Applicability of the Extensions of the Erlang Multirate Loss Model on ABR Services in ATM Networks

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Abstract *In this paper, we evaluate three extensions of the* Erlang Multirate Loss *Model by comparing them, based on the resultant call blocking probabilities for ABR services in ATM networks. In the first extension, the* retry models, *blocked calls can retry with reduced resource requirements and increased arbitrary mean residency requirements. In the second one, the* threshold models*, request sizes and residency times are state dependent. We propose a third extension, the* connection-dependent threshold model*, which resembles* the threshold models, *but the state dependency is individualized among call connections. Our investigation shows that the retry models can hardly approach the behavior of ABR services, while the proposed model performs much better than the other two extensions.*

1. Introduction

ATM networks are designed to accommodate a variety of service-classes with different traffic description parameters and quality-of-service (QoS) requirements. We study the QoS assessment of call level traffic in the multi-service environment of ATM networks which is very important since it is basic requirement for several network/traffic controls like connection admission control, virtual path bandwidth control and network planning. In order to assess the call-level QoS of ABR and CBR services, we evaluate the call blocking probability (CBP). On the call level, ATM networks that accommodate CBR and VBR can be modeled as multi-rate circuit switched networks [1] due to the notion of *equivalent bandwidth* [2]. Therefore, we manage the call-level traffic of CBR and VBR services by using the Erlang Multirate Loss Model (EMLM) [3]. In the case of ABR services the notion of CBP needs to be reconsidered, because no resource allocation is made prior to the information transfer phase. The CBP depends strongly on the required holding (service) time of an ABR call-connection, while the holding time depends on the available bandwidth and it is not known in advance for ABR services. Nevertheless, it is possible to calculate the CBP of ABR and QoS guarantee services, by using the notion of "total" offered traffic-load [4]. The traditional models for calculation of CBP pay no attention to congestion control, which is quite important for ABR services. Two models, which comprise some kind of congestion control, are the retry and the threshold models [5,6].

In this paper we propose a generalization of the threshold models, called connection-dependent threshold model (CDTM), whereby we approach much better the behavior of ABR services. With application examples, we reveal the superiority of the CDTM in respect of CBP while simulation results in [7] show the validity of the CDTM.

2. The connection-dependent threshold model (CDTM)

Consider k (k=1,2…K) independent service-classes of Poisson arriving calls, which offer traffic-load α_k and request an integer valued b_k bandwidth and μ_k^{-1} mean holding time, and a transmission link (Virtual Path, VP) of bandwidth C (C servers).

In the threshold model instead of waiting for calls to be blocked and then retry, bandwidth and service time requests depend on the total number of occupied bandwidth units, denoted by *j*. In other words, a call of service-class k, may attempt n+1 times to be connected; one initial attempt with parameters (b_{kc}, μ_{kc}^{-1}) and n more attempts, with parameters (b_{kc_l}, $\mu_{kc_l}^{-1}$), l= 1,…,n, where $b_{kc_n} < \ldots < b_{kc_1} < b_k$ and $\mu_{kc_1}^{-1} > \ldots > \mu_{kc_n}^{-1} > \mu_k^{-1}$; the pair ($b_{kc_l}$, $\mu_{kc_l}^{-1}$) is used when $J_l < j \le J_{l+1}$, $J_{n+1} = C$, while the highest possible threshold is $J_n = C - b_{kc_n}$. According to [7] the final unconditional CBP for the threshold models, B_k, is defined as:
$B_k = \text{Prob}\{ j > C - b_{kc} \} = \text{Prob}\{ j > C - b_{kc} \mid j > J_n \} * \text{Prob}\{ j > J_n \}$.and is given by:

$$B_k = \sum_{j=C-b_{kcn}+1}^{C} G^{-1} G(j) \quad (1)$$

where:

$$G(j) = \left\langle \begin{array}{ll} 1 & \text{for } j = 0 \\ \frac{1}{j}\sum_{k=1}^{K} a_k b_k \delta_k(j) G(j-b_k) + \frac{1}{j}\sum_{k=1}^{K}\sum_{l=1}^{n} a_{kc_l} b_{kc_l} \delta_{kc_l}(j) G(j-b_{kc_l}) & \text{for } j = 1,\ldots,C \\ 0 & \text{otherwise} \end{array} \right\rangle \quad (2)$$

and: $\delta_k(j) = 1$ when $1 \le j \le C$ and $b_{kc} = 0$, or, when $j \le J_1 + b_k$ and $b_{kc} > 0$, otherwise $\delta_k(j) = 0$.

$\delta_{kc_l}(j) = 1$ when $J_{l+1} + b_{kc_l} \ge j > J_l + b_{kc_l}$, otherwise $\delta_{kc_l}(j) = 0$.

