Packet Switched Networks: A Buffer with Two Priority Inputs.

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Abstract: An Enhanced Traffic Aggregation (E_TA) technique for acceleration simulation of packet switched network is proposed. This technique simplifies the simulation model and improves the efficiency by using 'packet-train' or packet rate source traffic with non FIFO scheduler in the buffer. The model employs power law traffic which recently proved to be able to capture both long-range dependence and the burstiness of aggregate broadband network traffic. Our results show that using E_TA with FIFO scheduler simulation times can be reduced by 39%, and using E_TA with non FIFO scheduler by 83 %.

I. INTRODUCTION

Self-similar or fractal-like behaviour of certain aggregated packet traffic e.g. Ethernet, can be very different from conventional telephone traffic so the standard models of packet traffic (e.g. pure Poisson models or Markov-Modulated Poisson process) [1,2] no longer apply. The main feature of self-similar traffic is that it exhibits long range dependence (LRD), where the autocorrelation function decays not exponentially but as a power law. This is in contrast with the traditional stochastic models, which all exhibit short range dependence (SRD), and has autocorrelation functions that decay exponentially fast. In the modern packet switched network traffic i.e. IP traffic, LRD characteristics were found invalidating the use of traditional traffic models.

Network performance is usually estimated using simulation, or mathematical analysis. The validity of the conclusion obtained, either from simulation or analysis, depends greatly on how accurately the model captures the actual operation of the system under study. Because packet networks are becoming more complex, an analytical approach quickly becomes intractable, thus simulation is needed. To simulate rare events, such as cell losses or buffer overflow probability, conventional simulation methods can be extremely inefficient. So recently there have been many proposals aimed at providing methods to accelerate simulations involving self-similar traffic [5-12].

These methodologies can be categorized as three different types [16]: computational power, simulation technology and simulation model. In computational power, simulation can be speeded up by using more powerful and faster machines (i.e. concurrent or parallel simulation [17, 18]). In simulation technology, new enhanced algorithms for implementing the simulation can accelerate the simulation, for example the RESTART [13] mechanism uses a statistical technique that explores the rare event of interest, which in the case of [13] is the cell loss probability in ATM. The last type in the category simplifies the simulation model and improves its efficiency. An example of this type is the 'packet-train' simulation technique, which was first proposed in [14] to model data network traffic. In this technique, the network traffic is modelled in terms of a continuous packet flow rather than discrete packet instances. Another example is Traffic Aggregation (TA) which has been recently proposed as a generic technique for packet networks that significantly reduces the number of simulation events required to achieve steady state in a simulation experiment [8-12]. This technique focuses on the ON-OFF traffic models which are commonly used for IP and ATM. These ON/OFF sources may have power law distributed sojourn times to represent self-similar traffic.

TA can be further accelerate by using enhanced TA (E_TA), proposed here, where different types of traffic flows are applied at the source and buffered by non- FIFO schedulers [15]. An example of a packet network is the internet which is used in most of our daily life, either for business, entertainment or education. The underlying fabric of the successful internet is the Internet Protocol (IP). IP was designed to provide best-effort service for delivery of data packets and to run across virtually any network transmission media and system platform. However, the increasing popularity of IP for commercial and real time activities requires quality of service (QoS) levels in addition to best-effort. Different applications have varying needs for delay, delay variation (jitters), packet loss and availability. Hence, packet networks should be designed to provide the required QoS to applications. Differentiated Services ((DiffServ) is one of the model defined by the Internet Engineering Task Force (IETF) to facilitate QoS on the IP network. DiffServ categorizes traffic into different classes and tries to apply parameters to those classes. In E_TA the non FIFO scheduler model will categorize two different traffic classes which are for real time applications, such as VoIP, and non real time applications such as FTPs.

In this paper we will investigate E_TA models with a FIFO scheduler and E_TA with a non FIFO scheduler. We discuss the parameterization method of E_TA in both cases. The rest of the paper is structured as follows: Section II gives a brief review of parameterize

E_TA with FIFO scheduler. In section III original packet-by-packet technique with a non FIFO scheduler is presented. In section V, the approach of E_TA with non FIFO scheduler is presented. Preliminary results are provided in section V. Finally, concluding remarks and discussions are presented in section VI.

