Paper

Optimization of Call Admission Control for UTRAN

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Abstract—This paper addresses the traffic's grade of service indicators: call blocking and dropping rates as well as the optimization of their mutual relation, corresponding to the call admission control procedure configuration. In the presented results of simulations authors showed opportunities for the CAC load threshold adaptation according to the traffic volume and user mobility changes observed in the mobile radio network.

Keywords—blocking and dropping of calls, call admission control, measurement based optimization, radio resource management, traffic analysis.

1. Introduction

Basically, there are two major ways to increase efficiency of mobile networks. The first one is to enhance performance of systems (in particular, radio technologies). The main objective of the system development is to better and better cope with problems related to the transmission in a mobile radio channel, which is faded and interfered. The second way is to ensure that the systems are effectively deployed and used. This regards to the issues of network planning, configuration and optimization. Putting into practice new technologies requires gaining knowledge about their efficient usage. Hence, looking for new solutions of adaptation the network to specific conditions of its operation in a given geographic area, taking into account the current state of environment, generated traffic and the radio resources occupation in that particular area, becomes the essential part of mobile communications development.

In this paper we focus on two important indicators of the traffic's grade of service (GoS), namely the call blocking and dropping rates (denoted *BR* and *DR*). They correspond to the operation of the call admission control (CAC) and congestion control (CC) procedures, respectively. We show the impact of the traffic volume and user mobility profile on the abovementioned indicator values as well as their mutual relation. According to the purpose of CAC procedure optimization we show new opportunities and consider limitations of their taking.

2. Dropping and Blocking of Calls

Users' perception of the mobile network performance is based on their experience on its operation. Their feelings result from several factors, like e.g., the availability of services, their quality as well as the frequency of unwelcome events. Providing availability and quality of services is the issue of both network planning and system characteristics. It is up to the operator to design the network layout in the best way to enable the radio transmission with required signal to interference ratio (SIR) and serve users with expected quality, i.e., popularly speaking to provide a "good range" over the network operation area. The service quality and related SIR requirements are characteristics of used technology and provided services.

The WCDMA radio interface load may vary while serving a constant number of transmissions in particular cells due to changes in radio channels [1], [2]. If we assume the system is able to provide users with a guaranteed quality of service (QoS), which for CS domain should be ensured, then the quality of serving traffic can be expressed with the GoS indicators. In UMTS, the CAC and CC procedures take care of keeping the load below a certain threshold to ensure the stability of network operation. These two procedures are responsible for preventive blocking of new calls and dropping of the serving ones in case of congestions, respectively. The CAC procedure estimates the additional load of each new call before it is accepted and based on the total estimated load level decides whether to block it or not. Unfortunately, due to some traffic variations (caused mainly by users mobility) as well as signal fading (e.g., due to shadowing) the threshold of maximum allowed load may be occasionally exceeded. In such a case the CC procedure performs actions to keep the load below this threshold and protect the system against congestions. The order of performed actions starts from higher layers, where at first bit rates for particular transmissions are tried to be reduced. If the quality of served calls cannot be decreased anymore and next no handover to any other cell or radio access technology is possible, then finally, one or more calls have to be dropped. Other common reasons for dropping of calls include not defined cell neighborhoods, faults that may occur during the handover signaling procedure, in which whole the protocol stack is involved as well as not enough transmitter maximum power.

Dropping of calls is perceived very frustrating by users, much more than blocking of new ones and impacts their mean opinion on the network quality more than blocking. Hence, operators pay attention to protect their networks against dropping more than blocking. For this purpose, usually a certain reserve of load is assumed in the CAC procedure, which means that the CAC load threshold for new calls (denoted as η_{max_new}) is set below the CC one (η_{max}).

Both blocking and dropping rates are important measures used for the network quality assessment in terms of the traffic serving efficiency. They can also be used as key performance indicators (KPIs) for the network optimization process. Blocking rate is defined as the ratio of blocked calls to all call attempts and the dropping rate is the ratio of dropped calls to the admitted calls number. Their definitions are based on counters, which indicate numbers of events that occurred during the observation (measurement) time period ΔT.

