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COMPARING SYSTEMS WITH EARLY AND LATE RESOURCES ASSIGNMENT IN A NETWORK OF MOBILE USERS

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Abstract. This paper presents the procedure of late traffic channel seizure. The procedure increases traffic channels utilization in the networks of mobile users. Besides the procedure short description, its quantitative estimation and comparison to the other methods of traffic channels utilization are presented in the paper. The results are verified by simulation. The traffic loss is analyzed for the groups with different number of channels. It may be concluded that the procedure of traffic channels late assignment increases their traffic utilization a few tens of percent.

***Key words**:* mobile users' network, traffic, traffic loss, early assignment, late assignment.

1. INTRODUCTION

The rapid development of mobile users' networks has shown very early that the number of resources, i.e. channels, is the limit to the network development. That's why some technics for channel utilization increasing have been applied. These technics are half-rate voice signal transmission [1], VAMOS technics [2], technics of late assignment, i.e. late channels seizure. The technics of telecommunications channels late assignment, which is the subject of the analysis in this paper, is relatively new technics, not used in classic telephone technics. Unfortunately, it has some disadvantages. It is the reason why its implementation is not recommended when there are enough traffic channels in the network. In this paper we calculate the efficiency rate increase if late assignment is applied instead of early assignment and what this advantage depends on. Section 2 describes the procedure of early channel assignment, while section 3 describes late channel assignment. Section 4 defines main designations, which are later used in the paper. It is also defined which model is applied in the analysis. Basic equations are developed in section 5 and the obtained results are presented in section 6. Short qualitative comparison of already emphasized methods for channel resource saving in the networks of mobile telephony is given in section 7. The method and the results of simulation are presented in section 8. At the end, there is the paper conclusion.

2. EARLY ASSIGNMENT

In classical telephony only the case of early (voice) channel assignment was known, regardless of the technics of telephone network construction (space division multiplex, SDM or time division multiplex, TDM). Channel seizure or reservation is realized immediately after called user address and idleness determination, the moment t_1 (Fig. 1). It was possible to transmit signalling over voice channels, sometimes through several telephone exchanges (signalling system *end to end*, E2E). The lack of idle voice channels caused call loss soon after dialling end. In the case that there were idle voice channels, called user answer guaranteed connection establishment.

Early assignment is also used in the mobile users network [3] such that signalling message *PROGRESS (CALL PROCEEDING)* is sent to user phone and tone signal is sent by voice channel. The main disadvantages of traffic channel early assignment are: longer time of traffic channel seizure than it is the call duration and traffic channel seizure in (rare) cases of called user absence [4]. This case is presented in Fig. 1b.

One remark: very early assignment also exists besides early assignment [3]. Very early assignment is realized at the very beginning of signalling process, but early assignment and very early assignment may be considered as same for traffic comparison to late assignment, as it is explained in [5]. The process of various channel types assignment in GSM systems when very early, early or late assignment is implemented is described in [5]. The possibility of service improvement in early assignment by short waiting on some busy channel release is emphasized in [5]. In this paper waiting will not be considered, but only serving with loss will be analyzed.

3. LATE ASSIGNMENT

Late assignment is implemented in the mobile users' network in the case of small number of traffic channels [4]. The connection set-up is always realized without voice channel seizure (reservation) until the moment of available, idle called user's answer [6]. That's why ring-back tone signal to the caller is generated locally, after the command *ALERT*. The other important consequence is that, till the called user answer, call loss may not exist.

After called user answer two outcomes are possible, which depend on traffic channels (un)availability in the moment of answer.

The first outcome is when there is idle traffic channel in the moment of answer. The connection is established.

The second outcome is when there is no idle traffic channel in the moment of answer. In such a situation the call is lost and this situation is irregular because connection is not established after ringing signal and ring-back tone. This is the main imperfection in late assignment realization. The method of call control in this case by corresponding announcement transmission to the called user is defined in [7].

