Impact of Marking Strategy on Aggregated Flows in a Differentiated Services Network *

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ABSTRACT: Diff-serv framework is receiving wide attention as an architecture for implementing service guarantees in the Internet. This paper looks at the impact of marking strategies employed by aggregated sources (customers) on the provided service in a diff-serv network. The paper proposes two new marking algorithms that improve the fairness among the individual flows within an aggregation.

1 Introduction

Differentiated services (diff-serv) architecture proposes to provide different services over networks by providing different drop preferences [1, 2, 3]. This preferential drop mechanism is expected to provide better throughput for IN (In-Profile) packets than OUT (Out-of-Profile) packets. This paper looks at the QoS and bandwidth management issues at an aggregated source.

In this paper, we study how a customer can mark packets within an aggregation to achieve specific performance goals while staying within the contract-profile.

2 New marking Strategies

We consider maintaining state for each flow within an aggregation at the boundary router. Average sending rate of a flow is maintained as state information for each flow at the marker of the aggregated source. This information is used in balancing resources across the different flows within the aggregation.

If we apply the marking strategy proposed by [3] for aggregated sources, average sending rate of n aggregated sources at time t, $r_{agg}(t)$, is

$$r_{agg}(t) = \sum_{i=1}^{n} r_i(t) \quad (1)$$

When a packet arrives and $r_{agg}(t)$ exceeds reserved rate, r_{resv}, at that instance, the packet is marked as OUT with probability, P_{OUT},

$$P_{OUT}(t) = (r_{agg}(t) - r_{resv})/r_{agg}(t) \quad (2)$$

Therefore, the number of OUT packets of each source, N_i, in interval, τ, is

$$N_i = \int_0^\tau \frac{\max(r_{agg}(t) - r_{resv}, 0)}{r_{agg}(t)} \times r_i(t)\ dt \quad (3)$$

Then, the number of OUT packets of aggregated sources, N_{agg} is

$$N_{agg} = \sum_{i=1}^{n} N_i = \int_0^\tau \max(r_{agg}(t) - r_{resv}, 0)\ dt \quad (4)$$

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From (3), a packet is determined to be marked OUT or IN not by the sending rate of its source but by the aggregated sending rate. Even if the sending rate of a source is less than the individual target rate, $r_{each} = r_{resv}/n$ (since RTT is longer than others or it experienced congestion), the packets from that flow are marked OUT with the same probability as others. We term this marking strategy *Proportional marking* in this paper. We will use fair sharing of aggregated bandwidth as a target of this study. It is easy to generalize this to allow different bandwidth allocations if necessary.

We propose two new marking algorithms, called *IN-fair* and *BW-fair marking*. In designing the new marking algorithms, there are two conditions we need to consider: (1) The total number of OUT packets should be the same as in the original algorithm. (2) The packets from a flow with sending rate less than r_{each} should be marked OUT with a relatively smaller probability (to improve fairness).

Figure 1 shows the proposed algorithm. For each packet arrival, the algorithm calculates average rates of individual sources as well as the average rate of aggregation. If the average rate of aggregation is less than the reserved rate, it marks the packet as IN. Otherwise, it compares the average rate of the individual flow with the individual target rate. We study the following two choices for the individual target: (1) r_{res}/No. of active flows for equal sharing of IN packets, and (2) $r_{agg}(t)$/No. of active flows for achieving equal throughput. By setting the individual target as the first choice, every individual flow is expected to get a fair-share of the aggregated reserved bandwidth (*IN-fair marking*). The second choice is for achieving equal total throughput by assigning more IN packets to the flows going through congested links (*BW-fair marking*).

From Figure 1, it is clear that the proposed algorithm satisfies the second condition of marking a higher fraction of packets IN when the source rate is less than r_{each}. From the algorithm, P_{OUT} is given by

$$P_{OUT}(t) = \begin{cases} (r_{agg}(t) - r_{resv})/r_{exceed}(t) & \text{if } r_i(t) > r_{each} \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

Here, r_{exceed} is the sum of r_i that is greater than r_{each}. The number of OUT packets of each source, N_i is

$$N_i = \int_0^\tau Pout(t) \times r_i(t)\ dt \quad (6)$$

Since P_{OUT} is zero for sources with r_i less than r_{each}, the number of OUT packets of aggregated sources, N_{agg} is

$$N_{agg} = \sum_{exceed} N_i = \int_0^\tau \max(r_{agg}(t) - r_{resv}, 0)\ dt \quad (7)$$