2.1. The Model for UTRAN Traffic Analysis

For 2G FDMA/TDMA systems, analytical models of serving policies for fresh and handover calls, including various network load and user mobility, were deeply investigated and described, e.g., in [3] and [4]. For UMTS, the state of WCDMA interface load, distinct from 2G systems, may change not only according to the traffic volume, but also to its distribution as well as the propagation environment variations. Thus, the radio resource occupation in particular cells may change in continuous manner. Moreover, it depends nonlinearly on the number of calls being served as well as on the users' distance to their base stations. The analytical approach to such a dynamic process for a network with cell coupling, such as UTRAN, is very complex and problematic. Hence, we used computer simulations to better recognize blocking and dropping occurrence characteristics and appropriate rate indicators.

For the sake of the considered problem nature we built a dynamic model, in which consecutive evaluated system states were correlated in time. Only fresh voice calls were generated in the network model and the handover ones resulted from users' mobility. New calls appeared with exponentially distributed intervals. The same distribution, with an average value of 120 s, characterized the connection duration. Mobile stations could have moved over straight lines in randomly selected directions and with speeds assigned according to the normal distribution characterized by four factors: average, standard deviation, minimum and maximum value.

Based on defined this way traffic volume and density, user mobility as well as all link budgets analysis, the implemented system procedures generated blocking and dropping of calls. The load factor and the maximum transmit power were the only reasons for the performed actions by CAC and CC procedures. To ensure the results accuracy, it was necessary to assure the events occurrence precisely in time. Therefore, all transmissions in the network must have been treated asynchronously, as in real. Hence, all transmitter powers were calculated each time the active set update procedure was performed by any active mobile station. The frequency of network evaluations depended on the number of mobile stations served and the event schedule configured for particular simulation scenarios. Simulations usually examined several hours of the network operation, during which a huge number of events were processed. Note that each mobile station performed its active set update procedure every one second. All that led to the simulations were time consuming and required considerable computing power. Hence, while planning of simulation experiments the issues of their feasibility in terms of a reasonable time to achieve results had to be considered.

The author's concept of dynamic network model assumed simplifications leading to decrease the simulation time. Most of all the highest system time resolution related to the fast power control loop was not considered. The toroidal network structure (presented in Fig. 1) was chosen and limited just to seven cells in which calculations were performed. Users could have moved in the area served by seven base stations and never left it. A user served, e.g., in cell 2, if moved outside the network, would hit the cell 4, 6 or 5, depending on the movement direction. It corresponds to the 4', 6' and 5' cells layout in the model shown in Fig. 1, however, the user's position was automatically shifted to the appropriate cell with the indicator 4, 6 or 5. According to [5] and [6] at least two rings of neighboring cells should be taken into account for the correct external interference calculation for WCDMA interface. Therefore, appropriate copies of cells, marked with ' were used for that purpose. They are just the same only geographically shifted cells, thus they do not need to be evaluated and introduce no additional computational load. The nominal cell radius was assumed to 1 km.

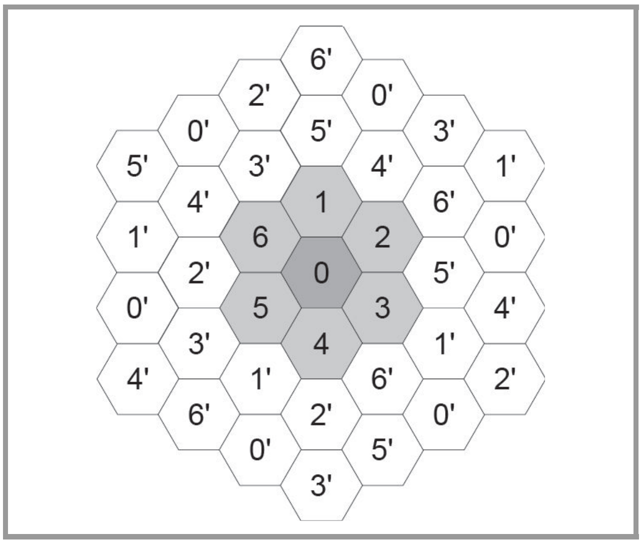

Fig. 1. The network layout model used for simulations.

