Mobility Effects on Teletraffic in GSM

Francisco A. Monteiro, Luis M. Correia
Instituto de Telecomunicações / Instituto Superior Técnico, Technical University of Lisbon
Av. Rovisco Pais, 1049-001 Lisbon, Portugal
Tel: +351 218418478; Fax: +351 218418472; E-mail: frmo@lx.it.pt

ABSTRACT

This paper presents some results on teletraffic for environments with a dominant vehicular user profile in GSM. A model permitting exclusive channels for handover traffic is used and a discussion on the number of reserved channels for handover traffic is made. Blocking, handover failure and call dropping probabilities are examined for a typical traffic case on a GSM base station. For the analysed situation, 78 traffic channels, it is shown that a single dedicated channel is enough for a good quality of service.

I. INTRODUCTION

Traffic modelling for mobile communications has been done importing models used in fixed networks, thus not considering the spatial cellular structure and handovers caused by users mobility. Apart from new calls originated in a cell, a base station (BS) must also deal with calls already in progress from neighbouring cells. Even a simple model should reflect a binary traffic partition: *new* and *handover* traffic. In this paper one applies a model described in [1] which makes that separation.

Fig. 1 exhibits the channels arrangement in a cell and the offered traffic partition.

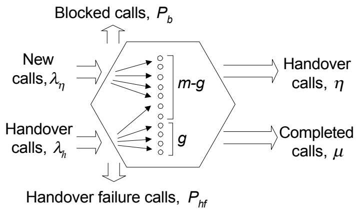

Figure 1: Used cell traffic model for mobility (from [1]).

The total traffic arriving to a cell, ρ, is divided into *new calls*, ρ_n, and *handover* ones, ρ_h, $\rho=\rho_n+\rho_h$. In Fig. 1 they are represented by their respective arriving call rate (λ_n and λ_h). Cells are assumed to have a total of m channels, g being only for handover, named guard channels, and the remaining $c=m-g$ having no priority assignment.

II. MODEL DESCRIPTION

The analytical model for the presented channel structure emerges when some hypotheses are added [1]. Those are the Poissonian nature of new and handover traffics (making ρ also a Poisson process), the existence of no queuing on each traffic class, a continuous space radio coverage, and finally a random call mean duration, $\bar{\tau}$, having an exponential distribution:

$$p(\tau)=1/\mu\cdot\exp(-\tau/\mu) \tag{1}$$

the system service rate being $\mu=1/\bar{\tau}$.

The mean cell dwell time is

$$\bar{\tau}_h=\frac{1}{\eta} \tag{2}$$

where η is the cell cross-over rate given by

$$\eta=V\frac{L}{\pi S} \tag{3}$$

V being the mobile terminal velocity, S the cell area and L the inter-cell boundary length. Mobile's direction is assumed to have a uniform distribution in [0, 2π]. For a hexagonal cell pattern of radius R (hence $L=R$) it is well known that $S=3/2\sqrt{3}R^2$, therefore:

$$\eta=\frac{2V}{3\sqrt{3}\pi R} \tag{4}$$

The mean active call time inside a cell is

$$\tau_c=\min\{\tau,\tau_h\} \tag{5}$$

The first case occurs when a complete call takes place inside a single cell, while the second one is associated to handover performing. The respective service rate is $\mu_c=1/\bar{\tau}_c=\mu+\eta$.

From the above exposition, the blocking probability for new calls, P_b, and handover failure probability, P_{hf}, are:

$$P_b=\frac{(\rho_n+\rho_h)^c\sum_{k=c}^{c+g}\frac{\rho_h^{k-c}}{k!}}{\sum_{k=0}^{c-1}\frac{(\rho_n+\rho_h)^k}{k!}+(\rho_n+\rho_h)^c\sum_{k=c}^{c+g}\frac{\rho_h^{k-c}}{k!}} \tag{6}$$

$$P_{hf}=\frac{(\rho_n+\rho_h)^c\frac{\rho_h^g}{(c+g)!}}{\sum_{k=0}^{c-1}\frac{(\rho_n+\rho_h)^k}{k!}+(\rho_n+\rho_h)^c\sum_{k=c}^{c+g}\frac{\rho_h^{k-c}}{k!}} \tag{7}$$

where $\rho_n=\lambda_n/\mu_c$ and $\rho_h=\lambda_h/\mu_c$. It can be proved that the total traffic ρ is a constant. For g=0 both (6) and (7) become equal, the expected Erlang-B expression.

