

A Role of Excel Program in Telecommunication Processes Simulation

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This paper presents the simulation of mobile telephony systems realized in Excel program. Although primarily intended for other applications, Excel has several advantages over other specialized programs for simulation purposes. Excel application for simulation is illustrated by several examples from already published papers with the main goal to describe the most important part of realized simulations that allows determination of all important characteristics of telecommunication traffic process. Beside traffic process, the Excel application allows a reliable simulation of base station emission power starting from a random distance between the base station and mobile station.

Key words: Excel; mobile telephony system; traffic simulation; random distance.

Introduction

NOWADAYS a complexity of telecommunication systems grows rapidly. Different and new traffic types are introduced to satisfy growing consumers' needs. Besides, various environmental influences contribute to the expected system behaviour dealing with power consumption or served traffic intensity, especially when considering mobile telephony. It is hard, or sometimes even not possible, to include all such elements in mathematical models intended for traffic characteristics calculation. From these several sentences three main reasons why traffic process simulations have increasing importance in modern analysis of traffic processes in telecommunication systems follow [1]: 1. easier verification of calculation results than it would be using the results obtained by measurements (sometimes it is not possible to perform measurements, especially in the system installation phase); 2. investigation of the properties of systems with complex traffic relations for which there is not a suitable analytical model; 3. analysis of various non-traffic influences to the traffic characteristics of systems for which already known traffic models may be applied.

Simulation of telecommunication systems may be realized on different programming tools, i.e. software packages. There are two kinds of programming languages for simulation: simulation language (GNU licenses software) and general-purpose language (proprietary software). In the beginning, the former group included GPSS, SIMSCRIPT and SLAM II while the latter included FORTRAN, PL/1 and ALGOL [2]. Today, programs are often developed in MATLAB [3], [4], C [4], Perl [5], Python Programming language [6], Wolfram language MATHEMATICA [7] or .NET Framework may be applied on Microsoft Windows operating system as a base for software development [8], etc. Some other examples that use C/C++ programming language are [9], [10]. Implementation of the system or its parts in a real situation is dynamically tested and predicted using specially developed network simulation

programs such as NS2 [11] and NS3 [12]. Nevertheless, in any of these cases, it is necessary to have specific tools that are not always easy to provide or its procurement is connected with additional, not negligible expenses. That is why our investigations related to the telecommunication systems simulation are also performed using Excel as an easily available software tool on each computer device [13] - [16]. The references [13] - [16] are only a part of internationally verified contributions realized by the Excel simulation and they illustrate a simulation method together with the Excel implementation in an adequate way. Our implementation of general-purpose language Excel for simulations in the traffic and base station (BS) emission power analysis of mobile systems starting from GSM is an innovative contribution. However, we are not limited only to the Excel applications for simulation of mobile telephony systems: reference [17] deals with one specific analysis of a real life problem in the area of university teaching.

The benefits and drawbacks of Excel implementation for simulation program execution

Excel program is not intended to realize some complex programming functions as systems simulation. It is the reason why writing such programs is sometimes tremendous, although achievable task. It is necessary that a programmer is skilled and patient to write and test the program.

Program loops in Excel are not a part of program realization itself. Instead, one pass through the program loop is coded in the program and the number of iterations is defined using the standard menu by sequential selection of Excel 2003 functions: 1. Tools; 2. Options; 3. Calculations; 4. Maximum iterations – number between 1 and 32768. After this procedure the program is executed selecting the F9 key. The program passes its complete realization as many times as it is given by the number of iterations.

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Such process of the program loop realization is possible only for one loop and this is the widest loop. The narrower loops are replaced by “If” functions when the program is coded. For example, the program loop for all traffic channels is replaced by a coded program which is written separately for each one of the total number of channels. Of course, it is significantly more complicated to write a program and to control the execution of such program in comparison to the same function is realized as a program loop in some other program language than Excel.

The other important function in the program realization is an initial reset or starting value definition of necessary registers. The choice of this initial definition or program loops execution is performed by one special register in Excel: 1. if the value in this register is “empty”, the registers obtain their initial content; 2. if there is some content in the register (“delete to start” in our case), the program iterations are executed.

