INSTITUTE OF NATURAL AND APPLIED SCIENCES
UNIVERSITY OF ÇUKUROVA

MSc THESIS

Abdulkadir Hakan ŞİRİN

SIMULATION OF GSM NETWORK TRAFFIC WITH RESPECT TO NETWORK SERVICE QUALITY PARAMETERS

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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ÇUKUROVA UNIVERSITY
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ABSTRACT

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While founding a GSM network, planning stage involves the usage of geographical and demographical information about the considered locality. The operational effectiveness of a network can be analyzed a posteriori by evaluating the operational data after the network has been up and running. The changes in human settlement in the locality, short term and long term fluctuations in the number of users and user mobility are factors that effect the network traffic and, in turn, the service quality. Technically, the service quality is related with factors such as signal strength and interference ratio. The concept of "handover", the transferring of an ongoing call from one channel to another in the network, is particularly important with respect to service quality. Networks have certain capacities and operate under certain constraints. That is why it is important that the network should operate optimally providing the maximum possible service quality. Consequently, for the effectiveness of the network, it is important that the handover should occur according to the right criteria. A realistic model of a GSM network will allow us to see how quality parameters vary with respect to various system variables and can help us to do a priori planning about the system.

Key Words: Simulation, GSM, Cell, Quality Parameters

ÖZ

YÜKSEK LİSANS TEZİ

GSM AĞ TRAFİĞİNİN AĞ KALİTE PARAMETRELERİ BAĞLAMINDA SİMÜLASYONU

Abdulkadir Hakan ŞİRİN

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Bir GSM ağı kurulurken, ilgili yöreye ait coğrafi ve insani bilgiler kullanılarak planlama yapılabilir. Bir ağın çalışma etkinliği ise ancak ağ kurulduktan sonra, kullanım bilgileri değerlendirilmek suretiyle deneysel olarak analiz edilebilir. Bölgenin yerleşim yapısındaki değişiklikler, kullanıcı sayısı ve hareketindeki günlük ve daha uzun vadeli oynamalar ağ trafiğini ve buna paralel olarak servis kalitesini etkiler. Teknik olarak, servis kalitesi, sinyal gücü, girişim oranı gibi parametrelere bağlıdır. Hareket eden bir kullanıcının bağlantısının bir hücreden diğer bir hücreye aktarılması olan "handover" olgusu, özellikle servis kalitesinin üst düzeyde tutulması açısından önemlidir. Ağlar belli bir kapasite çerçevesinde ve belli kısıtlar altında işlerler. Bu bakımdan ağların maksimum servis kalitesini sağlayacak şekilde optimal kullanılması önemlidir. Sonuç olarak handover'in doğru kriterlere göre gerçekleşmesi de ağın etkinliği açısından önemlidir. Bir GSM ağının gerçekçi bir modeli, kalite parametrelerinin farklı değişkenlere göre nasıl değiştiğini görmemizi sağlar ve sistem hakkında öngörülü planlama yapmamıza yardımcı olabilir.

Anahtar Kelimeler: Simülasyon, GSM, Hücre, Kalite Parametreleri

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1. INTRODUCTION

While founding a GSM network, planning stage involves the usage of geographical and demographical information about the considered locality. The operational effectiveness of a network can be analyzed a posteriori by evaluating the operational data after the network has been up and running. The changes in human settlement in the locality, short term and long term fluctuations in the number of users and user mobility are factors that effect the network traffic and, in turn, the service quality. Technically, the service quality is related with factors such as signal strength and interference ratio. The concept of "handover", the transferring of an ongoing call from one base transceiver station, commonly known as cell, to another in the network, is particularly important with respect to service quality. Networks have certain capacities and operate under certain constraints. That is why it is important that the network should operate optimally providing the maximum possible service quality. Consequently, for the effectiveness of the network, it is important that the handover should occur according to the right criteria. A realistic model of a GSM network will allow us to see how quality parameters vary with respect to various system variables and can help us to do a priori planning about the system.

In this work, a GSM traffic model is proposed considering a specific locality with a definite network infrastructure and a proposed number of mobile users. In the model, the signal strength as a function of location is given based on realistic data. The user mobility is taken into account by assigning a random speed and direction. The speed spectrum from which a random speed value is taken is varied to simulate cases with different percentage of pedestrian users. The number of users, the cell capacity and the parameters governing the handover could also be varied as a part of the simulation process.

The dependence of various service quality parameters to the above mentioned variables is investigated in this study. Since actual field data of GSM operators are mostly confidential, the aim of this project could not be a one-to-one comparison with the predictions of the proposed model with actual field data. Our main objective

is to lay out a framework for a model that can be used as a tool for characterizing the performance of a network *a priori* under varying conditions. The appropriateness of the randomness assumption induced on certain problem variables will be assessed by running several example simulations and checking if the outcome is in unison with the basic knowledge we have about GSM networks.

While the model includes several simplifying assumptions, it can be easily extended to include further details for a more realistic simulation.

2. BACKGROUND

2.1. Basics of Modeling and Simulation

A ‘’model’’ can be defined as a mathematical representation (abstraction) that describes the functioning mechanism of a system or process under consideration. ‘’Modeling’’ is the action of deriving a model for a given system or process.

Models serve to three general purposes:

1) Understanding the system: grasping the functioning mechanism

2) Prediction of the system: To foresee how the system will respond under certain conditions

3) Control of the system: To manipulate the system to obtain a desired effect.

A model should be a close-enough approximation to the system under consideration on one hand. On the other hand, an overly complex model might be very hard to work with and/or to comprehend. In other words, a “good” model constitutes a judicious trade-off between realism and simplicity. (ANU, 1997)

A ‘’simulation’’ can be defined as an experiment performed on a model (FRITZSON, 2003). This experiment is typically a virtual experiment performed on a computer environment. Compared to an actual experiment, such a computational experiment has the advantage of being practically free of any physical constraint and much less costly to perform. Simulations allow researchers to study events that might be impossible to mimic in a laboratory environment and determine parameters that could not be measured experimentally.

In the current work, a model is developed mainly for the first purpose mentioned above; namely, to develop a basic understanding for the observed system.

2.2. Basics of Global Systems for Mobile Communication (GSM)

The global system for mobile communication (GSM) is a worldwide accepted standard for digital cellular systems. The first commercial GSM system was installed in 1991 in Europe and since then GSM networks spread throughout the world with hundreds of millions of customers using this technology regularly today (GROZEV, MARKSJÖ, FOO 2008).

GSM is basically a system where a potentially mobile user with a mobile phone or a similar device (namely, a ‘’mobile station’’) communicates with another user via a ‘’base transceiver station’’ (BTS), or simply a ‘’cell’’, which is regulated by a ‘’base station controller’’ (BSC) that provides connection with more centralized units such as “transcoder” (TC) which converts the signal to an appropriate bit rate and passes it to the “mobile switching center” (MSC) (Fig. 2.1).

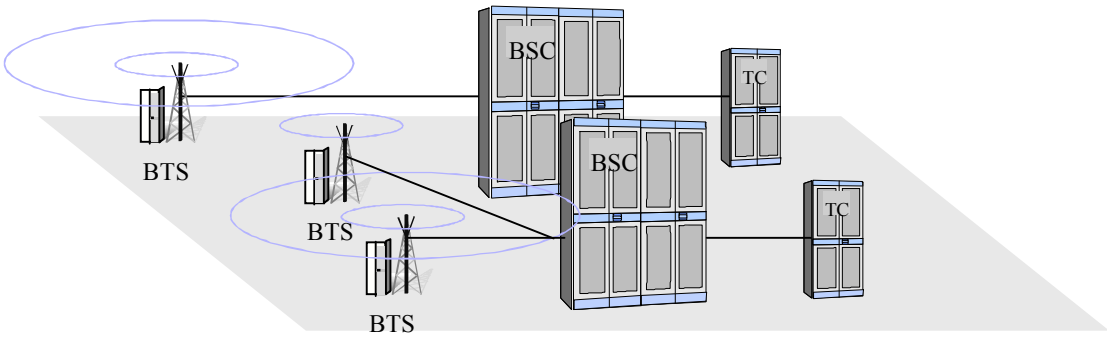


Figure 2.1. Graphical depiction of a GSM system

GSM cellular radio networks are complex systems that cannot be described by exact models or equations. The fundamental reason behind this behaviour is the complex interactions (reflection, absorption, diffraction, dispersion, etc.) of electromagnetic waves in different environments as well as the random behaviour of signal propagation. This is particularly true for human-created settlements like cities and villages, where the variety of structures, shapes, and materials is huge and people’s mobility and call behaviours introduce additional random factors to this already complex system (GROZEV, MARKSJÖ, FOO 2008).

2.2.1. Handover

Clearly, GSM users are all potentially mobile and they should be provided with uninterrupted service as they move. To accomplish this task, sometimes the cell through which a user communicates has to be changed to a different, more suitable cell for continuous service as the user changes geographical location. ‘’Handover’’ is the automatic transfer of the user from one cell to another during the call process, without causing any hindrance to the call. There are two main aspects associated with the handover process: The necessity to find a dedicated mode in the next cell as the mobile user is on call, and a switching process fast enough such that a call drop is prevented. Different criteria for handover can be used, but the one most frequently used is based on signal strength (i.e. power). During a call, the mobile station (i.e. the mobile phone of the user) periodically sends measurement results to the base transceiver system about the quality of the radio link. The serving cell forwards the measurement result from the mobile station, together with its own measurements, to the controller. Processing the information obtained from the reports, the base station controller is able to decide whether a handover to another cell is needed. When an active user is at the interface of two cells, the base station system measures the power that is received by the base stations of the two cells, and then the one satisfying the minimum power criteria (and with smaller interference) is selected (MISRA, 2004 - AGUSTINA, ZHANG, KANTOLA, 2008).

The other cells to which a call can be transferred are said to be the ‘’neighbours’’ of the considered cell.

The handover process is taken into account in our model.

2.2.2. Coverage

The penetration level of signals in different geographical spots on the network determines the coverage of the network. The signal level map is formed typically through a ‘’drive test’’ where signal levels are constantly monitored while driving around in the network region. The coverage is naturally less at far away points. Particularly in urban regions, the coverage could be problematic in the areas behind

high buildings and inside buildings. Despite a careful planning stage, it could occur that important areas and buildings do not have the desired signal level of signal. Such problems are usually handled by changing the antenna locations and altering the tilting of the antennas (MISRA, 2004).

2.2.3. GSM Network Quality Parameters

The quality of the service in a GSM network can be assessed with different parameters. For a user, it is important that a call can be initiated easily without many redials and once a call is initiated the signal strength is high enough for a satisfactory sound quality. For a mobile user, it is important that the transfer of the call from one cell to the other (i.e. the handover) is achieved effectively as the user changes geographical location.

Various quality parameters are described below:

Call Set Up Success Rate (CSSR): This indicator measures the ease in which connections are established or set up. The higher the value of CSSR, the easier it is to set up a call. It can be calculated using the formula:

$$CSSR = \frac{number\ of\ unblocked\ call\ attempts}{total\ number\ of\ call\ attempts} \tag{2.1}$$

For instance, a CSSR of 75 % means that out of every 100 call attempts, 75 are successfully turned into a call while the remaining 25 are unsuccessful (POPOOLA, MEGBOWON, ADELOYE, 2009).

The CSSR rate is one of the most important key performance indicators used by all mobile operators. Since the establishment of a connection is more involved than we cover here, this quantity could be measured in different ways (KOLLAR, 2008).

Call Drop Rate (CDR): CDR measures the ability of the network to retain a call conversation once it has been established or set up. Mathematically, it is expressed by the simple formula

$$CDR = \frac{number\ of\ dropped\ calls}{total\ number\ of\ call\ attempts} \tag{2.2}$$

For example, a CDR value of 7% means that, out of every 100 calls established or setup, 7 will drop before any of the calling parties voluntarily terminate the call (POPOOLA, MEGBOWON, ADELOYE, 2009).

CDR might be affected by several factors. Internal interference from the same network and external interference from other wireless (usually military) networks are such factors. Coverage limitation and insufficient cell capacity are other important factors affecting CDR which we have taken into consideration in our model.

Congestion Rate (CR): This parameter indicates the ratio of the number of the users congested to the total number of active users:

$$CR = \frac{total\ number\ of\ congested\ users}{total\ number\ of\ active users} \tag{2.3}$$

CR is an indicator for the effective usage of capacity and the requirement for extra capacity requirement. It is a parameter taken into account in our model.

Call Completion Success Rate (CCSR): This indicator can be derived either from network statistics or from drive test statistics. The indicator takes into account the fact that all failures are either drops or unsuccessful call set ups. It is a good parameter for evaluating the network accessibility and retainability as perceived by the customers (POPOOLA, MEGBOWON, ADELOYE, 2009).

$$CCSR = \frac{total\ number\ of\ completed\ calls}{total\ number\ of\ call\ attempts} \tag{2.4}$$

Handover Success Rate (HSR): HSR is the ratio of the number of successful handovers to the total number of handover attempts. It indicates the effectiveness of the handover process in a network (POPOOLA, MEGBOWON, ADELOYE, 2009).

2.3 GSM Traffic Simulations

Most of the GSM traffic simulations encountered in the literature deal with the traffic in an individual cell and are probabilistic in nature (HONG,RAPPAPORT, 1986, TRAN-GIA,MANDJES, 1997). Based on available statistics or mathematical intuition, various distributions for GSM parameters are assumed in these studies. Multiple cell models simulate the cells as discrete entities with coverage over simple geometries such as hexagons. In these studies, a constant user exchange is assumed between the cells. The mathematics involved is typically complex (ASHTIANI,SALEHI,AREF, 2003).

The user mobility has been the main subject of a few papers. In one work, the geographical and demographical data in a certain region is used to build a probabilistic model. The intensity and direction of the traffic is also taken into account (TUTSCHKU,TRAN-GIA, 1998).

3.MATERIAL and METHOD

3.1. Introduction

In the current work, the cell traffic due to mobile users located in an actual urban region (Fig. 3.1) located in Southern Turkey is simulated. The geographical features of this locality are the main input material of the simulation. The actual user number in this urban setting is not a concern since the right conclusions could be drawn with a prespecified (but statistically large enough) number of users distributed over this region. In other words, this region prescribes merely the problem domain in our simulation. Other actual regions can also be selected for simulation purposes. However, our main focus in this model is on the method rather than the results for a specific locality; hence we choose not to explore the model behavior in different types of geographies and stick to a single geography.

The model involves several simplifications and assumptions that are discussed in Section 5 of this manuscript. An associated computer code for the model is written using the MATLAB (The MathWorks Inc, Natick, MA, USA) package.



Figure 3.1 The satellite view of the modeled urban region (Taken from Google Earth)

3.2. Simulation

In the preprocessing stage, the depiction of an actual geographical region with exact locations of the cell sites and the corresponding map showing signal strength distribution in the region is obtained.

The signal strength maps of individual cells, obtained by ATOLL software (Forsk, Blagnac, France) package are provided for this work by a mobile communication company operating in the related region.

The signal strength map of an isolated cell displays the signal strength in discreet strength intervals. There are nine cells operating in the considered locality (Fig. 3.2).

This information constitutes the input for our model and the associated files are imported to the MATLAB program.