The most of link parameters for mobile and base stations were set according to the specification [7] and [8] requirements and commonly used values for CS voice service [1], [2]. For the estimation of propagation loss we used the Okumura-Hata model. We assumed the area was flat and the propagation environment homogenous, without shadowing.

In case of a congestion, the most commonly applied strategy for selection of connections to be dropped uses the load or power criterion, which can be met either for uplink or for downlink. We examined the voice service in CS FDD

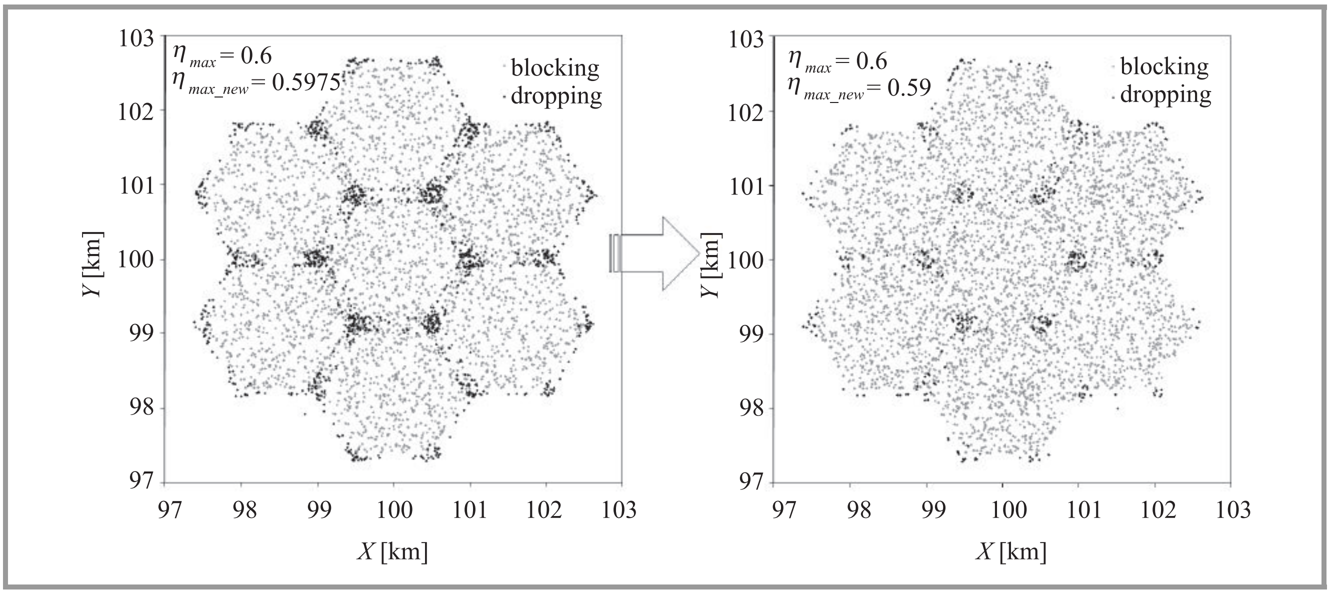

Fig. 2. Positions of blocking and dropping events in the simulated network model for selected CAC configuration cases.

domain, thus at least one congested transmission direction could have caused the CC procedure action.