There are three important benefits of coding simulation programs in Excel. The first one is that the program may be available for execution to anyone due to the fact that Excel is practically operable on each personal computer or laptop. Depending on the achievable computer execution speed, only the necessary time consumption is different. It is not necessary to implement programs, which are not available to everybody including the ones whose price of providing and operability maintenance is often very high. The other benefit is that the desired characteristics presentation may be realized directly in the implemented Excel program, which is simpler than with the majority of other programs where it is usually necessary to process calculation or simulation in one program unit and perform a graphical presentation in other program unit. The third benefit is related to the process of program testing. The test may be easily performed in such a way that an option of one or some other desired number of iterations is selected and after this number of steps is executed, the values of all registers are directly available at the program sheet. It is not necessary to add program instruction just to present the values of important registers or to use special tools for program testing.

The written program code to simulate telecommunication systems behaviour is significantly longer in Excel than in other programming languages. It is the reason why we usually have that a great part of the program sheet is occupied by the program instructions. When testing the program execution, often the programmer has to follow the results in a great part of space on the program sheet and to be very concentrated in each moment to know at least where he/she must check the expected results to appear.

Principles of events generation during simulation

The process of events generation during a telecommunication system simulation is called Roulette or Monte Carlo method. The method is developed more than 40 years ago and references [18] - [20] represent only several examples where it has been implemented starting from the early ages. The principle benefits and drawbacks of the Monte Carlo simulation are emphasized in [20].

The principle of Monte Carlo simulation is simple: new connection, termination of the existing connection, or empty event is generated based on generated random number. The simulation process starts from the generation of uniformly distributed random number in the range $\{0,1\}$. The number obtained in this way is further spread to the range $\{0,A+N\}$ where A is total offered traffic and N is total number of available traffic channels. Relation between the generated random number and the corresponding event may be explained for the system with n different traffic types using the Fig.1.

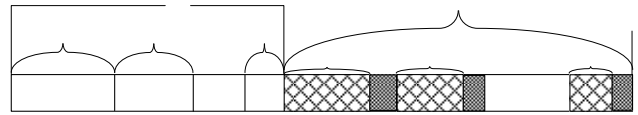


Figure 1. Principle of events generation in system with n different traffic types

The total range of numbers has two parts: the first one with values $\{0,A\}$ corresponds to the call generation and the second one with values $\{A,A+N\}$ corresponds to the call termination if the call exists in the selected sub-range of numbers. The offered traffic of calls designated by the index i is $A_i=A \cdot f_i$. Frequencies of calls generation satisfy the condition $f_1+f_2+\dots+f_i+\dots+f_n=1$. It is clear that the call corresponding to the traffic with the index i is generated if the random number falls in the range $\{A \cdot (f_1+f_2+\dots+f_{i-1}), A \cdot (f_1+f_2+\dots+f_{i-1}+f_i)\}$.

The number of traffic channels that serves to the traffic with the index i in some moment is K_i (Fig.1). This number of channels is alterable during time and this is symbolically designated by Y besides K_i ($i=1,2,\dots,n$) in Fig.1. There are two possibilities on how to determine whether the connection is terminated and they both provide approximately the same reliability of results. The first one is to define the ordinary number of the channel that is seized each time the connection is established. Then the ordinary number of the channel which is a candidate for connection termination follows directly from the generated number from the range $\{A,A+N\}$. In this case busy channels are not arranged continually one after another. This approach is implemented, for example, in [16] or in older, original contributions [18], [19]. The second possibility (Fig.1) is not to determine the ordinary numbers of the busy channels. Instead, channels that serve the traffic component i are placed in the range $\{A+K_1+K_2+\dots+K_{i-1}, A+K_1+K_2+\dots+K_{i-1}+K_i\}$ and the connection is terminated if the random number falls in this range. This second approach is simpler for the realization and is applied in [13].