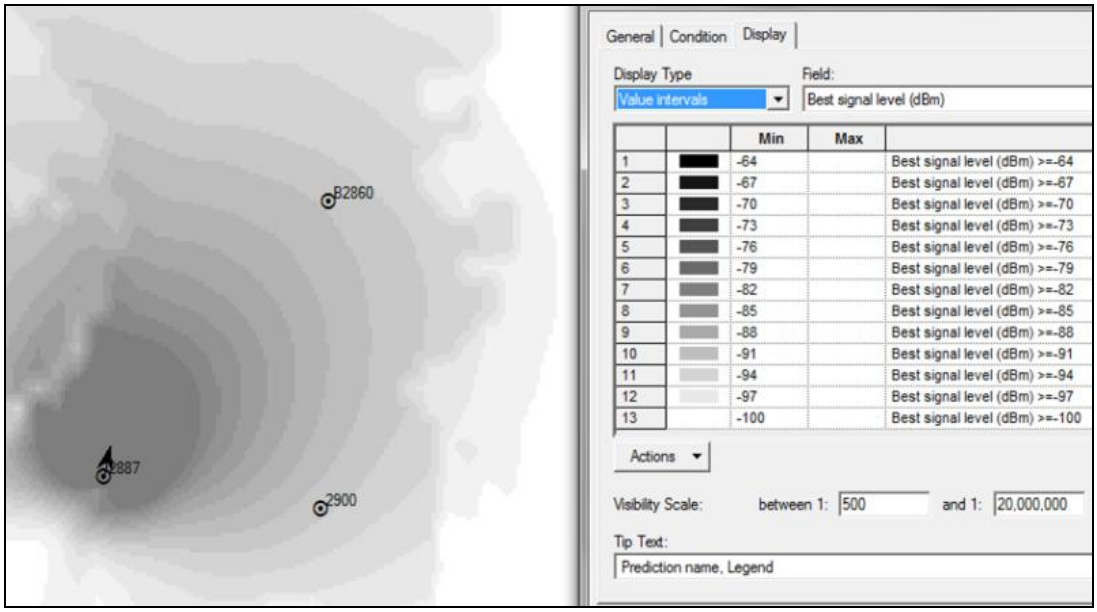


Figure 3.2. Signal strength distribution due to a single cell with signal strength legend

The images displaying the signal strength map of each individual cell is converted to gray scale (Fig. 3.3). The grayscale images are appropriately cropped to

a chosen size which represents the computational problem domain. It should be noted that an image of a different size could be chosen as well.

The signal strength maps of all cells are then superimposed to obtain the best signal level at each spot in the problem domain which results to map displaying the best signal level (Fig. 3.4).

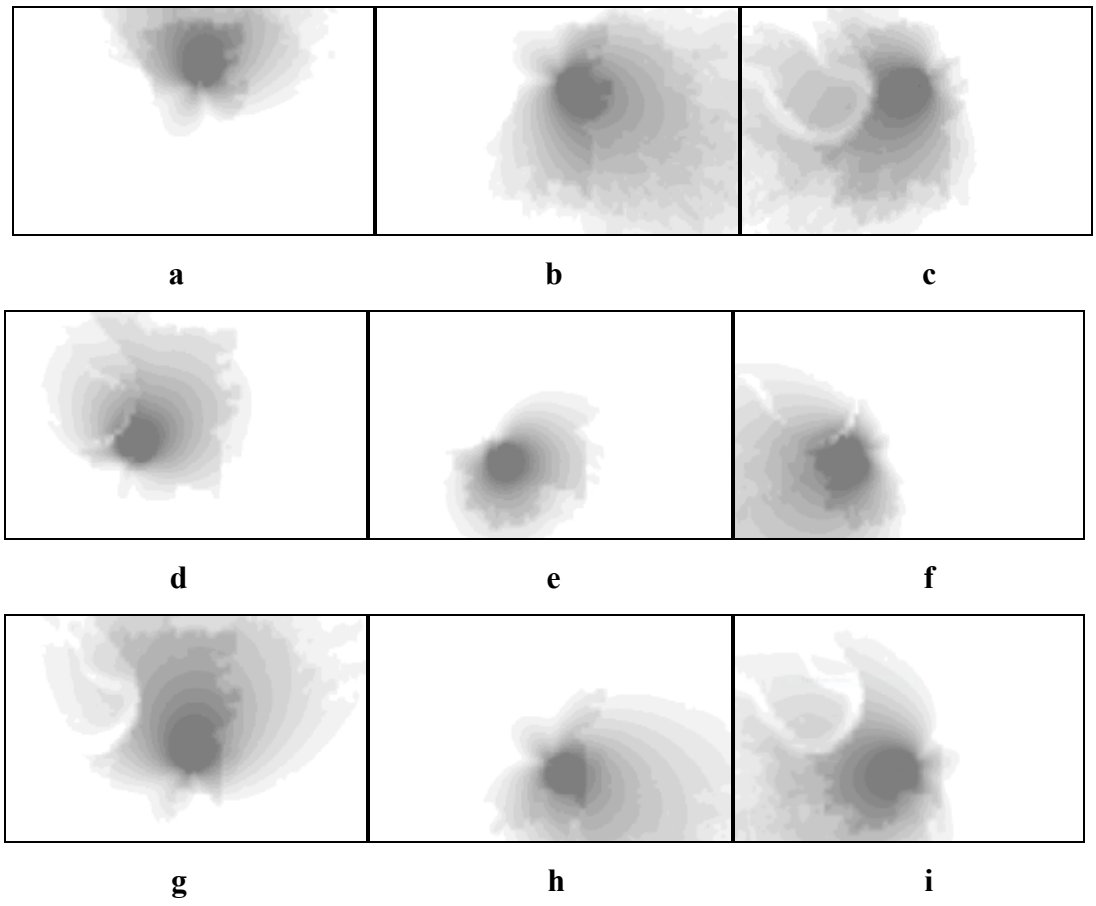


Figure 3.3. Signal strength distribution map for each of the nine cells.

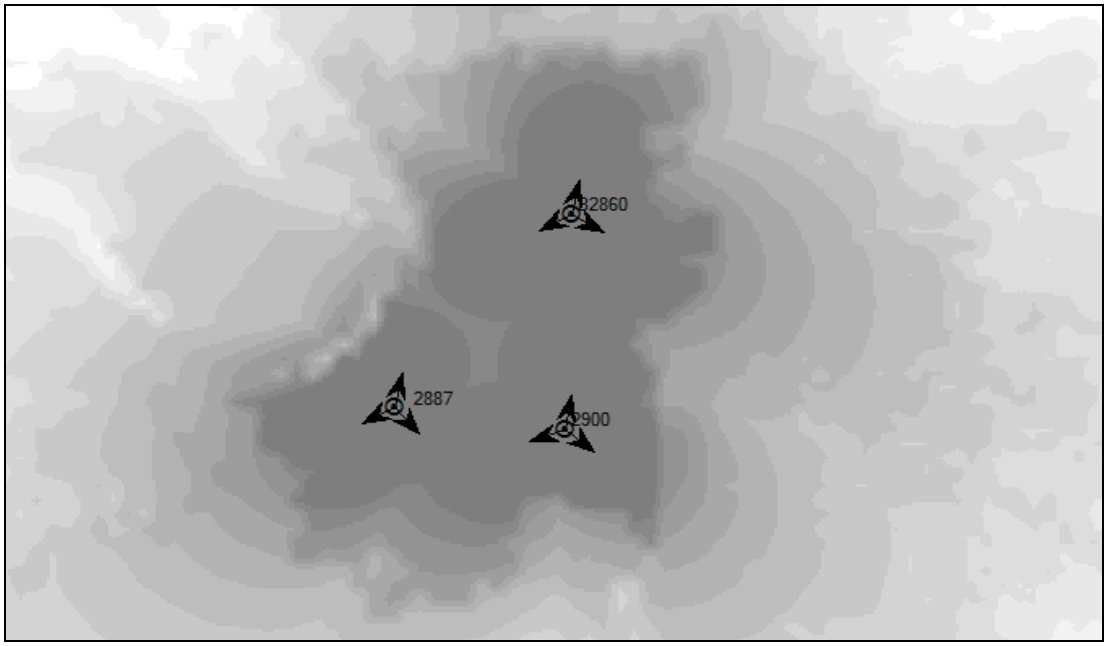


Figure 3.4. Map of best signal strength obtained from the superposition of the individual signal strength maps of each cell. The cell sites are also indicated.

A certain number of active users (i.e., users either on call or constantly attempting to make a call) is specified and randomly distributed over the computational domain. Depending on the location of the user, a cell is tried to be assigned to each user. Clearly, as a part of the simulation, some users are successfully assigned a cell while others are not. The coverage, cell capacity and congestion are the factors directly affecting cell assignment. For instance, if a user happened to be outside the coverage or if the only cell that the user receives proper signal from is working already at full capacity, an assignment can not be possible. The system will try to assign the cell with the best possible signal to each user.

At each time step, all active users are assigned a speed with a random magnitude taken from a certain speed range and move along a randomly chosen direction. The simulation is discrete in time and at each time step, the signal strength each user receives is reevaluated according to his new locations. If necessary a handover is considered to keep the drop rate to a minimum.

The program is run for a specified number of time steps. The time evolution of various parameters including the quality performance parameters, outlined in Section 2.2.3, is observed.

3.3. Implementation

The model is implemented through a computer code written in the MATLAB programming environment. MATLAB is a general purpose mathematical package consists of several subpackages designed for different purposes. It also provides its own Fortran-like programming language which is utilized in this work.

MATLAB is particularly efficient to handle matrices and vectors. In the implementation of our model, quantities such as cell neighborhood and signal strength with respect to each cell are stored in vector/matrix form and manipulated. Thus MATLAB package seems particularly suitable for our purposes.

4. EXAMPLE PROBLEM and RESULTS

4.1. Example Problem

As mentioned earlier, a realistic geography (Fig. 3.1), with 3 base stations each equipped with 3 cells (a total of 9 cells) provides the input to our example problem. Signal strength maps for each cell is input to the program and converted to grayscale for further handling (Figs. 3.3 and 3.4)

The variation in four parameters is studied in this example: number of users (Case 1), cell capacity (Case 2), cell neighborhood (Case 3) and acceptable minimum signal strength (Case 4).

In each case, the observed quantity is varied while the remaining parameters are kept at their default values. The defaults values are:

Number of users: 100

Cell capacity: $9 \times 9 = 81$ users

Neighborhood: The matrix given in Table 4.1.

Signal strength: -94 dBm

The analysis utilizing the default parameters takes part in the comparison in all four cases.

In our analysis users are distributed randomly to the problem domain (Fig.4.1). In an effort to observe the effect of the level of user mobility, we have considered three different speed distributions of the users. In the first distribution (referred to as D1), each user is assigned a random speed between -40 and 40 pixels/time unit. The second distribution (referred to as D2) considers a % 60 probability for the user to be a pedestrian in which case the speed varies randomly between -5 and 5 pixels/time unit. The speed of a non-pedestrian is chosen randomly between ±25 and ±40 pixel/time unit. The third distribution (referred to as D3) assumes a 90% probability of a user to be a pedestrian in an effort to simulate a situation where only a small fraction of users are highly mobilized. Pedestrian and non-pedestrian speed values are assigned as in D2. In our analysis, every time step is

taken to be one time unit long. Hence, the assigned speed values are numerically equal to the displacements taken place in one time unit.

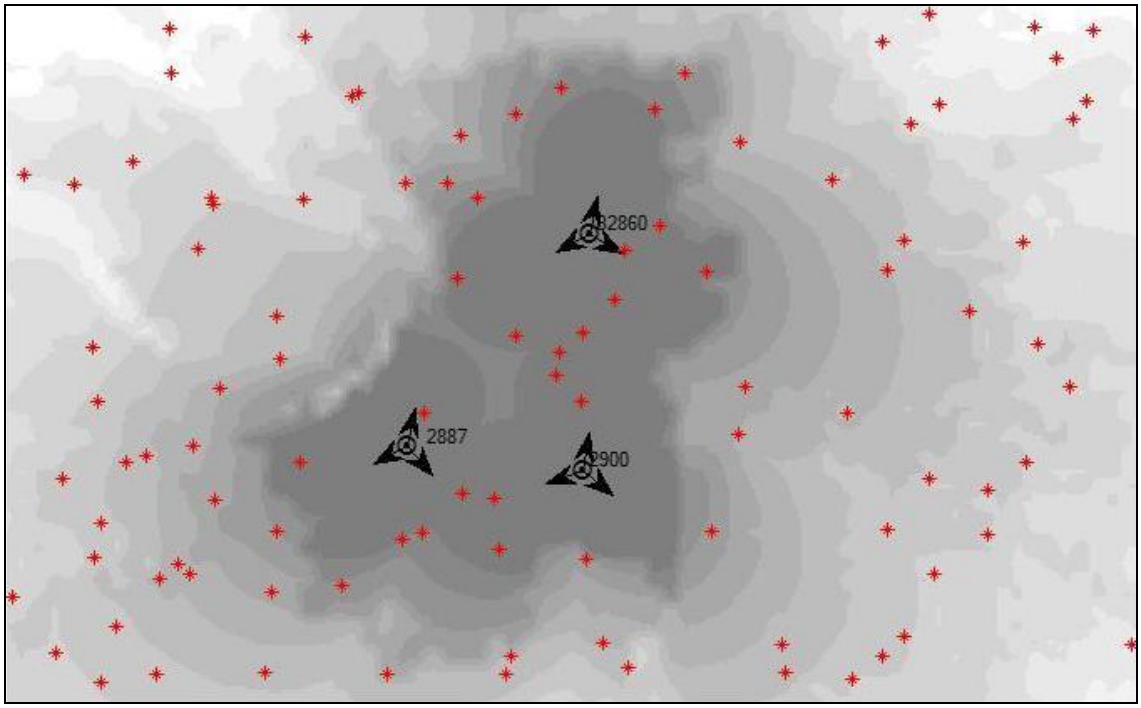


Figure 4.1. An example for the initial distribution of users in the problem domain with stars indicating user location. (100 users in this case)

The speed (or, equivalently, the displacement) and the motion direction are reevaluated after every time step considering the specified ranges for pedestrians and non-pedestrians. The users are not allowed to leave the problem domain. If, at any time point, the user is assigned a displacement which would put him outside the problem domain, only that part of the displacement components that would keep the user in the domain is taken into account. Every analysis is run for 20 time steps. Relevant parameters are evaluated at each time step and a time-average value is calculated for each parameter in each analysis.

Due to the randomness involved in the problem, every analysis with the exact same input is repeated 10 times and the average values of time-averaged quality parameters are calculated over these 10 runs.

4.2. Results

4.2.1 Results for speed distribution D1

In Case 1, the number of active users is changed from 50 to 250 (default 100), while other parameters are kept at their defaults. The capacity usage, the number of drops, congestions and handovers increases with the user number. An increase in user number increases the congestion rate and but decreases the drop and handover rates if the user number exceeds the capacity drastically. The average signal level seems to be independent from the number of users. (Tables and Figures 4.2.- 4.6.)

In Case 2, the cell capacities are varied such that the total capacity was 54 and 108 (default 81) in the two subcases considered. It is observed that an increase in cell capacity decreases capacity usage, drop and congestion parameters. The handover rate and number seems to increase as the capacity comes nearer to the user number. As the excess capacity grows the handover parameters start to decrease. Signal level, once again, is independent from the variation in cell capacities. (Tables and Figures 4.7.- 4.11.)

