Tomislav ŠUH, Dragan MITIĆ, Žarko MARKOV, Aleksandar LEBL

Institute for Telecommunications and Electronics, IRITEL A.D. BELGRADE

How to Calculate Call Blocking in One GSM Cell with Intra-cell Traffic

***Abstract**. In this paper we present the influence of the connections between GSM users, situated in the same base station (intra-cell connections), on the increase of traffic loss. The utilization of Erlang model in this case gives underestimated loss. We suggest one known queuing model for the more accurate calculation in this case. Several numerical examples prove that traffic loss increases with the increase of intra-cell traffic in total traffic and with the increase of the number of channels in the group. The results are confirmed by the simulation.*

***Streszczenie.** W artykule opisano wpływ połączenia miedzy odbiorcami (połączenia intra-cell)stacji GSM na zwiększenie strat w komunikacji. Wykorzystanie do tego celu modelu Erlanga daje przeszacowanie strat. Zamiast tego zaproponowano model kolejkowania. (**Jak obliczać blokowanie połączeń w komórce GSM z komunikacją typu intra-cell**)*

Keywords: Mobile network, Air-interface, Telephone traffic
Słowa kluczowe: sieć mobilna, komunikacja telefoniczna GSM

Introduction

Radio channels on the Air-interface are the most critical resource in GSM network. There are few developed techniques, which increase the efficiency of the available number of channels, as, for example: usage of the half rate traffic channels for one connection, i.e. usage of one channel for two connections, or assignment of the traffic channel when the called subscriber goes off-hook (late assignment, OACSU). That's why the number of necessary channels in one cell must be calculated carefully. Erlang formula (when the number of users in one cell is great and they generate small traffic each) and Engset formula (when the number of users in one cell is small and the number of existing connections has the influence on the call arrival rate), [1], are used for calculation. The common property of these formulas is that one connection uses one channel on Air-interface. In this short paper we shall consider the case when two traffic channels are used for some connections and we shall present how this method affects the calculation of necessary number of channels on the Air-interface of base station in GSM. Section 2 presents the considered model, and section 3 presents the traffic process and the formulas for the calculation of this model. Section 4 presents numerical examples of traffic loss calculation.

Model, designations and assumptions

Let us consider one base station (BTS) and the cell in GSM network. The principle of network functioning is combining of frequency (FDMA) and time multiplex (TDMA). The number of traffic channels (TCH) on Air-interface is N_t. The specific characteristic of the considered cell, i.e. of BTS, is that it involves the users, who very often intercommunicate. It can be rural area overlaid by one cell, or the base station, which overlays great enterprise with the employees, who perform their business traffic over this network. The connection between two users from the same cell will be called intra-cell connection (ICC), and the traffic intra-cell traffic (ICT). The connection between the user from this cell and the user, who is situated outside of this cell, will be called external connection (EC). It is clear that ICC takes two channels on Air-interface, and EC only one. Fig. 1.a) presents ICC, and Fig. 1.b) presents external call. Switching of both connection types is performed in switching centre (MSC).

The probability that the connection cannot be established because there are no free traffic radio channels will be called in this paper loss, connection loss or blocking and will be designated by symbol B.

It is supposed that the number of users in one cell is great, and that each user offers relatively small traffic (for example 20 mErl, as in [3]). Offered telephone calls (intra-cell and external) make Poisson process. The offered ICC traffic is A_i and the offered external traffic is A_e. The both components of offered traffic are constant, i.e. they do not depend on the number of busy channels. Internal and external calls are mutually independent. The call duration is random variable with negative-exponential probability distribution function same for both types of traffic. ICC takes two channels on the Air-interface in the same moment, and in the same moment it releases them. External connection takes one channel. State $\{i,e\}$ is the state in BTS where there are i internal and e external connections. The probability of the state $\{i,e\}$ is designated as $p(i,e,A_i,A_e,N_t)$, $i=0,1,2,...T[N_t/2]$, $e=0,1,2,....N_t$, where $T[X]$ is the integer part of the positive real number X, i.e. $T[N_t/2] = N_t/2$ if N_t is even number and $T[N_t/2] = (N_t-1)/2$ if N_t is odd number.

