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QUALITY OF SERVICE SYSTEM APPROXIMATION IN IP NETWORKS*

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Abstract. This paper presents Quality of Service analyses in wired and wireless IP networks based on the three popular techniques – RSVP, IntServ, and DiffServ. The analyses are based on a quick approximation schema of the traffic system with static and dynamic changes of the system bounds. We offer a simulation approach where a typical leaky bucket model is approximated with a G/D/1/k traffic system with flexible bounds in waiting time, loss and priority. The approach is applied for two cascaded leaky buckets. The derived traffic system is programmed in C++. The simulation model is flexible to the dynamic traffic changes and priorities. Student criterion is applied in the simulation program to prove results. The results of the simulation demonstrate the viability of the proposed solution and its applicability for fast system reconfiguration in dynamic environmental circumstances. The simulated services cover a typical range of types of traffic sources like VoIP, LAN emulation and transaction exchange.

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1. Introduction. IP networks and their high demand of Quality of Service (QoS) support is a challenging area for investigation. Recently the greater part of people's working time depends on the network and storage capabilities. There are many papers that try to deal with QoS in IP networks. In this paper we analyse the traffic policing and shaping effect of the three most used techniques – IntServ, DiffServ, RSVP and highlight the way it can be done for Network Signalling Protocol (NSIS). The analyses are made on the basis of the three popular services – VoIP, LAN emulation, transaction exchange [7, 8, 14, 16]. The traffic shaping effect is estimated with application of priorities and under observation of delay and delay jitter. The model uses queues and priorities specific for the IntServ, DiffSerf, RSVP.

Dynamic capacity requirements and environment quality parameters are estimated for video and audio traffic sources in [1]. The sensitivity of the quality parameters towards delay and delay jitter is demonstrated for wire and wireless networks. The author conclusion is that the end-to-end quality cannot be guaranteed with DiffServ technique. In [3] multimedia services and their QoS requirements are investigated for a WiFi network. In [4] authors demonstrate call admission control procedures for WiFi in order to guarantee QoS. A comparison between IntServ and DiffServ can be seen in [2]. A traffic model with cascaded queues suitable for core networks is shown in [12]. An analytical approach to queueing behavior of IP buffers is demonstrated in [13]. The specific queue behavior in WiMAX access channel is shown in [15]. A WLAN Brady voice traffic model is demonstrated in [17].

2. Traffic sources. Voice over IP, LAN emulation and transaction exchange types of traffic sources are assumed in an example local area network. Some adjustments are made for every traffic type. In a Voice over IP (VoIP) service silence and talk intervals are exponentially distributed with equal mean values [7] with activity detection. There are authors who use a talk to silence ratio of $1/2$. Others prefer to use an on-off model for voice service [14, 17]. The limits for waiting times are calculated under consideration of end-to-end delay limits for every service [11]. The same is valid for queue length [10]. Servicing times per packets are fixed according to the assumed fixed length packet header. Table 1 represents all the traffic source parameters in the model.

Table 1. Traffic Sources Parameters

Parameter	**VoIP**	**LAN**	**Transactions**
Pear rate, packets per second	10	164	0
Mean call/session duration, sec	180	20	10
Mean duration between calls/sessions, sec	360	10	15
Mean talk/silence duration, sec	20	5	2
Distribution of call/series duration	Exp.	Exp.	Exp.
Maximal waiting time, sec	0.00072	0.6	1
Maximal number of waiting packets	210	1804	2
Traffic sources	5000	500	1500
Priorities	High	Medium	Low
Packet length, bytes	800	800	800

3. Integrated Services. Integrated Services (IntServ) is a complex technique often called protocol that ensures Quality of Service in IP networks. It is applied usually in access routers or switches and tries to serve packets from different services in different ways depending on the quality requirements. IntServ classifies services into three main classes depending on the traffic requirements [8]:

- Elastic applications
- Tolerant real-time applications
- Intolerant real-time applications

Elastic applications are served with "best effort" discipline [16]. There is no guarantee of quality level . Tolerant real-time applications are delay sensitive and usually require high bandwidth. A token bucket model with peak rate control is a proper model for LAN emulation. Some authors propose token bucket with series length and mean rate control as a model for more accuracy. Many authors propose cascaded queues as shown below [16]. Intolerant real-time applications require low delays and almost guaranteed bandwidth. The model with two cascaded token buckets is used in this case [7]. The VoIP service is intolerant to quality degradation. The IntServ simulation model is based on two cascaded token buckets that bound the peak rate, series length and mean rate of the traffic (Fig. 1) [5, 6].