Table 4.1. The neighborhood matrix of the default case

Cell Number	1	2	3	4	5	6	7	8	9
1	1	1	1	0	0	0	0	0	0
2	1	1	1	1	0	0	1	1	1
3	1	1	1	1	0	0	1	1	0
4	0	1	1	1	1	1	1	1	0
5	0	0	0	1	1	1	1	1	0
6	0	0	0	1	1	1	0	0	0
7	0	1	1	1	1	0	1	1	1
8	0	1	1	1	1	0	1	1	1
9	0	1	0	0	0	0	1	1	1

The variation in neighborhood is investigated in Case 3. The first subcase is the no-neighborhood case while the second one assumes neighborhood between each cell pair. (The neighborhood matrix of the default case is given above in Table 4.1.) An improved neighborhood decreases drastically the congestion rate and capacity

usage. With congestion decreasing, the drop increases. The average signal quality drops since and the number of handovers increases with an improved neighborhood. (Tables and Figures 4.12-4.16)

The variation in the allowed signal strength is studied in Case 4. In the first subcase, the signal quality is kept high (-91 dBm) while the second subcase describes a low (-97 dBm) signal quality situation (default -94 dBm). As the allowed signal quality is decreased, the capacity usage and consequently the congestion rate increases whereas the drop rate and average signal strength decreases. The handover rate also increases parallel to the capacity with a low quality signal (Tables and Figures 4.17.-4.21.)

4.2.1.1 D1-Case 1

Table 4.2. D1 Case 1- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 1-1	60,29	59,70	59,44	62,56	60,50	55,71	57,07	60,35	62,33	63,91	61,38
DEFAULT	86,99	83,71	86,86	90,37	88,70	86,67	83,14	87,41	91,36	81,54	90,19
CASE 1-2	99,96	99,69	99,94	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 1-1	5,43	5,37	5,35	5,63	5,45	5,01	5,14	5,43	5,61	5,75	5,52
DEFAULT	7,83	7,53	7,82	8,13	7,98	7,80	7,48	7,87	8,22	7,34	8,12
CASE 1-2	9,00	8,97	8,99	9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00

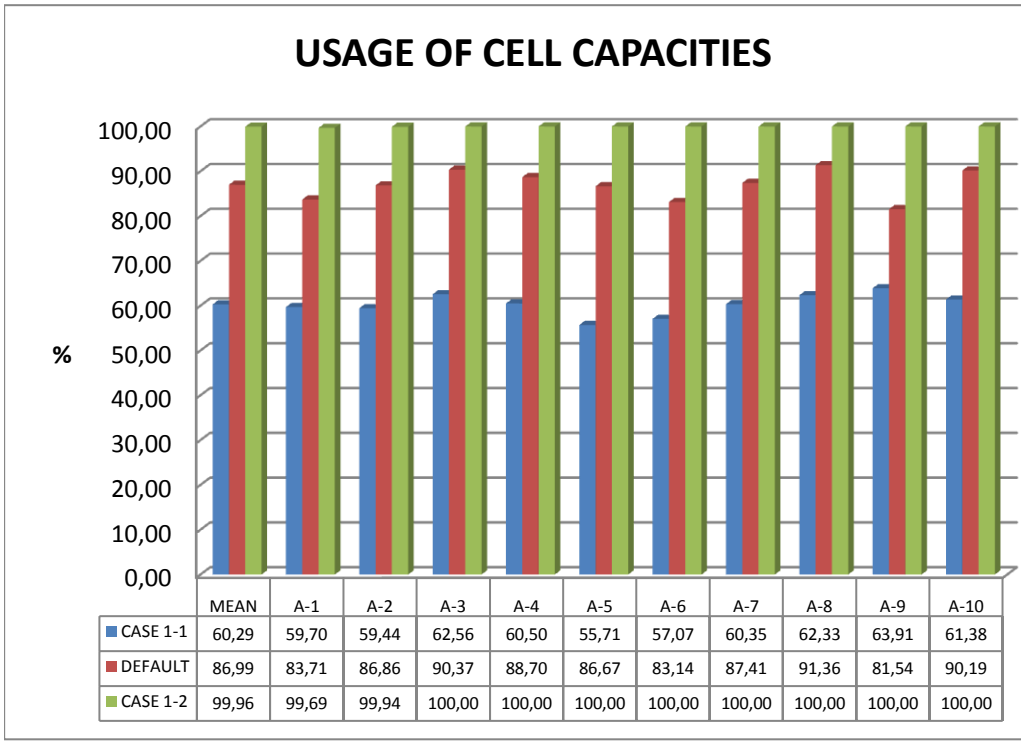


Figure 4.2. D1 Case 1- Average cell capacity usage

Table 4.3. D1 Case 1- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	80,37	81,71	79,84	81,64	80,70	78,97	80,84	80,19	79,66	78,92	81,21
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 1-2	80,43	80,71	80,18	78,76	80,99	81,72	80,69	78,43	81,20	81,32	80,34
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	80,37	81,71	79,84	81,64	80,70	78,97	80,84	80,19	79,66	78,92	81,21
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 1-2	80,43	80,71	80,18	78,76	80,99	81,72	80,69	78,43	81,20	81,32	80,34

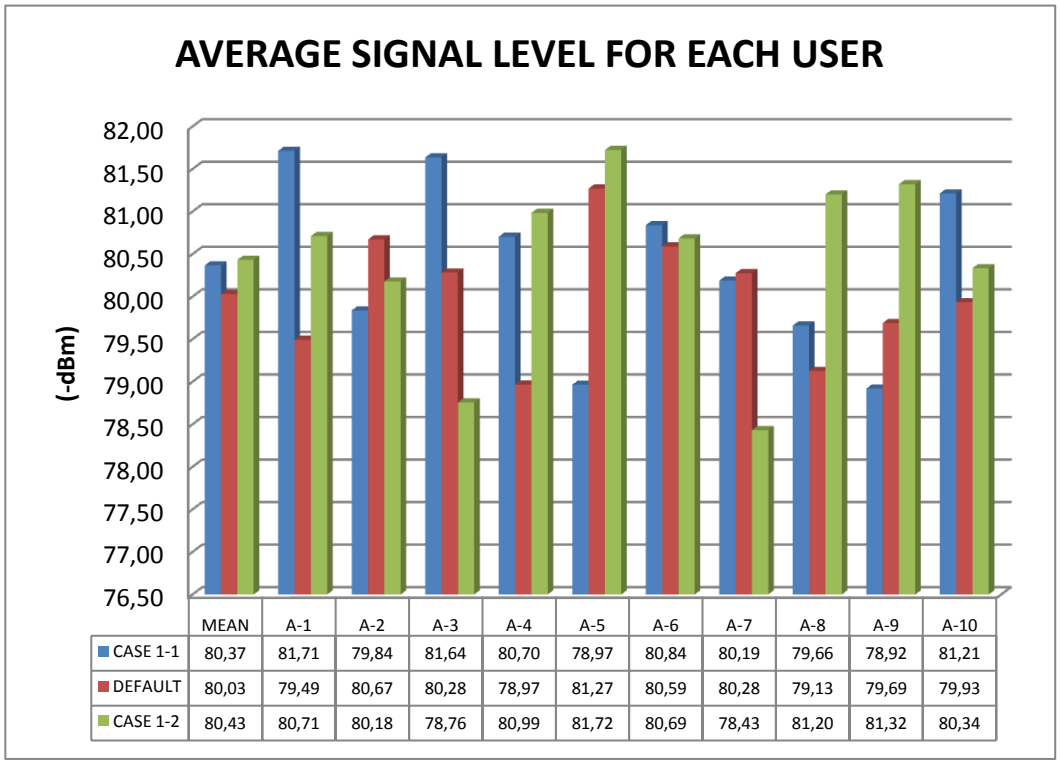


Figure 4.3. D1 Case 1- Average signal level per user

Table 4.4. D1 Case 1- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,20
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 1-2	45,57	37,78	44,00	49,52	46,28	44,28	48,26	43,68	44,32	51,22	46,38
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,10
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 1-2	113,93	94,45	110,00	123,80	115,70	110,70	120,65	109,20	110,80	128,05	115,95

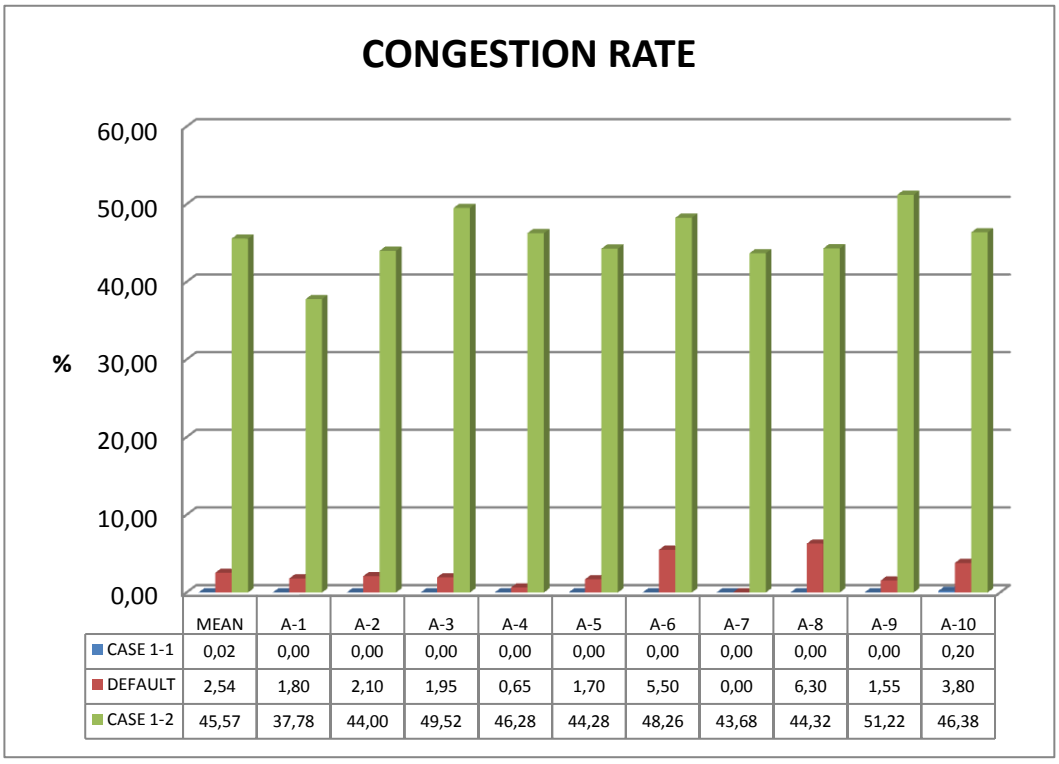


Figure 4.4. D1 Case 1- Congestion rate

Table 4.5. D1 Case 1-Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	9,89	9,20	8,80	11,60	8,80	14,00	15,50	5,80	9,30	5,50	10,40
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 1-2	22,04	29,92	23,62	18,08	21,32	23,32	19,34	23,92	23,28	16,38	21,22
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	4,95	4,60	4,40	5,80	4,40	7,00	7,75	2,90	4,65	2,75	5,20
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 1-2	55,10	74,80	59,05	45,20	53,30	58,30	48,35	59,80	58,20	40,95	53,05

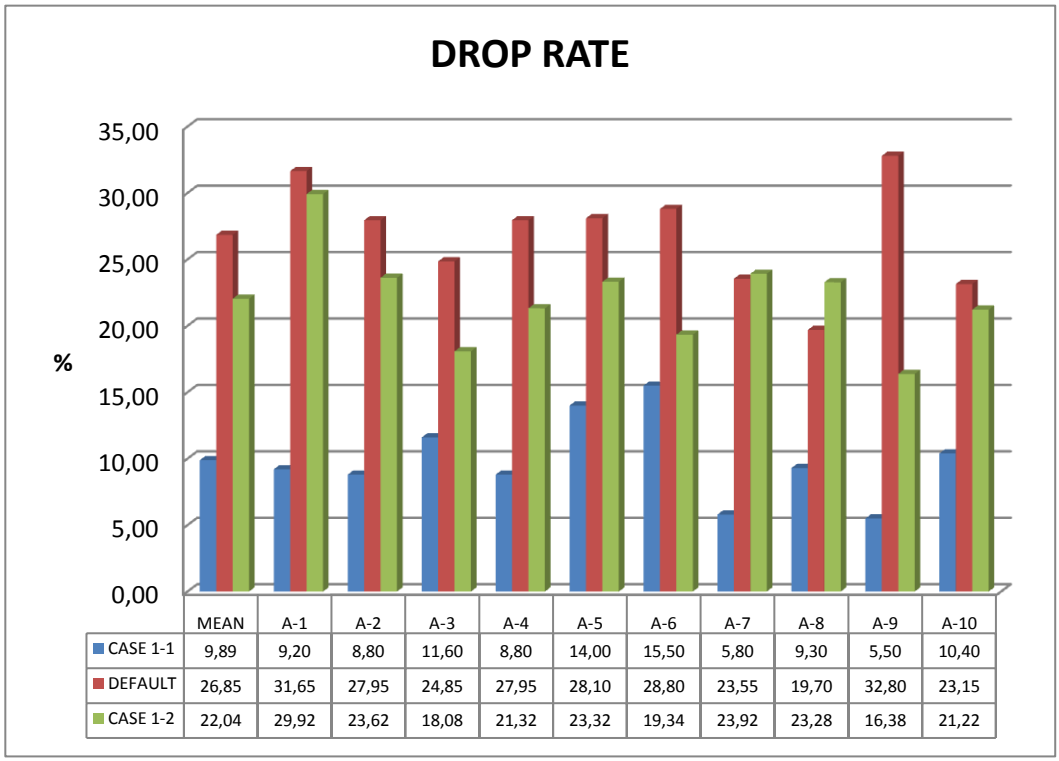


Figure 4.5. D1 Case 1- Drop rate

Table 4.6. D1 Case 1- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	6,76	4,10	5,70	13,40	4,00	10,10	4,40	4,60	6,60	7,60	7,10
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 1-2	9,99	11,24	9,56	9,46	9,58	11,10	9,08	10,00	11,24	10,26	8,34
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	3,38	2,05	2,85	6,70	2,00	5,05	2,20	2,30	3,30	3,80	3,55
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 1-2	24,97	28,10	23,90	23,65	23,95	27,75	22,70	25,00	28,10	25,65	20,85

