

Event-Based Tele-Traffic Simulation of Mobile Communication Systems Beyond 3G

Jesús M. Juárez Valero, Rui R. Paulo, Fernando J. Velez

Instituto de Telecomunicações, DEM-UBI, Calçada Fonte do Lameiro, 6201-001 Covilhã, Portugal

Phone: +351-275329919, Fax: +351-275329972, e-mail: jejuva@iespana.es, rfrpaulo@e-projects.ubi.pt, fjbv@ubi.pt

Abstract — By considering the deployment scenarios and tele-traffic parameters from the Vehicular scenario of SEACORN, a simulator was produced to extract conclusions about blocking and handover failure probabilities in Enhanced UMTS. Simulations, which consider the burstiness of traffic, were performed for different cases, from single- to multi-service situations, and from absence to presence of mobility. The simulator allows for extracting conclusions about the validation of the Bernoulli-Poisson-Pascal model for the computation of the ON/OFF blocking probability, the ratio between the number of call rejected at the beginning of an ON period and the total number of bursts generated during a session. As the theoretical and the simulation results agree, the validation was achieved, and there is an almost perfect concordance between theoretical and simulation values when the average sojourn time in cells is equal to the average holding time. In the multi-service case, the behaviour is not exactly the same but a coherent trend is achieved.

I. INTRODUCTION

The goal of Third Generation (3G) mobile communication systems is the delivery of multimedia services to the user in the mobile domain. The IST-SEACORN [1] project proposed a set of enhancements to UMTS, which include, among others, advanced modulation and radio transmission techniques, improved strategies for IP routing and QoS assurance. Enhanced UMTS (E-UMTS) is a UMTS evolution step which provides bit rates higher than 2 Mbit/s in the uplink and the downlink directions over 5 MHz frequency carriers. So E-UMTS enables the provision of new wideband services and significant reduction of the price per bit, running over flexible QoS enabled IP based access and core networks, and making possible an effective end-to-end packet based transmission. The study of E-UMTS tele-traffic behaviour drove us to build a simulator that represents source traffic and its aggregation. For testing the enhancements, various models were built with the most relevant activity/inactivity characteristics of this technology, in different scenarios, very useful for validation purposes. The simulator was developed with AweSim [2], a general purpose simulation system for network discrete-event and continuous simulation approaches. The most fundamental feature of the AweSim architecture is its openness and interconnectivity to databases, spreadsheets, and word processing programs. The main objective of this work consists of producing the simulator to obtain results for blocking and handover (HO) failure probabilities, and extracting conclusions about the results and the validation of the traffic model in the presence of mobility, with very simple hypothesis.

In Section II the traffic model is presented. After defining the main parameters of the model, the model itself is presented. Section III briefly describes E-UMTS applications and deployment scenarios, as well as the physical and mobility simulation scenario and their parameters. In Section IV, simulation results are presented and the validation of the model is achieved. Finally, Section V contains conclusions.

II. TRAFFIC MODEL

A. Main Parameters

One should start by defining the parameters being used in the model [3]:

- N is the number of available channels/codes per cell [4];
- M is the number of potential users in a cell;
- C is the capacity vector and gives the number of codes/channels that each application demands;
- K is the number of applications being available in a cell;
- $U(t)$ is the vector that defines the number of active users of each application in a time instant t ;
- λ_k is the arrival rate for the static case (λ_k when mobility is taken into account); the arrival process follows a Bernoulli distribution;
- μ_k is the service rate for the static case (H_k when considering mobility), and is Poisson distributed;
- $prop_k$ is the proportion of users of an application k among the K available ones i.e., the usage;
- b_k is the application k data rate.

The arrival rate can be obtained through,

$$\lambda_k = (U_k - M_k) \cdot (-\beta_k), \quad (1)$$

where U_k is the number of active users of the application k , M_k is the number of potential users of the application k being in the system and β_k is the activation rate ($\beta_k < 0$ in the Bernoulli case of the Bernoulli-Poisson-Pascal, BPP, model [3]). Fig. 1 shows the way applications are activated. A user can be either in an idle state or using one of the K applications.