From (4) and (7), it is seen that the proposed algorithm

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Algorithm:

Upon receiving a packet arrival in ith flow
   calculate the new avg_agg_rate and avg_rate[i]
   if avg_agg_rate <= target
      mark this packet IN
   else
      if avg_rate[i] > individual_target
         calculate sum_exceeds
         With probability Pout=(avg_agg_rate-target)
                                    /sum_exceeds
            mark this packet OUT
         else
            mark this packet IN
      else
         mark this packet IN
end

Fixed parameter:
   target: reserved rate for aggregated sources

Saved variables:
   avg_agg_rate: average rate of aggregated sources
   avg_rate[i]: average rate of ith individual source
   individual_target: target/the number of active flows
   sum_exceeds: the sum of avg_rate[i] which is greater
                than individual_target

Other:
   Pout: current packet OUT-marking probability
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Figure 1: New marking algorithm for aggregated sources

satisfies the first condition.

3 Simulation results

In this section, we present simulation results and show how the new algorithm achieves fair sharing of bandwidth within an aggregation. We will show that this bandwidth management results in improved throughput realization. In all simulations, we used a TCP-Reno agent in ns-2 as a source and FTP application as a traffic generator.

3.1 Dealing with different RTTs

Five aggregated sources (each with 10 flows) compete for bandwidth on a bottleneck link. We assign RTT_j^i, RTT of i^{th} individual source in j^{th} aggregated source as;

$$RTT_j^i = 130 + 4 \times (i-1) \times (j-5.5) \text{ (ms)} \quad (8)$$

The average throughput of each aggregation is not much different from each other in both schemes even though RTTs of individual sources are different. This again shows that the impact of different RTTs can be reduced by aggregation. The row STD shows the standard deviation among the individual rates within an aggregation. It is observed that STD increases significantly with increased RTT differences within an aggregation. The IN-fair marking algorithm achieves significantly smaller variation compared to proportional marking. The row Max/Min compares the maximum and minimum rates realized within an aggregation. Again, it is observed that fairness is considerably improved with the IN-fair marking algorithm.

3.2 Aggressive bandwidth management in congested networks

Figure 2 shows the network topology used for simulations. There are two aggregated sources (each with ten individual flows). Each aggregated source reserves 1 Mbps. The network as a total has enough capacity (3 Mbps) to support

Table 1: Quantitative comparisons

Proportional marking					
Aggregation	1	2	3	4	5
RTT Max/Min	1	1.32	1.77	2.42	3.48
Average(Kbps)	112.7	110.0	112.2	113.8	114.5
STD (Kbps)	14.3	19.3	21.2	44.4	62.1
Max/Min	1.41	1.72	2.06	3.83	4.80
IN-fair marking					
RTT Max/Min	1	1.32	1.77	2.42	3.48
Average(Kbps)	116.9	111.4	115.5	113.3	117.0
STD (Kbps)	7.7	8.8	12.3	14.8	25.3
Max/Min	1.22	1.28	1.39	1.43	1.82

the two aggregated sources (total reservation of 2 Mbps). Due to the dynamic nature of flows, one of the links may be oversubscribed as in this example. In the first simulation, we applied proportional marking to the marker for aggregation 1 and the IN-fair marking for aggregation 2. In the second simulation, we applied proportional marking for aggregation 1 and the BW-fair marking for aggregation 2.

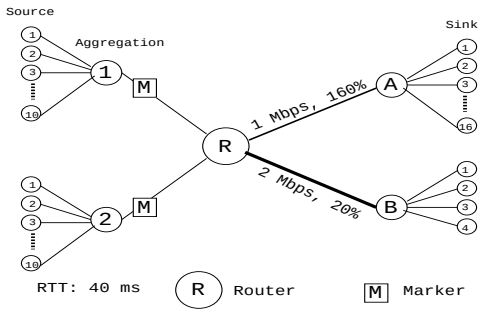


Figure 2: Aggregated network topology with different congestion levels

Figure 3 shows the results of Simulation 1. Each bar shows the average throughput of individual source, and the dark portion in each bar indicates the throughput achieved by IN packets. In the proportional marking, it is observed that each packet is marked OUT with the same probability even if its source cannot reach its reserved rate, and IN packets are unfairly distributed to flows achieving higher rates. In IN-fair marking, however, each individual source achieves a fair-share of the reserved rate and shares IN packet throughput equally even with different levels of congestion. Clearly, fair sharing of IN-profile bandwidth improved the performance of the flows through the congested link. When source 1 and source 2 compete for bandwidth on the congested link, source 2 achieves higher share due to marking higher number of packets IN.