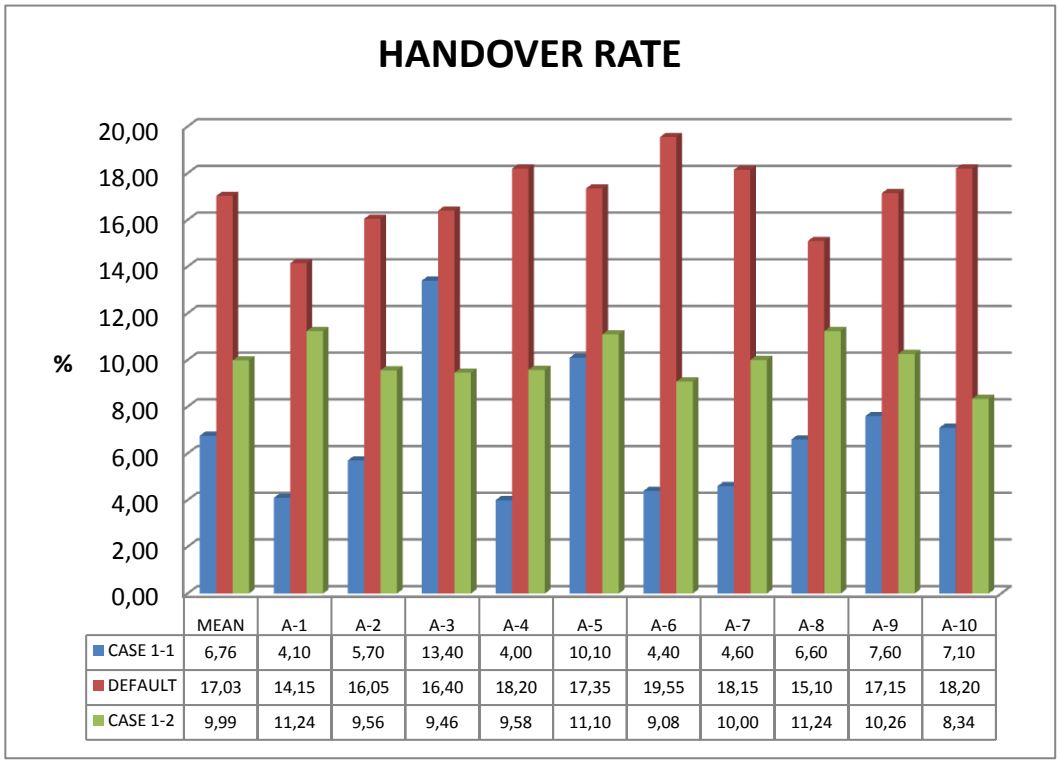


Figure 4.6. D1 Case 1- Handover rate

4.2.1.2 D1-Case 2

Table 4.7. D1 Case 2- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	94,85	93,52	99,07	99,35	92,50	94,81	91,75	94,35	96,48	91,94	94,72
DEFAULT	86,99	83,71	86,86	90,37	88,70	86,67	83,14	87,41	91,36	81,54	90,19
CASE 2-2	76,04	75,17	75,44	75,64	75,77	73,35	76,68	75,13	75,05	81,09	77,09
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	5,69	5,61	5,94	5,96	5,55	5,69	5,50	5,66	5,79	5,52	5,68
DEFAULT	7,83	7,53	7,82	8,13	7,98	7,80	7,48	7,87	8,22	7,34	8,12
CASE 2-2	9,12	9,02	9,05	9,08	9,09	8,80	9,20	9,02	9,01	9,73	9,25

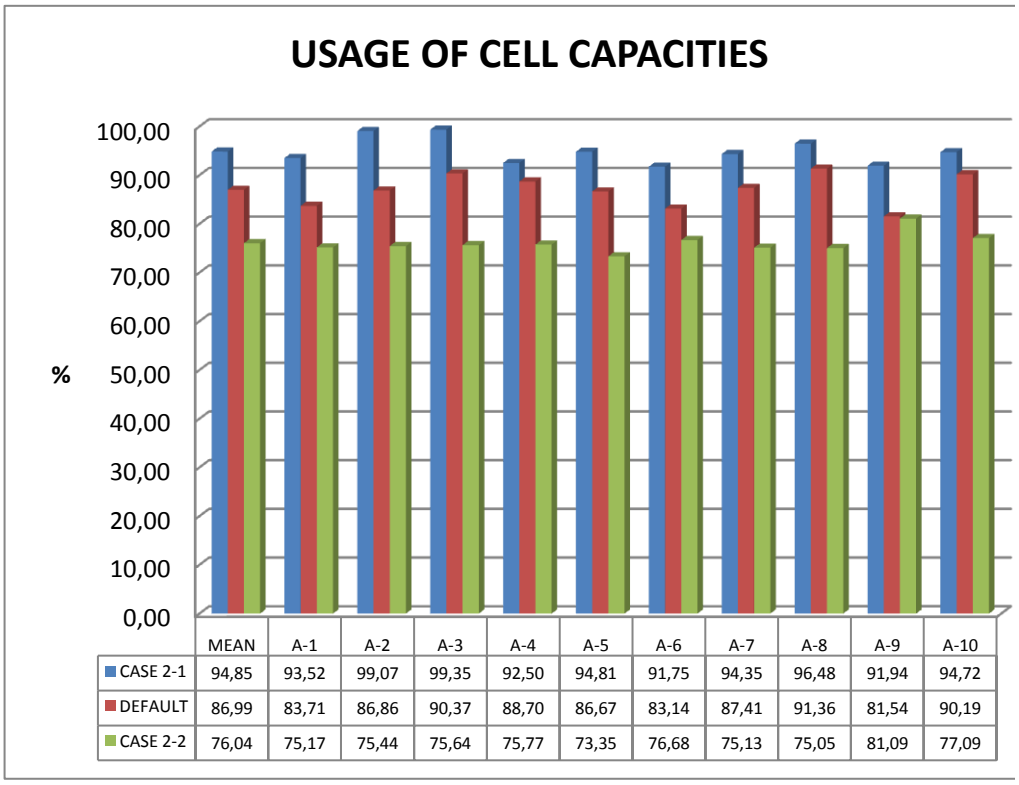


Table 4.8. D1 Case 2- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	80,48	79,24	80,47	81,05	81,66	81,39	81,09	80,48	78,74	80,49	80,24
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 2-2	80,34	78,73	80,36	80,25	81,37	78,84	80,41	80,32	80,92	81,45	80,71
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	80,48	79,24	80,47	81,05	81,66	81,39	81,09	80,48	78,74	80,49	80,24
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 2-2	80,34	78,73	80,36	80,25	81,37	78,84	80,41	80,32	80,92	81,45	80,71

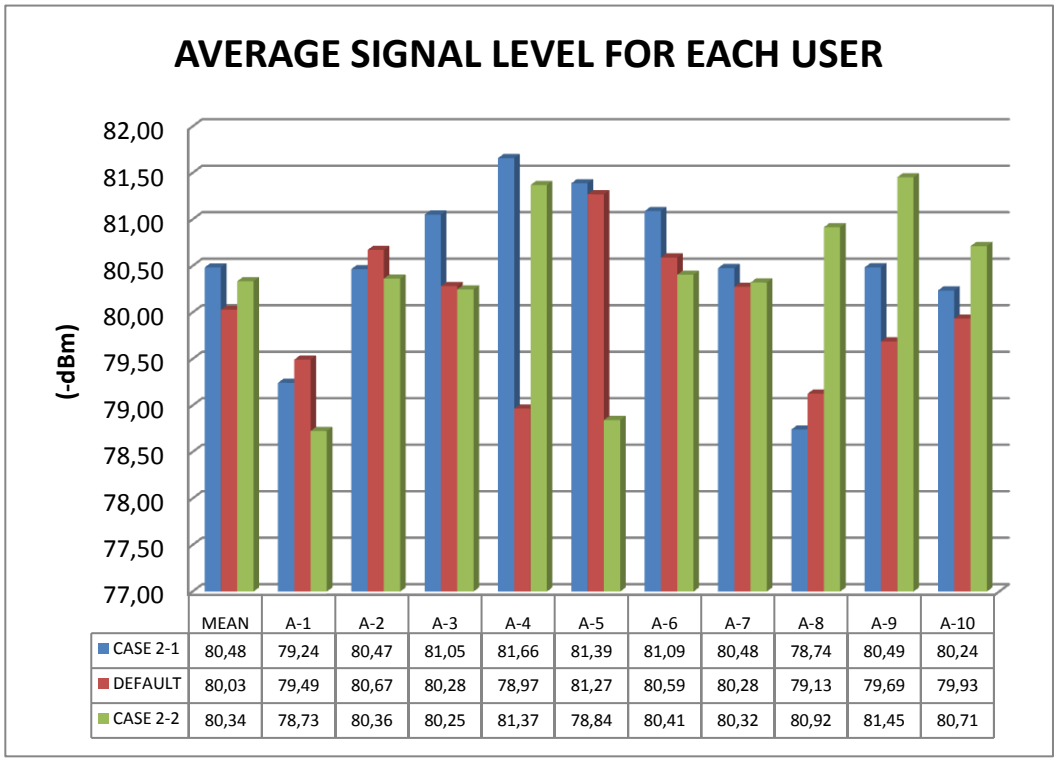


Figure 4.8. D1 Case 2- Average signal level per user

Table 4.9. D1 Case 2- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	16,42	15,40	22,70	22,75	11,30	18,85	14,65	13,95	18,50	11,40	14,65
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 2-2	0,83	0,00	2,45	2,00	0,20	0,00	0,05	0,45	1,00	0,00	2,10
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	16,42	15,40	22,70	22,75	11,30	18,85	14,65	13,95	18,50	11,40	14,65
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 2-2	0,83	0,00	2,45	2,00	0,20	0,00	0,05	0,45	1,00	0,00	2,10

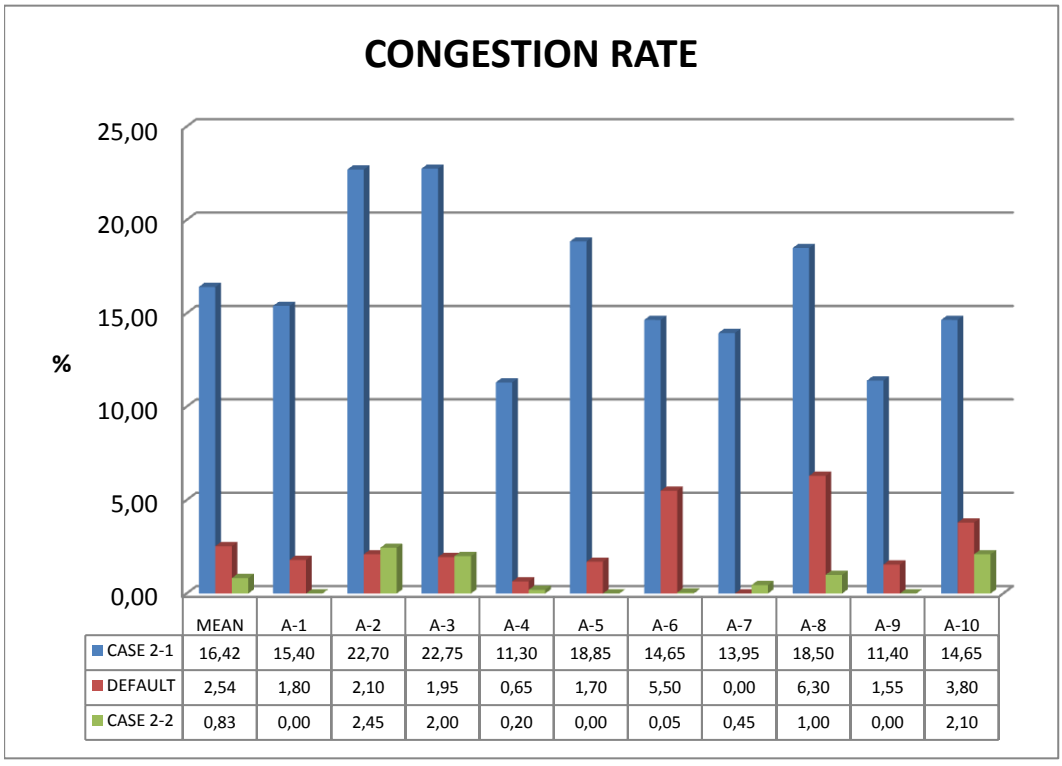


Figure 4.9. D1 Case 2- Congestion rate

Table 4.10. D1 Case 2- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	32,40	34,10	23,80	23,60	38,75	29,95	36,10	35,10	29,40	38,95	34,20
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 2-2	18,65	19,30	16,60	19,20	19,45	22,70	18,65	19,40	17,95	18,05	15,15
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	32,40	34,10	23,80	23,60	38,75	29,95	36,10	35,10	29,40	38,95	34,20
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 2-2	18,65	19,30	16,60	19,20	19,45	22,70	18,65	19,40	17,95	18,05	15,15

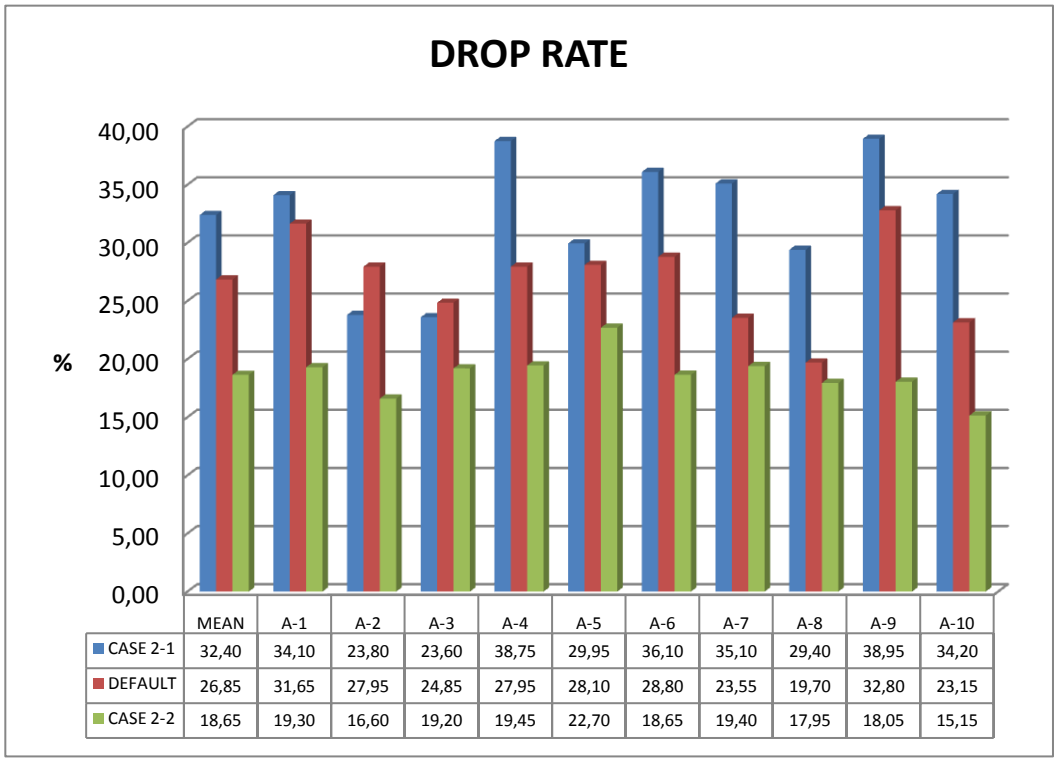


Figure 4.10. D1 Case 2- Drop rate

Table 4.11. D1 Case 2- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	15,16	13,10	17,15	18,80	16,45	18,20	15,60	12,00	11,85	15,15	13,30
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 2-2	13,63	8,95	11,65	12,95	12,35	12,10	16,50	13,65	16,75	17,55	13,80
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 2-1	15,16	13,10	17,15	18,80	16,45	18,20	15,60	12,00	11,85	15,15	13,30
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 2-2	13,63	8,95	11,65	12,95	12,35	12,10	16,50	13,65	16,75	17,55	13,80