Fundamental calculations in Excel

Table 1 presents the record of simulation for the system with traffic components in GSM system [13], which is executed in Excel program. Designations D-S in the first table row and 10-21 in the first table column together define the cell with data in the Excel program sheet. The values in the Table 1 are obtained after 50000 generated random numbers and are directly copied from the program. The light green highlighted cells are only designations what data are placed in the adjacent cells. Turquoise highlighted cells represent input data while yellow highlighted cells contain output data. For example, the content N in the green highlighted cell I10 (cross-section of the column I and row 10) shows that the number of available traffic channels is in the mobile telephony cell I11 and it is 22. This is an input data because it is highlighted turquoise. Or further, the green highlighted contents *int* in the cell F14 and *con. begin* in the cell E15 show that yellow highlighted content 3496 in the cell F15 mean that this is the number of initiated connections in the mobile telephony cell (MTC), etc.

The two components of traffic ($n=2$) are external traffic and internal traffic. External traffic represents the connection between the user from the considered MTC and the user from some other MTC and it is necessary to reserve only one traffic channel in the considered MTC. Internal traffic represents the connection between two users in the considered MTC and thus it occupies two traffic channels. The number of channels in the system (N), offered internal (A_i) and external traffic (A_e) are defined in the table cells I11, J11 and K11, respectively.

Table 1. Excel record of simulation for two-component traffic

	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
10	delete to start					N	Ai	Ae								
11	delete to start					22	2.74	10.96								
12	rand{0,1}	rand{0,A+N}														
13	0.6675455	23.8313771														
14			int	ext												
15		con. begin	3496	14600												
16		con. end	3495	14590												
17			busyi	busye	busych				trafi (serv)	trafe (serv)		blocki	blocke		trafi (ofer)	trafe (ofer)
18			1	10	12		11		122914	518779		4884	2128		136219.7	541839.2
19		0						traffic	2.458231	10.37537	probab.	0.097678	0.042559	traffic	2.724339	10.83657
20									tcalli	tcall		blockm				
21								time	35.16853	35.55716	probab.	0.053583				

The generated random number in the range $\{0,1\}$ appears in the cell D13, while it is then spread in the range $\{0,A+N\}$ in the cell E13. The number of initiated and terminated internal connections during the simulation may be followed in the cells F15 and F16 and its difference in the cell F18 represents the number of instantaneously active internal connections (*busyi*). The same data for external connections exist in the cells G15, G16 and the number of active external connections in G18 (*busye*). Now the total number of busy channels is calculated as

$$busych = 2 \cdot busyi + busye \quad (1)$$

The value of served internal (*trafi (serv)*) and external traffic (*trafe (serv)*) is obtained in the table cells L19 and M19. The lost (blocked) offered internal (*blocki*) and external calls (*blocke*) are counted during simulation in the cells O18 and P18. Internal calls are blocked if the number of available idle traffic channels in the moment of call generation (difference of values in the cells I11 and H18) is less than 2. When considering external calls, they are blocked when there are no idle traffic channels (values in the cells I11 and H18 are the same). Blocking probability for both kinds of calls is calculated in O19 (*blocki* for internal calls) and P19 (*blocke* for external calls). The mean blocking probability in the cell O21 is calculated as

$$blockm = blocki \cdot A_i + blocke \cdot A_e \quad (2)$$

The final verification of simulation correctness is achieved on the base of calculated offered traffic in the table cells R19 (for internal calls) and S19 (for external calls). This calculation is performed using equations

$$trafi(offered) = \frac{trafi(serv)}{1 - blocki} \quad (3)$$

i.e.

$$trafe(offered) = \frac{trafe(serv)}{1 - blocke} \quad (4)$$

These values in the Table 1 differ less than 1.5% from the starting values in the cells J11 and K11 after 50000 of generated random numbers and this is the proof of simulation correctness. Even better accuracy may be reached if more generated random numbers are applied. Besides, the mean duration of internal and external calls as the multiple of the time interval between two generated random numbers is available in the cells L21 and M21.

Data in the Table 1 are only the main part of the simulation program in this case. The complete simulation program is available upon the request.

Just as an illustration on how the data in the table cells are calculated, here is presented only how the generated and terminated internal calls are determined. The number of generated internal calls is counted in the cell F15 as:

$$=IF(D10="" ; 0 ; IF(AND(E13 < J11 ; H18 < I11 - 1) ; F15 + 1 ; F15)) \quad (5)$$

and the number of terminated internal calls is counted in the cell F16 as:

$$=IF(D10="" ; 0 ; IF(AND(E13 >= J11 + K11 + G18 ; E13 < J11 + K11 + G18 + F18 ; H18 > 1) ; F16 + 1 ; F16)) \quad (6)$$

Base station emission power simulation

An important characteristic of all generations of mobile systems starting from GSM systems is adjusting BS emission power according to its distance from mobile stations (MS). This power is decreased at the approximately minimum power to keep the connection in order to decrease total power consumption and interference. Estimation of emission power is the subject of majority of papers among [13] - [16]. This function is explained in [14].