Assuming equal users priorities, the connection selected to be dropped should be the one, which occupies the largest amount of resources at a given moment in time. In UMTS this means that such a connection introduces the largest interference or uses the largest transmission power among all the existing ones. This approach leads to minimization of unwelcome dropping events. Due to such a strategy, positions in the network of users suffering call dropping are usually close to the cell boarder, if no indoor users are assumed. The occurrence of blocking and dropping events in the regular simulated network model is shown in Fig. 2.

2.2. Call Admission Control

The most important procedure responsible for the *BR* and *DR* values mutual relation is call admission control. It assures a required balance between these indicators, which is always a trade-off. To decrease dropping, the network must accept a smaller number of new calls and thus, decreased *DR* is paid with increased *BR*. Unfortunately, the overall number of both unwelcome events may increase in this case, so, in the effect we can serve less traffic, but with a better (or more desirable) GoS. En example of this trade-off achieved thanks to the CAC procedure configuration is illustrated in Fig. 2.

For all the examined cases the constant value of $\eta_{max} = 0.6$ was used. It was assumed that the CAC procedure worked perfectly. This means that there was no possibility of making wrong decision about the admission of a new call. Thus, there was no possibility of dropping any call due to the new one admission in a cell. If the CAC decided to admit a new call it meant that all transmissions in the particular cell would be maintained directly after that. Moreover, it was assumed that CAC worked immediately, so the decisions were made without any delay.

The cost of achieved dropping improvement for the defined network operation scenario (with a constant traffic volume and user mobility profile) is shown in Fig. 3. Served traffic rate (*SR*) is defined as the ratio of well served calls number to all call attempts, where "well served" means all the ones which were admitted and successfully served.

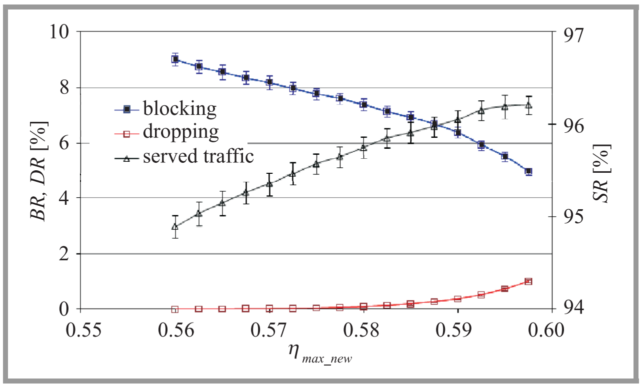

Fig. 3. CAC threshold configuration: reward and costs.

We can observe that the dropping protective CAC configuration (achieved by decreasing the load threshold η_{max_new} while maintaining a constant value for η_{max}) causes an increase in the overall number of unwelcome events as well as a decrease in the served traffic rate. The difference between η_{max} and η_{max_new} implies how much the network is better protected against dropping than blocking. By examining consecutive values of the CAC load threshold we can also estimate a curve showing the *BR* versus *DR* relation that is possible to obtain for the particular network operation case. This curve shows Pareto front for the CAC optimization if only *BR* and *DR* are taken into account. The results obtained by simulations for consecutive η_{max_new} values assuming a constant value of η_{max} are presented in Fig. 4.

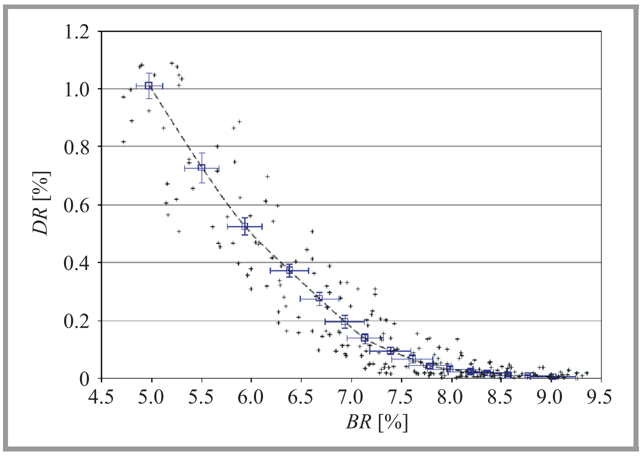

Fig. 4. Blocking-dropping Pareto front estimation for the simulated case of CAC procedure configuration.