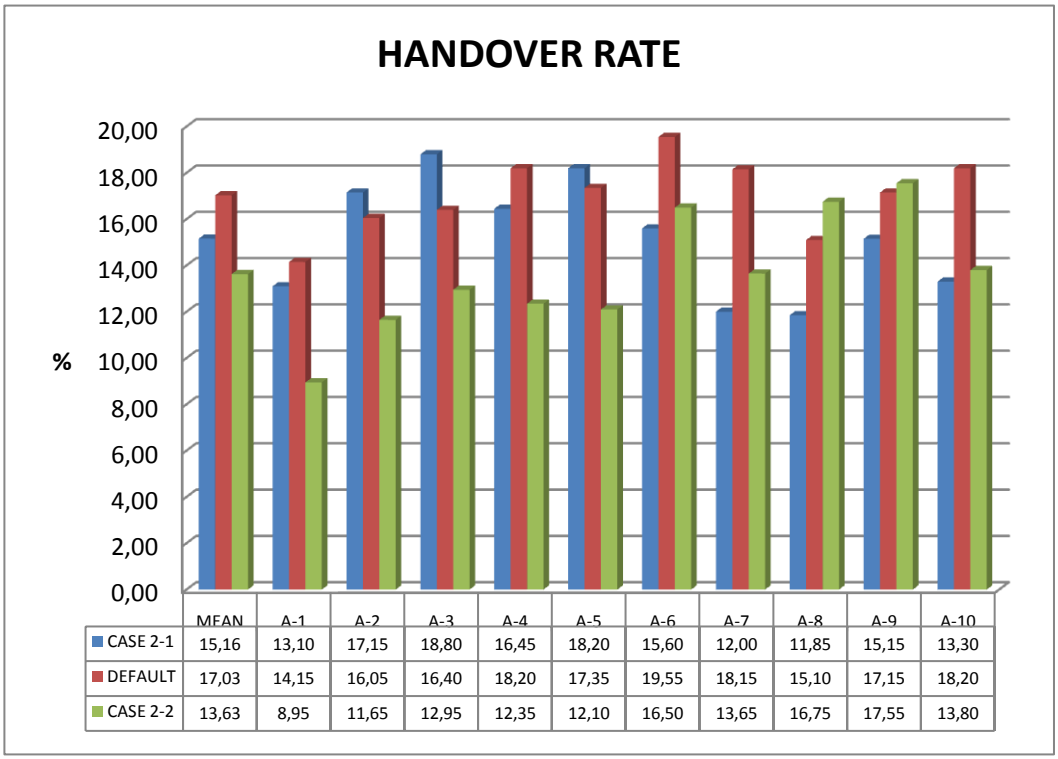


Figure 4.11. D1 Case 2- Handover rate

4.2.1.3 D1-Case 3

Table 4.12. D1 Case 3- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 3-1	75,69	80,35	74,40	75,65	77,66	73,77	73,33	75,53	80,49	68,91	76,83
DEFAULT	86,99	83,71	86,86	90,37	88,70	86,67	83,14	87,41	91,36	81,54	90,19
CASE 3-2	90,63	92,69	91,98	90,56	90,93	89,34	91,15	90,80	90,74	92,16	85,99
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 3-1	6,81	7,23	6,70	6,81	6,99	6,64	6,60	6,80	7,24	6,20	6,91
DEFAULT	7,83	7,53	7,82	8,13	7,98	7,80	7,48	7,87	8,22	7,34	8,12
CASE 3-2	8,16	8,34	8,28	8,15	8,18	8,04	8,20	8,17	8,17	8,29	7,74

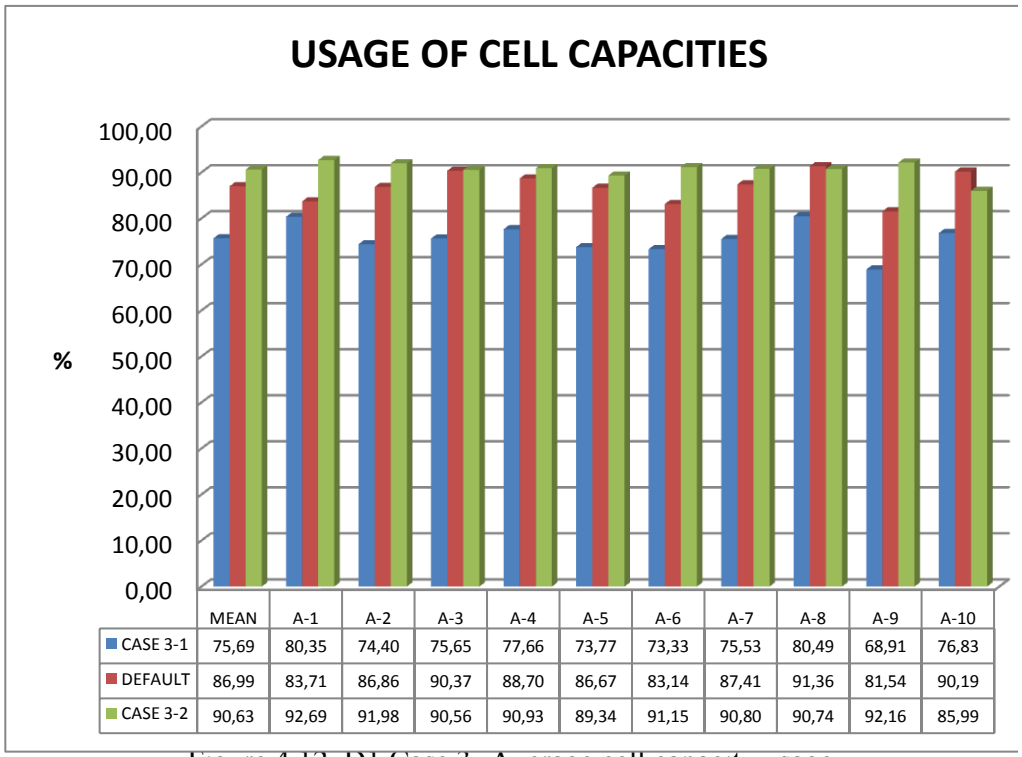


Figure 4.12. D1 Case 3- Average cell capacity usage

Table 4.13. D1 Case 3- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 3-1	78,87	77,86	78,74	79,11	77,89	79,40	79,30	79,50	79,91	79,26	77,77
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 3-2	81,21	81,66	80,82	81,26	80,75	81,55	81,00	82,05	79,05	81,87	82,06
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 3-1	78,87	77,86	78,74	79,11	77,89	79,40	79,30	79,50	79,91	79,26	77,77
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 3-2	81,21	81,66	80,82	81,26	80,75	81,55	81,00	82,05	79,05	81,87	82,06

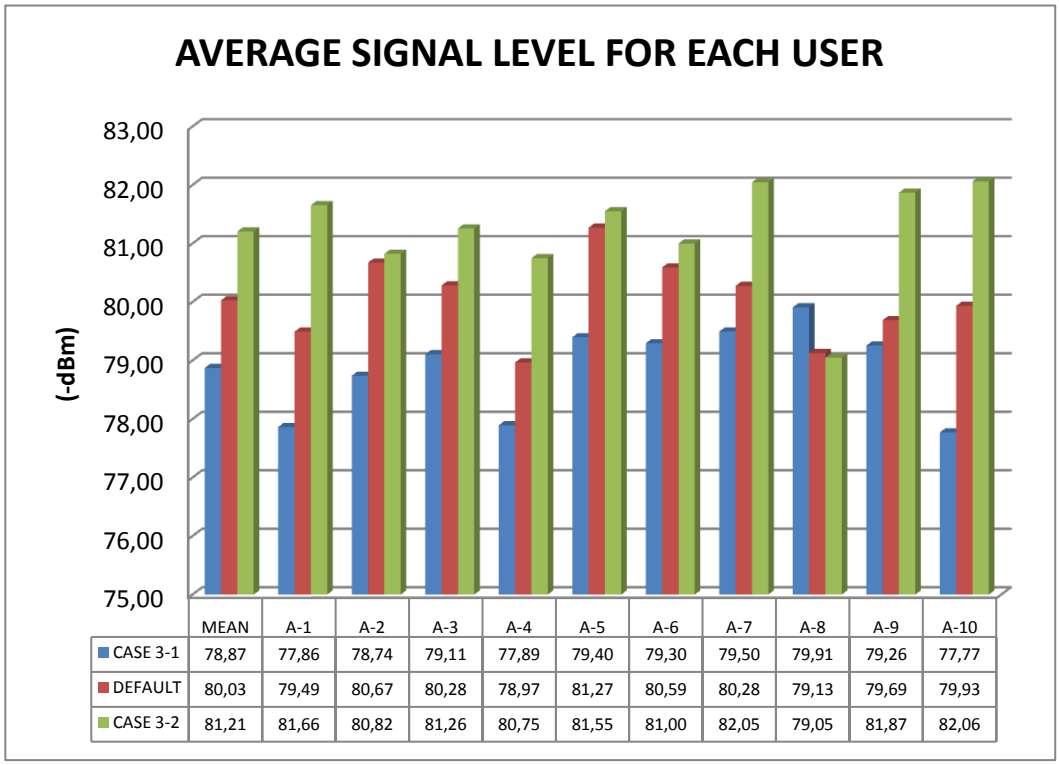


Figure 4.13. D1 Case 3- Average signal level per user

Table 4.14. D1 Case 3- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	38,11	32,80	44,50	36,95	34,90	35,80	40,95	38,70	36,40	42,40	37,70
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	38,11	32,80	44,50	36,95	34,90	35,80	40,95	38,70	36,40	42,40	37,70
DEFAULT	2,54	1,80	2,10	1,95	0,65	1,70	5,50	0,00	6,30	1,55	3,80
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

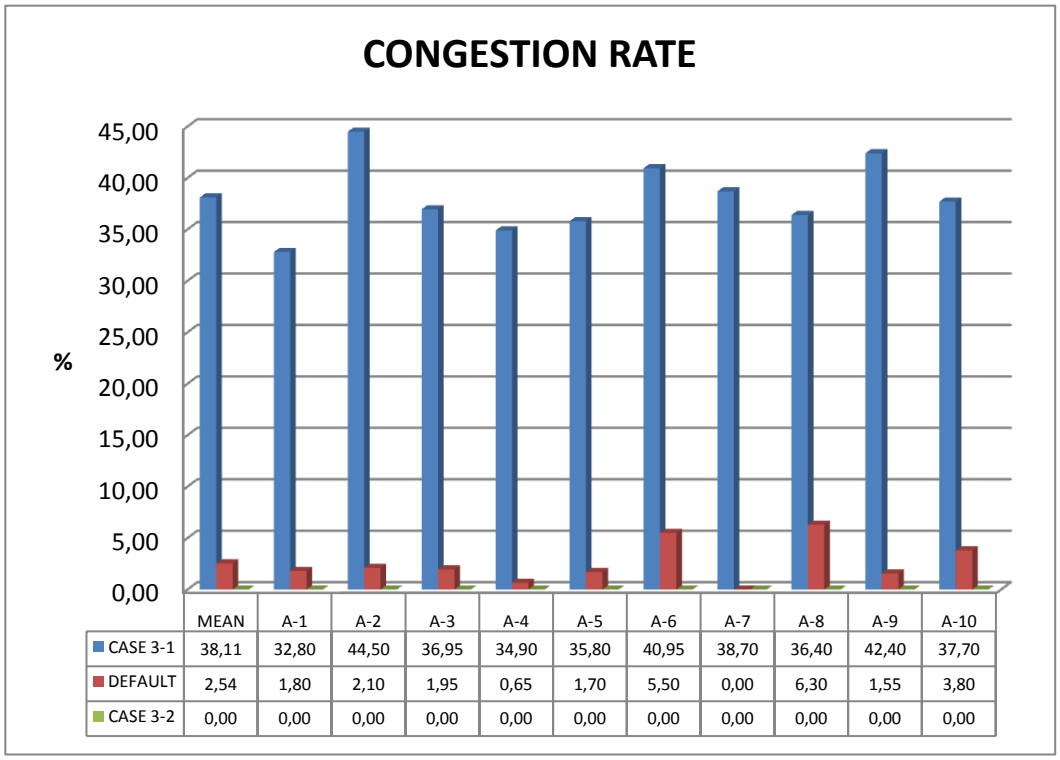


Figure 4.14. D1 Case 3- Congestion rate

Table 4.15. D1 Case 3- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,12	5,25	2,85	4,00	4,75	6,90	2,05	3,70	3,70	4,10	3,85
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 3-2	27,12	28,05	25,50	26,65	26,35	28,50	27,50	26,45	26,50	25,35	30,35
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,12	5,25	2,85	4,00	4,75	6,90	2,05	3,70	3,70	4,10	3,85
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 3-2	27,12	28,05	25,50	26,65	26,35	28,50	27,50	26,45	26,50	25,35	30,35

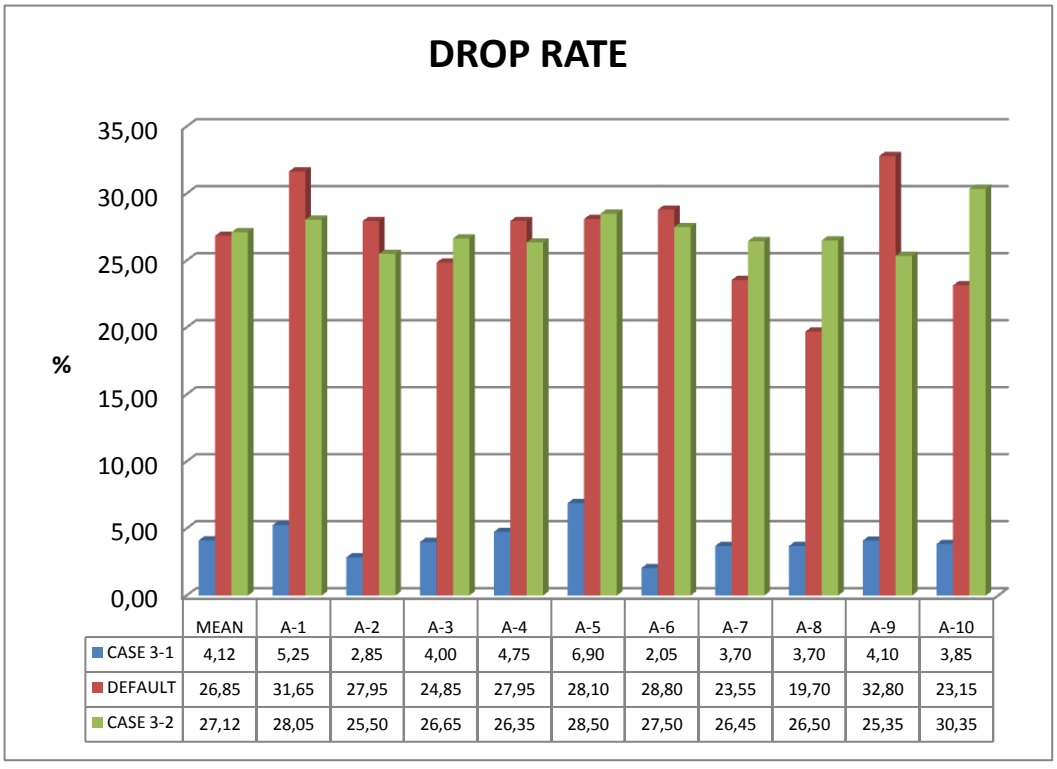


Figure 4.15. D1 Case 3- Drop rate

Table 4.16. D1 Case 3- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 3-2	22,14	26,00	23,10	24,70	21,50	23,85	18,05	24,65	17,40	22,60	19,50
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 3-2	22,14	26,00	23,10	24,70	21,50	23,85	18,05	24,65	17,40	22,60	19,50