The second imperfection is visible when connection is successfully established: the voice path realization in this case is slower and it is possible that first syllables after called user answer are not transmitted between connection participants [4]. The time interval between called user answer and voice path establishment does not exceed 1s with the probability 95% [8].

The process of GSM system channel seizure as well as what channels are implemented to establish connections according to early, very early and late assignment protocol are explained in more detail in [9].

4. MODEL, DESIGNATIONS AND ASSUMPTIONS

Let us consider two mobile cells, and let us suppose that N completely idle channels are available in both of them. Early channel assignment (index E) is implemented in the first of them and late channel assignment (index L) in the second one. The incoming call intensity in both cells is λ. The number of users is significantly greater than the number of channels, meaning that Erlang traffic model may be applied. That's why call intensity does not depend on the number of busy channels. Call duration and the time between successive calls are random variables with negative exponential distribution. The mean call duration in both cells is t_m. The mean duration of ringing signal till called user answer is t_a. The mean duration of ringing signal to absent user is t_f. The part of calls which are directed to absent users is f ($f \leq 1$). Channel seizure for a call intended to an absent user (early assignment) will be called ineffective traffic. Channel seizure, which finishes as telephone conversation, will be called real traffic. It is supposed that calls' serving is with traffic loss probability B. The offered traffic, A, is equal to the product of call intensity and the mean service time. The probability that j of N channels are busy according to Erlang model when the offered traffic is A is designated as $P_j = \mathrm{ERL}(j,N,A)$ and equals

$$P_j = \mathrm{ERL}(j,N,A) = \frac{\dfrac{A^j}{j!}}{\sum_{i=0}^{N} \dfrac{A^i}{i!}} \tag{1}$$

The call loss probability in this model is $B = P_N = ERL(N,N,A)$.

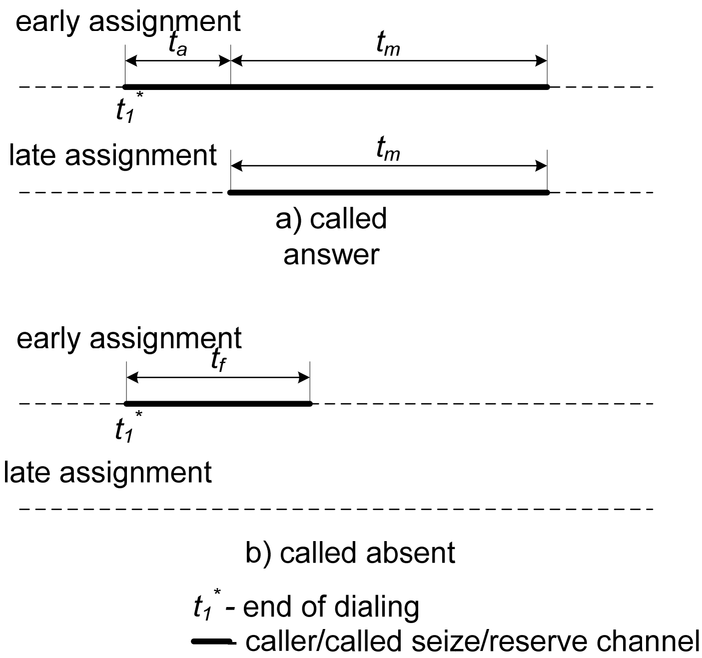

Fig. 1 – The time intervals of channel seizure for early and late assignment in the case of: a) called user answer; b) called user absent.

5. SERVING

It is clear from the model assumptions that serving in the group of resources, i.e. channels, is according to Erlang model with traffic loss.

The offered traffic in the model with early assignment consists of real traffic and ineffective traffic, i.e. channel seizure for the calls, which will not be established because of the called user absence. The offered traffic to idle, present called users is $(1-f)\cdot\lambda\cdot(t_m+t_a)$. The offered traffic to absent users is $f\cdot\lambda\cdot t_f$.