Each averaged point corresponds to a different value of the load threshold η_{max_new} set the same in all the simulated base stations. Each configuration case is presented in the figure as a cloud of small crosses measured during the simulation in all the cells as well as their average estimator. Results from all the cells in the simulation model could have been averaged because they were obtained for the same traffic and environment conditions. Moreover, it is important to note that all the simulations covered the same network operation period as well as to enable reliable comparisons, every time the random generator was initiated with the same value. The confidence level was assumed at 95%.

2.3. Traffic Volume and User Mobility Impact on BR and DR

Blocking and dropping rates are function of the traffic volume and the user mobility profile (especially their average speed). Based on the described network model we examined the impact of the offered traffic volume and the mean mobile stations speed of movement on *BR* and *DR* values. The measurement period ΔT was defined to 900 s and the overall simulation time was set to 50 000 s.

Figure 5a presents results of performed simulations assuming a constant user mobility profile and different (uniformly distributed) traffic volumes offered to the network. We can observe much bigger increase of blocking rate than the dropping one in case of a heavy network load, which is a direct result of the CAC operation.

In the second case, shown in Fig. 5b, a constant volume of the offered traffic was assumed, but tests were performed for mobile stations moving with different velocities (V_{MS}). When mobile stations moved fast, variations of the interface conditions increased, more handovers were performed and thereby the risk of dropping a call was also increased. That caused, on the other hand, more room for admission of new calls and resulted in decreased *BR* value.

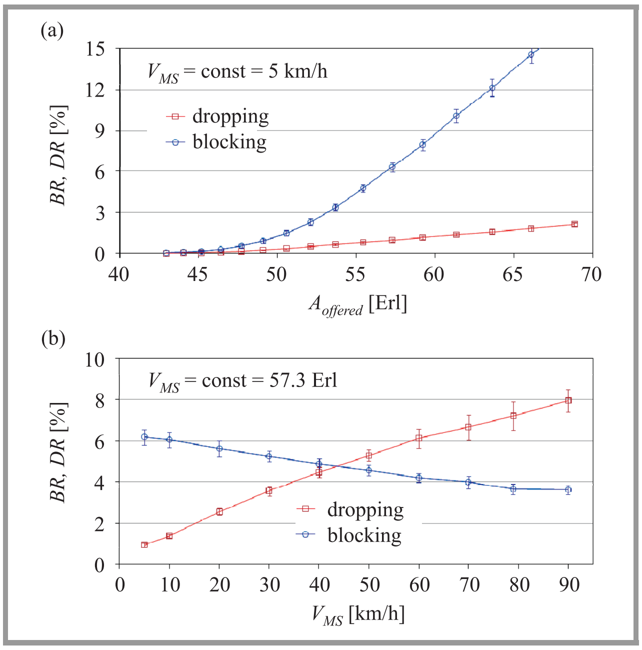

Fig. 5. Impact of (a) traffic volume offered per one cell and (b) users velocity on blocking and dropping rate values for a selected CAC configuration case.

3. Optimization of CAC

The values of the η_{max_new} and η_{max} thresholds impact the *BR* and *DR* indicators. Besides an obvious care about the rates minimizing, a proper relation between them should be assured according to an operator's policy that can be defined by the following objective function:

$$CF = BR + W\ DR, \tag{1}$$

where $W \geq 0$ is a weight factor that was assumed as $W = 4$ (similar as in [5]). The optimization of the CAC procedure can be based on the cost function CF (η_{max_new}) minimization.