$\alpha_{kc_l} = \lambda_k \mu_{kc_l}^{-1}$ (λ_k is the arrival rate of calls).

In the CDTM, these thresholds are not common for all service-classes but they are individualized among the call-connections. Therefore, the pair (b_{kc_l}, $\mu_{kc_l}^{-1}$) is used for service-class k when $J_{kl} < j \le J_{k\,l+1}$, $J_{k\,n+1} = C$, while the highest possible threshold is $J_{kn} = C - b_{kc_n}$. By convention, $b_k = b_{kc_0}$ and $\mu_k^{-1} = \mu_{kc_0}^{-1}$. Based on [6,7], we conclude that we can use equation (1), in the proposed CDTM, as the recurrent formula for calculating G(j), the probability j out of C trunks to be seized, by introducing the following modifications:

- $\delta_k(j) = 1$ when $1 \le j \le C$ and $b_{kc} = 0$, or, when $j \le J_{kl} + b_k$ and $b_{kc} > 0$, otherwise $\delta_k(j) = 0$.
- $\delta_{kc_l}(j) = 1$ when $J_{k\,l+1} + b_{kc_l} \ge j > J_{kl} + b_{kc_l}$, otherwise $\delta_{kc_l}(j) = 0$.
- $\alpha_{kc_l} = \lambda_k \mu_{kc_l}^{-1}$ (λ_k is the arrival rate of calls).

3. Numerical results

We consider a VP link in ATM network that accommodates four service-classes with bandwidth capacity 300 bandwidth-units (b.u.). The first two, s_1 and s_2 are CBR services, which require 1 b.u. and 6 b.u. per call, respectively. For example, assuming that 1 b.u. = 64 Kbps, s_1 could correspond to the telephony, and s_2 to the videophony (of 384 Kbps). The other two s_3 and s_4, are ABR services. S_3 requires 6 b.u. per call and can reduce it to 2 b.u., unit by unit, according to the amount of bandwidth that is available in the VP link (see Fig. 1). We choose s_3 from a set of 7 ABR services, which all have the same behavior, but they are distinguished from the first point of available bandwidth at which they change the required bandwidth per call (see Fig. 1, horizontal axis). Two out of the 7 ABR services, ABR 1_1 and ABR 1_7, are shown in Fig. 1, for s_3. S_4 requires 24 b.u. (1.536 Mbps) per call and it can reduce it to 8 b.u. per call, in steps of 4 b.u., or unit by unit. Alternatively, s_4 can reduce the required bandwidth per call to 11 b.u., unit by unit, according to the available VP bandwidth. So, we choose s_4 from three sets of 7 ABR services per set, which are distinguished by: a) the contingency minimum required bandwidth per call, b) the step whereby the bandwidth per call is reduced and c) the first point of available bandwidth at which they change the bandwidth per call.

Fig. 1 portrays two ABR services from each set: ABR 2_1 and 2_7 (first points for resize = 24 b.u. and 84 b.u., respectively, min. bandwidth per call = 8.b.u., step = 4.b.u.) from the set of ABR 2, ABR 3_1 and 3_7 (first point for resize = 24 b.u. and 84 b.u., respectively, min. bandwidth per call = 11 b.u., step = 1.b.u.) from the set of ABR 3 and ABR 4_1 and 4_7 (first point for resize = 24 b.u. and 84 b.u., respectively, min. bandwidth per call = 8 b.u., step = 1 b.u.) from the set of ABR 4.

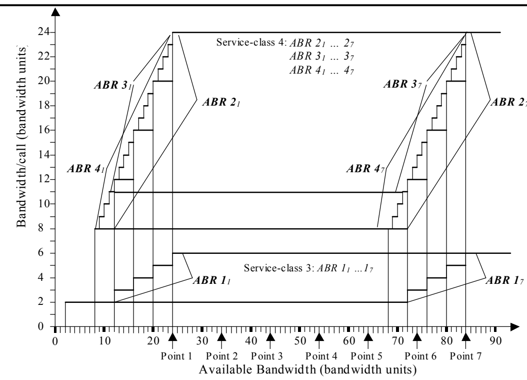

Figure 1: ABR services for service-class s_3 and s_4.

We calculate the CBP by applying the formulas of [5,6] and section 2 and compare their results. We consider the following traffic-loads offered to the VP: 100 erl for s_1, 12 erl for s_2 and s_3, and 1 erl for s_4. Since small values of CBP result from the above traffic characteristics (light traffic), we assume the double amount of offered traffic-load for s_3 and s_4 (heavy traffic). We consider s_3 and s_4 as any combination of ABR services shown in Table 1, and we apply the multi retry model (MRM). The retry models cannot distinguish ABR services that belong to the same set. Therefore, we apply the MRM only once for each combination of ABR-service set, in order to get approximated CBP. This approximation takes into account that calls decrease their bandwidth, while, at the same time, they increase their holding time. Nevertheless, this mechanism is not incorporated into the retry models with accuracy, and it is performed step by step. Thus, the retry models hardly approach the behavior of ABR services.

