Traffic Models and Associated Parameters in GSM/(E)GPRS Networks

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Abstract: - GSM/(E)GPRS networks support a mixture of traffic consisting of voice and data. A key concept of dimensioning radio resources in such networks is represented by sharing resources between different users and different services. In this paper we address the problem of voice and data traffic models according to different resources allocations strategies: CP (Complete Partitioning) and PP(Partial Partitioning) and define specific parameters in each case. The proposed traffic model depend in each case on the resources allocation strategy: for voice traffic it is based on both cases, CP and PP, on Erlang law meanwhile for data traffic we build different models depending the scheme used for resources allocation. For CP scheme we propose two models: the model based on Erlang law and those based on modified Engset law. For PP scheme we also proposed two models: one is based on the bi-dimensional Markov chain and the other on the modified Engset law. Both consider voice-data interaction according to the PP scheme. In all cases we define specific performance parameters. We also implement the studied models and evaluate the proposed performance parameters. Finally we compare the results in order to find the adequate model to use for dimensioning purposes.

Key-Words: - GSM/(E)GPRS, blocking and preemption probability, Erlang-B law, Engset law, average throughput, cell utilization

1 Introduction

Initially, GSM (Global System for Mobile Application standard) cellular networks were developed to offer, mainly telephonic services. GSM combines time division multiple access (TDMA) and frequency division multiple access (FDMA) for radio channel allocation. With this approach a frequency carrier is divided into eight time-slots per frame which are used to support speech and data transmission. Only a basic circuit oriented service at low transfer rate was provided to data access. Named CSD (Circuit Switched Data) this can achieves transfer rate up to 9.6 kbps per time slot.

The integration of the General Packet Radio Service(GPRS) and the Enhanced (E)GPRS into GSM system world wide raises many problems. Analysis and study of data services in a cellular network require new models since traditional ones (like Erlang's formulas) are not applicable to this kind of traffic. At the same time, the particularities of each GSM/(E)GPRS mainly on the resources allocation require an adaptation of the general model depending on the needs of each provider. For networks operators, equipment vendors and system integrators dimensioning rules have to be developed to plan and estimate the radio capacity that is needed for the predicted amount of data users when the radio resources are shared between circuit and packet switched services.

GSM operators have been dimensioning their networks for voice service in terms of offered voice traffic and blocking probability. The reference performance parameter for this system model is the Erlang-B formula [1], [2]. This formula gives the proportion of calls that are blocked as a simple function of system capacity and traffic intensity.

The (E)GPRS network is designed for supporting several types of data traffic such as Wap, Web, E-Mail, etc. Therefore (E)GPRS traffic process characterization is very demanding. Usually the data traffic is characterized by bursts and is application dependent. A communication session may last for an extended period of time with intermittent packet transmissions.

On the other hand the (E)GPRS service allows dynamic allocation of bandwidth resources. Wireless channels are allocated to a mobile terminal based on its traffic demands which results in a better resource utilization. This traffic behavior coupled with flexible bandwidth allocation in a (E)GPRS network represent the starting point for constructing an appropriate model in order to evaluate the performance and to establish dimensioning rules for the system. Another major problem of GSM/(E)GPRS networks dimensioning is the choice of strategy to partition the available cell capacity between traditional GSM and new (E)GPRS services. The Radio Resources Manager (RRM) is in charge of optimizing the usage of radio resources, based on a specific resource sharing algorithm. Two static resources sharing schemes are used frequently:

- In the first one, called Complete Partitioning, time-slots are divided into two sets and each type of traffic is allowed to use only its dedicated set.
- The second scheme, known as Partial Partitioning, contains the following channel sets: one set shared between voice and data traffic and two sets each one being reserved for strict usage of its dedicated traffic: voice or data. This scheme, offers many advantages: first, reserving a set of time-slots for each type of traffic allows guaranteeing, as in CP a minimum QoS for each type of traffic. Second, PP scheme provide a better efficiency than CP which is not suitable for maximizing radio utilization, especially in highly varying demand. Due to these advantages PP is widely implemented in a number of actually operating GSM/(E)GPRS networks.

Several papers have been published on traffic modeling and performance evaluation in GSM/GPRS networks. The major works in this field are based on analytical models using queuing theory and continuous-time Markov chains, and assuming an infinite number of users in the cell [1], [3] - [6].

In [7] Dahmouni et al. present an approach for dimensioning (E)GPRS networks based on the modified Engset model.

In [8]-[10] analytical models based on discrete-time Markov chains have been proposed and a single type of traffic (data traffic) is considered. It is assumed to be generated by a finite number of users and modeled by an Erlang-like law.

Recently published papers address the problem of improving the quality of service and performance parameters for GSM/(E)GPRS systems [11], [12].

In this paper we consider voice and data traffic models according to different resources allocations strategies: CP and PP and we define particular parameters in each case. The proposed traffic model depend in each case on the resources allocation strategy: for voice traffic it is based on both cases, CP and PP, on Erlang law meanwhile for data traffic we construct different models depending on the scheme used for resources allocation.