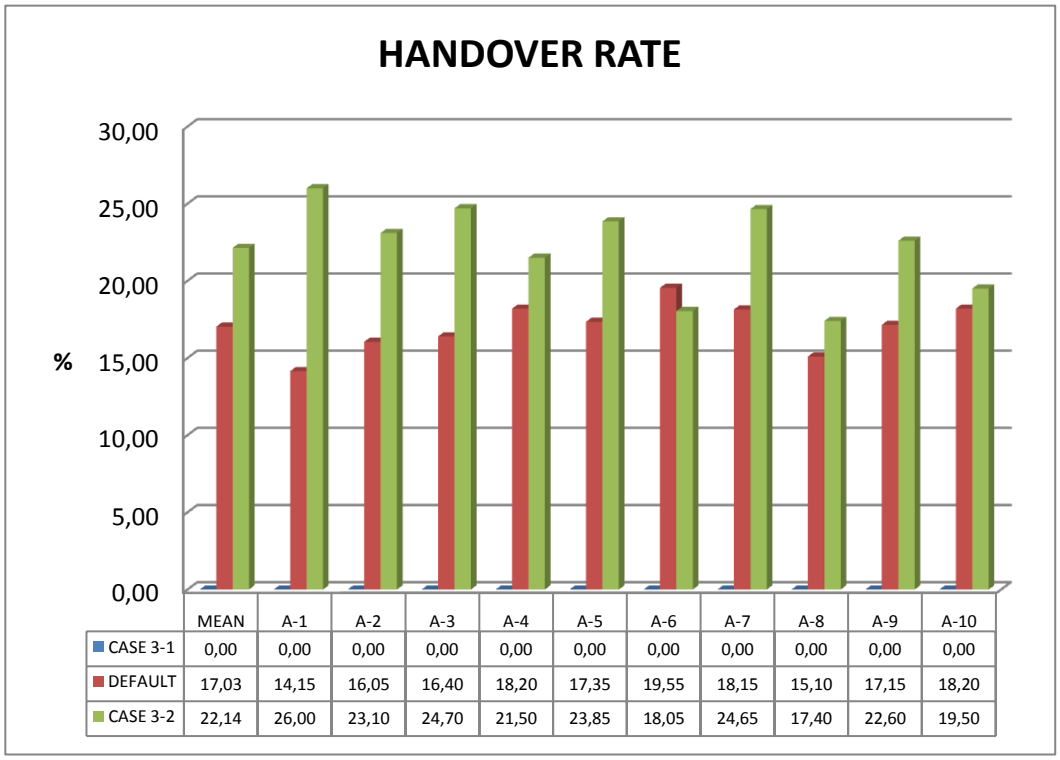


Figure 4.16. D1 Case 3- Handover rate

4.2.1.4 D1-Case 4

Table 4.17. D1 Case 4- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	83,68	88,48	84,04	78,21	85,30	82,75	86,60	84,58	84,54	81,48	80,80
DEFAULT	86,99	83,71	86,86	90,37	88,70	86,67	83,14	87,41	91,36	81,54	90,19
CASE 4-2	91,19	90,99	89,58	90,00	92,10	94,44	90,80	93,02	89,75	87,90	93,27
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	7,53	7,96	7,56	7,04	7,68	7,45	7,79	7,61	7,61	7,33	7,27
DEFAULT	7,83	7,53	7,82	8,13	7,98	7,80	7,48	7,87	8,22	7,34	8,12
CASE 4-2	8,21	8,19	8,06	8,10	8,29	8,50	8,17	8,37	8,08	7,91	8,39

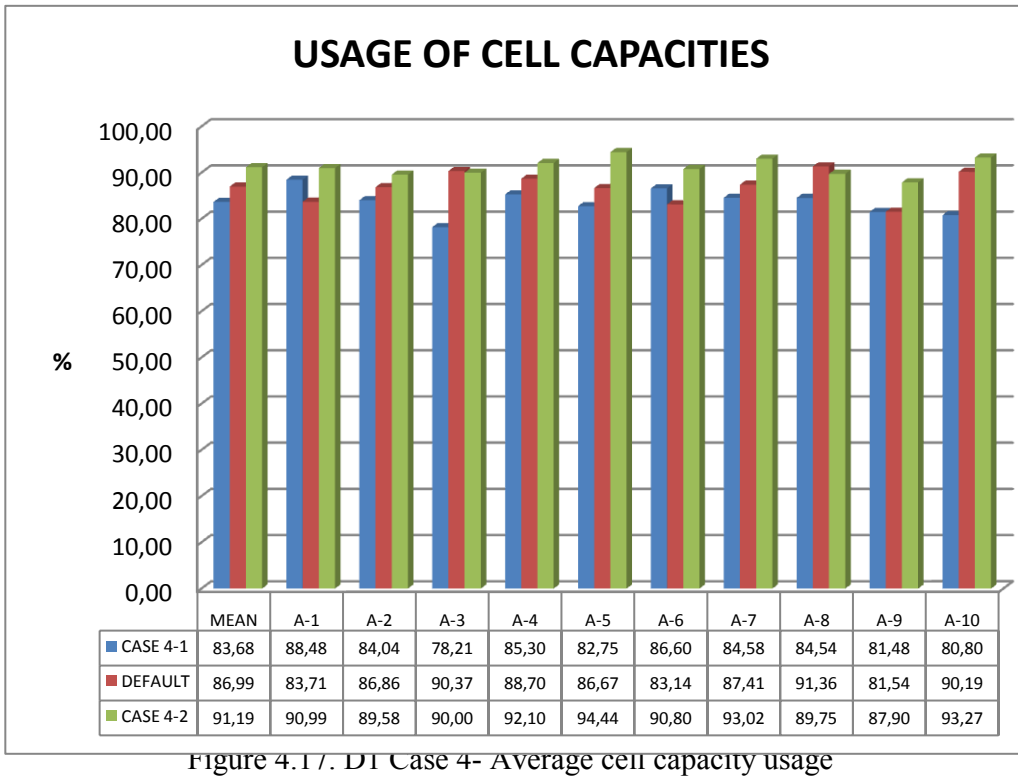


Figure 4.17. D1 Case 4- Average cell capacity usage

Table 4.18. D1 Case 4- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	78,81	79,13	79,85	79,85	78,73	78,09	78,18	78,97	77,60	79,62	78,04
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 4-2	81,67	82,12	81,98	81,22	80,94	81,15	81,78	80,58	82,09	81,76	83,05
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	78,81	79,13	79,85	79,85	78,73	78,09	78,18	78,97	77,60	79,62	78,04
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 4-2	81,67	82,12	81,98	81,22	80,94	81,15	81,78	80,58	82,09	81,76	83,05

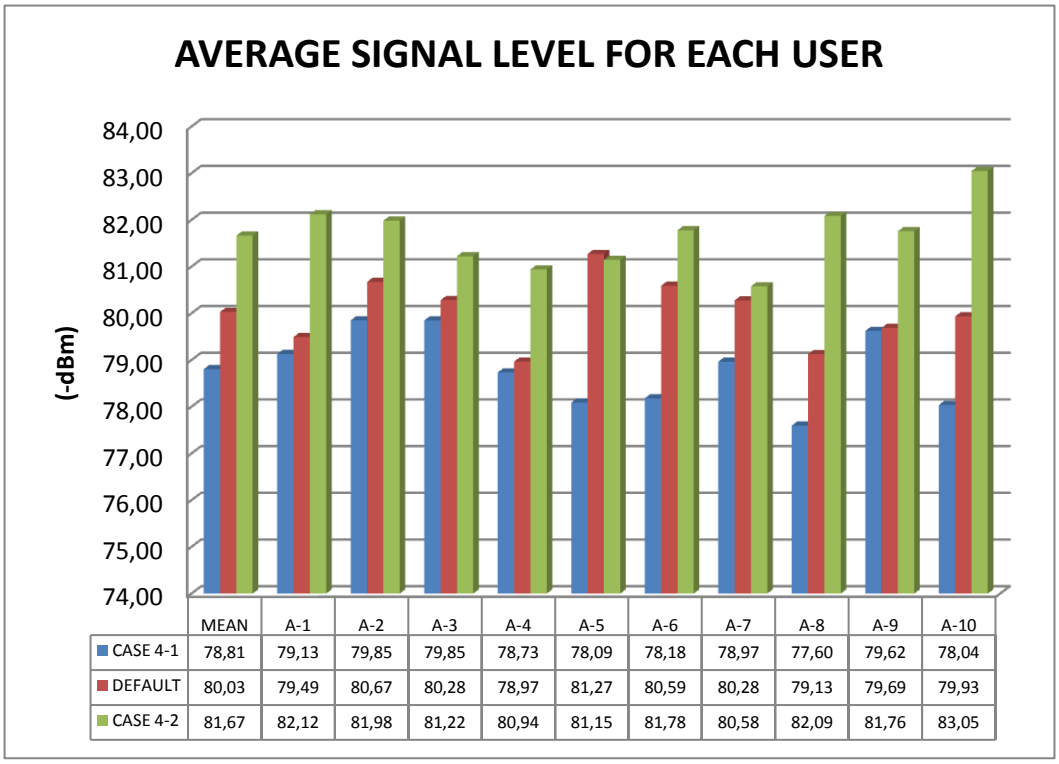


Figure 4.18. D1 Case 4- Average signal level per user

Table 4.19. D1 Case 4- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	3,59	2,95	3,70	0,10	0,80	5,60	4,90	1,75	4,75	3,80	7,50
DEFAULT	3,10	1,80	2,10	1,95	0,65	1,70	5,50	5,65	6,30	1,55	3,80
CASE 4-2	6,21	6,00	4,40	4,65	7,05	4,00	6,65	4,75	10,35	7,20	7,05
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	3,59	2,95	3,70	0,10	0,80	5,60	4,90	1,75	4,75	3,80	7,50
DEFAULT	3,10	1,80	2,10	1,95	0,65	1,70	5,50	5,65	6,30	1,55	3,80
CASE 4-2	6,21	6,00	4,40	4,65	7,05	4,00	6,65	4,75	10,35	7,20	7,05

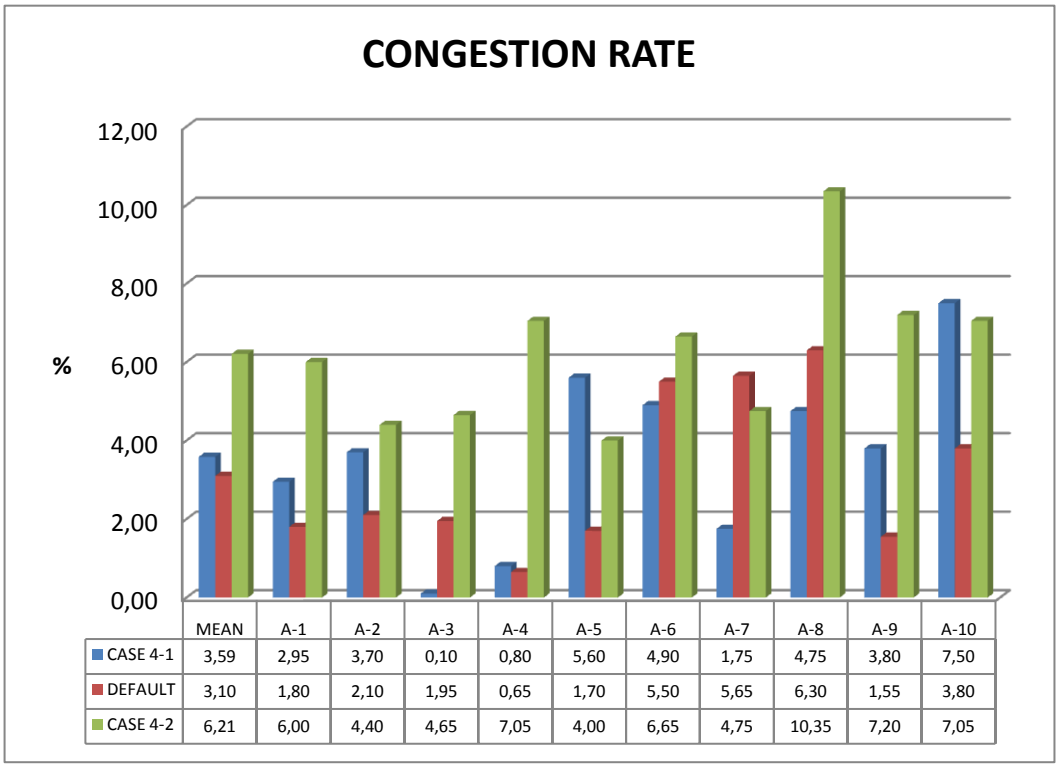


Figure 4.19. D1 Case 4- Congestion rate

Table 4.20. D1 Case 4- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	29,84	27,95	30,30	36,55	30,95	28,60	26,65	30,15	27,60	31,00	28,60
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 4-2	20,14	20,30	23,90	22,45	18,35	19,50	19,80	18,90	17,85	22,05	18,30
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	29,84	27,95	30,30	36,55	30,95	28,60	26,65	30,15	27,60	31,00	28,60
DEFAULT	26,85	31,65	27,95	24,85	27,95	28,10	28,80	23,55	19,70	32,80	23,15
CASE 4-2	20,14	20,30	23,90	22,45	18,35	19,50	19,80	18,90	17,85	22,05	18,30

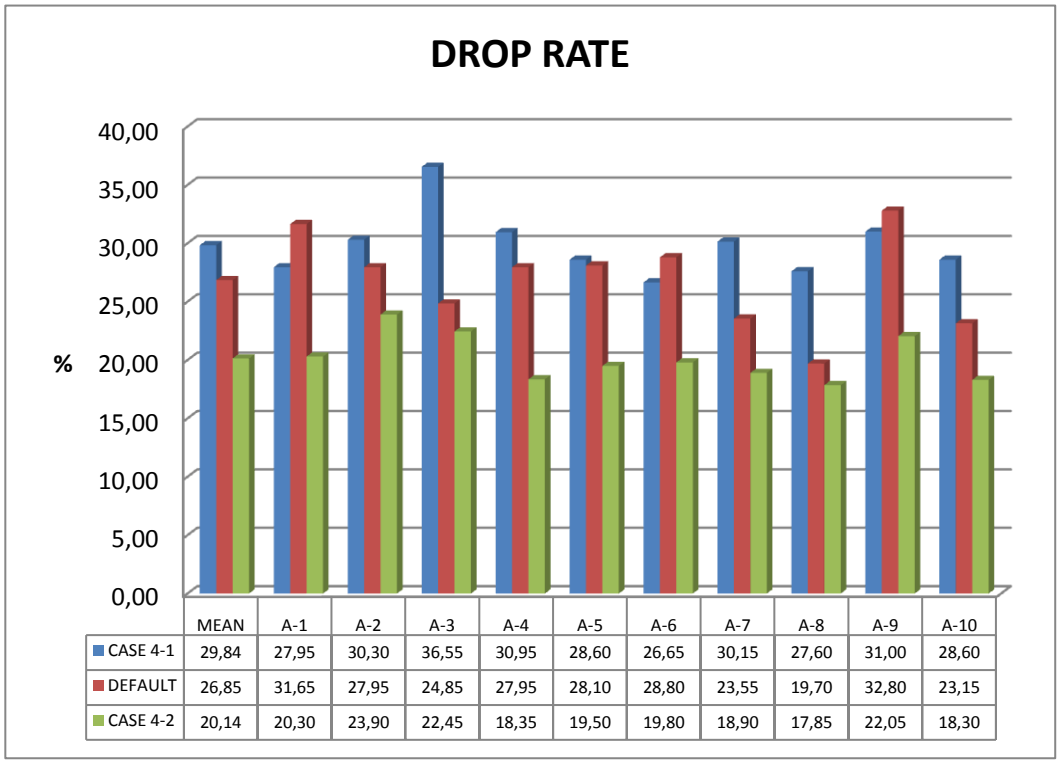


Figure 4.20. D1 Case 4- Drop rate

Table 4.21. D1 Case 4- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						20		20		20	
CASE %	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	12,55	15,50	15,90	12,35	11,15	9,70	12,85	14,90	9,50	14,65	9,00
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 4-2	19,57	21,70	17,35	18,90	19,30	20,95	23,15	19,85	16,20	14,80	23,50
CASE	MEAN	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10
CASE 4-1	12,55	15,50	15,90	12,35	11,15	9,70	12,85	14,90	9,50	14,65	9,00
DEFAULT	17,03	14,15	16,05	16,40	18,20	17,35	19,55	18,15	15,10	17,15	18,20
CASE 4-2	19,57	21,70	17,35	18,90	19,30	20,95	23,15	19,85	16,20	14,80	23,50

