Traffic Capacity Improvement Factor when VAMOS Technique is Applied

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Professional paper

UDC: 656:629.056.6

DOI: 10.5937/tehnika2102187M

New modern technologies in mobile telephony overcome the possibilities of GSM systems. VAMOS technique is one way to improve traffic properties of traditional GSM systems. Our aim is to analyze the level of this improvement achieved by VAMOS implementation. The number of traffic resources is doubled, but it is proved that traffic capacity is more than doubled for full rate connections implementation and more than quadrupled for half rate connections regardless of offered traffic for all values of emission power difference between 4dB and 10dB when considering two paired subchannels. There are two loss types in VAMOS systems: unpairing loss and traffic loss when all subchannels are busy. The values of these two loss types whose sum presents the total loss in VAMOS systems are determined by originally developed simulation program. The achievable total loss may be decreased for 45% or even more when allowable power difference between paired channels is increased from 4dB to 10dB.

Key words: VAMOS, unpairing loss, traffic capacity ratio factor, traffic loss increase factor, simulation program

1. INTRODUCTION

VAMOS (Voice service over Adaptive Multi-user channels on One Slot) technique significantly increases traffic capacity in classical GSM cell. Each timeslot in GSM system may be used for two connections (over two OSC, Orthogonal SubChannels) when VAMOS is applied. In this way, the life cycle of GSM systems is prolonged. VAMOS implementation is based on AQPSK (Adaptive Quadrature Phase-Shift Keying) or α -QPSK modulation in downlink direction from base station (BS) to mobile user (MS) which means that signal is transmitted in the same time to two users over the same timeslot.

The process of two connections placing in the same timeslot is called pairing. The transmitted power to each MS depends on the distance between BS and MS and it is adjusted to its minimum value which allows connection existence to decrease necessary BS emission power and interference. The main limiting factor for pairing is that power ratio of two connections,

using the same timeslot (SCPIR – SubChannel Power Imbalance Ratio) is less than Δ_{max} . Typical values are between $\Delta_{max}=4\text{dB}$ and $\Delta_{max}=10\text{dB}$ in steps of 2dB.

The previous analysis related to the performances of VAMOS systems are not numerous [1] – [6]. In spite of its high traffic possibilities, VAMOS is pretty unknown technique. IRITEL published papers contribute to the VAMOS traffic properties better understanding. The probability that the power level difference for two users dedicated to the same timeslot is too great, i.e. that user pairing is unsuccessful is determined in [7]. Contribution [8] compares the traffic performances of two strategies of connections pairing: one which gives priority to connection quality and the other which gives priority to better traffic capacity. The factors which have influence on the pairing in VAMOS systems are user surface distribution and environmental propagation factor and this influence is modelled in [9]. Connections rearrangement as a method for traffic characteristics improvement is analyzed in [10].

Today there are still about 1.700.000.000 GSM subscribers in the world [11]. In some great, but poor countries 99% mobile telephony capacities are in the area of GSM technology [12]. When considering Serbia, about 6000 sites are still in GSM technology without tendency that this number decreases [13], [14].

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Paper received: 03.03.2020.

Paper accepted: 29.03.2020.

These are all reasons why developments and analysis related to GSM remains actual, especially when such research is related to methods for GSM systems improvement.

2. RESEARCH QUESTIONS

The research questions which are the subject of consideration in this paper are: 1) what traffic loss kinds appear in VAMOS systems and what are their values; 2) what is the more accurate value of traffic gain factor comparing to the system with the same number of traffic resources, but without implementing VAMOS technique; 3) what value of traffic loss factor introduces VAMOS technique comparing to the system which would have the same number of channels as the number of simultaneous connections allowed by VAMOS implementation.

Let us consider the base station (BS) with available N traffic channels to explain traffic loss types for the research question 1. Figure 1 presents one very simple example of VAMOS techniques and pairing (in)ability in the area covered by this BS. There are total 5 time slots (TS) in this system, each with 2 OSCs. The figure shows the part of the cell that is, according to the required power for one connection, divided into areas in the form of circular rings, designated by $a1, a2, \dots, a15$. The difference in signal power assigned to users with different attenuation is designated by Δ . The power emitted from BS to mobile user (MS) is designated as P , $P_{min} \leq P \leq P_{max}$.

