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Improved Performance of Traffic Dependent Outage Rate Cellular System

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Abstract: The designers of a mobile cellular system must evaluate the possible configurations of the system components and their characteristics in order to develop a system with greater efficiency. The useful parameters to estimate performances of the system are voice quality, frequency spectrum efficiency and grade of service (GOS). In this study, a scheme proposed to reduce the lost calls and interruptions due to the outage channels is tested in the traffic dependent outage rate wireless cellular system. In this scheme no call is dropped but could be delayed. The performance parameters considered for this study is the probability of delay and the mean waiting time for priority and non-priority calls for non-preemptive type. The system is evaluated for different conditions and the results are discussed.

Key words: Outage Channel, Delay Probability, Priority Calls, Waiting Time

INTRODUCTION

Mobile network rely on wireless links to communicate with the rest of the network. The quality of a wireless link is less predictable than that of a wire line link and may fluctuate considerably depending upon network conditions. The main environmental factors that effect the quality of a wireless link are distance between link end points, externally generated noise, interference accidental and intentional among multiple transmissions, varied terrain (resulting in multi-path propagation and obstructions between end points) etc. Although transmission power adjustments, error correction, data-link control protocols can reduce the effects of many of these factors and channels access procedures but cannot eliminate them completely. Hence, mobile networks must accommodate not only moving users and switches but also highly variable links [1]. It is a common practice to define channel loading in term of the number of mobiles each channel will support in the mean busy hour to give the users a desirable GOS [2]. Thus, the GOS can define as the number of unsuccessful calls relative to the total number of attempted calls [2-4]. GOS is a measure of the probability that a percentage of the offered traffic will be blocked or delayed. As such, GOS is commonly expressed in terms of fraction of calls failing to receive immediate service (blocked calls), or the fraction of calls forced to wait longer than a given time for service (delayed calls). The GOS in cellular system is affected not only by the system's traffic but also by co-channel interference. The communication between two subscribers in analog cellular system, the user experiences absence of the desired signal and some noise or crosstalk. Even if link outages are very short, they collectively degrade the system performance, although they may not be individually recognized [5]. In a cellular system, the presence of co-channel interference can cause the signal to noise ratio (C/I or SIR) to drop below a specified threshold level φ. Such an event known as outage can cause loss of the communication and affects the grade of service [6, 7]. Outage probability is one of the most important criteria for evaluating the performance of cellular networks [8]. A study of the grade of service degradation due to outage will be useful in evaluating the system performance. Also, it could help the telecommunications industry in developing more robust systems. The normal system models are developed on the basis of Markov chain using M/M/C queue model. A new call comes to the cellular system by arrival rate λ. If there is available channel in the cell, a call is connected and the channel becomes busy. The call service rate is taken to be μ. If there is no available channel the call is blocked. The Erlang's C formula is used to calculate the probability of delay as given by [9] and the formula is

$$P_D = C(N, A) = \frac{A^N}{N!}\frac{p_0}{1-\frac{A}{N}} \tag{1a}$$

where ,

$$p_o = \left[\sum_{i=0}^{N-1} \frac{A^{\ i}}{i!} + \frac{A^N}{(N)!}\frac{1}{1-\frac{A}{N}} \right]^{-1} \tag{1b}$$

Where N is the total number of channels available and A is the traffic intensity given by A = (λ /μ). Even when the call gets connected if the C/I ratio drops below threshold the channel goes to outage and communication is affected or lost. From the normal working condition the line goes to outage condition. When call is completed or channel recovers from outage again it becomes available. In some investigations [7] while estimating the effect of outage it was taken that if there is no available channel the call is blocked or dropped. In this case they did not consider the aspect of the mean waiting time with priority calls. Some researchers have evaluated the performance of mobile systems with priority concept where in when no line is available the call is queued up. Priority calls are placed in a queue before all non-priority calls but never interrupt a call in progress [10]. However they did not consider the concept of outage. In this study both outage and priority concepts are considered in system evaluation.

Present Scheme: A new scheme incorporating a buffer memory is proposed by the authors and performance was tested for fixed outage rate cellular system [11]. The buffer queues up the incoming calls and the outage calls as well for large cellular system. The same scheme is now used to analyze the performance of traffic dependent outage system. In traffic dependent outage system both call arrival rate λ and departure rate μ are state dependent. Such a system at a given time has low traffic (few users), but suddenly the traffic begins to rise (for example, at the beginning of the busy hour). This increased traffic will cause higher interference leading more number of channels to outage. Therefore, it can be assumed that both γ_i and α_i are state dependent. In other words, $\gamma_i = (i+1)*\gamma$, $\alpha_i = i*\alpha$, where i is the state considered.

At any time we can consider that new calls arrive at rate λ and outage occurs at rate γ. Thus the effective arrival rate to memory is $\lambda_e=\lambda+(i+1)\gamma$. Similarly calls are completed at rate μ and outage channels recover at rate $i*\alpha$. Thus the effective rate at which channels are becoming available will be $\mu_e=(\mu+\alpha)$. With these considerations we define the effective traffic intensity as $Ae = (\lambda_e/\mu_e)$. When k channels are in outage, the available channels will be N-k. Thus using the effective rates and number of channels as (N-k) instead of N in Erlang's C equation (1) the probability of delay will be given by:

$$P_D = C(N-k, A_e) = \frac{A_e^{N-k}}{(N-k)!}\frac{p_0}{1-\frac{A_e}{(N-k)}} \tag{2a}$$

Where,

$$p_o = \left[\sum_{i=0}^{N-k-1}\frac{A_e^{\,i}}{i!}+\frac{A_e^{\,N-k}}{(N-k)!}\frac{1}{1-\frac{A_e}{N-k}}\right]^{-1} \tag{2b}$$