The model from Fig. 1 is quite complicated for simulation. Due to this reason it is approximated as a black box that changes the characteristics of the

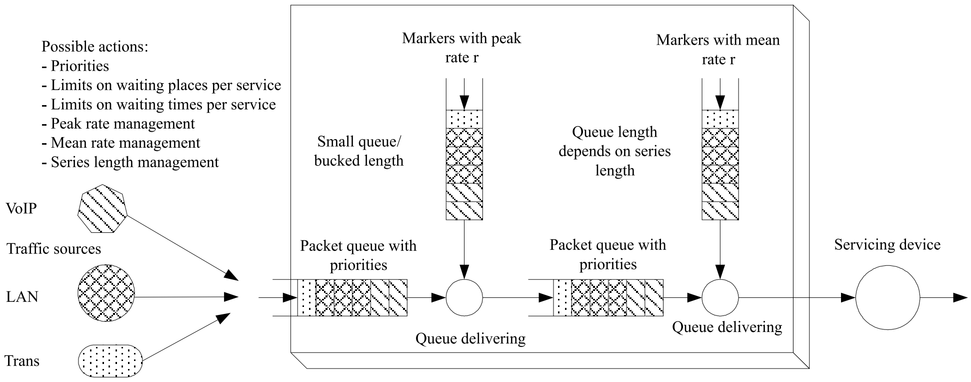

Fig. 1. An approximation of a Black box IntServ model

data into output data in a way specific for IntServ. As a result after approximation and some calculations the simpler model is derived with one FIFO queue, priorities, fixed rate at the output and different limits for waiting times in the queue. The approximation technique is called further on a quick approximation technique with static and dynamic changes of the system bounds and is represented on Fig. 2. The accuracy of the derived model is not changed end-to-end due to the fact that the interfaces at both ends are the same and with the same characteristics. The only thing changed during approximation is the internal packet management due to the work of the IntServ. This is the model that has been simulated further. Table 2 includes main data for model behaviour.

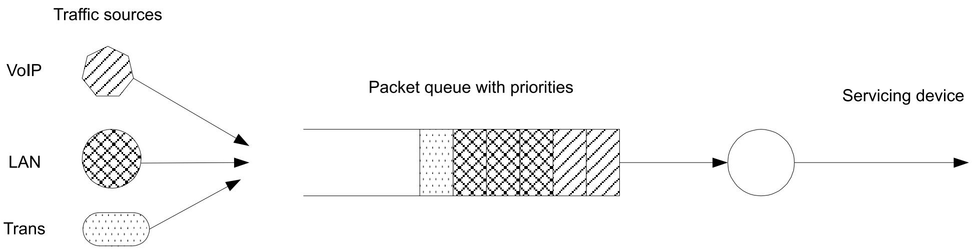

Fig. 2. Final IntServ model with input data, bounds in waiting times and queue length

4. Differentiated Services. Differentiated Services (DiffServ) is another quality management technique that is more applicable nowadays. Due to its nature DiffServ applies its rules on aggregated traffic. After appropriate marking

Table 2. Model characteristics in IntServ

Parameter	**Value**
Queue length, packets	2016
VoIP queue length fraction, packets	210
LAN queue length fraction, packets	1804
Transaction queue length fraction, packets	2
Maximal waiting time for VoIP, sec	0,000716
Maximal waiting time for LAN, sec	0,6
Maximal waiting time for transactions, sec	1
Priority for VoIP	Highest
Priority for LAN	Medium
Priority for transactions	Low

of the aggregated packets they are gathered in the way that is defined for their class. There are three types of services we try to highlight in this paper [14]:

- Premium service—low delays, low losses, guaranteed bandwidth like VoIP;
- Assured service—less requirements to the delays and losses in comparison to the premium service like LAN emulation;
- Olympic service—no time requirements at all like transaction exchange.