Power control in BS is realized in 15 steps 2dB each one. Mobile user (MS) from the area ai requires 2dB higher emission power than MS from the area $a(i-1)$. Let us, further, suppose that the allowed emission power difference between two connections which may be paired equals 4dB, $\Delta_{max}=4dB$. This, practically, means that two connections from the same, from the neighbouring or two rings distant areas may be paired. Users MS2 and MS3 from $a2$ and $a3$ may be paired in the time slot 1 (TS1) as well as users MS5 and MS6 from $a5$ and $a6$ may be paired in TS2 in the example from the Figure 1.

The connections of the users from $a4$ and $a7$ may not be paired in TS3, because these connections require powers that differ for 6dB, i.e. more than $\Delta_l=4dB$ which is allowed. This situation causes the call loss due to the pairing inability. As a consequence, one call will not be realized although there is an idle sub-channel (OSC2) in the channel TS3. By this feature, the resource group that uses the VAMOS technique differs from the resource group described by the Erlang model. This is the first loss kind in VAMOS based mobile system. The theoretical analysis to calculate unpairing loss probability may be found in [7].

The second loss kind is the classical loss in Erlang model, but with $2 \cdot N$ traffic channels, meaning that it may appear when all $2 \cdot N$ OSCs are busy.

When considering the second emphasized research question, the simplest approximation is the statement that traffic capacity is doubled if full rate connections are used and even quadrupled for half rate connections because one full rate channel may be used by two half rate connections and, then, each full rate or half rate channel may be used by two VAMOS based connections. But, such a statement for traffic capacity ratio factor (T_{coeff}) does not take into account traffic loss. The idea in this paper is to determine the value of T_{coeff} for two systems with equal traffic loss probability.

Figure 1 gives one example which explains the situation when traffic loss exists although there is an idle traffic resource (idle OSC). The additional loss due to unpairing in VAMOS systems with N channels is the cause why the loss in such systems is greater than the loss in a pure Erlang system (system with full availability) with $2 \cdot N$ channels. The traffic loss increase factor due to unpairing in such a comparison (L_{coeff}) is the subject of the third research question. The situation could be improved by the implementation of additional existing connections rearrangement [10], but this method is not the subject of the analysis in this paper.

Figure 1 - An example of VAMOS based cell when pairing is not possible

The loss values and, as a consequence, the values of T_{coeff} and L_{coeff} mainly depend on Δ_{max} [7]. Dependence also exists on the environmental propagation coefficient (γ) [7] and on the users' surface distribution [9]. The results in the paper will be presented for one characteristic value of γ and for uniform users' distribution, which is the most often found in practical implementations.

3. METHODOLOGY

Traffic processes in mobile telephony systems are often pretty complicate and it is not easy to develop their analytical model. In such a situation processor

simulation is a choice which allows us to analyze system performances. Before practical implementation of simulation program it is necessary to verify its accuracy in some simpler situation than it is the desired system by comparing the results of simulation and the results of analytical approach. The most reliable results of verification are obtained when values of state probabilities (for example, the number of busy channels) are the parameter for comparison.

We used our originally developed simulation program for the verification. Program is developed in C programming language. It simulates the system which priority gives to traffic characteristics, i.e. connections are first paired and then a completely idle channel is searched. The initial point in the simulation is classical Monte Carlo or Roulette simulation process [15] - [17]. This simulation program is further modified [7] in such a way that, as in classical case, the first generated random number determines the event – new call start or call end and the second random number determines the distance between BS and MS. The results in simulation are obtained as a mean value from three simulation trials where 1.000.000 random numbers which define a new event are generated in each trial. The finally determined performances of simulated VAMOS systems are compared to the characteristics of classical Erlang systems defined in some well known source as, for example, [18].

The flow-chart of the simulation program is presented in the Figure 2. The first uniformly distributed random number (RN) in the range between 0 and 1 (0,1) is generated in the block 1. The range (0,1) of generated random number is modified in the block 2 to the range (0, $A+2 \cdot N$) where A is the offered traffic in Erlangs and N is the number of available traffic channels. The multiplication $2 \cdot N$ follows from the fact that 2 connections may be realized in each traffic channel when VAMOS is applied. In the block 3 is determined whether obtained number corresponds to the new call generation or to the call end. The new call is generated if this number is lower than traffic A , otherwise the call is ended. Such Roulette simulations are classical in teletraffic theory and their aim is to achieve in discrete time moments behaviour similar to the systems whose characteristics are exponential distribution of calls duration and Poisson distribution of the number of busy channels [19, question 3.66].

Blocks 4-10, 14 and 15 may be executed if the new call starts. Blocks 11-13 are realized if it is necessary to finish the call. The number of channels in the blocks 2 and 4 is $2 \cdot N$ as this is the total number of traffic channels for the simulation due to pairing.