The total offered traffic in the cell with early assignment is

$$A_E = (1-f)\cdot\lambda\cdot(t_m + t_a) + f\cdot\lambda\cdot t_f . \tag{2}$$

The serving system in this case may be represented as the system with mixed traffic (real and ineffective), as in [10]. This traffic calculation method allows evaluation of each traffic component characteristics.

The total offered traffic in the cell with late assignment is:

$$A_L = (1-f)\cdot\lambda\cdot t_m \tag{3}$$

because there is no channel seizure/reservation during ringing signal sending.

The simple service comparison in the case of early and late assignment may be performed the total loss in both situations. The total call loss may be expressed as ERL(N,N,A_E) in the cell with early assignment and as ERL(N,N,A_L) in the cell with late assignment.

It follows from (2) and (3) that it is

$$A_E > A_L \tag{4}$$

That's why it is also

$$\mathrm{ERL}(N, N, A_E) > \mathrm{ERL}(N, N, A_L) \tag{5}$$

The inequalities (4) and (5) are satisfied in a greater extent when the values of f, t_a, and t_f are greater.

6. NUMERICAL EXAMPLES

The traffic loss (B) in the cells with early (B_E) and late (B_L) channel assignment is presented in Figs. 2 to 7. The parameters for these figures are emphasized in the Table 1. The parameters t_m , t_f , t_a and f are the same for the Figs, 2, 3, and 4, and the number of available traffic channels is different for these figures. After that, Fig. 5 is presented for the same parameters as Fig. 2, but with the addition of the characteristics for $f = 0.2$. In the similar way, Figs. 6 and 7 present only the traffic loss characteristic for early channel assignment as in Figs. 3, i.e. 4, but with additional characteristics for t_f = 30 s (Figure 6), i.e. t_a= 16 s (Fig. 7). The variations of t_f and t_a have no influence on the offered traffic in the case of late assignment.

Table 1

Traffic parameters for the cells with early and late channel assignment which traffic loss (B_E and B_L) is presented as a function of offered call intensity (λ) in the figures 2 to 7

Figure	N	t_m (s)	t_f (s)	t_a (s)	f	Figure	As figure	plus
2	6	100	20	12	0.1	5	2	$f = 0.2$
3	14					6	3	t_f= 30 s
4	21					7	4	t_a = 16 s

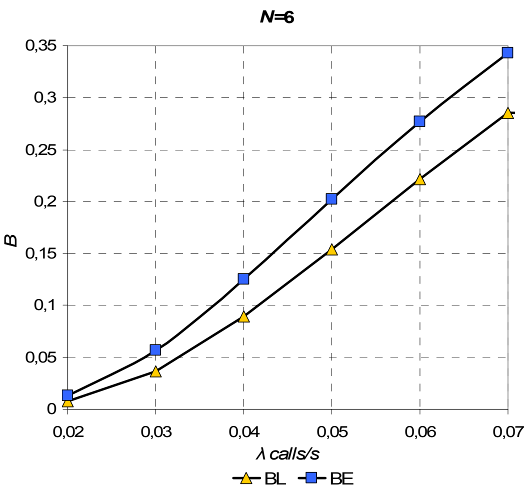

Fig. 2 – Call loss as a function of offered traffic in the cells with early (B_E) and late (B_L) channel assignment for 6 traffic channels.

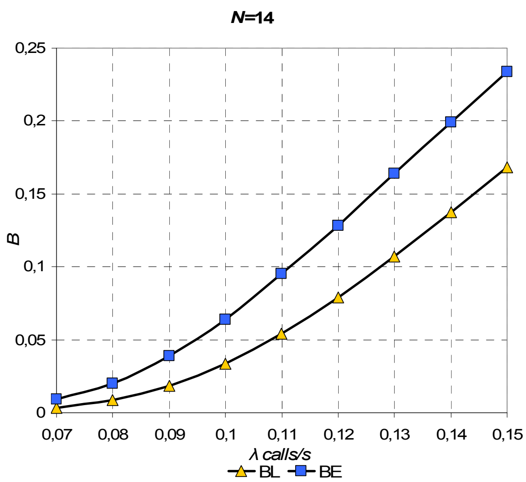

Fig. 3 – Call loss as a function of offered traffic in the cells with early and late channel assignment for 14 traffic channels.