The two cascaded queues from Fig. 1 are approximated again with one single queue as it was done for IntServ above. The architecture is shown in Fig. 2 and calculated for DiffServ procedure. System parameters derived for DiffServ are shown on Table 3.

Table 3. Model characteristics in DiffServ

Parameter	**Value**
Queue length, packets	1840
VoIP queue length fraction, packets	200
LAN queue length fraction, packets	1640
Transaction queue length fraction, packets	2
Maximal waiting time for VoIP, sec	0,0303
Maximal waiting time for LAN, sec	0,27876
Maximal waiting time for transactions, sec	1
Priority for VoIP	Highest
Priority for LAN	Medium
Priority for transactions	Low

5. RSVP. Resource Reservation Protocol (RSVP) is a technique useful for delay sensitive traffic like VoIP. Three types of services are identified for RSVP, as follows:

- Wildcard filter—applied to gather maximal requirements for given interface like LAN emulation;
- Shared explicit—applied to gather maximal requirements for the interface taking into account the called address. Transaction exchange is modeled as shared explicit service;
- Fixed filter—full reservation for quality sensitive services like VoIP

The queue architecture for RSVP is shown on Fig. 2. After application of the quick approximation schema calculation of RSVP parameters is done and the results are shown in Table 4. Similar results can be derived having any other VoIP signaling protocol in the network like SIP or H.323. The signalling capabilities of NSIS protocol will not change drastically the model parameters for VoIP service in comparison to the one in Table IV. Connection establishment and connection release procedures in almost all VoIP applicable protocols are similar.

Table 4. Model characteristics in RSVP

Parameter	**Value**
Queue length, packets	1840
VoIP queue length fraction, packets	200
LAN queue length fraction, packets	1640
Transaction queue length fraction, packets	2
Maximal waiting time for VoIP, sec	0,07508
Maximal waiting time for LAN, sec	0,69
Maximal waiting time for transactions, sec	1
Priority for VoIP	Highest
Priority for LAN	Medium
Priority for transactions	Low

6. Results. The simulation is performed in the language C++. The pseudo-exponential pseudo deterministic characteristics of the traffic sources are reached after combination of many random generators [9, 10, 11]. The behavior of the queue is complex due to the priorities and limits on waiting times. Many parameters have been derived from the model like probability of packet loss due