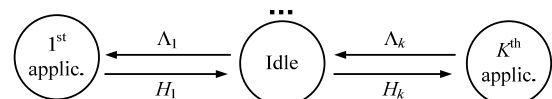


Fig. 1. Model for user applications activation.

The proportion of users of an application among all the available ones can be expressed by its usage,

$$prop_i = \frac{\Lambda_i/\eta_i}{\sum_{k=1}^K \Lambda_k/H_k}, \quad (2)$$

hence,

$$\rho_i = \rho \cdot prop_i, \quad (3)$$

where,

$$\rho = \sum_{i=1}^k \rho_i, \quad (4)$$

and ρ is the average traffic per user. By writing the system of equations for the probability of transition between states (plus the normalization equation), it is straightforward to obtain the probability of a user having an active application,

$$p_i = \frac{\rho_i}{1 + \sum_{k=1}^K \rho_k} = \frac{\rho}{1 + \rho} \cdot prop_i = f \cdot prop_i, \quad (5)$$

where f is the fraction of active users,

$$f = \frac{\rho}{1 + \rho}. \quad (6)$$

Multiplying f by the population of potential users, one obtains the number of users being simultaneously active in a cell. The system cell average load can be obtained by (in kb/s or Mb/s),

$$L = f \cdot c_{av} \cdot M \quad (7)$$

where

$$c_{av} = \sum_{i=1}^K prop_i \cdot b_i. \quad (8)$$

c_{av} gives information about the average amount of resources (in kb/s or Mb/s) that is used by each user.

B. Theoretical Model

The main objective of the model is to obtain an algorithm to compute P_b , having the parameters defined above (f and L) as inputs. The number of channels used at an instant t is given by

$$Y(t) = U(t) \cdot C. \quad (9)$$

The set of feasible states gives the number of active users of each application that can be served by the system and is defined by

$$U = \{n \in N^K : n \cdot C \leq N\}. \quad (10)$$

Blocking situations, i.e., the ones when a new user arriving to the system does not find enough resources available can be expressed by,

$$B_k = \{n \in U : n \cdot C + C_k \leq N\}, \quad (11)$$

where B_k is the set of blocking states for application k , and C_k is the number of channels requested by application k . In a blocking situation, the request is cleared, which means that the system remains in the same state. Application k blocking probability is obtained by dividing the expectation of the

number of blocked requests by the total number of class k requests.

$$P_b^k = \frac{\sum_{n \in B_k} \lambda_k(n_k) \cdot p(n)}{\sum_{n \in U} \lambda_k(n_k) \cdot p(n)}. \quad (12)$$

The state probability marginal function, $p(n)$, represents the probability of the system being in the state n or, equivalently, the probability of n users being in the system.

A standard algorithm for multi-service traffic [3] is used for P_b computations, which does it in a time-efficient way. Results are obtained for P_b as a function of the fraction of active users or, alternatively, as a function of the average load. Based on these results, a P_b threshold of 2 % can then be considered, and the maximum number of simultaneous active users supported by the system is obtained, as well as the cell resource occupancy (i.e., the spectral efficiency). A similar approach is also followed for the handover failure probability, P_{hf} .

III. E-UMTS SIMULATION SCENARIOS

In the SEACORN project [1] there are various services and environments defined. However, from the IST-SEACORN deployment scenarios [1], in this work, we consider the applications defined for the Vehicular (VEH) scenario, an outdoor one with high mobility, which corresponds to the following services: Voice (VOI) at 12.2 kb/s, Video Telephony (VTE) at 144 kb/s, Multimedia Web Browsing (MWB) at 384 kb/s, and Assistance in Travel (ATR) at 1536 kb/s.

