requires a differentiated treatment, e.g., different dropping probability. The three color convention calls committed packets green; excess packets, yellow; and packets which are outside of the contract (the SLA) red. If the yellow region will be divided to multiple yellow hues, the ones representing the lower rates (i.e., closer to green) will be called light hues, while the ones closer to red will be called dark hues.

In a fair per-aggregate treatment, the color distribution in an aggregate is proportional to the contract. For example, assume that aggregate A has 10Mbps excess traffic, while aggregate B has 40Mbps excess traffic. If we use two yellow hues for the excess traffic and equally divide the excess traffic between the two layers that are represented by these hues, aggregate A will have up to 5Mbps of its excess traffic colored with light yellow, while B will be able to use this color for up to 20Mbps of its excess traffic. However, a 'good' coloring method depends on the queue management scheme at the router.

We distinguish between two combinations of coloring and queue management approaches. In the first approach, the flow rate is estimated and the coloring mechanism randomly assigns a packet a color with a probability that is drawn from the ratio of this color rate to the estimated rate. The drop mechanism in this case will be deterministic, dropping all packet above some threshold color. The well-known Rainbow Fair Queuing (RFQ) [2] algorithm is a good example.
of this approach. The option of using multiple TBs for the multi-coloring was briefly mentioned in [2] but was not investigated.

In the second approach, the coloring mechanism colors the packet deterministically trying to fit the packet in the lowest possible rate layer, by using, for instance, token buckets as markers. Any memory division or queue management scheme can be applied at the router to a color-aware dropping policy. In this research we concentrate on this approach.

1. MARKING USING TOKEN BUCKETS

An \((r,b)\)-token bucket is a classical model that regulates the traffic envelope using two parameters: \(r\), the fill rate of the tokens, that dictates the average traffic rate, and \(b\), the bucket size, that determines the allowed burstiness. In a metering and a policing system, the token bucket acts as a rate estimator (or a meter) and a marker.

Heinanen and Guerin [3] suggested a three color marking, termed trTCM (two rate three color marking) that was adopted by the IETF DiffServ working group. It uses two cascading token buckets: for committed and for excess traffic. The packets are colored in three colors: green (within the \(CI\,R\)), yellow (above the \(CI\,R\) but within the \(PI\,R\)), and red (above the \(PI\,R\)), according to the allocation of the buckets. The MEF standard [1] proposed a different two bucket implementation for three color marking: A \((CI\,R,CBS)\)-token bucket, as before, and an excess \((EIR,EBS)\)-token bucket. Here, \(EIR\) refers to the excess rate and equals \(PI\,R\) minus \(CI\,R\) and, \(EBS\), the size of the yellow bucket and its goal is to allow bursts within the \(EIR\) range.

We extended the DiffServ scheme to an \(N\)-color marking system that colors packets as they arrive using \(N\) colors: green for the committed traffic, \(N-2\) yellow hues for the excess traffic and red for the non-conforming traffic, according to the corresponding bucket allocation. The traffic demand that compose the SLA is expressed by two rates: \(CI\,R\) the average Committed Information Rate and \(PI\,R\) average Peak Rate; and two burstiness parameters \(CBS\) the Committed Burst Size and \(PBS\) Peak Burst Size. \(N-1\) buckets are used rather than one: the ‘green’ \((CI\,R,CBS)\)-token bucket; \(N-2\) excess \((r_i, bs_i)\)-token buckets that are associated with the yellow hue \(y_i\), where \(r_{N-1}\) equals the \(PI\,R\) and \(bs_{N-1}\) equals \(PBS\). Similarly, we extended the MEF deployment according to its specific code and buckets setting as presented in the MEF site.

These two deployments and various parameters setting can result in a different coloring proportions, that dictates different marking distribution, sometimes other than was meant by the contract. The following list illustrate it more details:

- **The Bucket Size** parameter is difficult for tuning. Too large bucket size enables high burstiness namely many packets will be colored as conforming. Too small bucket size may lead to a state where delay jitter will cause some packets to be marked as out-of-profile and eventually may be dropped.

- **Packet Size** Conceptually, the token bucket algorithm is based on a fluid model. Whenever packets arrive, smaller packets are significantly more likely to be colored as conforming, and in the case of multi-coloring, are more likely to be colored lightly. More than that, each deployment react differently, with regards to the ratio between the packet and each bucket size. Any packet that is larger than the bucket size will be marked as out-of-profile. Table 1 presents a distorted coloring proportions in some of our simulations where we used three packet sizes. This coloring can get worse, whenever a multiple TBs is used for the multi color marking. The situation where shorter packets are favored in coloring may cause users to artificially send shorter packet to improve their performance through markers. Thus, it is important to devise coloring implementations that do not exhibit such behavior. We suggest a simple-to-deploy in hardware credit-based algorithm, termed virtualTB, that bypass this preference.

- **Bucket Refill** The resulted coloring can also be affected by the way the token bucket is refilled. It can be refilled whenever a packet arrives or periodically every \(b/r\ seconds. The first refill permits more flexible traffic distribution. The second refill method may be easier for hardware implementation, but permits no more than a burst of \(b\) bytes during an interval of \(b/r\ seconds resulting in a higher burst and a huge number of drops.

- **Number of Colors and Rate assignment** More colors enable better service differentiation, but require more resources. We claim, that to achieve good service differentiation there should be a token bucket that works at a rate close to the system fair rate. Since in practice the fair share keeps changing by the load on the system, a good separation must allocate colors and assign rates in a way that will optimize all possible cases doing better in the more ‘important’ system regimes.

Our research observes the different aspects of each implementation, and compares three-color vs. multi-color marking. In addition we want to simulate the virtualTB algorithm and verify its correctness.

<table>
<thead>
<tr>
<th>three-color marking</th>
<th>(S=40)</th>
<th>(M=140)</th>
<th>(L=1500)</th>
<th>(S:M)</th>
<th>(S:L)</th>
<th>(M:L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5381</td>
<td>10563</td>
<td>14533</td>
<td>0.51</td>
<td>0.37</td>
<td>0.73</td>
</tr>
<tr>
<td>Colored Green</td>
<td>5367</td>
<td>6330</td>
<td>3328</td>
<td>0.85</td>
<td>1.61</td>
<td>1.9</td>
</tr>
<tr>
<td>Green / Total</td>
<td>0.997</td>
<td>0.599</td>
<td>0.228</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: An example for short packets preference. Denote by \(S,M,\) and \(L\) the number of the packets of sizes \(40, 440,\) and \(1500B\), respectively and by \(X_g\) the number of the green packets per each size. Upon a uniform coloring distribution, we expect that: \((S:M) = (X_g \cdot M_g)\) etc.

2. REFERENCES