Traffic process

The traffic model, where some customers use one server (channel), and some more ones, is for a long time well-known. Ref. [4] presents the model of PABX where external (outgoing and incoming) calls are realized using one channel, while two channels (circuits) are necessary for internal connections. Ref. [5] considers one general model with more components and [6] suggests the way of calculating the necessary number of channels of different flows in radio network. Finally, description of known models and the survey of their sources are presented in [7].

We consider here the model with two components of traffic. The requirement for establishment of one intra-cell connection is that at least two traffic channels are free, and for external connection the requirement is at least one free channel. We can differentiate three groups of states in this model. The first ones are the states $\{i,e\}$ where it is possible to adopt both kinds of new calls, i.e. the states, which satisfy the condition $2\cdot i+e\le N_t-2$. The second ones are the states in which intra-cell connections are only blocked, i.e. the states $\{i,e\}$ where is $2\cdot i+e=N_t-1$. The third ones are the states of blocking for both type of calls, i.e. the states $\{i,e\}$ where $2\cdot i+e=N_t$.

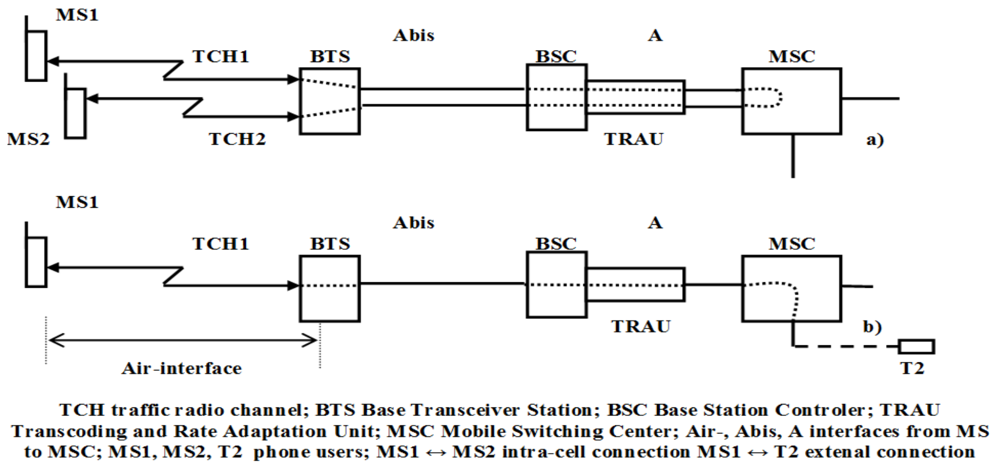

Fig.1. Intra-cell (a)) and external (b)) connection

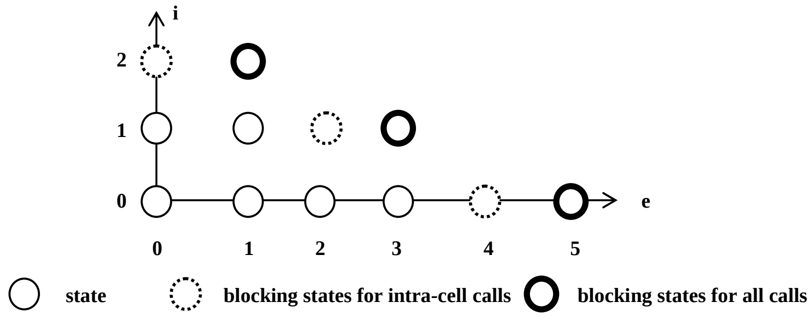

Fig.2. Symbolic presentation of all states in the 5-channel group serving both intra-cell and external calls

Fig. 2 presents all three groups of states for the group of N_t=5 channels.