The physical scenario has a cellular architecture composed by three cells with the shape of a roundabout. The cellular architecture consists of a backbone network which interconnects fixed base stations, and mobile units communicating with the base stations via wireless links. Each cell has access to the same capacity, N channels. When a mobile user wants to communicate, first it has to obtain a channel from its base station. When there are not enough channels available the new call is blocked.

The call holding time is the average call duration if the call is not prematurely dropped, and it is assumed to be exponentially distributed with average

$$\bar{\tau} = \frac{1}{\mu}, \quad (13)$$

where μ is the service rate.

The transference of a mobile communication from one cell to another, while a call is in progress, is called handover (HO). If there are not enough available channels in the new cell this call will be dropped, this phenomenon is known as handover failure. Details on sojourn time in cells, HO rate and channel occupancy time are given in [8] where details on the computation of the busy hour call attempt (BHCA), as a function of the usage, the number of user in the cells, M_T , the

average call duration $\bar{\tau}_j$, and the average traffic per user, ρ , are also given.

The new calls are generated following a Poisson distribution with rate λ (which is represented by the BHCA in this case). So, the time between calls is exponentially distributed, and is computed according [4]. Packet switched traffic is commonly modelled as ON/OFF processes. Our simulator models the ON/OFF behaviour by using active/inactive time periods, according to [5].

In a roundabout scenario, the traffic is homogeneous, Fig. 2. As a consequence, there is a homogeneous probability of generating new and handovers calls in the three cells

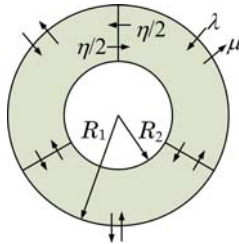


Fig. 2. Physical roundabout mobility scenario.

By considering values of 300, 450 and 600 m for the perimeter in the roundabout, the number of users is calculated by the area of the crown defined by the street. As an example, for a perimeter of 300 m, $R_1=57.75$ m, $R_2=37.75$ m, and the area of the crown 6000 m². Therefore, for a density of users of 0.012 users/m², the number of users is 72.

IV. SIMULATION RESULTS

The simulator was used for the validation of traffic models. Simulation call duration parameters call generation parameters, parameters related with handovers, and the session activity parameters for the active and inactive states, are the ones from Table II, III, IV, V and VI of [6]. One performed a comparison between the theoretical values obtained by considering the Bernoulli-Poisson-Pascal model for multi-service traffic [7], [8] and the results obtained by using the AweSim simulator. Although results for the four simultaneous applications were obtained in [6], in this work we started by analyzing the single-service case, Table I.

Table I. Time intervals between arrivals

ρ	Time between calls [s]		
	Single Service, VOI	Multi-service	
		VOI	VTE
0.05	257.14	149.17	391.30
0.10	128.57	74.59	195.65
0.15	85.71	49.72	130.43
0.20	64.2	37.29	97.83

Results for bursty VOI are presented in Fig. 3, where a comparison of theoretical and simulation results for $P_{b ONOFF}$ is performed for different ρ s, with γ as a parameter (VOI, $N=4$).

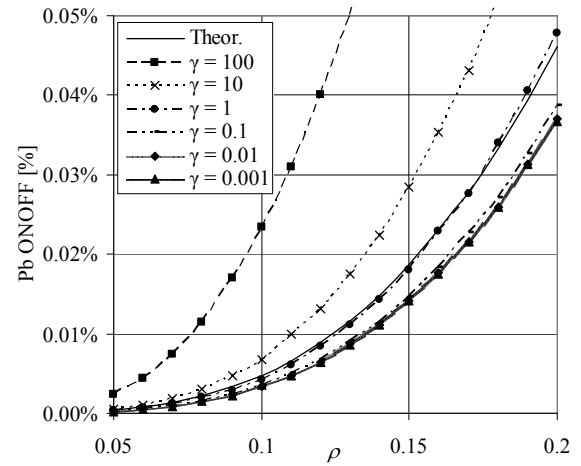


Fig. 3. Results for $P_{b ONOFF}$ for different ρ s, with γ as a parameter (VOI, $N=4$).