The means of estimation of the optimal η_{max_new} value for selected and similar in all cells traffic conditions is illustrated in Fig. 6. Each point on the plot is a result of multiple tests performed for a given simulation scenario and the η_{max_new} threshold value. The cost function approximation CF (η_{max_new}) enables finding its minimum.

The above case assumed stable conditions of traffic and user mobility during all the simulation time. In a real network they change periodically, so, obtained this way result would provide an optimal value of the CAC threshold ($\eta_{max\_new\_opt}$) for averaged traffic conditions.

To examine the dependence of $\eta_{max\_new\_opt}$ on traffic volume offered within a cell ($A_{offered}$) and the mean speed of mobile stations (V_{MS}) we simulated the network model described in subsection 2.1 for many configuration cases.

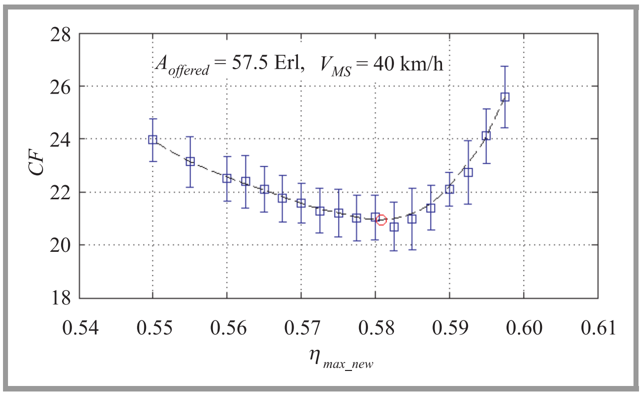

Fig. 6. Optimal η_{max_new} value estimation for the selected traffic volume and mobile stations speed.

Tests related to the traffic volume and users velocity were performed separately, assuming stability of other conditions. To estimate the relation of $\eta_{max\_new\_opt}$ to $A_{offered}$ the network model was examined for different values of mean time interval between consecutive calls. During simulations a constant value of mobile station speed equal to 40 km/h was assumed. Next, the dependence of $\eta_{max\_new\_opt}$ on V_{MS} was analyzed for the constant value of $A_{offered} = 53.6$ Erl.

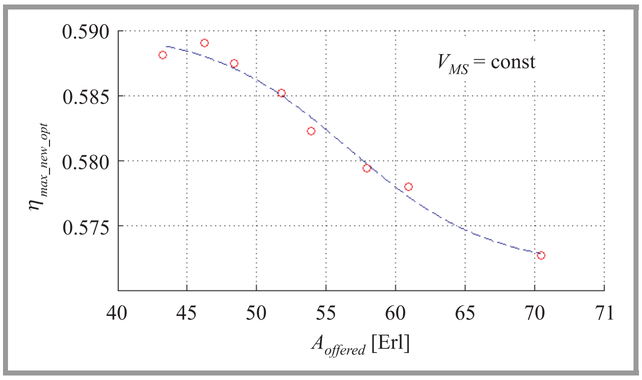

Fig. 7. Optimal η_{max_new} value dependence on the traffic volume offered to one cell for a constant speed of mobile stations.

As shown in Fig. 7, when the traffic volume is bigger the cost function Eq. (1) reaches its minimum for smaller values of η_{max_new}. Thus, the difference between η_{max} and η_{max_new} increases.

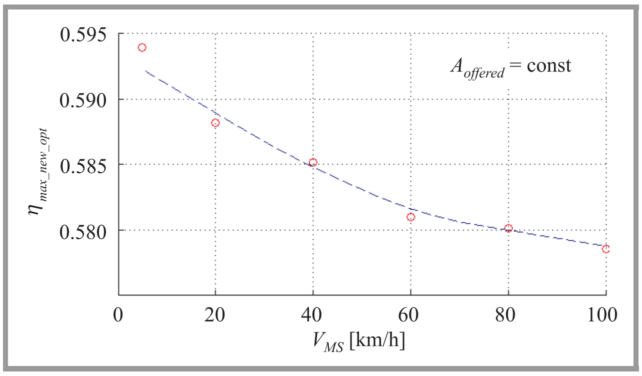

Fig. 8. Optimal η_{max_new} value dependence on the mobile station speed for a constant traffic volume offered to one cell.