When there are no channels in outage k will zero and the above equations reduce to those in (1). The probability of delay calculated according to equation (2) is used in the evaluation of waiting times. For the calculation of mean waiting time of priority and non-priority calls the relations of Francisco et al [4] are used with N replaced by N-k in the modified relations will be:

$$WT_1 = \frac{(P_D*d)}{(N-k)(1-p\rho)} \tag{3}$$

$$WT_2 = \frac{(P_D*d)}{(N-k)(1-p\rho)(1-\rho)} = \frac{WT_1}{(1-\rho)} \tag{4}$$

WT_1 and WT_2 are the waiting time for calls with priority and non-priority respectively, d is the average call duration, ρ is overall system load and p is the priority proportion. The load due to priority calls will be ρ x p [4]. The evaluation conditions of channel system are heavy traffic (high ρ) and low priority propagation (low p) to maintain the effectiveness of the priority system. To evaluate the system performance the following parameters are selected. The number of channels N= 100. The traffic is 500 calls/hour. Average call duration 3 minutes. The outage arrival rate γ=0.00664 and outage recovery rate α=0.5.

RESULTS AND DISCUSSION

The values of probability of delay and waiting times calculated for traffic dependent model for several conditions are presented in Figs. 1 and 2. From the results we find that the probability of delay P_D increases with increase in outage channels and decreases with increase in recovery rate. Further we notice that P_D depends on traffic intensity. Increase in traffic intensity causes higher values for probability of delay P_D (Fig. 1). It is observed that the probability of delay varies linearly for lower values of k. For higher values of k this variation is exponential. When priority is introduced the waiting times for priority calls is less than those of non-priority calls and their variation is in line with those reported in literature [4]. This helps in understanding the delay of calls with outage

Table 1: Mean Waiting Time for Priority and Non-Priority Calls for 500 Call Where N=100 A_e = 40 and α = 0.5

	k	PD	Priority Percentage				
			0.1	0.2	0.3	0.4	0.5
WT1	0	3.635E-02	6.576E-04	6.609E-04	6.642E-04	6.676E-04	6.711E-04
WT2			6.922E-04	6.957E-04	6.992E-04	7.028E-04	7.064E-04
WT1	10	8.142E-02	1.637E-03	1.645E-03	1.653E-03	1.662E-03	1.670E-03
WT2			1.723E-03	1.731E-03	1.740E-03	1.749E-03	1.758E-03
WT1	20	1.693E-01	3.829E-03	3.848E-03	3.868E-03	3.888E-03	3.908E-03
WT2			4.031E-03	4.051E-03	4.072E-03	4.093E-03	4.114E-03
WT1	30	3.280E-01	8.477E-03	8.520E-03	8.563E-03	8.607E-03	8.651E-03
WT2			8.924E-03	8.969E-03	9.014E-03	9.060E-03	9.107E-03
WT1	40	5.933E-01	1.789E-02	1.798E-02	1.807E-02	1.816E-02	1.826E-02
WT2			1.883E-02	1.893E-02	1.902E-02	1.912E-02	1.922E-02

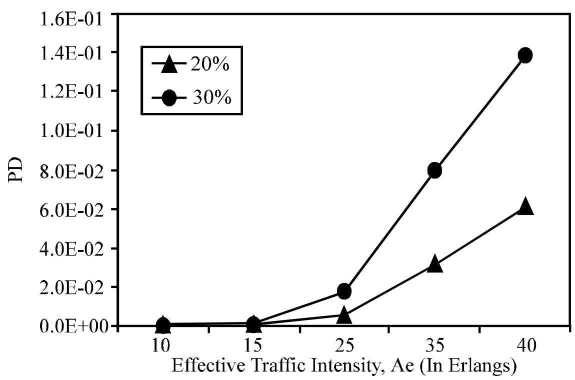

Fig. 1: Probability of Delay versus Effective Traffic Intensity for Different Outage Load where N=100 and γ =0.00664

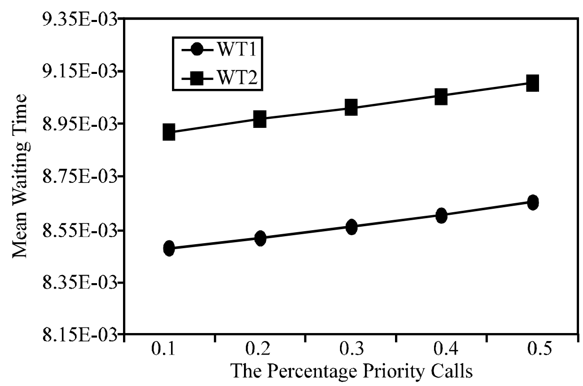

Fig. 2: The Mean Waiting Time for Priority Calls for 100 Channels where A_e =40, α=0.5 and the Outage Channel 30%

consideration and indicates how long a customer has to wait under various traffic conditions. This also helps to decide the proper buffer size. The mean waiting times of priority and non-priority calls for several conditions estimated using the proposed model are given in Table 1. The values for k=0 do represent the results of Francisco *et al*., model [4]. It is observed that for any load condition the delay is more for non-priority calls than that of priority calls. Since the outage calls are queued along with normal arriving calls into the buffer, as the number of outage channels increase the waiting times also increase. With the present scheme, due to the introduction of buffer, there will be marginal increase in delay but no call is lost. In other words the probability of blocking is zero with the proposed method.

CONCLUSION

The performance parameters that considered in this study is the probability of delay and the mean waiting for priority and non-priority for non-preemptive type. With the present scheme the normal calls and outage calls are queued up, the calls may be delayed more but never dropped. The priority calls are delayed less than non-priority calls. This improves the system reliability.

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