Exponential distributions are considered for the active/inactive periods, an average session duration of 60 s is assumed (to simplify the analysis), and the time intervals between arrivals are the ones from [6]. The theoretical and the experimental values of $P_{b ONOFF}$ are close to each other, Fig. 4 (example for $\rho=0.15$ Erl for the latter), and there is an almost perfect concordance between theoretical and simulation values for $\gamma=1$, i.e., when the average sojourn time in cells is equal to the average holding time. The curves for P_b and P_{hf} follow a similar behaviour but P_{hf} takes lower values.

A mixture of VOI and VTE was chosen for the multi-service cases. When it is active (60 s), voice has a bursty behaviour, and ON/OFF periods have exponential distributions with average durations 1.4 and 1.7 s, respectively. However, the video-telephony (60 s) application does not present a bursty behaviour and is permanently active. The time intervals between arrivals are the ones presented in Table I. While for VOI values of P_b are different from $P_{b ONOFF}$, for VTE the curves for P_b and $P_{b ONOFF}$ are coincident, Figs. 5-6.

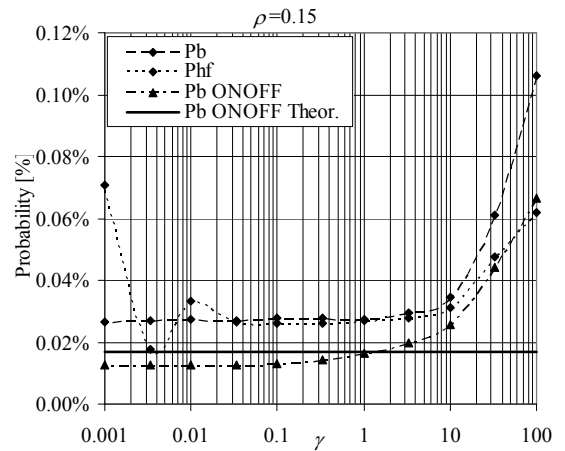


Fig. 4. P_b , P_{hf} , $P_{b ONOFF}$ and theoretical $P_{b ONOFF}$ as a function of γ for $\rho=0.15$ Erl (VOI, $N=4$).

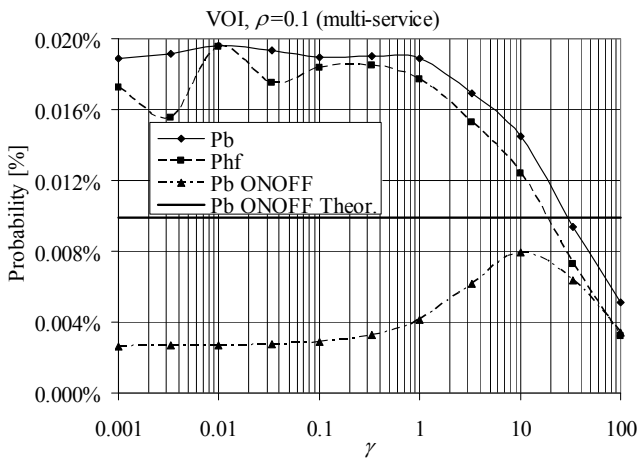


Fig. 5. P_b , P_{hf} , $P_{b\ ONOFF}$ and theoretical $P_{b\ ONOFF}$ for VOI in the multi-service case ($N=48$, and $\rho=0.05$ Erl.).