Considering the second simulation scenario for constant $A_{offered}$ and variable V_{MS}, when mobile stations are moving faster the optimal η_{max_new} value is smaller (Fig. 8).

Results presented in Figs. 8 and 9 show relations of the optimal CAC configuration in a qualitative manner. Although the estimated curves should be treated as only approximated, the crucial fact is that the optimal CAC configuration depends on the values of $A_{offered}$ and V_{MS}, which in a real network change periodically. En example of traffic volume measurement result is shown in Fig. 9.

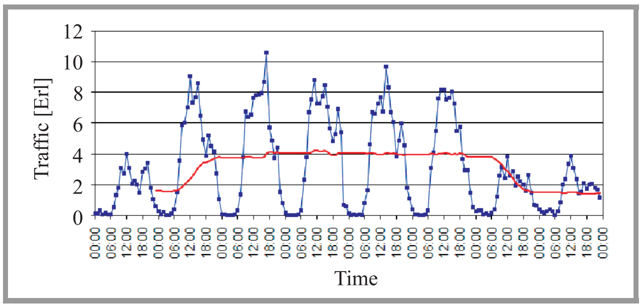

Fig. 9. Traffic volume for a sample cell (8 day period) with a moving 24 h average; real cell measurements, data received from a Polish operator.

We can expect that if we are able to adjust the η_{max_new} parameter according to the traffic variation during a day or a week, we could reach a better traffic GoS in the meaning of the defined objective function. To ensure the optimal relation between blocking and dropping of calls the η_{max_new} threshold value should be decreased when the offered traffic volume increases as well as in the case of increased speed of mobile stations (as shown in Figs. 8 and 9).

The relations presented in Figs. 8 and 9 can help in definition of such a dynamic CAC adaptation process, however there are some important issues that must be considered. If we are going to take advantage of measurements performed online, we must take into account their reliability and feasibility.

Basically, if we want the adaptation process to work effectively we need to perform the η_{max_new} threshold changes on a relatively short time scale. Hence, direct usage of *BR* and *DR* indicators in this process (as proposed, e.g., in [9]) might be problematic. First of all, short periods of measurements result in a poor reliability of the obtained indicators. According to *BR* and *DR* it is crucial, since these indicators are based on counters of events which happen rarely and thus, require long periods of measurement. Moreover, for frequently performed measurements a lot of resources are required for sending reports from all the monitored cells as well as for data processing in RNC [10] which is the entity responsible for gathering measurement reports.

To solve these problems the concept of decentralized (single cell oriented) RRM architecture can be applied. It is assumed to pass over information about cell coupling and close the whole measurement and decision process in a single cell. Although it suggests to reorganize the scheme of measurement gathering and processing in UMTS, which would require a certain effort, the reward of opening new possibilities for managing the network seems to be tempting. Moreover, reconfigurations of the η_{max_new} threshold can be based on indicators that are related to *BR* and *DR* but measured with much better reliability during short periods of time.

The offered traffic volume can be better estimated in a short period. It is also based on event counters but such that occur much more often, i.e., incoming new calls. Hence, the measurement of $A_{offered}$ provides much better reliability results than the measurement of *BR* and *DR* during the same period ΔT. The reliability of these three indicators can be compared based on scattering of consecutive samples shown in Fig. 10. The same simulation scenario assuming stationary traffic conditions was examined for different measurement schedules. Note that the $A_{offered}$ standard deviation related to its average estimator value is one order of magnitude smaller that for *BR* and *DR*.

