Mobile Cellular Traffic with the Effect of Outage Channels

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INTRODUCTION

The designer of the cellular network must evaluate the possible configurations of the system components and their characteristics in order to develop a system with greater efficiency. This article studies the grade of service (GOS) degradation in the presence of outage for a mobile cellular network where the number of channels in outage can be used as an indicator of the traffic load for two models, namely fixed outage rate and traffic dependent outage rate. The performance parameters considered for this article are: the probability of delay, waiting time for priority and non-priority calls, mean waiting time, and priority gain; each is estimated for both models. The system is evaluated and compared under different conditions.

BACKGROUND

The mobile user behavior has a higher traffic impact (in both space and time) than in the fixed network line. The call initiation sites are scattered and dynamically changing over a geographical area, while the bandwidth associated with a connection may have to be provided to different sites throughout the call; the radio signal will change from one cell to another following the user call movement, and in such environments, the efficient allocation of wireless channels for communication sessions is of vital importance as the bandwidth allotted for cellular communication is limited. The number of wireless communication service users as well as the frequency of the available services increased with an unexpected rate. The analysis of traffic deployed with wireless communication networks is important for determining the operation for a mobile user's status. Mobile cellular traffic varies greatly from one period to another and not in any uniform manner, but according to the cellular user's needs. Teletraffic theory is used to specify the methods to ensure that the actual GOS is fulfilling the requirements. The calls in the cellular network are made by individual customers according to their habits, needs, and so forth, and the overall pattern of calls will vary throughout the day. The cellular network equipment should be sufficient in quantity to cope satisfactorily for the period of maximum demand in the busy hour, depending on availability of free channel. In order to determine the optimal channel loading, it is necessary to relate the GOS to traffic characteristics. Traffic modeling is necessary for cellular network provisioning, for predicting utilization of cellular network resources, and for cellular network planning and developments (Vujicic, Cackov, Vujicic, & Trajkovic, 2005) to specify emergency actions when systems are overloaded or technical faults occur. GOS could be defined as the number of unsuccessful calls relative to the total number of attempted calls (Nathan, Ran, & Freedman, 2002; Zhao, Shen, & Mar, 2002; Hong, Malhamd, & Gerald, 1991).

Voice traffic network has been modeled by the Erlang C formula (Yacoub, 1993), which is used in cases where all users have access to all channels in the mobile network and where there are a large number of users using the available channels (Nathan et al., 2002). The number of required channels is used as a fraction of user traffic intensity and desired GOS. The GOS in a cellular system is affected not only by the system's traffic but also by co-channel interference. The cellular system presence of co-channel interference can cause the carrier-to-interference ratio (C/I) to drop below a specified threshold level (Annamalai, Tellambura, & Bhargava, 2001; Aguirre, Munoz, Molina, & Basu, 1998; Yang & Alouini, 2002, 2006; Zhang, 1996**); s**uch an event is known as outage. In some cases, outage can cause the loss of the communication system.

Aguirre et al. (1998) estimated the effect of an outage channel for many models where there are no available channels and the call is blocked or dropped. In this case they did not consider the aspect of buffering the dropped calls (outage calls) and the mean waiting time with priority calls. Another researcher evaluated the performance of mobile systems with priority concept, where no channel is available when the call is queued through to when the available channel has been assigned, and the priority calls are placed in a queue before all non-priority calls but never interrupt a call in progress (Barcelo & Paradells, 2000); however they did not consider the concept of outage.

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Figure 1. Outage parameter
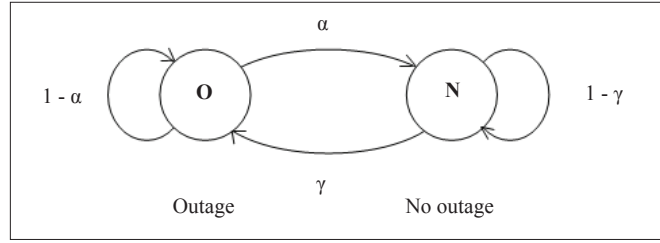
The major contributions of this article are to analyze the performance of a mobile communication system including GOS degradation due to the outage, when the calls as well as the outage channels in the cellular system are queued in the same buffer according to their priority, and for two different models to evaluate the performance of outage channel on the cellular network.

THE OUTAGE PARAMETERS

When the C/I is dropped below a certain quality threshold (ϑ) in a given channel, it becomes unusable and it affects the GOS in the cell. While two subscribers are communicating in the cellular network, the user could experience an 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. Generally only outages listing longer than tens of milliseconds are recognized and can cause the dropout of the communication (Caini, Immovilli, & Merani, 2002). When the new calls come to the cellular system (by arrival rate λ) and there is a free channel in the cell, the call will engage one of the free channels and the channel becomes busy. The channel can go into outage with outage arrival rate γ, and the outage channel may recover by the outage recovery rate α. Thus, the numbers of available channels for service become a random variable due to the stochastic nature of the outage.

A channel from a normal working condition may become unavailable (or move into the outage state) due to drop in C/I. Thus, the two-state simple model shown in Figure 1 can represent its behaviors. The state O represents a channel in outage, while state N represents a state in it normal condition. The parameters γ and α represent failure and recovery rates. These rates can be represented in terms of steady-state probabilities O and N by the following analysis.

The probabilities of being in states O and N are:

$$O = \gamma N + (1 - \alpha)O \qquad (1)$$

$$N = (1-\gamma)N + \alpha O \qquad (2)$$

In addition, they satisfy $O + N = 1$. After solving this system of equations, the following is obtained:

$$O = \frac{\gamma}{\gamma + \alpha} \qquad (3)$$

$$N = \frac{\alpha}{\gamma + \alpha} \qquad (4)$$

By sorting out $\gamma + \alpha$ in both previous equations and equalizing them, it is found that

$$\alpha = N\gamma / O \qquad (5)$$

With the above equation, the outage arrival rate γ or the outage recovery rate α, assuming one of them, a value of the outage probability can be obtained. The relations for the outage γ and α are used to find the probability of delay for a different cellular system under different conditions. The design is extended for the normal cellular system by considering the outage channels where the outage channel calls as well as the normal incoming calls are queued in the same buffer as shown in Figure 2.

Queues occur wherever an unbalance occurs between requests for a limited resource and the ability of a service facility to provide that resource. The size of the buffer depends on the amount of the resource available and the demand for it by subscriber. The most common service discipline in real life is called first in first out (FIFO) or first come first served (FCFS); non-preemptive priority calls are used in this article where the priority calls have been affected by outage and thus the priority calls will be re-queued in the head of the buffer as it is assigned as high priority. Queuing of new calls and waiting for requests to be served can generally improve channel utilization at the expense of time spent in the queue.

PRESENT MODELS

Outage can cause the loss of the communication system and affects the GOS. Study of the GOS degradation due to

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