For CP scheme we propose two models: the model based on Erlang law and those based on modified Engset law.

For PP scheme we also proposed two models: one is based on the bi-dimensional Markov chain and the other on the modified Engset law. Both consider voice-data interaction according to the PP scheme.

In all cases we define specific performance parameters. We also implement the studied models and evaluate the proposed performance parameters.

Based on resulted performance parameters we compare the studied models in order to find the adequate model to use for dimensioning purposes.

2 GSM/(E)GPRS system parameters

The analysis is focused only on one cell of cellular mobile system submitted to two different types of traffic: GSM voice calls and (E)GPRS data flows.

GSM uses a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access. The FDMA scheme divides the GSM frequency band into a number of carrier frequencies, which in their turn are split into time-slots by means of a TDMA scheme. A frame consists of a number of consecutive time-slots. The time-slots in a frame are then assigned to individual users.

In traditional circuit-switched GSM networks, on each frequency carrier a 200 kHz bandwidth is shared between 8 voice calls. Each voice call is given a circuit, also called time-slot (TS) because it is a Time-Division multiplexing scheme (TDMA). Each voice call needs the assignment of a single time-slot for its entire duration.

(E)GPRS data traffic uses the same radio interface as GSM voice calls hence radio resources available in the cell have to be shared among GSM and (E)GPRS traffic.

(E)GPRS is a packet switching technology over circuit-switching based GSM system. In (E)GPRS technology a mobile station can use several time-slots simultaneously for one application (data flow) to perform its transmission with a higher throughput. Each time-slot can be shared among several users by assigning different Temporary Flow Identities (TFI) to the mobiles. Each TFI identifies a (E)GPRS physical connection called Temporary Block Flow (TBF). Up to 32 TFI's can be allocated per TDMA frame due to the 5 bits allocated for TFI encoding at TRX level. Data flows are multiplexed by a PCU-based scheduling algorithm. In addition to time-slot partitioning, (E)GPRS system allows time-slot aggregation: for a single mobile user the system can allocate up to *d*-time-slots simultaneously for downlink and up to *u*-time-slots simultaneously for uplink, depending on mobile station capability class (*d*+*u*). The choice of the number of TBF's that a PDCH can have in uplink and downlink depends on the operator's choice.

Our study is focused on the radio allocator which distributes the downlink radio channels among voice calls and (E)GPRS data flows.

We make the following assumptions regarding the system to be modeled:

- t_B : the radio block duration, equal to $20ms$;

- x_B : the number of data bytes that are transferred over one time-slot. The ratio: $\frac{x_B}{t_B}$ represents the throughput offered by the RLC/MAC layer to the LLC layer.

The RLC radio block size x_B depends on the radio coding scheme, according to TABLE 1 for the coding schemes CS1-CS4 used for GPRS and according to TABLE 2 for coding schemes MCS1-MCS9 used for EGPRS. The used coding schemes depend on the radio condition.

TABLE 1

GPRS Coding Schemes	CS-1	CS-2	CS-3	CS-4
RLC block radio (*bytes*)	23	33	39	53
Data rate: $\mu_{GPRS}(kbits/s)$	9.05	13.4	15.6	21.4

TABLE 2

EGPRS Coding Schemes	MCS1	MCS2	MCS3	MCS4	MCS5
x_B (bytes)	22	28	37	44	56
EGPRS Schemes	MCS6	MCS7	MCS8	MCS9	
x_B (bytes)	74	112	136	148	

- TS : the number of time-slots of the TDMA partitioned into a contiguous set of TS_V time-slots dedicated to voice calls, TS_{VD} time-slots shared between voice and data and TS_D time-slots dedicated to GPRS; time-slots used by data $TS_D + TS_{VD}$ are on a single TDMA which has a total of 8 time-slots.

- d (resp. u): is the number of time-slots that can be used simultaneously for downlink (resp. uplink) traffic. All GPRS mobiles have the same radio capability, denoted $d+u$.

- Voice calls have a preemptive priority over data flows on the shared part of the TDMA due to the fact that they generate the largest amount of revenue in most actual operating systems. As a consequence, if all TS_V time-slots dedicated to voice are occupied and all TS_{VD} time-slots are in use with at least one of them allocated to data, then one time-slot assigned to (E)GPRS traffic in the shared part of the TDMA will be reallocated to voice on the arrival of a GSM request.

3 System Models

3.1 Voice traffic model

In order to model the GSM traffic, it can be assumed that the calls arrivals are a Poisson process of intensity λ_V . Each call will have a random exponential duration of mean $1/\mu_V$.