The basis for the calculation of probability of state is the fact that traffic flows are mutually independent. This fact allows us to write equations of statistical equilibrium for each traffic type (local balance). That's why we can obtain the solutions for state probabilities as product form [7]. It can be easily proven, as in [4], that the probabilities of states $\{i,e\}$ are presented by the expression:

(1)
$$p(i,e,A_i,A_e,N_t)=\frac{\dfrac{A_i^i\cdot A_e^e}{i!\cdot e!}}{\sum\limits_{j=0}^{2\cdot j+k\le N_t}\sum\limits_{k=0}\dfrac{A_i^j\cdot A_e^k}{j!\cdot k!}}=\frac{\dfrac{A_i^i\cdot A_e^e}{i!\cdot e!}}{\sum\limits_{j=0}^{T[N_t/2]}\sum\limits_{k=0}^{N_t-2\cdot j}\dfrac{A_i^j\cdot A_e^k}{j!\cdot k!}}$$

where is i=0,1,2,...$T[N_t/2]$, e=0,1,2,....N_t.

It is clear that two characteristics of this distribution are:

(2) $$\lim_{A_i\to 0} p(i,e,A_i,A_e,N_t)=ERL(e,A_e,N_t)$$

(3) $$\lim_{A_e\to 0} p(i,e,A_i,A_e,N_t)=ERL(i,A_i,T\left[N_t/2\right])$$

where $ERL(j,A,N)$ is the probability that j of N servers with the offered traffic A are busy in the well-known model of Erlang group with N channels.

$$ERL(j,A,N)=\frac{\dfrac{A^j}{j!}}{\sum\limits_{k=0}^{N}\dfrac{A^k}{k!}}$$

The probability that j of N_t channels are busy in the group with intra-cell and external traffic is equal to the sum that there are i intra-cell and e external connections such that $2\cdot i+e=j$:

(4)
$$p(j,A_i,A_e,N_t)=\sum_{2\cdot i+e=j}p(i,e,A_i,A_e,N_t)=\sum_{m=0}^{T[j/2]}p(m,j-2\cdot m,A_i,A_e,N_t)$$

The probability of the loss of first type is equal to the probability that all channels are busy, i.e.:

(5)
$$B_1=P(N_t,A_i,A_e,N_t)=\sum_{2\cdot i+e=N_t}p(i,e,A_i,A_e,N_t)=\sum_{i=0}^{T[N_t/2]}p(i,N_t-2\cdot i,A_i,A_e,N_t)$$

The probability of the loss of second type is equal to the probability that intra-cell connection cannot be established, because only one free channel exists, i.e.:

(6)
$$B_2=P(N_t-1,A_i,A_e,N_t)=\sum_{2\cdot i+e=N_t-1}p(i,e,A_i,A_e,N_t)=\sum_{i=0}^{T[N_t/2]}p(i,N_t-2\cdot i-1,A_i,A_e,N_t)$$

The probability of external connection loss is $B_e=B_1$ and the probability of intra-cell connection loss is a $B_i=B_1+B_2$.

The mean value of traffic loss, i.e. the probability that some connection cannot be established because there are no free channels, is:

$$B = \frac{A_i \cdot B_i + A_e \cdot B_e}{A_i + A_e} \quad (7)$$

The influence of intra-cell traffic on loss probability

It is intuitively clear that the probability of connection loss is as greater as intra-cell component in mixed traffic consisting of intra-cell and external traffic is greater, because one ICC uses two channels. The opposite is valid also: if external component is greater, service is better.

Numerical examples, which present the influence of intra-cell traffic on connection loss, are presented in Fig. 3. In this figure, the connection loss is presented for three channel groups, containing 10, 20 and 30 channels. The value of offered traffic to each group is the one, which causes 1% of connection loss when there is no intra-cell traffic: for the group of 10 channels this traffic is 4.46 *Erl*, for the group of 20 channels it is 12 *Erl*, and for the group of 30 channels it is 20.3 *Erl*. Therefore, the traffic is chosen in such a way that it is *ERL(10,4.46,10) = 0.01*; *ERL(20,12,20) = 0.01* and *ERL(30,20.3,30) = 0.01*. These are the most left points in Fig. 3, i.e. the points where there is no intra-cell traffic. The influence of intra-cell traffic is expressed by the parameter p. When p=0, it is the pure external traffic, when $0<p<1$, it is the mixed external and intra-cell traffic, and when p=1, it is the pure intra-cell traffic. It is obvious that this last case (p=1) corresponds to the Erlang model with half number of traffic channels.