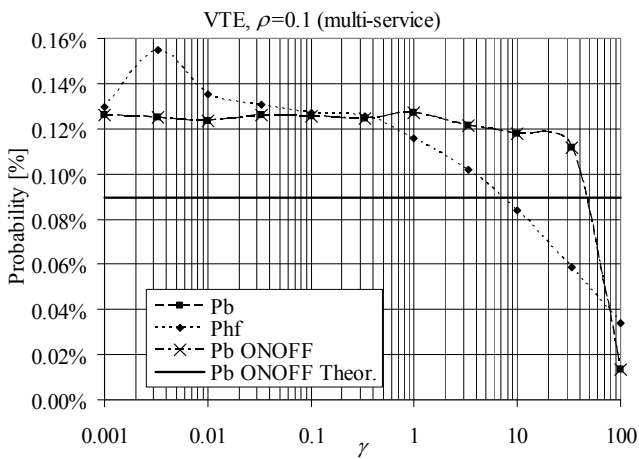


Fig. 6. P_b , P_{hf} , $P_{b\ ONOFF}$ and theoretical $P_{b\ ONOFF}$ for VTE in the multi-service case ($N=48$, and $\rho=0.1$ Erl.).

In this case, while the theoretical $P_{b\ ONOFF}$ is always higher than the simulated values for VOI, for VTE, it takes values lower than the simulation ones for γ s up to ~ 10 . The theoretical and simulation values are close to each other for $\gamma \approx 10$ in both cases.

V. CONCLUSIONS

A model was proposed for multi-rate multi-service traffic engineering purposes which is based in the BPP model. Simulations were ran for a roundabout vehicular scenario in the presence of mobility to obtain results for multi-service QoS measures like blocking, and ON/OFF blocking probabilities. Simulations were run for 1 year time. By comparing call blocking and handover failure probabilities we can observe that they have similar values in all cases, as there is no privilege for handover calls relatively to new ones. However, the difference between call blocking and handover failure probabilities increases when average velocity of users increases, or if the size of the cell is reduced.

By comparing theoretical results with the ones from 10 years time simulations, a perfect validation was achieved in the single-service case when the sojourn time in cells is equal to the average duration of voice calls. In the multi-service case, the behaviour is not exactly the same but a coherent trend is achieved.

ACKNOWLEDGMENTS

This work was partially funded by MULTIPLAN and CROSSNET (Portuguese Foundation for Science and Technology POSI and POSC projects with FEDER funding), MobileMAN (an internal project from Instituto de Telecomunicações/LA), IST-UNITE, and by "Projecto de Re-equipamento Científico" REEQ/1201/EEI/2005 (a Portuguese Foundation for Science and Technology project).

REFERENCES

- [1] <http://seacorn.ptinovacao.pt/>
- [2] A. Alan B. Pritsker and Jean J. O'Reilly, *Simulation with Visual SLAM and AweSim*, John Wiley & Sons, New York, New York, USA, 1999.
- [3] G. A. Awater and H.A. van de Vlag, "Exact Computation of Time and Call Blocking Probabilities in Large, Multi-traffic, Multiresource Loss Systems," *Performance Evaluation*, Vol. 25, No. 1, Mar. 1996, pp.41- 58.
- [4] H. R. Pinto, J.G. da Silva and A. Rodrigues, "Uplink Capacity of the WCDMA FDD Mode in UMTS Networks for Mixed Services," in *Proc. of VTC'2000 Fall - IEEE Vehicular Technology Conference*, Boston, MA, USA, Sep. 2000.
- [5] Jaime Ferreira, "Final report on traffic estimation and services characterization," IST SEACORN CEC Deliverable 34900/PTIN/DS/014/d6, IST Central Office, Brussels, Belgium, Sep. 2003.
- [6] J. M. J. Valero, Rui R. Paulo and Fernando J. Velez, "Tele-Traffic Simulation for Mobile Communication Systems Beyond 3G," in *Proc. of AICT'06 - The 2nd Advanced International Conference on Telecommunications*, Guadeloupe, French Caribbean, Feb. 2006.
- [7] R. M. Carvalho, *Multi-service Traffic Models for Cellular Mobile and Personal Communication Systems*, (in portuguese), Graduation Report, Instituto Superior Técnico, Technical University of Lisbon, Lisbon, Portugal, Jan. 1998.
- [8] J. M. J. Valero, *Tele-Traffic Simulation for Mobile Communication Systems Beyond 3G*, Graduation Thesis, University of Beira Interior, Covilhã, Portugal, Sep. 2005