The classical Markov chain model applies for voice traffic and the steady-state voice probabilities given by Equation (1) are generated by the birth-death structure of this model shown in Fig.1.

$$p_V(t) = \frac{\frac{\rho_V^t}{t!}}{\sum_{i=0}^{TS_V} \frac{\rho_V^i}{i!}}, \quad \rho_V = \frac{\lambda_V}{\mu_V}, \quad t \in [0, TS_V] \qquad (1)$$

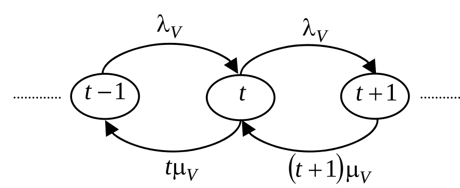

Fig.1 The voice traffic model

The performance parameter in this case is represented by the blocking probability also known as Erlang-B formula:

$$B_{V,CP} = \frac{\frac{\rho_V^{TS_V}}{TS_V!}}{\sum_{i=0}^{TS_V} \frac{\rho_V^i}{i!}} \qquad (2)$$

This model applies independent of the resource allocation strategies and the data model adopted. The allocation strategy influences only the total number of resources available for voice calls in

Equation 2 (CP: TS_V ; PP: $TS_V + TS_{VD}$), due to the priority of voice over data calls.

3.2 Data Traffic Models

3.2.1 General features and assumptions

Data traffic is modeled assuming the following parameters:

- *N* represents the fixed number of data mobiles in the cell. Each mobile is doing an ON/OFF traffic with an infinite number of pages
- *ON* periods correspond to the download of an element like a WAP, a WEB page, an email, a file, etc. Its size is characterized by a discrete random variable X_{on}, with an average value $E[\sigma]$.
- *OFF* periods correspond to the reading time of the last downloaded element, which is modeled as a random variable T_{off} with an average value of $E[\tau]$ seconds.
- The maximum number of (E)GPRS users in active transfer is given by:

$$n_{\max}(TS_D) = \min(N, 32, mTS_D) \quad (3)$$

m- is the maximum number of users that can use a single time-slot.

For constructing our model based on the ON/OFF traffic we define the average data traffic parameters as follows:

- The average rate of data arrival process:

$$\lambda_D = \frac{1}{E[\tau]} \quad (4)$$

- The average data rate per time-slot:

$$\mu_D = \frac{x_B}{E[\sigma]t_B} = \frac{\mu_{(E)GPRS}}{E[\sigma]} \quad (5)$$

Based on these two parameters we define, as shown in Equation (6) a parameter ρ_D, similar to ρ_V, that characterize the data traffic.

$$\rho_D = \frac{\lambda_D}{\mu_D} = \frac{t_B E[\sigma]}{x_B E[\tau]} = \frac{E[\sigma]}{E[\tau]} \frac{1}{\mu_{(E)GPRS}} \quad (6)$$

- The timeslot transmission rate.

In many (E)GPRS networks, the transmission rate assigned to a timeslot depends on the Coding Scheme used by the endpoints which allows different transmission rates. The number of slots of each kind depends on the radio condition. In order to incorporate this feature in the model we define the timeslot transmission rate as follows: considering that there are n_1 time-slots with transmission rate μ_1 and n_2 with μ_2. Let's denote by *j* the number of active flows in the system and by x_j^i the number of time-slots of type *i* being used when there are *j* concurrent flows in the system.

The timeslot transmission rate is given by:

$$\mu_D = \frac{\overline{\mu_{(E)GPRS}}}{E[\sigma]} = \frac{x_j^1\mu_1 + x_j^2\mu_2}{x_j^1 + x_j^2} \quad (7)$$

with $x_j^i, i = \{1,2\}$ indicated by the Equation (8) :

$$\begin{aligned} x_j^1 &= \min\{n_j d, n_1\} \\ x_j^2 &= \min\{(n_j d - n_1)\ , n_2\} \end{aligned} \quad (8)$$

and $n_j d$ representing the number of time-slots in use when there are *j* flows in the system.

3.2.2 Data traffic model based on Erlang law

System with complete partitioning (CP)

Based on system parameters indicated by Equations $(3) \div (8)$, the data traffic model is represented by the continuous-time Markov-chain shown in Fig.2.

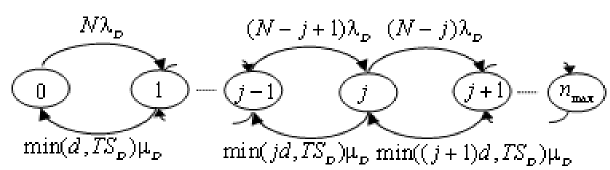

Fig. 2 Continuous-time Markov-chain model

As indicated in Fig. 2, the state *j* of the Markov chain corresponds to the number of the data mobiles that are simultaneously in active transfer. The maximum bandwidth capacity they can use is TS_D.

The stationary probabilities of having *j* data mobiles in active transfer, derived from the birth-death structure of the Markov chain are:

$$for\ j \in (0, j_0]:$$

$$p_D(j) \quad = \frac{N!}{j! d^j (N-j)!} \rho_D^j p_D(0) \quad (9)$$

for $j \in (j_0, n_{\max}]$:

$$p_D(j) = \frac{N!}{j_o! d^{j_0} TS_D^{j-j_0} (N-j)!} \rho_D^j p_D(0) \quad (9')$$

where j_0 is the maximum value of integer j satisfying the relation: $jd < TS_D$.