After determination of mutual distance between BS and MS in the block 5, the area (number of the

annulus or the circle next to the BS in which mobile user, participant in a connection, is located) is determined in block 6. Then it is checked whether the call can be realized. It is first tested whether the new connection may be paired with some of already existing connections. Pairing may be realized if at least one idle OSC exists in the pair where one OSC is already busy (block 7) and if the annulus (AN), where the new offered call is located, is between the up threshold annulus (UTAsc) and down threshold annulus (DTAsc) previously defined threshold for some of currently unpaired OSCs (block 8). If pairing cannot be realized with any of previously active OSCs when the second OSC in the pair is idle, it is tested in block 9 whether some completely idle channel exists (i.e. channel with two idle OSCs). If there are no such channels, the pairing impossibility is declared (block 15). Therefore, in the case of VAMOS system simulation, besides blocking caused by the lack of idle OSCs – traffic blocking (block 14), unsuccessful pairing, caused by pairing impossibility, must be also predicted (block 15).

Figure 2 - Flow-chart of the simulation program

The new offered connection may be established if pairing may be realized or if some completely idle channel exists. In that case, one OSC is seized in the block 10 and up and down threshold (annulus) is determined for possible future pairing. At the end of simulation, the elements, which are important for the analysis, are determined in block 16: the probability of traffic loss, the probability of unsuccessful pairing and the probabilities of system states (i.e. probabilities of the number of busy OSCs).

4. VAMOS TECHNOLOGY IMPLEMENTATION BENEFITS ANALYSIS

The probabilities of both loss kinds for the system with $N=6$ traffic channels are presented in the Figures 3 and 4.

Figure 3 - Probabilities of unpairing loss (Figure 3a)), traffic loss (Figure 3b)) and total loss (Figure 3c)) in the system with implemented VAMOS technology as a function of the maximum allowed power difference between two paired connections (delta - Δ_{max}) and offered traffic (A) for full rate connections realization in the system with $N=6$ traffic channels when it is $\gamma=3.5$ and users' distribution is uniform

The graphs for full rate connections realization are presented in the Figure 3 and for half rate connections realization in the Figure 4.

The graphs for the first loss kind – unpairing loss are presented in the Figures 3a) and 4a). Classical Erlangian loss is illustrated in the Figures 3b) and 4b). Finally, Figures 3c) and 4c) present the sum of two loss kinds. The loss probabilities are presented as a function of the maximum allowed power difference between two paired OSCs (delta (Δ_{max})).

The offered traffic values are the parameter for the curves presentation. As typical values of γ are between 2 and 5 [20], the results are presented for the mean value $\gamma=3.5$. It is supposed uniform users' distribution in all presented graphs.

Figure 4 - Probabilities of unpairing loss (Figure 4a)), traffic loss (Figure 4b)) and total loss (Figure 4c)) in the system with implemented VAMOS technology as a function of the maximum allowed power difference between two paired connections (delta - Δ_{max}) and offered traffic (A) for half rate connections realization in the system with $N=6$ traffic channels when it is $\gamma=3.5$ and users' distribution is uniform

Figure 5 - Probabilities of unpairing loss (Figure 5a)), traffic loss (Figure 5b)) and total loss (Figure 5c)) in the system with implemented VAMOS technology as a function of the maximum allowed power difference between two paired connections (Δ_{max}), offered traffic (A) and environmental propagation coefficient (γ) for full rate connections realization in the system with $N=6$ traffic channels and uniform users' distribution

The dependence of all traffic loss kinds on γ is illustrated by graphs in the Figure 5. Characteristics are presented for $\gamma=2$, $\gamma=3.5$ and $\gamma=5$. Dependence of total loss on γ comparing to unpairing loss and traffic loss is lower and for the extreme γ values it is in the limits $\pm 20\%$ comparing to the mean γ .

Figures 6 and 7 present the values of T_{coeff} and L_{coeff} as a function of Δ_{max} . The factors T_{coeff} and L_{coeff} are presented for the case of full rate connections (Figures 6a) and 6b)) and half rate connections (Figures 7a) and 7b)). The parameter for all graphs is the value of offered traffic A . The criterion when graphs are created is that probabilities of total loss in both mutually compared cases are equal.