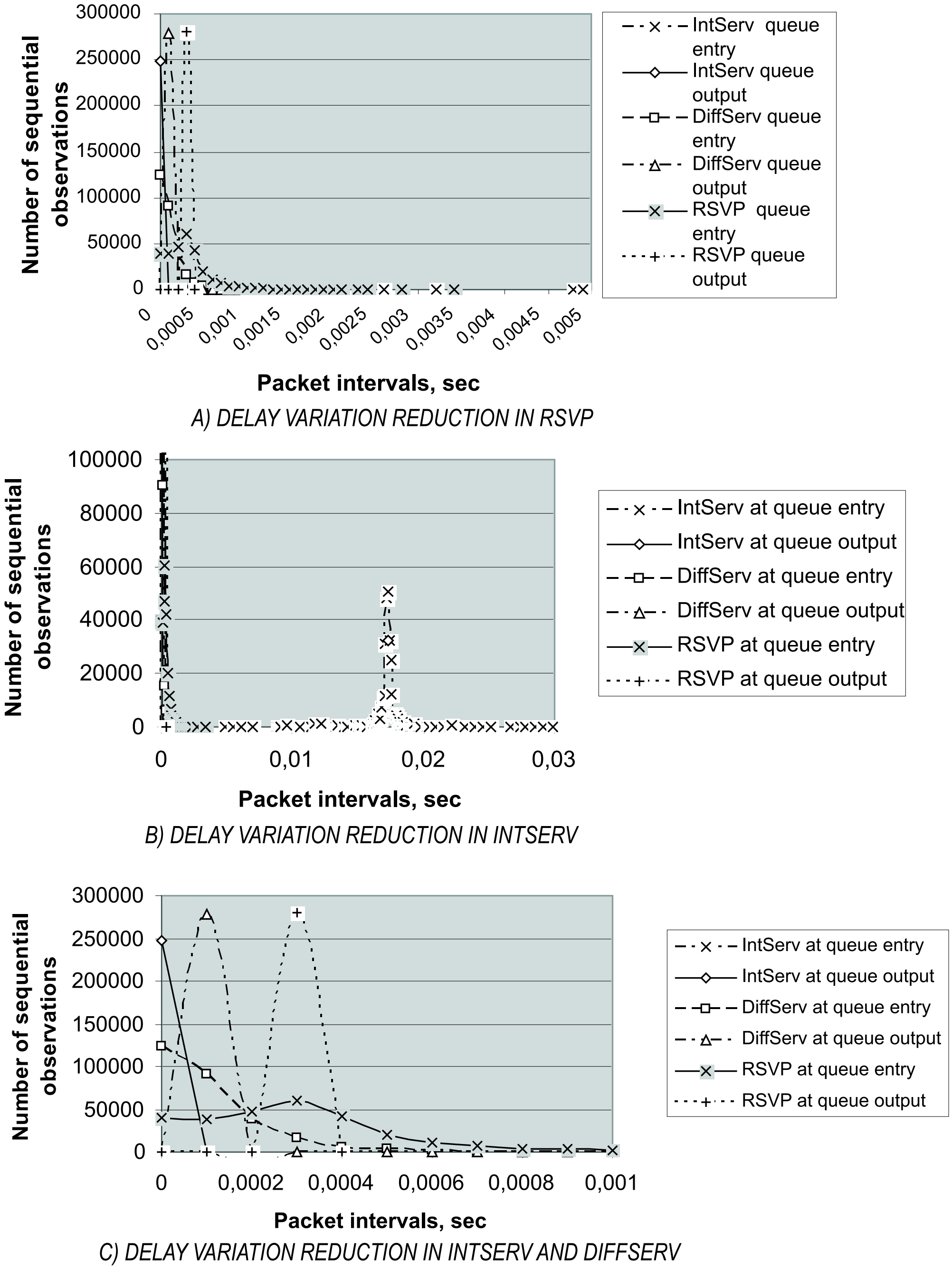

Fig. 3. Delay variation of packets in queue input and output for IntServ, DiffServ and RSVP