Based on these distributions we have considered the following performance parameters:

- the blocking probability, similar to the Erlang-B law [8], [10]:

$$B_{CP}^{(1)} = \frac{N!}{j_0! d^{j_0} TS_D^{n_{\max}-j_0} (N-n_{\max})!} \rho_D^{n_{\max}} p_D(0) \quad (10)$$

- the average total throughput:

$$X_{CP}^{(1)} = \sum_{j=1}^{n_{\max}} p_D(j)\, j \min(d, \frac{TS_D}{j}) \mu_{GPRS} \quad (11)$$

- the average throughput per user:

$$X_{u/CP}^{(1)} = \frac{X_{CP}}{E[j]} = \frac{\sum_{j=1}^{n_{\max}} p(j) \min(jd, TS_D)}{\sum_{j=1}^{n_{\max}} jp(j)} \mu_{GPRS} \quad (12)$$

where $E[j]$ represents the average number of data mobiles in active transfer.

- cell utilization defined as:

$$U_{CP}^{(1)} = \frac{\sum_{j=1}^{n_{\max}} p_D(j) \min(jd, TS_D)}{TS - TS_V} \quad (13)$$

where the numerator is the average number of channels in use in the cell.

System with partial partitioning (PP)

We denote by $TS_{\max}(t)$ the number of time-slots that data mobiles can use when there are t voice calls in the system:

$$TS_{\max}(t) = TS_D + TS_{VD} - \max(0, t - TS_V) \quad (14)$$

with t taking the values: $t \le TS_V + TS_{VD}$.

We also consider $N_{\max}(t)$, the maximum number of data mobiles that can simultaneous be in active transfer, when there are t pending voice calls. $N_{\max}(t)$ can be derived, for $t \le TS_V + TS_{VD}$, as follows:

$$N_{\max}(t) = \min(32, 7TS_{\max}(t), mTS_{\max}(t), N) \quad (15)$$

The model applied to this system is a bi-dimensional Markov chain proposed in [11]. A state of the bi-dimensional Markov chain is represented by a couple (t,n) of the number t of voice calls pending and the number n of data mobiles in active transfer. For better understanding the model we have represented in Fig.3 the transitions out of a generic state (t,n) with $0 < t < TS_V + TS_{VD}$ and $n = 0, \cdots, N_{\max}(t+1)$.

The vertical transitions in Fig.3 correspond to the classical Erlang-B model transitions for voice traffic described in Fig.1.

Horizontal transitions correspond to the continuous-time model derived in Fig.2, where we have replaced the value TS_D by the adequate value $TS_{\max}(t)$.

The transition rate from the state (t,n) to the state $(t,n-1)$ is given by: $\min(nd, TS_{\max}(t))\mu_D$. On the other hand the transition rate from state (t,n) to state $(t,n+1)$ is equal to $(N-n)\lambda_V$ because of the ON/OFF assumptions regarding the data traffic.

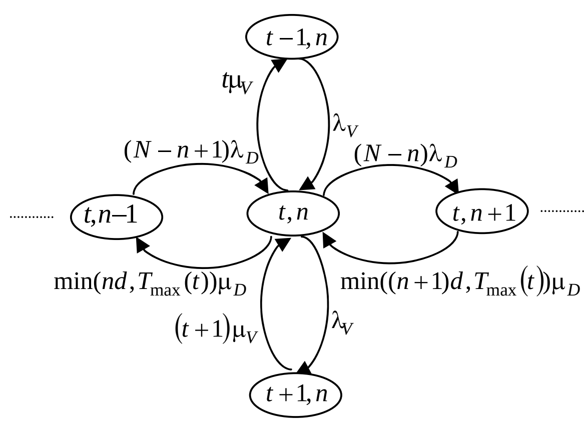

Fig.3 Transactions out of a generic state in the bi-dimensional model

Another important part of the bi-dimensional model is represented by the transitions that occurs if a new voice call starts when the number of existing voice communications is greater then TS_V (and lower than $TS_V + TS_{VD}$).

This new call preempts a time-slot that could be in use by GPRS mobile and can results in GPRS rejections, when the data mobile capacity is reached. These transactions out of a limiting state $(t, N_{\max}(t))$ are represented in Fig.4.

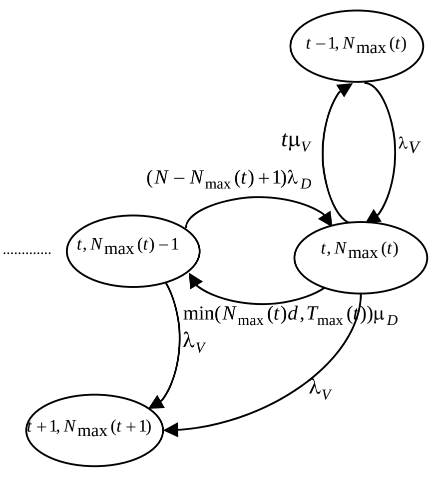

Fig.4 Transactions out of a limiting state in the bi-dimensional model

As indicate in Fig.4, the rejections are represented in the Markov chain by transitions going from any state (t,n) where $t \in [TS_V, TS_V + TS_{VD}]$ and $n = N_{\max}(t+1)+1, \cdots, N_{\max}(t)$ to state $(t+1, N_{\max}(t+1))$. At most $\min(m,7)$ rejections may occur.