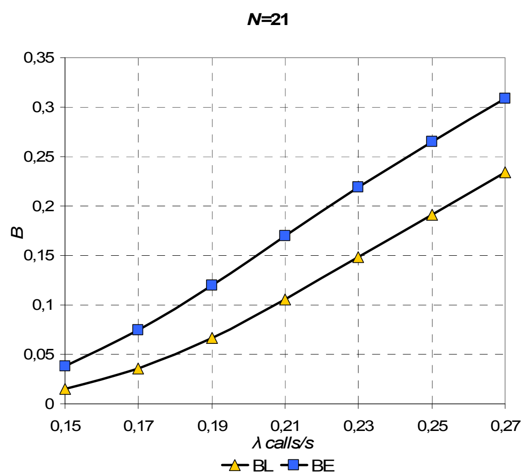

Fig. 4 – Call loss as a function of offered traffic in the cells with early and late channel assignment for 21 traffic channel.

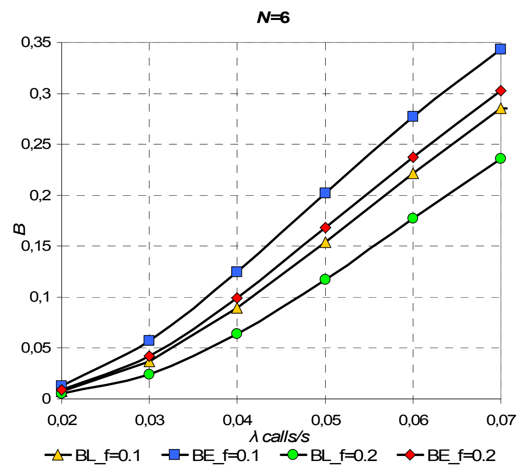

Fig. 5 – Influence of the part of calls, which are directed to absent users, on the call loss in the cells with early and late channel assignment.

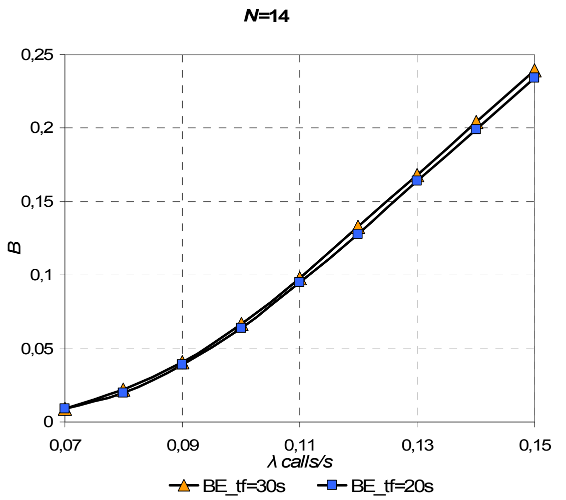

Fig. 6 – Influence of mean call duration time to absent user on the call loss in the cells with early channel assignment.

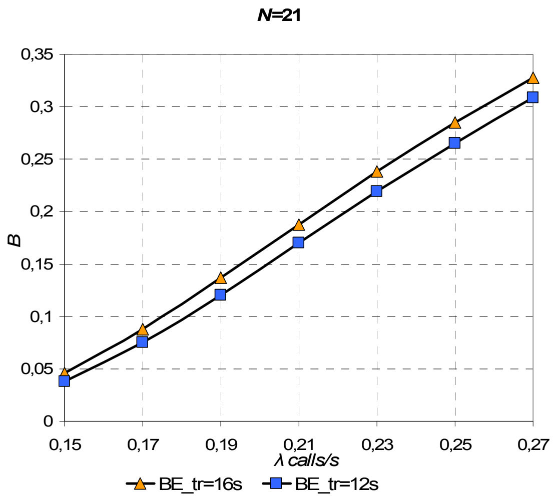

Fig. 7 – Influence of mean call duration time till called user answer on the call loss in the cells with early channel assignment.