Figure 6 - The values of traffic capacity ratio factor T_{coeff} (Figure 6a)) and traffic loss increase factor due to unpairing L_{coeff} (Figure 6b)) as a function of maximum allowed power difference between two paired OSCs (Δ_{max}) for different values of offered traffic A as a parameter, graphs for full rate connections in the case of $\gamma=3.5$ and uniform users' density distribution

Figure 7 - The values of traffic capacity ratio factor T_{coeff} (Figure 7a)) and traffic loss increase factor due to unpairing L_{coeff} (Figure 7b)) as a function of maximum allowed power difference between two paired OSCs (Δ_{max}) for different values of offered traffic A as a parameter, graphs for half rate connections in the case of $\gamma=3.5$ and uniform users' density distribution

Higher values of T_{coeff} are contribution factor of traffic capacity while higher values of L_{coeff} are degradation factor for traffic capacity. According to Figures 6a) and 7a), T_{coeff} is always higher than the declared value 2 for full rate connections, i.e. higher than 4 for half rate connections, meaning that traffic capacity estimation on the base of the number of OSCs is „on the safe side“. When considering L_{coeff} , higher values are obtained for lower values of offered traffic A where total loss is quite low and high values of L_{coeff} may not significantly contribute to this loss. When the values of traffic A are high, the values of L_{coeff} are only a bit higher than 1.

The well-designed mobile systems should have total loss in the area of several percent (2% or 3% are satisfactory values). When considering graphs from the Figures 3c) and 4c), it may be concluded that implementation of higher values of Δ_{max} significantly contributes to the decrease of loss probability. In the system with full rate connections implementation, the total loss decreases from ~3.5% to ~1.9% when Δ_{max} is increased from 4dB to 10dB when the offered traffic is $A=6E$ (according to the Figure 3c)). The similar values are obtained in the case of half rate connections implementation when the offered traffic is $A=16E$ (according to the Figure 4c)). The improvement is for these traffic values about 45%. The contribution of Δ_{max} increasing is lower for higher traffic values (for example, total loss is ~25.5% for $\Delta_{max}=4dB$ and ~22% for $\Delta_{max}=10dB$). This improvement of about 14% is still not negligible, although the total loss level is not representative for mobile systems design.

6. CONCLUSIONS

This paper presents the performances of VAMOS system in GSM systems traffic properties improvement. VAMOS techniques allows the number of available traffic channels doubling, but it is proved that effective number of simultaneous connections may be more than doubled when the offered traffic loss equality is the criterion of comparison. Such a statement is valid both for full rate ($T_{coeff}>2$ for all A and Δ_{max} values) and half rate connections realization ($T_{coeff}>4$ for all A and Δ_{max} values). It is further proved that total loss increase due to pairing comparing to the systems with doubled number of traffic channels (when full rate connections are considered) or quadrupled number of traffic channels (when half rate connections are analyzed) without VAMOS, is not high for significant traffic values (coefficient L_{coeff} is a bit higher than 1). The maximum level difference between two paired connections may be variable and this difference increase to the maximum technologically possible level of 10dB leads to total loss decrease of 45% or even more at reasonable offered traffic values.

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REZIME

FAKTOR POBOLJŠANJA SAOBRAĆAJNOG KAPACITETA KADA SE PRIMENJUJE VAMOS TEHNOLOGIJA

Nove moderne tehnologije u mobilnoj telefoniji poboljšavaju mogućnosti GSM sistema. VAMOS tehnika je jedan način da se poboljšaju saobraćajna svojstva tradicionalnih GSM sistema. Naš cilj je da se analizira stepen ovog poboljšanja koji se postiže primenom VAMOS-a. Broj saobraćajnih kanala se udvostručuje, ali se dokazuje da se saobraćajni kapacitet više nego udvostručuje za veze koje zauzimaju ceo saobraćajni kanal i više nego učetrostručuje za veze koje zauzimaju pola saobraćajnog kanala nezavisno od ponuđenog saobraćaja za sve vrednosti razlike u emisionoj snazi između 4 dB i 10 dB za dve uparene veze. Postoje dva tipa gubitaka u VAMOS sistemima: gubitak zbog nemogućnosti uparivanja i saobraćajni gubitak kada su svi podkanali zauzeti. Vrednosti ova dva tipa gubitaka čija suma predstavlja ukupan gubitak u VAMOS sistemima se određuju korišćenjem originalno razvijenog simulacionog programa. Ukupan gubitak koji se postiže može se smanjiti za 45% ili čak i više kada se dozvoljena razlika snage dva uparena kanala poveća sa 4 dB na 10 dB.

Ključne reči: VAMOS, gubitak zbog nemogućnosti uparivanja, faktor odnosa saobraćajnog kapaciteta, faktor povećanja saobraćajnih gubitaka, simulacioni program