In order to reduce the bi-dimensional Markov chain complexity the probability of a generic state (t,n) was approximated with the conditional product-form probability as indicated by Equation (16).

The resulted model is represented in Fig.5.

$$p(t,n) = p_V(t)\, p_D(n|t) \quad (16)$$

As mentioned before, voice traffic can be modeled with the Erlang model. Due to the fact that there are currently t voice mobiles in communication, the data traffic is modeled by the Erlang-like model developed in [8] with a number of time-slots equal to $N_{\max}(t)$.

The stationary probabilities of having n data mobiles in active transfer conditioned by the state t of voice calls can be derived as follows:

$$\begin{aligned} &\mathit{for}\ n \in (0, n_0(t)] \\ &p_D(n|t) = \frac{N!\rho_D^n p_D(0|t)}{n!d^n(N-n)!} \\ &\mathit{for}\ n \in (n_0(t), N_{\max}(t)] \\ &p_D(n|t) = \frac{N!\rho_D^n p_D(0|t)}{n_o(t)!d^{n_0(t)} TS_{\max}^{n-n_o(t)}(t)(N-n)!} \end{aligned} \quad (17)$$

The PP system's performance parameters can be derived easily from the detailed stationary probabilities, $p_D(n|t)$:

- the data blocking probability formula is as indicated in [10]:

$$B_{PP}^{(1)} = \sum_{t=0}^{TS_V + TS_{VD}} p_V(t) p_D(N_{\max}(t)|t) \quad (18)$$

- the preemption probability (the probability that a data transfer ends prematurely due to voice call preemption) is given by Equation (19).

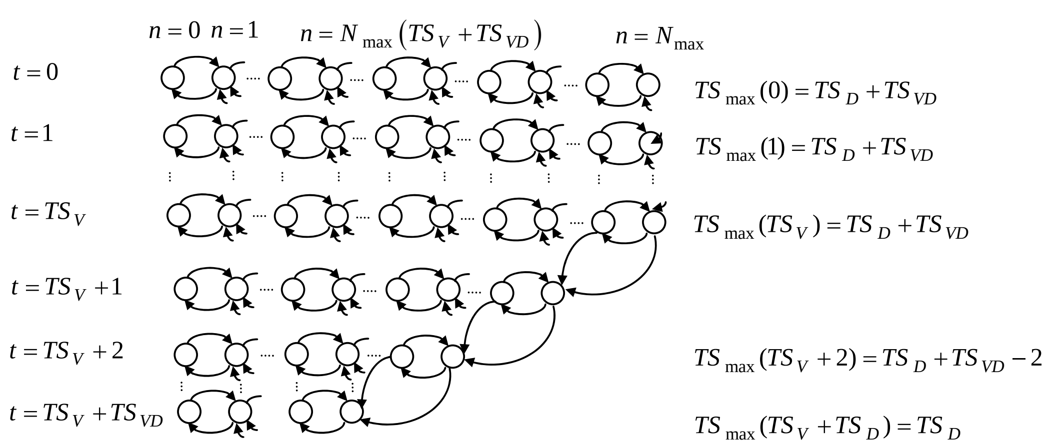

Fig.5 The conditional product-form model

$$B_{P,PP}^{(1)} = \sum_{t=TS_V}^{TS_V+TS_{VD}} \sum_{n=N_{\max}(t+1)+1}^{N_{\max}(t)} p_V(t)\, p_D(n|t) \quad (19)$$

- for the average total throughput we propose the formula:

$$X_{PP}^{(1)} = \sum_{t=0}^{TS_V+TS_{VD}} \sum_{n=1}^{N_{\max}(t)} p_V(t)\, p_D(n|t) \min(nd, T_{\max}(t))\mu_{GPR} \quad (20)$$

- the average throughput per user is:

$$X_{u/PP}^{(1)} = \frac{X_{PP}}{E[n]} \quad (21)$$

where $E[n]$ represents the average number of data mobiles in active transfer.

- cell utilization is defined as:

$$U_{PP}^{(1)} = \frac{\sum_{t=0}^{T_V+T_{VD}} \sum_{n=1}^{N_{\max}(t)} p_V(t)\, p_D(n|t) \min(nd, T_{\max}(t))}{TS - TS_V} \quad (22)$$

3.2.3 Data traffic model based on the modified Engset law

In order to construct our model we consider the same continuous- time Markov chain represented in Fig.2.

System with complete partitioning (CP)

According to the Engset model [7] and the data traffic parameters mentioned before, the steady-state probability $p_D(j)$ can be expressed as indicated by Equation (23).

$$p_D(j) = p_D(0) \frac{C_N^j}{\prod_{i=1}^{j} \min(d, \frac{TS_D}{i})} \rho_D^j \quad (23)$$

Based on these probabilities we have calculated the performance parameters: blocking probability $(B_{CP}^{(2)})$, average total throughput $(X_{CP}^{(2)})$, average throughput per user $(X_{u/CP}^{(2)})$ and cell utilization $(U_{CP}^{(2)})$ and have founded similar formulas as presented before for the Erlang-model.