Some important conclusion may be made upon each of the presented figures. First, according to the example in Fig. 2 traffic loss in the case of early assignment is greater, 20% to 100%, than in the case of late assignment when the system consists of 6 channels. After that, the conclusion from the example in Fig. 3 is that the difference in the quality of service increases when the offered traffic increases. It is valid in the rough approximation for the lower values of loss probability that

$$B_L = \mathrm{ERL}\left(13,13, A_L\right) \approx P_E = \mathrm{ERL}\left(14,14, A_E\right) \tag{6}$$

i.e. the cell with late assignment behaves as it has one channel more than the cell with early assignment when it is analyzed the system of 14 channels. When the number of traffic channels increases, the difference in the quality of service also increases. The system with 21 traffic channel and early assignment behaves similar to the system with 19 traffic channels and late assignment, i.e.

$$B_L = \mathrm{ERL}\left(19,19, A_L\right) \approx P_E = \mathrm{ERL}\left(21,21, A_E\right) \tag{7}$$

as is obvious from Fig. 4. When comparing graphs in Figs. 5, 6 and 7, it may be concluded that variations of f and t_a have greater influence on traffic loss than t_f.

7. COMPARISON

Late assignment as the method for better resources utilization has lower possibilities than half-rate channel transmission and VAMOS technics. The main advantages and disadvantages of these three methods are emphasized in the Table 2.

Table 2

Advantages and disadvantages of methods for resources utilization improvement

Method	Advantage	Disadvantage
VAMOS	Nearly doubling the number of channels, whether they are full-rate or half-rate channels	Unpairing loss [10]
Half-rate	Doubling the number of channels	The worse voice signal quality [11]
Late assignment	Equivalent increase in the number of channels	Improper user signalization in the case of traffic loss [7]

8. SIMULATION

The simulation method of telephone traffic in this case is classic roulette or Monte Carlo program [12], [13], but adjusted for mixed traffic analysis. This simulation confirms the results of calculation. The more versatile results may be obtained if the model with early assignment is analyzed as a model with mixed traffic. The first traffic component is ineffective traffic, i.e. channel seizure when the called user does not answer. The main feature of this traffic is short channel seizure.

The second traffic component (real traffic) is the consequence of connection establishment. The main feature of this traffic is channel seizure from the ringing signal start till the connection (conversation) end. The models with mixed traffic are analyzed in some references, among others for system with mixed voice and data traffic in mobile networks [14] and [15]. The theory of mixed traffic may be also applied to analyze mutual influence of primary traffic (calls realized in the considered mobile cell) and handover traffic (calls arriving from the neighbouring) on the cell traffic performances [16]. The basis of mixed traffic analysis may be found in older contributions intended for classic telephony systems analysis. Today significant contribution in traffic value is the consequence of video services [17] and theory of mixed traffic is also important to analyze common influence of even more traffic types included in multimedia services. The contribution of this paper is that mixed traffic model is used for the analysis of two voice traffic components. On the base of our original modification of classic Monte Carlo simulation program it is possible to familiarize with all the properties of the individual traffic components in the mixed traffic (offered, served, lost traffic, and so on), not merely with aggregate properties.

Figure 8 presents the results for the variation of offered and served ineffective traffic and real traffic as a function of the part of calls, which are directed to absent users (f). The presented traffic values are the mean values on the base of at least three simulation trials. Each simulation trial is not finished until at least 100 000 calls are realized. In this example it is $N=6$, $\lambda=0.05$, $t_m=100$s, $t_a=12$s, $t_f=20$s. As the comparison, the calculation results are also presented for one of the variables, for which the results are obtained by simulation (the served traffic of absent users – A_served_absent).