	(s_3:ABR **1**, s_4:ABR **2**)	(s_3:ABR **1,** s_4:ABR **3**)	(s_3:ABR **1,** s_4:ABR **4**)	(s_3:ABR **1,** s_4:ABR **2_7**)
1	(ABR 1_1, ABR 2_1)	(ABR 1_1, ABR 3_1)	(ABR 1_1, ABR 4_1)	(ABR 1_1, ABR 2_7)
…	(… , …)	(… , …)	(… , …)	(… , …)
7	(ABR 1_7, ABR 2_7)	(ABR 1_7, ABR 3_7)	(ABR 1_7, ABR 4_7)	(ABR 1_7, ABR 2_7)

TABLE 1: ABR services for service-classes s_3 and s_4.

The CBP obtained are presented in Table 2, assuming or not bandwidth reservation (BR).

Service-classes	Light traffic		Heavy Traffic	
	Without BR CBP (%)	With BR CBP (%)	Without BR CBP (%)	With BR CBP (%)
s_1: telephony	2.318	8.724	8.292	28.021
s_2: videophony	7.886	8.724	27.676	28.021
s_3: ABR 1	First:7.886 Final:3.627	First:8.724 Final:0.439	First:27.676 Final:12.874	First:28.021 Final:1.810
S_4:ABR2 or ABR 2_7	First:26.602 Final:9.716	First:8.724 Final:1.544	First:69.539 Final:33.696	First:28.021 Final:5.980

TABLE 2: Results of the MRM for s_3: ABR **1** and s_4: ABR **2**, or ABR **2_7**.

Then, we apply the multi threshold model (MTM) and CDTM to calculate the CBP. The MTM is not possible to be applied to any combination shown in the 1st column of Table 1, but ABR 1 and 2. For the rest of the combinations, we have to apply the CDTM. Due to space limitation we present only one figure (Fig. 2). The seven GoT correspond to the seven rows of Table 2. For example, the 1st GoT of Fig. 2 refers to ABR 1_1 and 2_1, and has the values (276, 280, 284, 288) for both ABR services, the 2nd GoT refers to ABR 1_2 and 2_2, and has the values (266, 270, 274, 278) for both ABR services, a.s.o. The CBP, shown by bars in figure 2, present final, unconditional CBP, without BR. Figure 3 show the results of the EMLM, MRM and MTM or CDTM when light traffic-load is assumed and the GoT is the 1st or the 7th. The 1st GoT is chosen because the resultant CBP of the MTM/CDTM is close to MRM. The 7th GoT is chosen not only because bigger differences between CBPs result, but also in order to show that as the set of thresholds draw away from the VP capacity C, the CBP converge to values very close to the right-hand-side CBP of Fig 2.

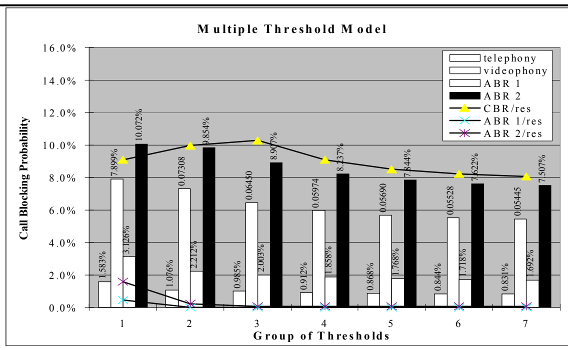

Figure 2: CBP obtained by MTM for s_3:ABR 1 and s_4:ABR 2

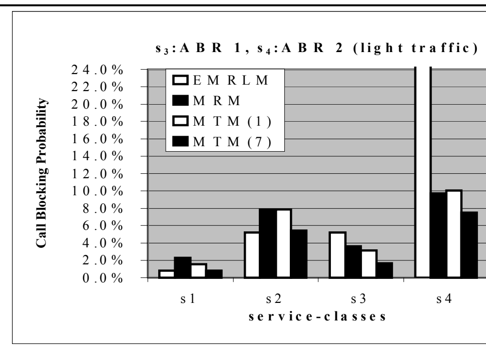

Figure 3: Models comparison, based on Table 2 and Fig. 2

4. Conclusion

We evaluate the call level QoS of both CBR and ABR services in a common way. We reveal the superiority of the proposed connection-dependent threshold model against the other models, in respect of its applicability and the resultant CBP, by applying them to realistic service-classes accommodated in a VP and comparing the results.

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