II. E_TA WITH A FIFO SCHEDULER

In the E_TA model, an event represents many packet-by-packet events in the TA model; this is illustrated in figure 1. Hence an event in E_TA is considered as the end of a TA ON period rather than at the end of a packet (as in TA). In order to get equivalent traffic accuracy (in the FIFO queue) a few things need to be considered, such as the potentially long active periods of arriving packets in a burst, and the service time in the buffer. In E_TA an accurate representation of the queue distribution in the buffer can only be obtained by increasing the mean ON time (filling the buffer), followed by a reduction of mean OFF time (emptying the buffer). This is because the increment of just the mean ON time would not affect the queue distribution in E_TA. The mean OFF time for E_TA is given by

$$mean_{OFF} = \left[\left(1-\frac{\rho}{R_{on}}\right)\times\frac{R_{on}}{\rho}\right]\cdot C \qquad (1)$$

where ρ is the load, R_{on} is the ON arrival rate of the aggregated traffic, C is the buffer capacity. All packets are assumed to be the same size because it makes little difference when the traffic is power law and it is simpler.

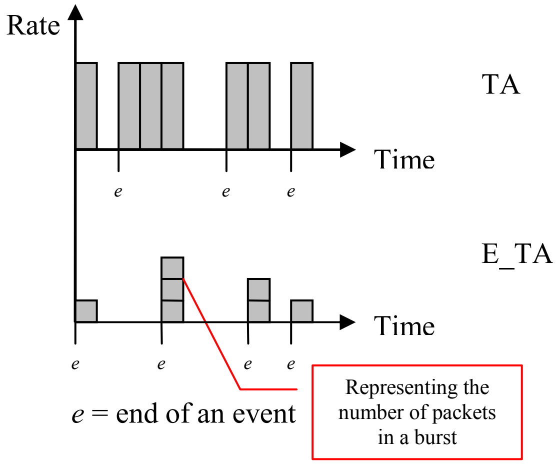

Figure 1: E_TA reduces the number of events

In terms of timeslots, the ON duration in E_TA is 1 time unit, but the "service time" of a burst of packets depends on the number of packets contained in that burst. Hence the service time for the first burst might not be as same as the second burst and so on. These non deterministic service times are important to ensure the queue distribution is equivalent (between E_TA and TA). E_TA accelerates simulation by incorporating the time that would have been taken in the buffer by a full packet-by-packet simulation into the service process of the traffic in study, which is burst arrivals traffic. In order for the simulators to be effective and accurate we must fulfil the criteria that they accurately reproduce the queuing behaviour of the original queuing system, i.e. the one that explicitly models the packet-by-packet traffic. This means that these two queuing systems have to produce the same results for certain measures of interest. The measure we choose (because it critically affects both information loss and delay) is the state probabilities as seen by arriving packets. Figure 2 illustrates the idea where the number of packets in the burst is incorporated as the service time of each burst.

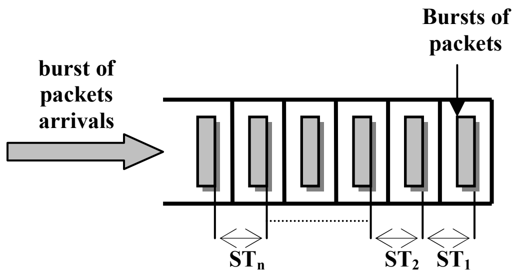

Figure 2: Service time in FIFO queue

III. CONVENTIONAL TECHNIQUE WITH NON-FIFO SCHEDULER

As explained, the services on broadband networks have diverse quality of service requirements. Network service provides benefit from being able to provide a range of quality of service guarantees. So the system in concern, see figure 3, is one of the simplest implementations which segments quality of service. This system uses a non-FIFO scheduler that allows more than one priority of source in a network. There are two levels of priority, high priority for real-time applications and low priority for non real-time applications. The buffer will have two sub-queues, sub-queue 1, sq1 holds high priority packets and sub-queue 2, sq2, holds low priority packets. Priority is given to sq1 because all the packets in busy period of sq1 will be service first then the buffer will switch to sq2. The busy period distribution of the sq1 is added to the service times of the sq2 traffic, and this is illustrated in figure 3.