S***ystem with partial partitioning (PP)***

The basic idea in constructing the model in this case relies on 2 assumptions: the voice calls are independent of (E)GPRS connections and the voice and data traffic evolves at different time scales [7].

The data traffic model is constructed with respect to the Engset model and the particularities imposed by the resources sharing capability as presented above.

The data blocking probability is deduced similarly as in [7]:

$$B_{PP}^{(2)} = \sum_{s=0}^{TS-TS_D} p_V(s) B_{CP}^{(2)}(\min(TS - TS_V, TS - s)) \quad (24)$$

For the total average throughput we have used the formula:

$$X_{PP}^{(2)} = \sum_{s=0}^{TS-TS_D} p_V(s) X_{CP}^{(2)}(\min(TS - TS_V, TS - s)) \quad (25)$$

The average throughput per user is:

$$X_{u/PP}^{(2)} = \sum_{s=0}^{TS-TS_D} p_V(s) X_{u/CP}^{(2)}(\min(TS - TS_V, TS - s)) \quad (26)$$

The cell utilization for PP scheme is :

$$U_{PP}^{(2)} = \frac{\sum_{s=0}^{TS-TS_D} \sum_{j=1}^{N_{\max}(t)} p_V(s)\, p(j) \min(jd, TS_D)}{TS - TS_V} \quad (27)$$

Finally the preemption probability due to voice calls priority over data users is:

$$B_{P,PP}^{(2)} = \sum_{s=TS_V}^{TS-TS_D-1} p_V(s) \sum_{k=N_{\max}(s+1)+1}^{N_{\max}(s)} B_{CP}^{(2)}(\min(TS - TS_V, TS - k)) \quad (28)$$

4 Comparative results

Both models have been implemented by Matlab programs and the performance parameters indicated in Fig.6 have been determined and compared.

In the first scenario we have implemented the Erlang model for PP scheme, considering a cell equipped with a single TRX that provides $TS_V = 3$, $TS_{VD} = 3$, $TS_D = 1$. One time slot is dedicated to broadcast and signaling purposes in the cell. The GPRS coding scheme was CS2, that provides $x_B = 30$ bytes transferred during t_B over one time slot and for the reading time we consider a typical average value $t_{off} = 7$.

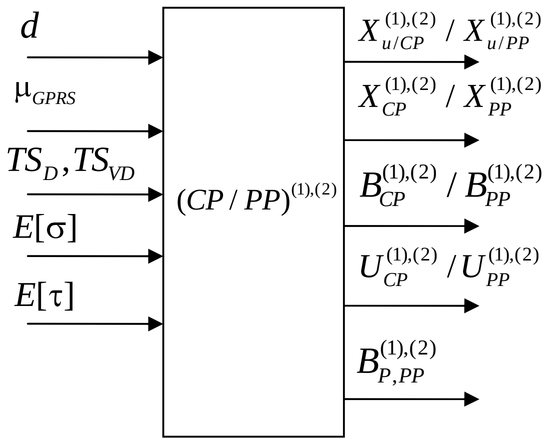

Fig.6 Traffic models and associated performance parameters

Fig.7 shows respectively the blocking probability and the preemption probability obtained according to Equations (18) respectively (19) for a large number of N values. We consider three voice loading situations as indicated in figure.

In each case a 2% for the lost voice traffic was considered according to Erlang-B formula.

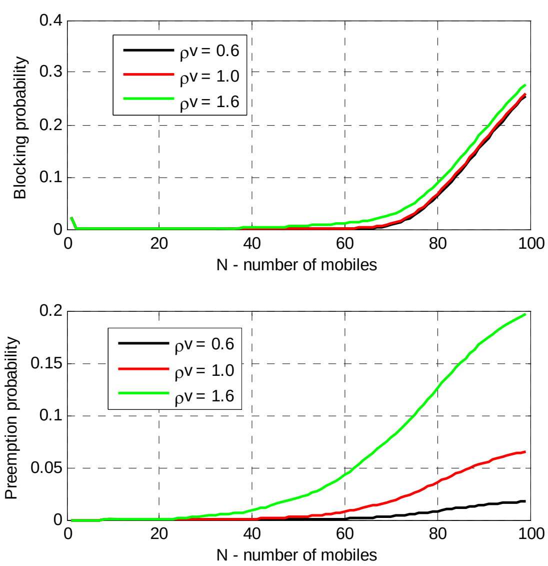

Fig.7 Blocking and preemption probability for Erlang model

The curves of Fig.7 show that the blocking probability for data depends on the number of data mobiles *N* and does not depend on the voice traffic load. The preemption probability strongly depends on voice traffic loads and is weakly influenced by the number of data mobiles *N*.

The average throughput per user for the same scenario and calculated according to Equation (21) is represented in Fig.8.