The process of random distance generation is illustrated in Fig.2. The first step, again, is generation of random number RN2U with uniform distribution in the range $\{0,1\}$. The second step is to calculate the distance between BS and MS (RN2). It is obtained as the inverse function (F_d^{-1}) of the generated random number. In general case, this step is a very demanding task: inverse function may not be often obtained in the closed mathematical form and approximate function has to be calculated using some special program as MATHEMATICA or MATLAB. However, we usually consider uniform users' distribution and in such a case the inverse function is simply obtained as a square root of RNU2. In the third step the calculated distance from the range $\{0,1\}$ is spread to the complete MTC radius R . Finally, BS emission power is determined in the step 4. This power is calculated by the expression [21]

$$w = v(d) = a \cdot d^\gamma \quad (7)$$

where a is constant for adjusting values and dimensions of variables and environmental attenuation coefficient γ has values between 2 and 5.

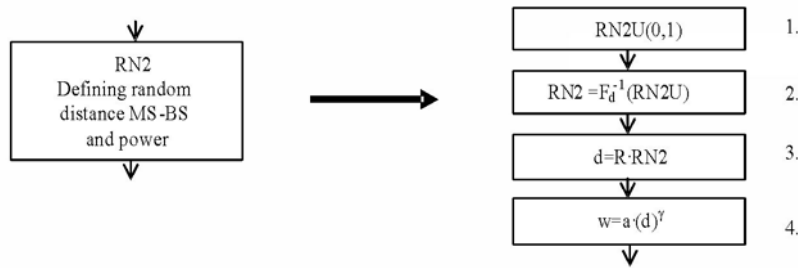


Figure 2. The principle of random distance generation [13]