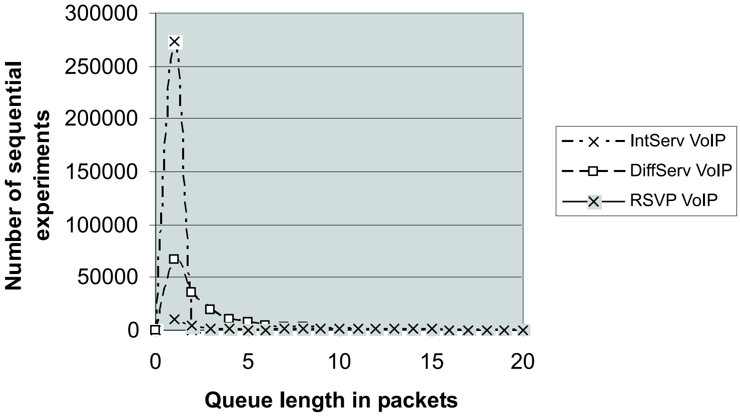

Fig. 4. Queue length in VoIP

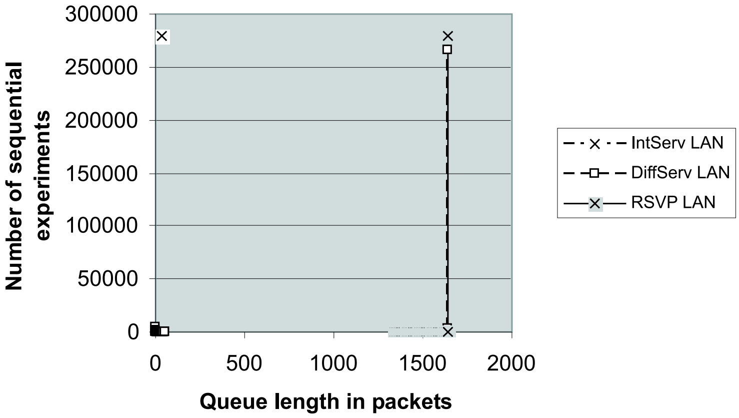

Fig. 5. Queue length in LAN

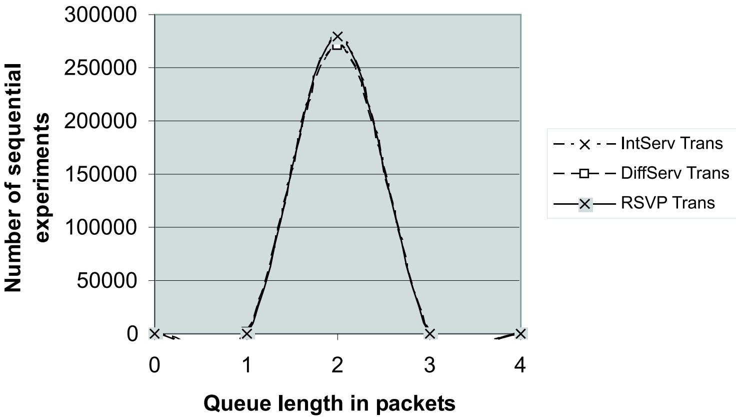

Fig. 6. Queue length in transaction exchange

to the lack of room in the queue, probability packets being dropped due to an exceeded waiting limit, probability to wait for different types of traffic, observations on of the packet intervals, queue lengths, delay, delay jitter, waiting times at many interface points in the model like output of the traffic sources, input and output of the queue. The statistical accuracy of the derived results is proven by Student criterion. The presented results are in the 90% confidence interval from a statistical point of view. IntServ, DiffServ and RSVP have different ways of dealing with packets and this influences the way they police, drop and shape them. In Fig. 3 packet intervals at the input and output of the queue are shown. It is interesting for jitter and shaping effect estimation. The effect of faster servicing in RSVP can be seen from a). The delay variation of the packet intervals is becoming smoother and tends to a constant value. A similar result is visible for IntServ on b). On c) the shaping of the IntServ and DiffServ is seen again.

Interesting results that influence directly interfaces and queue management are derived on the basis of queue length per service type. The queue fraction of the three services is observed. It is visible from Fig. 4 that for services with highest priority like VoIP IntServ is the most proper mechanism. Fig. 5 and Fig. 6 represent the same probability density function for LAN and transaction services. Because of the less critical waiting times and low priority the nature of waiting times for LAN packets tends to be deterministic. In Fig. 6 graphs for IntServ and RSVP are overlapped.

Table 5 represents mean values of the queue lengths per discipline and per service. They can be used for approximate planning of the time and space limits in the router interfaces.

Table 5. Mean queue length

Mechanism	Mean queue length, packets	Mean queue length of VoIP fraction, packets	Mean queue length of LAN fraction, packets	Mean queue length of Trans fraction, packets
IntServ	37.97523	1	35	2
DiffServ	1586.961	2.24207	1583.561	1.98331
RSVP	1798.409	156.9017	1639.675	2

7. Conclusion. In this paper we show observations on delay and delay jitter of packets in an IP router and queue length per service type. These results demonstrate the specific characteristics of the device as a packet policing/shaping facility in three QoS management algorithms: IntServ, DiffServ, RSVP. The deterministic nature of the packet streams suppress shaping and increases losses. The statistical multiplexing effect is limited due to the deterministic streams.

The results demonstrate the capability of IntServ to ensure excellent service for its higher priority applications. It is promising in access networks. DiffServ shows excellent resource management and utilization and therefore is better for core services. RSVP is a good counterpart of IntServ in access networks. Its development to NSIS protocol is going to be a powerful QoS assurance technique. The authors prove the capability of the quick approximation technique in fast interface bounds calculations and adjustments. The result is important in networks with dynamic changes in quality of service requirements. The fractional shaping phenomenon demonstrated in the paper is important in small enterprise Local Area Networks (LAN) or limited distance MAN. The authors refine the simulation model with more traffic sources and more precise generation of the packets from these sources based on the observation of the real traffic. MMPP and geometric/Weibull distributions are also considered. Limits criteria and threshold dynamic calculation for queue management are also under investigation.

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