We have also represented the cell utilization parameter according to Equation (22) in Fig.9.

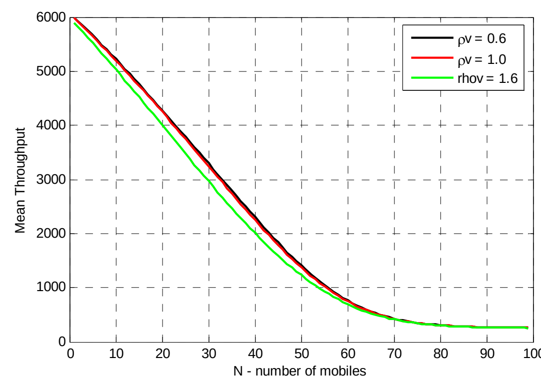

Fig.8 The average throughput per user for Erlang model

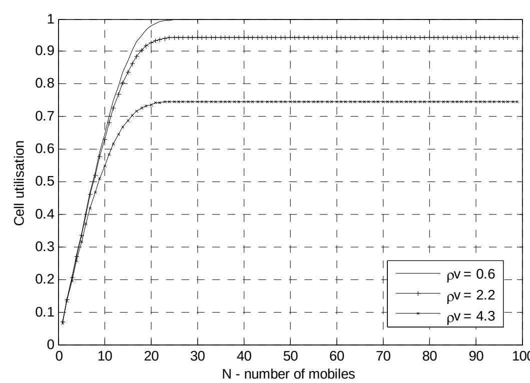

Fig.9 Cell utilization for Erlang model

In the following we have compared the two models based on the previously defined parameters. The same scenario has been experimented for the presented models: Erlang and Engset.

For the CP scheme we have considered a cell equipped with one TRX providing: $TS = 8;\ TS_V = 7;\ TS_D = 1$.

For the PP allocation strategy the cell was also equipped with a single TRX providing: $TS = 8;\ TS_V = 3;\ TS_D = 1; TS_{VD} = 4$.

The following system parameters have been considered in our comparative experiments:

- voice traffic parameters: $\rho_V = 2.94$ Erlang with a 2% lost traffic according to Erlang –B formula.

- data traffic parameters: $E[\sigma]=5KB$, $E[\tau]=12s$, GPRS mobile class: 4+1 and CS2 coding scheme ($\mu_{GPRS}=13,4kbits/s$).

In Fig.10 we have represented the blocking probabilities according to the presented formulas for $B_{CP}^{(1)}$, $B_{PP}^{(1)}$, $B_{CP}^{(2)}$ and $B_{PP}^{(2)}$. In the figure can be observed that differences between the two models are not significant (maximum 5% for B_{CP} and 2% for B_{PP}).

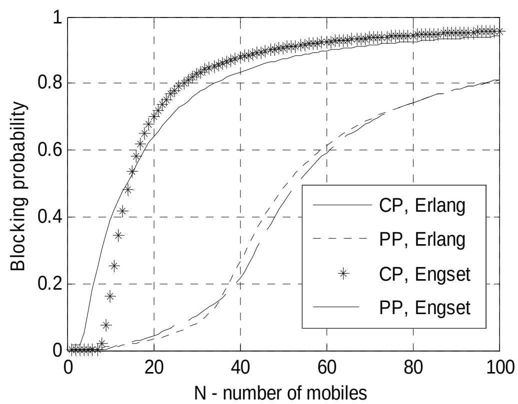

Fig.10 Comparative blocking probabilities for Erlang and Engset models

Figure 11 shows a perfect matching regarding the preemption probabilities according to Erlang and Engset models.

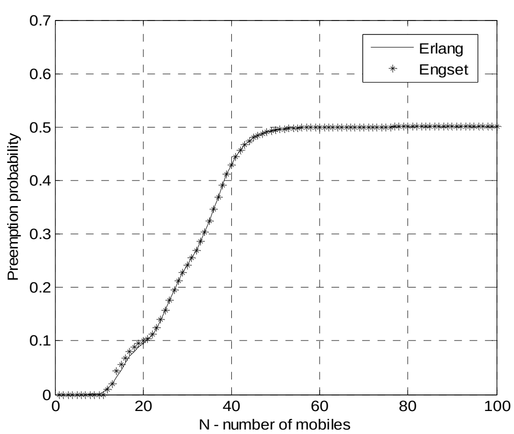

Fig. 11 Comparative preemption probabilities for Erlang and Engset models

For dimensioning purposes average throughput per user represents an important parameter.

Fig. 12 represents $X_{u/CP}^{(1)}, X_{u/PP}^{(1)}, X_{u/CP}^{(2)}, X_{u/PP}^{(2)}$. The curves show significant differences (20%) between the Erlang and the Engset models only for a relative small number of mobiles in the cell.

For the region of interest in dimensioning process, corresponding to a large number of mobiles, the two models provide identical results.