Figure 9 presents the simulation results for the variation of traffic loss as a function of the part of calls, which are directed to absent users (f). The other data in this simulation are as for Fig. 8.

Figures 10 and 11 present the same characteristics as Figs. 8 and 9, but for N=14 channels. The incoming calls intensity is $\lambda=0.12$. The other parameters of the simulation are the same as for Figs. 8 and 9. The last characteristic in Fig. 10, as in Fig. 8, presents the calculation results for the served traffic of absent users – A_served_absent.

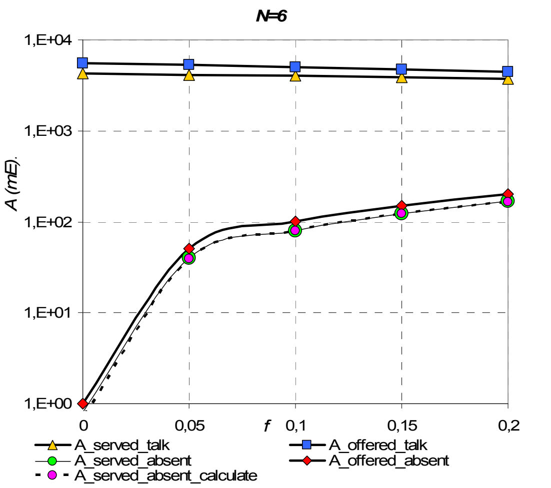

Fig. 8 – Traffic values of ineffective and real traffic as a function of the part of calls, which are directed to absent users for 6 channels.

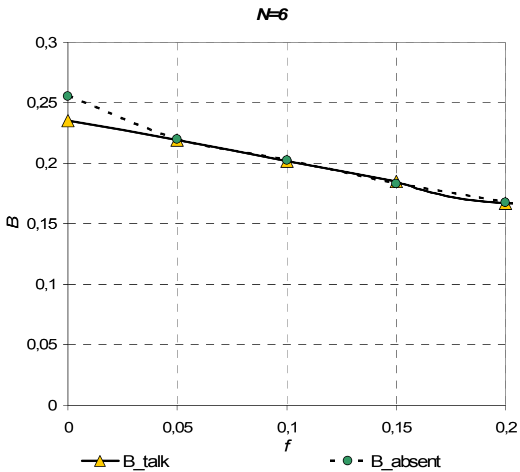

Fig. 9 – Ineffective and real traffic loss as a function of the part of calls, which are directed to absent users for 6 channels.

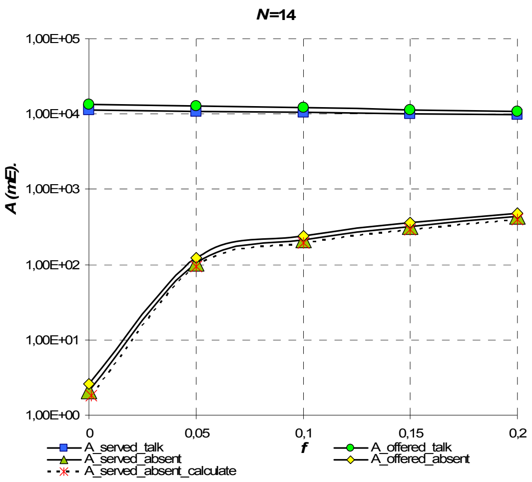

Fig. 10 – Traffic values of ineffective and real traffic as a function of the part of calls, which are directed to absent users for 14 channels.