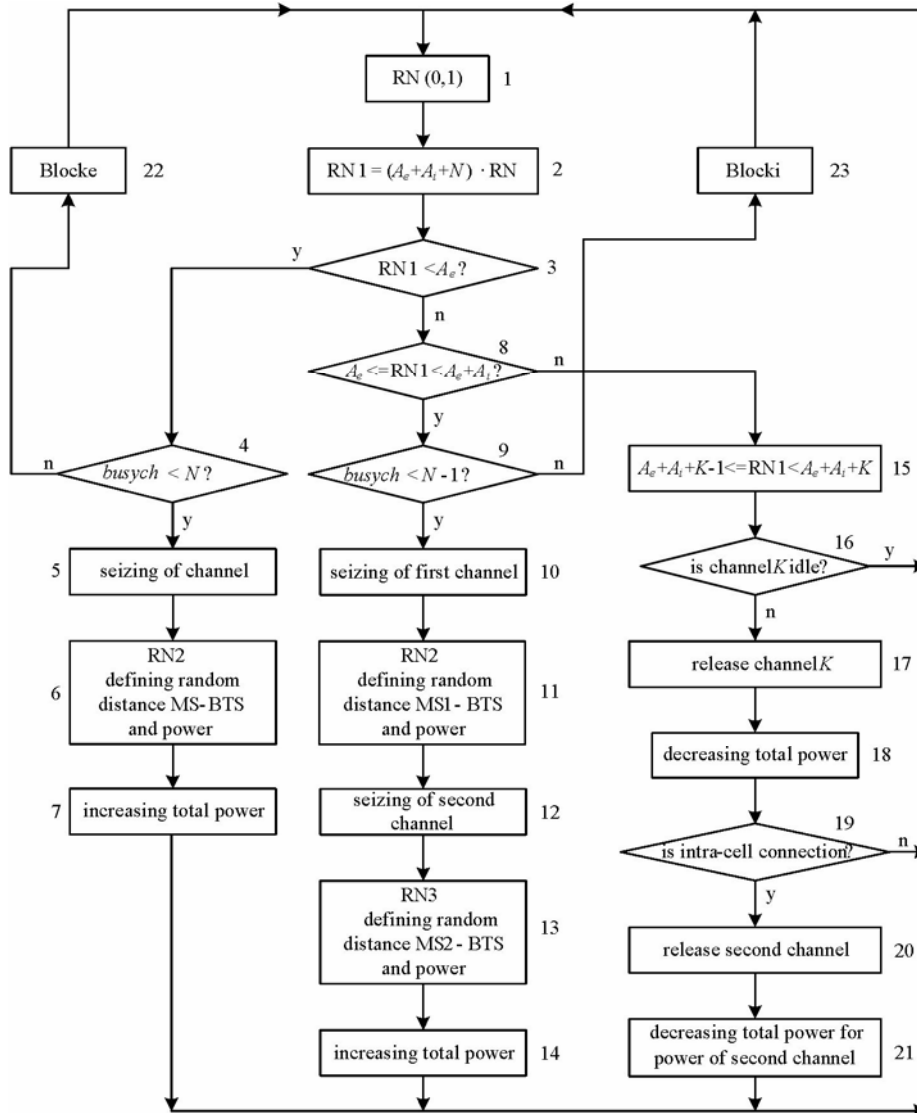


Figure 3. Flow-chart of simulation program for the system with external and internal connections [16]

Now Fig.3 presents the flow-chart of the simulation program whose Excel illustration is presented in the Table 1 [16]. Blocks 1-9, 22 and 23 correspond to the general part of simulation according to the description in the Table 1. Dealing with the rest of simulation, blocks 5-7 present the generation of external call, blocks 10-14 correspond to the generation of internal call and blocks 15-21 illustrate the connection termination. Distance between BS and MS is determined by the procedure from Fig.2 in blocks 6 for external calls and in blocks 11 and 13 for internal calls. Users' distribution in the MTC is uniform and thus it is necessary to apply square root of generated random number as the inverse function. Program part from blocks 15-21 allows termination

of both external and internal connections. During the program execution it is necessary to keep records for each available traffic channel whether it is busy or not and what type of connection is realized if the channel is busy. For internal connection it is noted which traffic channels are paired in one connection. All these data are then considered when the connection is released in the blocks 15-21.

Conclusions

This paper presents an implementation of the Excel program for simulation of traffic process in mobile telephony systems. Such Excel application is completely innovative

according to the available data. Reliability of realized simulations is proved by the comparison of calculation and simulation results in about dozen published papers in international journals from the SCI/SCIE list. Implementation of Excel for simulations has several benefits and drawbacks in comparison to conventional and specialized programs. The most important benefits emphasized in the paper are easy Excel program availability to everyone, easy simulation/calculation realization in the same program where the obtained results are graphically presented and not complicating the testing of the obtained results. Realized programs are used for traffic simulation and BS emission power determination – two most important characteristics when speaking about mobile telephony systems. These two Excel functions are illustrated by flow-chart examples and the table on the base of Excel record that presents the results of one specific scenario simulation. The concrete obtained results of simulations are available in the literature [13] – [17]. Here only the most important verification of simulation program is emphasized: comparison of predefined offered traffic values and the same values obtained by simulation shows that these two values differ for not more than 1.5% according to the Table 1 for only 50000 simulation steps.

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Uloga Excel programa u simulaciji saobraćajnih procesa u telekomunikacijama

Ovaj rad prikazuje simulaciju mobilnih telekomunikacionih sistema koja je realizovana u programu Excel. Mada je prvenstveno namenjen za druge upotrebe, Excel ima nekoliko prednosti u odnosu na neke druge specijalizovane programe namenjene simulacijama. Primena Excel-a za simulacije ilustrovana je sa nekoliko primera iz već publikovanih radova sa glavnim ciljem da se opiše najvažniji deo realizovanih simulacija koji omogućava određivanje svih važnih karakteristika saobraćajnog procesa u telekomunikacijama. Pored saobraćajnog procesa, primena Excel-a omogućava verno simulaciju emisione snage bazne stanice polazeći od slučajne udaljenosti između bazne stanice i mobilne stanice.

Ključne reči: Excel; mobilni telefonski sistem; simulacija saobraćaja; slučajna udaljenost.