Two main characteristics of the influence of intra-cell traffic on traffic loss can be noticed in Fig. 3. The first one is that the increase of intra-cell traffic component increases greatly the traffic loss, and the second one is that this influence is greater in the greater channel groups.

Calculated loss in all three groups of channels from Fig. 3 is successfully verified by the simulation of telephone traffic and service. Simulation model is the well-known *roulette* model, which is rearranged in order to obtain more accurate estimations, [8]. We have performed five simulations for each simulated value and the number of simulated connections was about 1000 per one channel for each simulation.

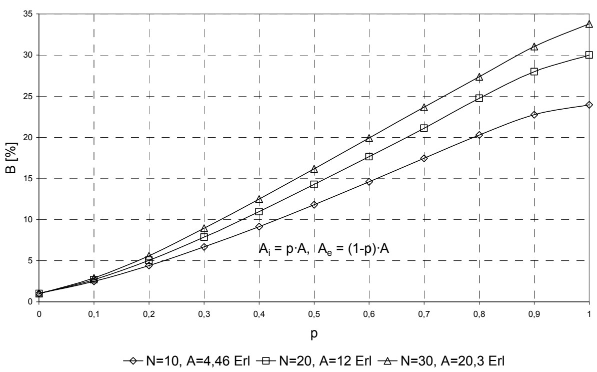

Fig.3. Influence of intra-cell traffic component (p) on the probability of connection loss

Conclusion

Intra-cell connections have negative influence on traffic serving in GSM cell. The main reason is the use of two channels on Air-interface for one connection, thus decreasing the efficiency of these most important resources. The traffic loss increases when increasing intra-cell traffic component, but also when increasing the number of channels in a group. The traffic loss, calculated using Erlang model, is underestimated, i.e. they are lower than it is real. The decrease of the influence of intra-cell traffic can be expected in the cell containing a small number of users, where Engset model of calculation can be implemented.

Acknoledgements

The authors thank to Prof. W. B. Iversen from the Technical University of Denmark for help in finding literature.

This work is partially supported by the Ministry of Science and Technological Development of the Republic of Serbia within the Project TR32007.

REFERENCES

[1] Ebersprächer, J., Vögel, H.-J., Bettstetter, Ch.: „GSM, Switching, Services and Protocols “, John Wiley & Sons, 1999.
[2] Gunar, H.: „GSM, Switching, Services and Protocols “, John Wiley & Sons, 1999.
[3] ITU-T: Recommendation E.760: „Terminal mobility traffic modelling“, March 2000.
[4] Rönblom, N.: „Traffic loss of a circuit group consisting of both-way circuits which is accessible for the internal and external traffic of a subscriber group, Teleteknik (English edition)“, no 2, 1959.
[5] Fortret, R., Grandjean, Ch.: „Congestion in a loss system when some calls want several devices simultaneously“, Proceedings of Fourth International Teletraffic Congress, London 1964.
[6] ITU-T Document 8F/434-E: „Refined Calculation Method of Multidimensional Erlang-B formula and its Sensitivity Analysis for Mixed Circuit-switched Traffic“, 2005.
[7] Iversen, W. B.: „DTU Course 34340, Teletraffic Engineering and Network Planning“, Technical University of Denmark, 2011.
[8] Markov, Ž: „A simple way for variance reduction of measured loss in teletraffic simulation“, Archüv für Elektronik und Übertragungstechnik, (AEÜ), vol. 44, no 5, 1990.

***Authors**: Mr Tomislav Šuh dipl.ing., IRITEL A.D., Batajnički put 23, 11080 Belgrade, Serbia, phone 381-11-3073480; e-mail: suh@iritel.com; dr Dragan Mitić dipl.ing., IRITEL A.D., Batajnički put 23, 11080 Belgrade, Serbia, phone 381-11-3073425; e-mail: mita@iritel.com; prof. dr Žarko Markov dipl.ing., IRITEL A.D., Batajnički put 23, 11080 Belgrade, Serbia, phone 381-11-3073403; e-mail: Zarko.Markov@iritel.com; dr Aleksandar Lebl dipl.ing., IRITEL A.D., Batajnički put 23, 11080 Belgrade, Serbia, (phone 381-11-3073403; e-mail: lebl@iritel.com.*