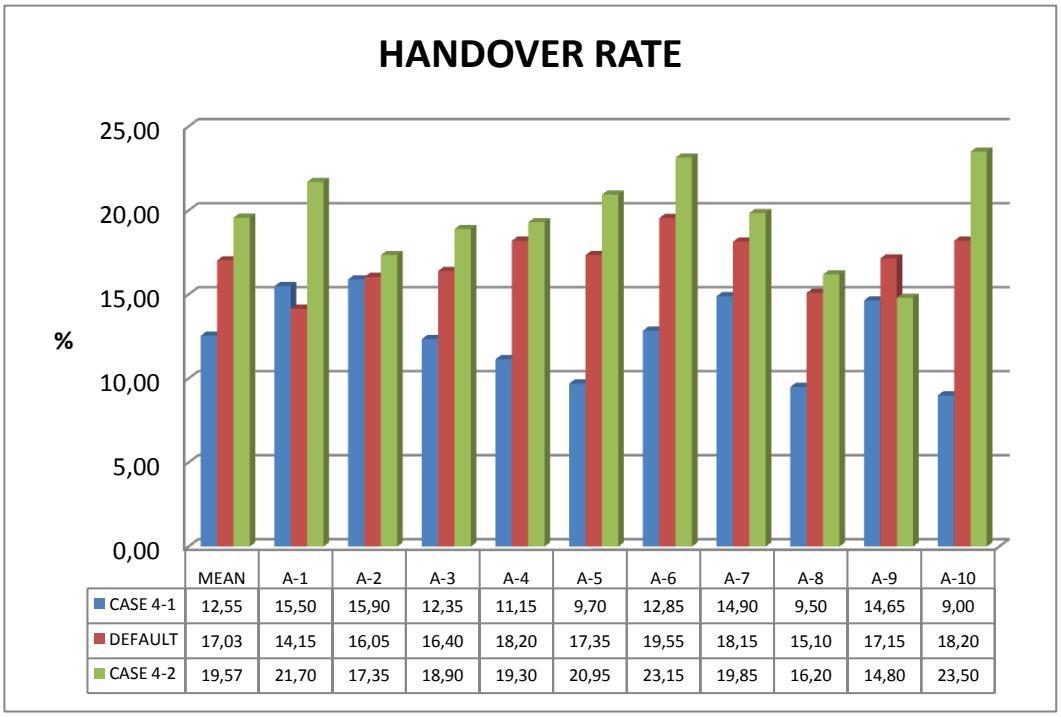


Figure 4.21. D1 Case 4- Handover rate

4.2.2 Results for speed distributions D2 and D3

The effect of different possible speed distributions on quality parameters are analyzed by considering two different user speed distributions, D2 and D3.

Considering the speed distributions, an average speed of 14.5 pixels/unit time and 5.5 pixels/unit time is calculated for D2 and D3 distributions, respectively.

The results corresponding D2 distribution (Tables and Figures 4.22.-4.41.) and D3 distribution (Tables and Figures 4.42.-4.61.) show, somewhat surprisingly, very similar tendencies to the results corresponding D1. A corresponding numerical comparison of D2 and D3 distributions with D1 distribution (Tables 4.62.-4.66.) show that the change in quality parameters from D1 is less than 1 %.

The reasons for this interesting observation are discussed in the next section along with other results.

4.2.2.1 D2-Case 1

Table 4.22. D2 Case 1- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	60,63	60,04	62,47	54,89	63,96	58,16	56,28	63,51	61,28	62,20	63,54
DEFAULT	87,10	87,80	86,17	86,81	83,30	88,09	85,67	87,56	89,01	88,56	88,03
CASE 1-2	99,93	100,00	99,94	100,00	99,88	100,00	100,00	100,00	100,00	99,44	100,00
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	5,46	5,40	5,62	4,94	5,76	5,23	5,07	5,72	5,52	5,60	5,72
DEFAULT	7,84	7,90	7,75	7,81	7,50	7,93	7,71	7,88	8,01	7,97	7,92
CASE 1-2	8,99	9,00	8,99	9,00	8,99	9,00	9,00	9,00	9,00	8,95	9,00

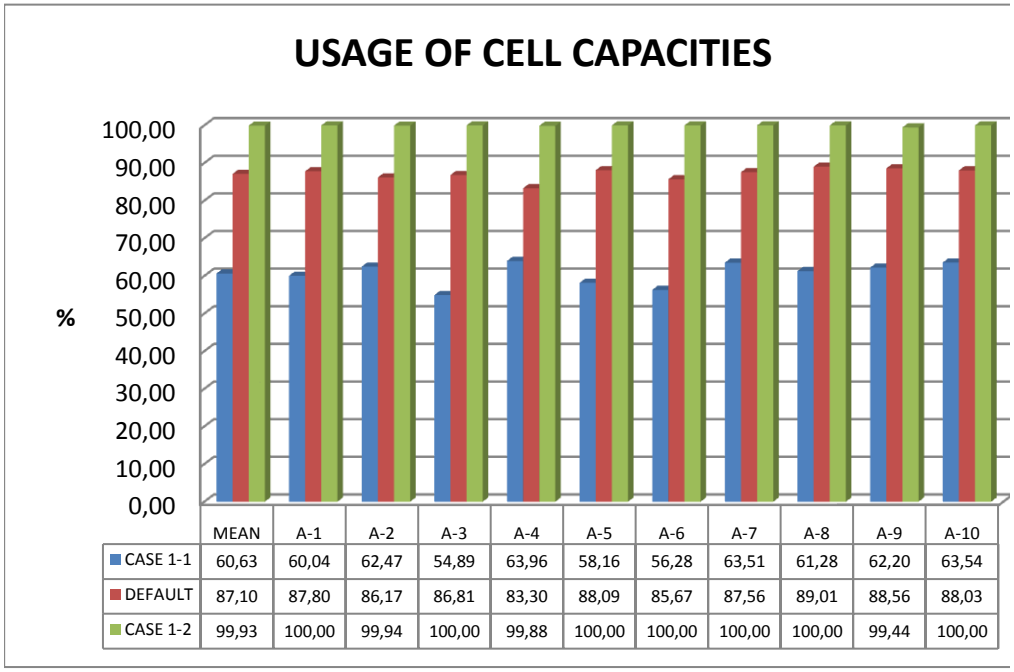


Table 4.23. D2 Case 1- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	80,37	81,71	79,84	81,64	80,70	78,97	80,84	80,19	79,66	78,92	81,21
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 1-2	80,43	80,71	80,18	78,76	80,99	81,72	80,69	78,43	81,20	81,32	80,34
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	80,25	80,25	81,38	79,94	80,76	79,49	80,75	80,37	79,65	80,00	79,91
DEFAULT	80,51	81,12	80,76	79,94	80,28	80,93	80,95	80,50	79,44	81,04	80,17
CASE 1-2	79,89	79,05	79,26	79,82	79,37	79,09	80,46	80,37	80,46	80,85	80,20

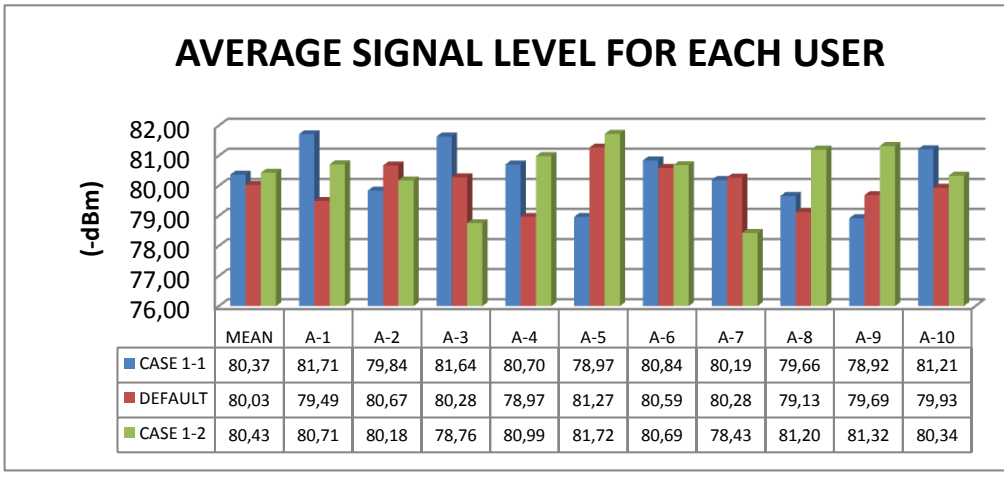


Table 4.24. D2 Case 1- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 1-2	44,99	49,40	37,38	47,68	46,72	42,62	48,80	45,36	48,64	39,74	43,56
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 1-2	112,48	123,50	93,45	119,20	116,80	106,55	122,00	113,40	121,60	99,35	108,90

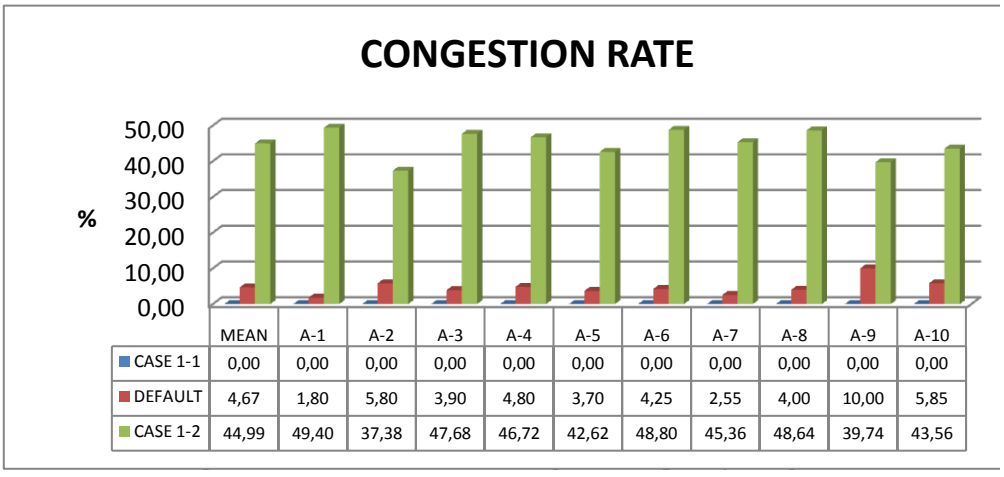


Table 4.25. D2 Case 1-Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	10,18	11,30	9,90	14,30	8,60	10,80	12,60	9,10	9,40	10,00	5,80
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 1-2	22,63	18,20	30,24	19,92	20,92	24,98	18,80	22,24	18,96	28,04	24,04
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	5,09	5,65	4,95	7,15	4,30	5,40	6,30	4,55	4,70	5,00	2,90
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 1-2	56,59	45,50	75,60	49,80	52,30	62,45	47,00	55,60	47,40	70,10	60,10

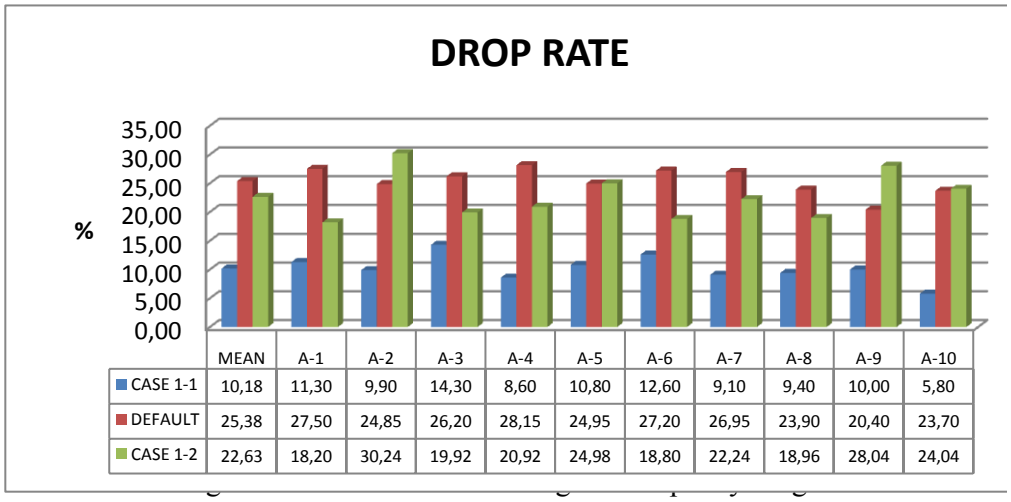
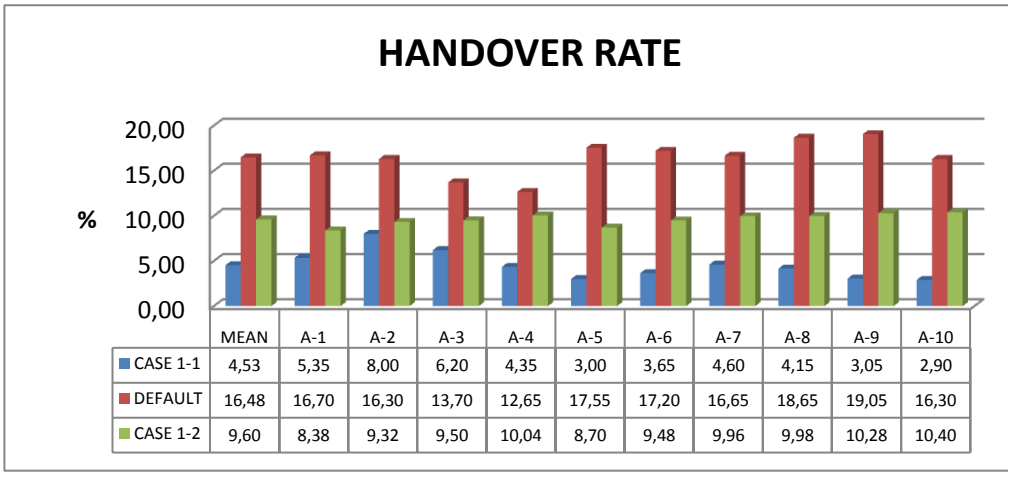


Table 4.26. D2 Case 1- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	4,53	5,35	8,00	6,20	4,35	3,00	3,65	4,60	4,15	3,05	2,90
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 1-2	9,60	8,38	9,32	9,50	10,04	8,70	9,48	9,96	9,98	10,28	10,40
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	3,38	2,05	2,85	6,70	2,00	5,05	2,20	2,30	3,30	3,80	3,55
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 1-2	24,01	20,95	23,30	23,75	25,10	21,75	23,70	24,90	24,95	25,70	26,00