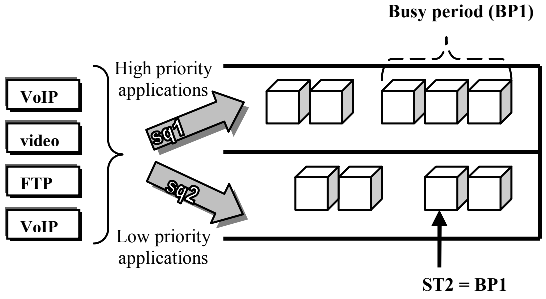

Figure 3: The original packet-by-packet non-FIFO scheduler

IV. E_TA WITH NON FIFO SCHEDULER

In E_TA with non-FIFO scheduler, a hybrid technique is applied on the service time of sq2 where it relies on prior knowledge by queue analysis of sq1. Hence, instead of simulating the scheduler in figure 3, an E_TA simulation with non FIFO scheduler is simulated as illustrated in figure 4.

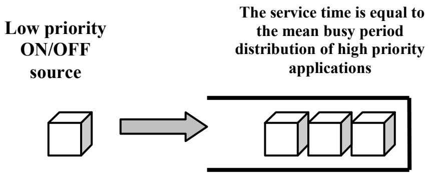

Figure 4: E_TA with non-FIFO scheduler

The busy period of a queue is defined as an uninterrupted period during which there is output leaving the buffer, it is followed by an idle period. If packet-by-packet source is simulated the service time of each packet in sq2 is equal to the mean busy period of sq1 but if the source is simulating burst of packets the packet service time is sq2 is

$$P_{ST} = \sum_{n=1}^{P_{\max}} ST_n \tag{2}$$

where ST is the service time and P_{max} is the number of packets in a burst. Each sub queue in E_TA with non FIFO queue is parameterized separately to ensure accuracy in the queue distribution of sq2 in the original non FIFO queue.

V. RESULTS AND DISCUSSIONS

Figure 5 shows that the E_TA model with FIFO queue has equivalent queuing accuracy to the TA model, in the example with mean ON duration, T_{on} = 3 unit time, OFF duration time, T_{off} = 10 unit time, ON arrival rate, R_{on} = 2 unit time and service rate of 1 unit time. Two different scenarios were analysed with E_TA with non FIFO scheduler. In the first scenario the ON and OFF period of the high priority traffic are exponentially distributed while the ON and OFF period of the low priority traffic are Pareto distributed. The second scenario the ON and OFF period of both high and low priority traffics are Pareto distributed. With ON duration time, T_{on} = 6 unit time, OFF duration time, T_{off} = 3 unit time, ON arrival rate, R_{on} = 2 unit time and service rate of 1 unit time comparison of the queue distribution in the low priority sub queue is given in figure 6. . For better visualization the queuing results were binned into exponentially wider bins. The queue distribution of the traffic with exponential distribution appeared close to the queue distribution of traffic with Pareto distribution. This experiment shows that even though one the traffic distribution is exponential, the queue distribution in the buffer will be power law distributed if one of the traffic input distribution is power law

The original non FIFO scheduler is compared to the E_TA with non FIFO scheduler and equivalent traffic accuracy is shown in figure 7. This example has ON duration time, T_{on} = 5 unit time, OFF duration time, T_{off} = 5 unit time, ON arrival rate, R_{on} = 2 unit time and service rate of 1 unit time.

The speed up of E_TA with FIFO scheduler and E_TA with non FIFO scheduler model are shown in table 1 and 2. In table 1 comparison was made to the TA model with FIFO scheduler and the simulation time is 18144000 seconds which is equivalent to 5040 hours. The number of events and time saved using E_TA with FIFO scheduler are 52% and 39 % respectively. In table 2 E_TA with non FIFO scheduler were compared to original non FIFO scheduler and the simulation time is 1814400 seconds which is equivalent to 504 hours. However significant acceleration was achieved using E_TA with non FIFO scheduler, where the number of events and time saved were 85% and 83% respectively.