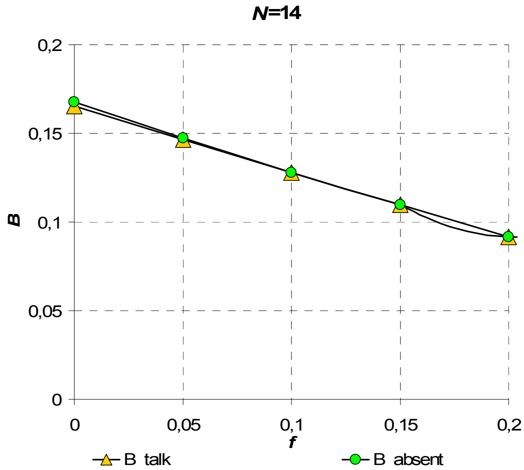

Fig. 11 – Ineffective and real traffic loss as a function of the part of calls, which are directed to absent users for 14 channels.

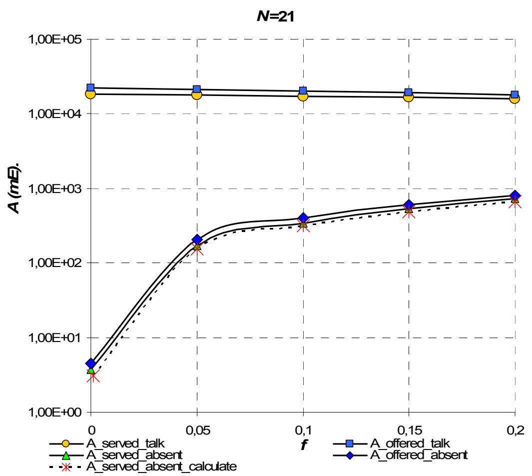

Fig. 12 – Traffic values of ineffective and real traffic as a function of the part of calls, which are directed to absent users for 21 channel.

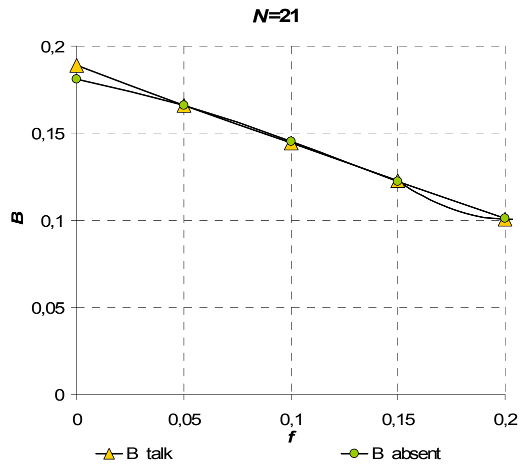

Fig. 13 – Ineffective and real traffic loss as a function of the part of calls, which are directed to absent users for 21 channel.

Figs. 12 and 13 present the variation of offered and served ineffective traffic and real traffic (Fig. 12) and the variation of traffic loss (Fig. 13) as a function of the part of calls, which are directed to absent users (f) when there is $N=21$ channel available. The incoming calls intensity is $\lambda=0.2$. The other parameters of the simulation are the same as for Figs. 8 and 9, i.e. 10 and 11. Figure 12, as in previous cases in Figs. 10 and 12, includes calculation results for the served traffic of absent users – A_served_absent as a comparison to the results of simulation.

9. CONCLUSION

Late assignment is the simple method for traffic channels efficiency increase in the mobile users' network. The main imperfection of this method is the possibility that there are no idle channels after the connection set-up in the moment of the called user answer. That's why unique call loss appears after the signalization of successful connection, when this method is applied.

The efficiency gain when late assignment is applied instead of early assignment depends on several factors: part of absent called users, mean duration time of ringing signal till called user answer, mean duration time of ringing signal to an absent user and mean connection time. As a simple definition, it may be said that the late assignment group behaves in the relation to the group with early assignment as the group with more traffic channels.

The group with late assignment as the oldest method for efficiency improvement of traffic serving in mobile telephony systems has the lower gain than half-rate group or VAMOS group.

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