The handover probability, P_h, is given by

$$P_h=P\{\tau>\tau_h\}=\frac{\bar{\tau}_c}{\bar{\tau}_h}=\frac{\eta}{\mu+\eta} \tag{8}$$

and the handover rate, ν, by

$$\nu=\bar{\tau}/\bar{\tau}_h=\eta/\mu \tag{9}$$

It can also be shown that the probability of call dropping, P_d, is:

$$P_d = \frac{P_h P_{hf}}{(1 - P_h(1 - P_{hf}))} \qquad (10)$$

A simplification for (10) and other relations are available in [1].

III. TRAFFIC ANALYSIS

In the following one suppose as an example a GSM BS having a total of 80 channels, 78 of them for traffic (i.e., 2 GSM signalling and control channels are used). Accepting P_b=2%, from Erlang-B formula one gets that a maximum of 66.8 Erlang can be offered to the BS.

Results are presented for macro cells. Great users concentrations with high velocities are quite not expected in small cells. In Fig. 2 one can see traffic transference from new to handover classes as cells get smaller and V increases. This is the effect of a higher cross-over rate.

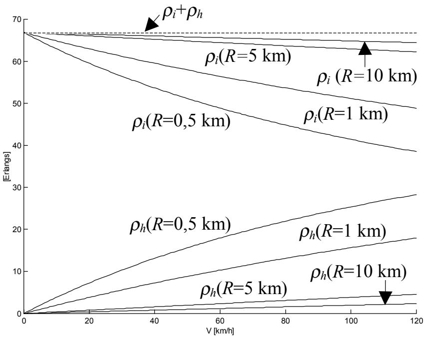

Figure 2: Traffic classes as a function of velocity V for different cell radius R.

When treating both traffic classes by the same manner (g=0), P_b and P_{hf} are the same (2%) and stay unvarying with V and R. However, in cells with R<1 km, it is not possible to guarantee a call dropping probability, P_d, less then 0.5 % (QoS target value), which can be seen in Fig. 3 (a). The handover probability is presented in Fig. 3(b); this one depends only on mobility, being independent of the channel structure.

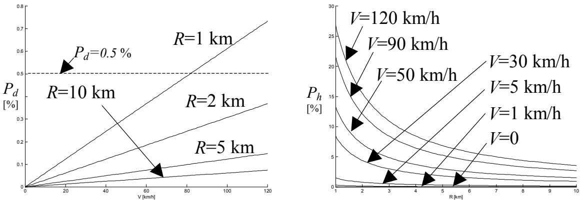

Figure 3: Dependence on R and V for P_d and P_h.

IV. CHANNELS RESERVATION

The possibility of exclusive handover channels was investigated. In Fig. 4 P_b can be seen to increase with users mobility as a consequence of more handover requests. Notice that those handover calls start to take up part of the c non-exclusive channels.

It can be verified that $P_d(R,V)$ curves with g=1 keep the same shape of g=0 cases, e.g. Fig. 3 (a), but with values about 1/4 of those. The usage of 2 and 3 guard channels was examined as well, leading to the results of Table 1. For R<1 km, g=2 is required to have P_d<0.5% for very high velocities (>120 km/h).

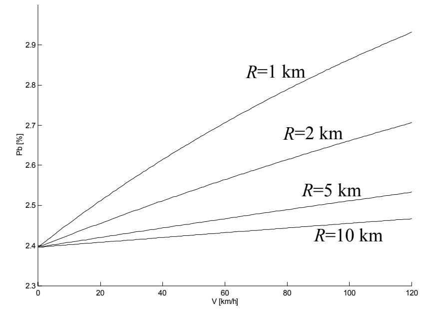

Figure 4: Blocking probability dependence on V and R when one guard channel is put to use.

g	P_b [%]	P_{hf} [%]	P_d [%]
0	2.01	2.01	0.73
1	2.93	0.55	0.20
2	3.62	0.15	0.06
3	4.28	0.04	0.02

Table 1: QoS parameters for a varying number of guard channels, for the worst case considered (R=1 km and V=120 km/h).

Although extremely (unnecessary) low values of P_{hf} and P_d can be achieved, the blocking probability more than duplicates when g=3. That comes from the profound non-linearity of (6).

V. CONCLUSIONS

Mobility effects are condensed in the cell cross-over rate parameter. User mobility magnifies the probability of call dropping when handover is needed. The creation of exclusive handover channels allows an easy compliance of QoS standards for on going calls (P_d) by handover failure reduction (P_{hf}). The main disadvantage is the new calls blocking (P_b) increase that happens because of the reduction of available ordinary channels. For a 78 traffic channels case, a single guard channel was seen to be the best option. Reservation of more channels brings P_{hf} and P_d to very small values, but a lack of ordinary channels produces a larger P_b.

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