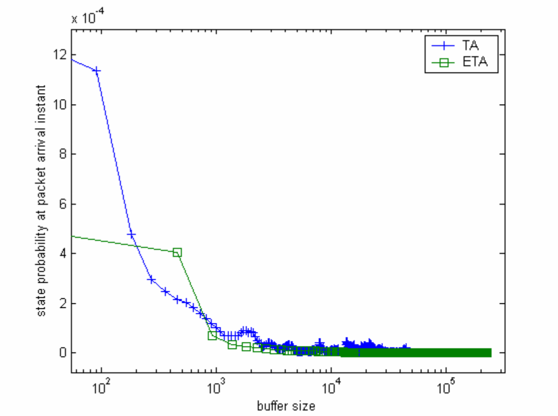

Figure 5: Queue distribution in the buffer of TA model and E_TA with FIFO scheduler model.

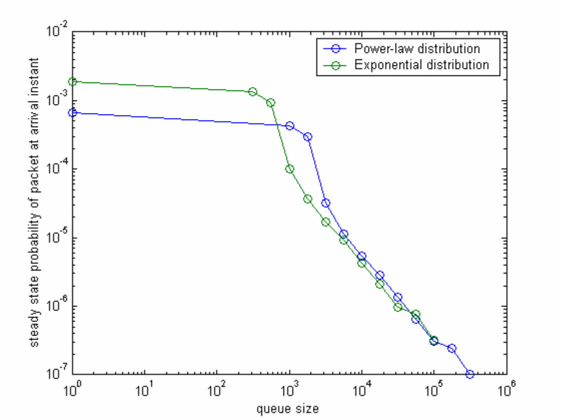

Figure 6: Queue distribution in the low priority sub queue comparing when one of the traffic sources has exponential distribution and all of the traffic sources have power law distribution.

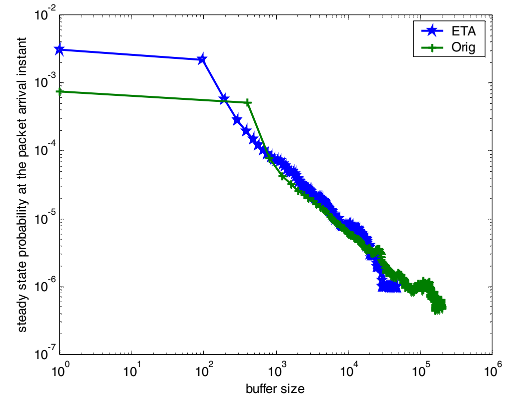

Figure 7: Comparing the queue distribution in the low priority sub queue of the original packet-by-packet of non FIFO scheduler method with the queue distribution in the buffer of E_TA with non FIFO scheduler.

TABLE 1
COMPARISON OF E_TA WITH FIFO QUEUE AND TA

load	**with FIFO queue**			
	TA		E_TA	
	No. of events (10^6)	Real time (s)	No of events (10^6)	Real time (s)
0.333	57	2276	33	1681
0.4	63	2514	33	1652
0.45	74	3050	32	1493
0.5	67	2644	29	1463

TABLE 2
COMPARISON OF E_TA WITH NON FIFO QUEUE AND CONVENTIONAL METHOD

load	**with non FIFO queue**			
	Conv		E_TA	
	No. of events (10^6)	Real time (s)	No. of events (10^6)	Real time (s)
0.333	23	1001	3	156
0.4	24	1058	3	191
0.45	28	1244	5	248
0.5	35	1552	5	239

VI. CONCLUSIONS

In this paper we developed an approach to accelerate simulation that can be used to simulate self-similar traffic in packet switched network efficiently. Using this approach we have simulated aggregate self-similar traffic in buffer of FIFO scheduler and non FIFO scheduler. Our simulation experiment provides E_TA with FIFO scheduler model accelerate simulation than TA model. Even though FIFO queue is a simple buffer to model but practically the real network support many type of services that have different priorities. Finally, the results show good agreement in the queue distribution of E_TA and TA with FIFO scheduler and E_TA and original with non FIFO scheduler when approaching the steady state.

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