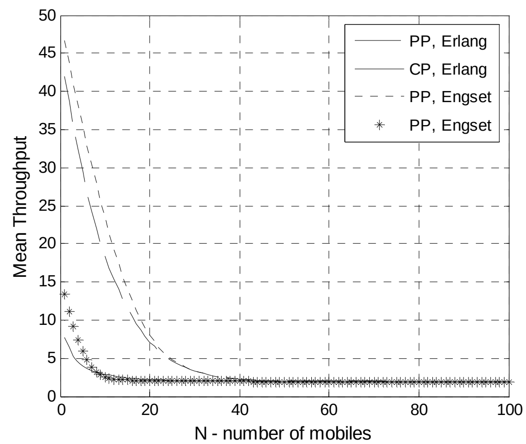

Fig. 12 Comparative average throughput per user for Erlang and Engset models

5 Conclusion

In this paper we have implemented two traffic models dedicated to GSM/(E)GPRS networks performances analysis. We have build particular models for voice and data that allow performance parameters computation based on voice and data traffic loads. The voice-data interaction is also address in order to optimize radio resources allocation.

For each model (Erlang and Engset) we have proposed and calculated performance parameters: blocking probability, preemption probability, average total throughput, average throughput per user and cell utilization. For each model we have considered two allocation strategies for voice and data traffic channels: CP and PP.

These parameters have been compared using the same test scenarios.

The comparative studies based on performance parameters mentioned before show that both models can be used for dimensioning purposes. The results show very small differences between Erlang and Engset models.

Regarding the computational complexity, the Engset model is much more simple then the bi-dimensional Markov chain used by the Erlang model.

References:

[1] L. Kleinrock, *Queuing Systems: Vol. I – Theory*, New-York Wiley, 1976

[2] S. Sa Esteves, "Algorithms for Higher-Order Derivatives of Erlang-C Function", *Proceedings of the 13th WSEAS International Conference on COMMUNICATIONS*, Rodos Island, Greece, July 23-25, 2009, ISBN 978-960-474-098-7, ISSN1790-5117, pp. 72-77

[3] S. Pedraza, J. Romero, J. Munoz, "(E)GPRS Hardware Dimensioning Rules with Minimum Quality Criteria", *Proc. of IEEE VTC* Spring, pp. 391-395, May 2002

[4] C. Lindemann, A. Thummler, "Performance Analysis of the General Packet Radio Service", *Computer Network*, 41, pp. 1-17, Jan., 2003

[5] S. Ni, S. Haggman, "GPRS Performance Estimation in GSM Circuit-Switched Services and GPRS Shared Resources Systems", *WCNC*, Vol.3, pp.1471-1421, 1999

[6] M. Mahdavi, R. Edwards, P. Ivey, "Performance Evaluation of Data Subsystem in GSM/GPRS Using Complete Sharing, *Proc. of London Communications Symposium*, Univ. College of London, 2001

[7] H. Dahmouni, B. Morin, S. Vaton, "Performance Modelling of GSM/GPRS Cells with Different Radio Resource Allocation Strategies", *IEEE Wireless Communications and Networking Conference,* March 2005, Volume 3, pp: 1317-1322

[8] B. Baynat, K. Boussetta, P. Eisenmann, N. Ben Rached, "Discrete-Time Markov Model for EDGE/GPRS Radio Engineering with Finite-length Sessions", *Int. Symp. On Performance Evaluation of Computer and Telecommunication Systems* (SPECTS'2004), San Jose, California, USA, July, 2004

[9] B. Baynat, K. Boussetta, P. Eisenmann, N. Ben Rached, "Towards an Erlang-like Law for the Performance Evaluation of GPRS/EDGE Networks with Finite-Length Sessions", *Proc. of 3rd IFIP-TC6 Networking Conference*, May 2004, pp. 1288-1293

[10] B. Baynat, P. Eisenmann, "Towards an Erlang-like law for GPRS/EDGE network engineering", *Proceedings IEEE ICC*, June 2004

[11] P.M. Papazoglu, A. Karras, R.C. Papademitriou, "Improved Integral Channel Allocation Algorithms in Cellular Communication Systems Enabling Multimedia QoS Services", *WSEAS TRANSACTIONS on COMMUNICATIONS*, ISSN 1109-2742, Issue 10, Volume 7, October 2008, pp. 1014 -1023

[12] R. Dobrescu, D. Hossu, S. Mocanu, M. Nicolae, "New algorithms for QoS performance improvement in high speed networks**",** ISSN: 1109-2742, *WSEAS TRANSACTIONS on COMMUNICATIONS*, Issue 12, Volume 7, December 2008, pp. 1192 -1201

[13] G. Budura, C. Balint, E. Marza, "Blocking Probabilities in GSM/(E)GPRS Cells with Different Radio Resources Allocation Strategies", *Scientific Bulletin of "Politehnica" University of Timisoara, ETc series*, Tom 53(67), Fasc.2, 2008, pp. 85-92

[14] P. Stuckmann, O. Paul, "Dimensioning GSM/GPRS Networks for Circuit- and Packet-Switched Services", *Proceedings of the 10th Symposium on Wireless Personal Communications*, Aalborg, Denmark, 2001, pp. 169-174