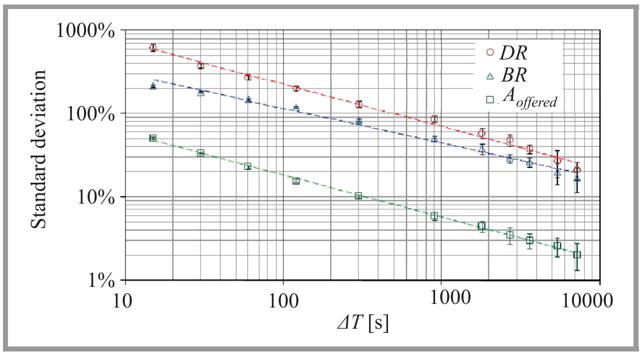

Fig. 10. *BR*, *DR* and $A_{offered}$ scattering for different measurement periods.

Because it is hard to get information about user speeds and movement directions, therefore, for the purpose of dynamic CAC adaptation the mean time of serving calls in a cell ($t_{average}$) can be used. It is directly related to V_{MS} as presented in Fig. 11.

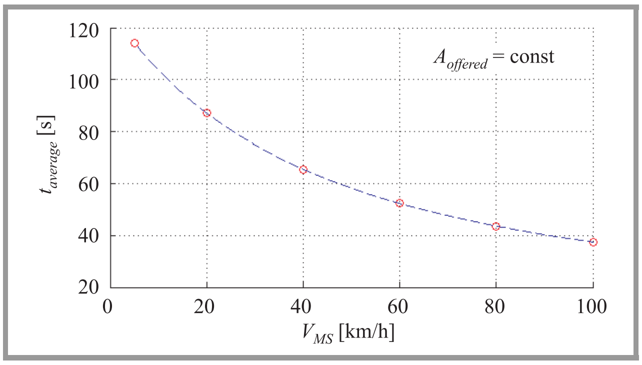

Fig. 11. Average calls duration in a cell dependence on the mobile stations velocity.

Based on relations shown in Figs. 8 and 11 the η_{max_new} dependence on the easy to measure $t_{average}$ was estimated (Fig. 12). If users move faster, there are more handovers in the network and the mean time of holding calls in a single cell decreases (assuming the mean overall connection duration remains the same).

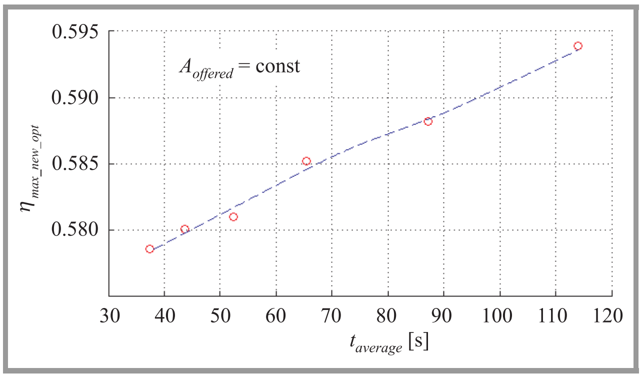

Fig. 12. Optimal CAC load threshold dependence on the average calls duration in a cell.

4. Conclusions and Future Work

Mobile radio network optimization and management methods have to follow the evolution of radio networks and systems. This evolution leads to more dynamic and flexible systems supporting a wider range of services and business areas. In this paper we indicated opportunities for dynamic adaptation of the call admission control procedure. The performed simulations showed that the optimal CAC load threshold depends on the traffic volume offered within a cell and the speed of mobile stations, which is related to the mean time of serving calls in the cell. Based on these relations as well as the indicated limitations a short term CAC threshold adaptation process can be applied. We expect it would enable a better network flexibility according to the traffic's GoS requirements.

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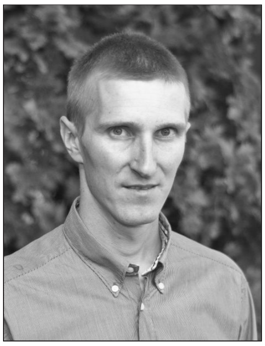

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