Figure 4 shows the results of Simulation 2. The BW-fair marking is more aggressive by the fact that it sends more IN packets on congested links than on uncongested links so as to get more bandwidth in congested links. In the proportional marking, the flows through congested link loose more bandwidth than the flows in Figure 3. The flows using the BW-fair marking in Figure 4 get more bandwidth than the flows in Figure 3. The flows within aggregated source 1 achieve significantly less bandwidth due to the pro-

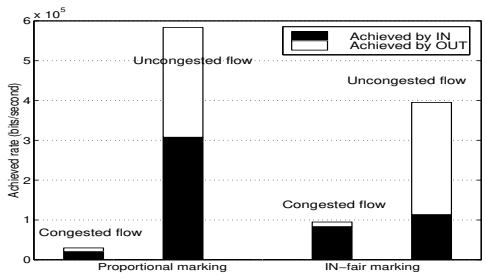


Figure 3: Throughputs of proportional and in-fair marking

portional marking. These two experiments show that individual marking strategies employed by customers can impact each other even when every source stays within the contract-profile.

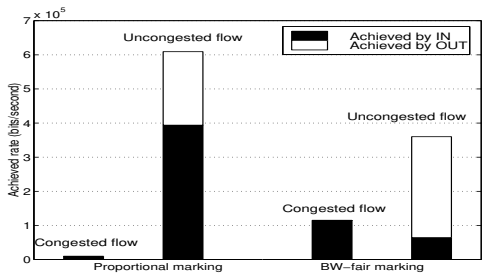


Figure 4: Throughputs of proportional and bw-fair marking

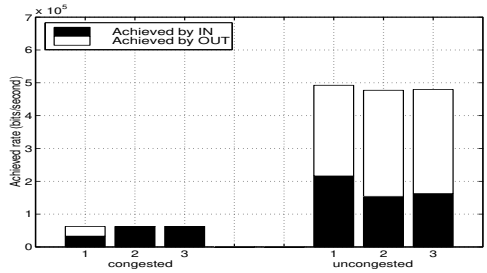
3.3 Scalability

To observe the scalability of these strategies, we conducted two sets of simulation experiments. In the first set, we used the same simulation topology as in Figure 2. In the second set, we added one best-effort aggregated source of ten individual sources. Each set consists of three experiments. For both the aggregated sources, we applied proportional marking in the first experiment, the IN-fair marking in the second experiment, and the BW-fair marking in the third experiment in each set.

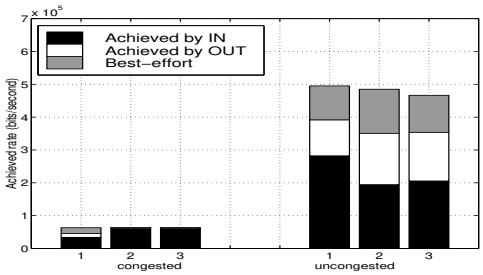
The results are presented in Figure 5. In Figure 5(a), the total throughput of each experiment is similiar to the throughputs of the others since network resources are limited even though the proposed algorithms send more IN packets. Only difference between proportional marking and the proposed algorithms is that throughput of proportional marking strategy in the congested link is achieved by both IN and OUT packets while throughputs of the proposed algorithms in the congested link are achieved only by IN packets. This results in different performance in the experiments with best-effort flows. In Figure 5(b), IN packet throughput of each flow is protected even in the presence of best-effort flows, but the OUT packet throughput is reduced by best-effort flows. As a result, the new marking algorithms achieve higher throughputs through the congested link.

4 Discussion

Our simulation experiments show that: (a) Even though individual TCP flows may respond to congestion, this congestion avoidance backoff can be muted by moving to next



(a) Without best-effort flows



(b) With best-effort flows

Figure 5: Impact of marking algorithms on throughput

higher service level (b) During such transitions, the congestion may actually increase even when individual flows respond to congestion (c) When employed universally, these strategies can result in a bidding war for resources as each aggregated source shifts its resources to congested links (by moving up the service levels) and (d) the congested links eventually settle down to serving packets of highest service level while shutting down service for other packets

5 Conclusions

We have shown that differences in RTTs of individual flows have less of an impact on the realized throughputs of aggregated sources than on the throughputs of individual sources. We have shown that proportional marking of packets within an aggregation can lead to significant unfairness among the flows within the aggregation. We have proposed new marking algorithms for aggregated sources that improve fairness among the individual flows within the aggragation.

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