4.2.2.2 D2-Case 2

Table 4.27. D2 Case 2- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	95,44	96,48	97,96	93,15	97,96	95,65	97,96	92,96	92,59	95,56	94,07
DEFAULT	87,10	87,80	86,17	86,81	83,30	88,09	85,67	87,56	89,01	88,56	88,03
CASE 2-2	77,29	79,57	75,30	74,81	74,33	80,03	76,55	73,66	80,57	78,76	79,31
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	5,73	5,79	5,88	5,59	5,88	5,74	5,88	5,58	5,56	5,73	5,64
DEFAULT	7,84	7,90	7,75	7,81	7,50	7,93	7,71	7,88	8,01	7,97	7,92
CASE 2-2	9,27	9,55	9,04	8,98	8,92	9,60	9,19	8,84	9,67	9,45	9,52

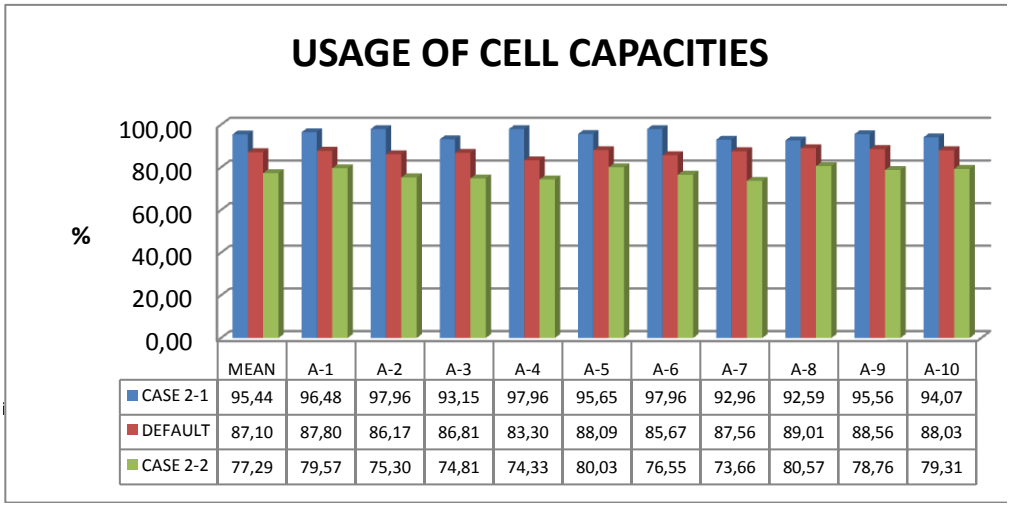


Table 4.28. D2 Case 2- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	80,48	79,24	80,47	81,05	81,66	81,39	81,09	80,48	78,74	80,49	80,24
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 2-2	80,34	78,73	80,36	80,25	81,37	78,84	80,41	80,32	80,92	81,45	80,71
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	80,23	79,88	80,41	81,11	79,25	80,69	79,88	78,96	79,73	80,10	82,33
DEFAULT	80,51	81,12	80,76	79,94	80,28	80,93	80,95	80,50	79,44	81,04	80,17
CASE 2-2	80,40	80,11	80,56	79,11	81,49	81,10	79,53	80,65	81,63	79,17	80,69

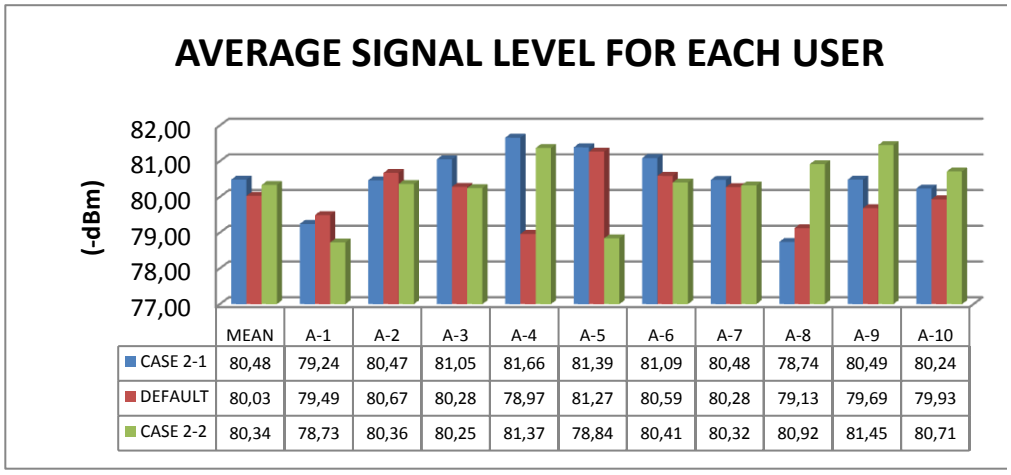


Table 4.29. D2 Case 2- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	17,94	17,85	26,50	18,30	15,05	11,70	17,15	16,20	20,40	21,40	14,80
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 2-2	0,75	0,00	0,45	0,35	0,10	0,40	2,30	0,25	1,50	1,25	0,90
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	17,94	17,85	26,50	18,30	15,05	11,70	17,15	16,20	20,40	21,40	14,80
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 2-2	0,75	0,00	0,45	0,35	0,10	0,40	2,30	0,25	1,50	1,25	0,90

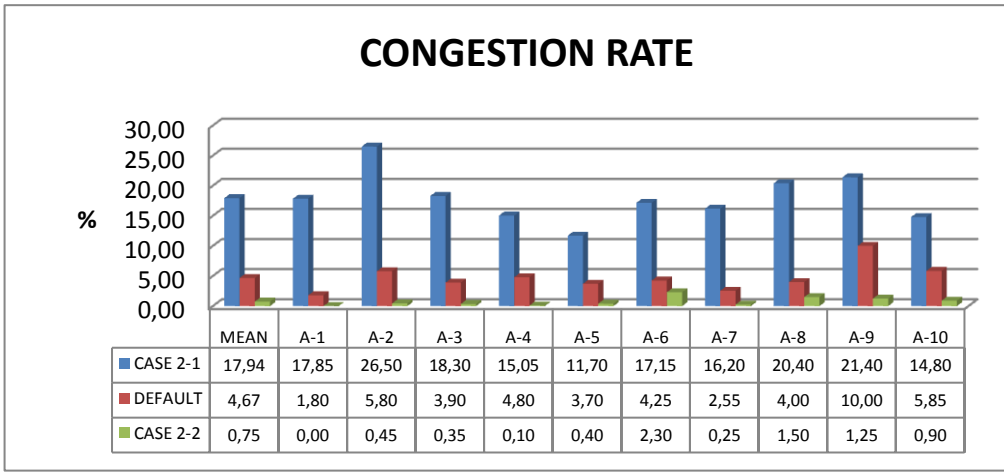


Table 4.30. D2 Case 2- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	30,56	30,05	20,90	31,40	32,05	36,65	29,95	33,60	29,60	27,00	34,40
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 2-2	18,66	16,65	20,20	18,85	22,15	16,35	15,55	21,70	18,90	17,70	18,50
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	30,56	30,05	20,90	31,40	32,05	36,65	29,95	33,60	29,60	27,00	34,40
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 2-2	18,66	16,65	20,20	18,85	22,15	16,35	15,55	21,70	18,90	17,70	18,50

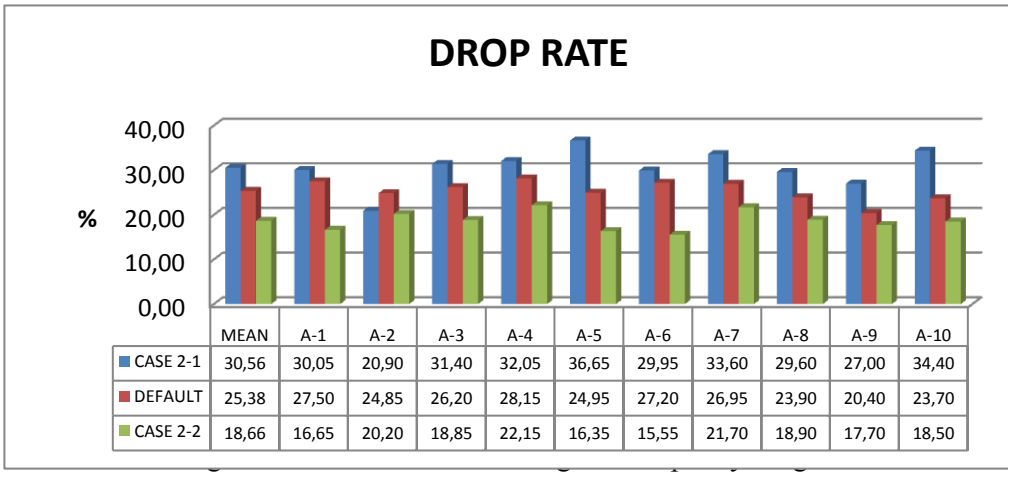
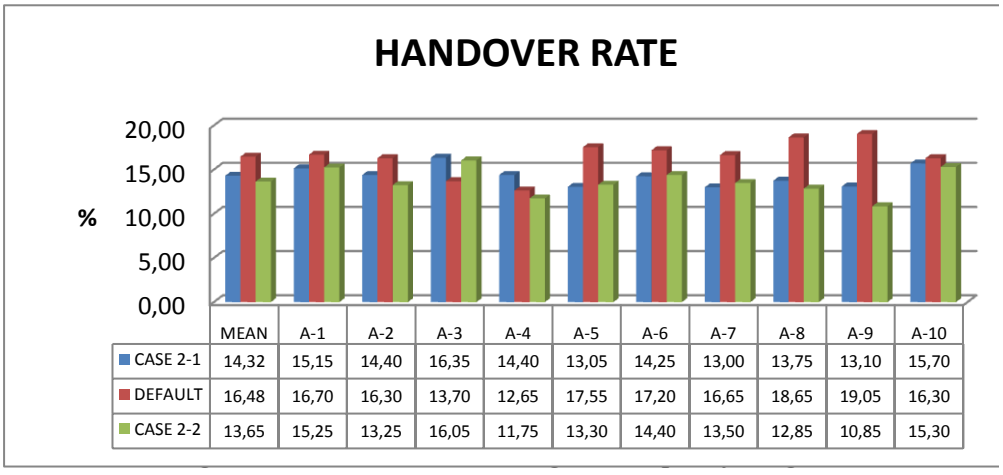


Table 4.31. D2 Case 2- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	14,32	15,15	14,40	16,35	14,40	13,05	14,25	13,00	13,75	13,10	15,70
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 2-2	13,65	15,25	13,25	16,05	11,75	13,30	14,40	13,50	12,85	10,85	15,30
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	15,16	13,10	17,15	18,80	16,45	18,20	15,60	12,00	11,85	15,15	13,30
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 2-2	13,63	8,95	11,65	12,95	12,35	12,10	16,50	13,65	16,75	17,55	13,80



4.2.2.3 D2-Case 3

Table 4.32. D2 Case 3- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	74,63	72,41	73,73	76,76	71,57	73,49	74,86	77,60	74,14	74,44	77,33
DEFAULT	87,10	87,80	86,17	86,81	83,30	88,09	85,67	87,56	89,01	88,56	88,03
CASE 3-2	91,82	90,25	90,99	92,01	93,21	91,08	92,90	90,99	91,36	91,98	93,46
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	6,72	6,52	6,64	6,91	6,44	6,61	6,74	6,98	6,67	6,70	6,96
DEFAULT	7,84	7,90	7,75	7,81	7,50	7,93	7,71	7,88	8,01	7,97	7,92
CASE 3-2	8,26	8,12	8,19	8,28	8,39	8,20	8,36	8,19	8,22	8,28	8,41

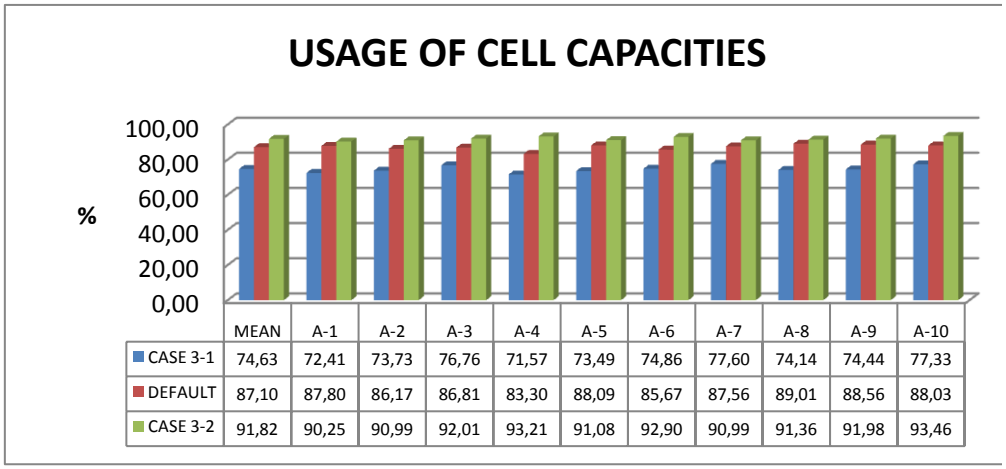


Table 4.33. D2 Case 3- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	78,87	77,86	78,74	79,11	77,89	79,40	79,30	79,50	79,91	79,26	77,77
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 3-2	81,21	81,66	80,82	81,26	80,75	81,55	81,00	82,05	79,05	81,87	82,06
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	78,64	78,79	78,41	80,44	79,55	79,31	79,14	77,45	77,54	78,93	76,87
DEFAULT	80,51	81,12	80,76	79,94	80,28	80,93	80,95	80,50	79,44	81,04	80,17
CASE 3-2	80,92	80,10	81,28	82,28	79,95	79,32	81,17	82,01	81,18	80,77	81,12

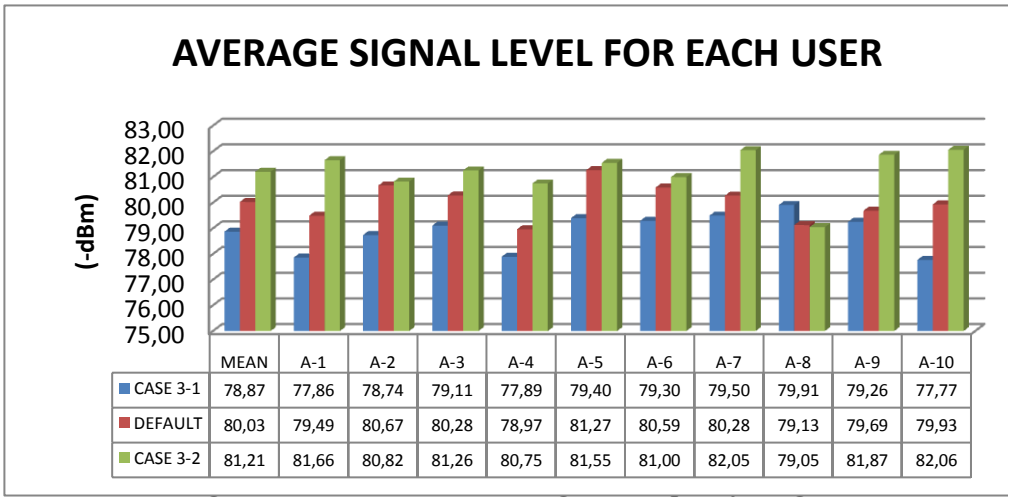


Table 4.34. D2 Case 3- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	38,39	39,30	39,60	35,45	41,75	37,65	38,70	36,40	37,55	39,65	37,80
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	38,39	39,30	39,60	35,45	41,75	37,65	38,70	36,40	37,55	39,65	37,80
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

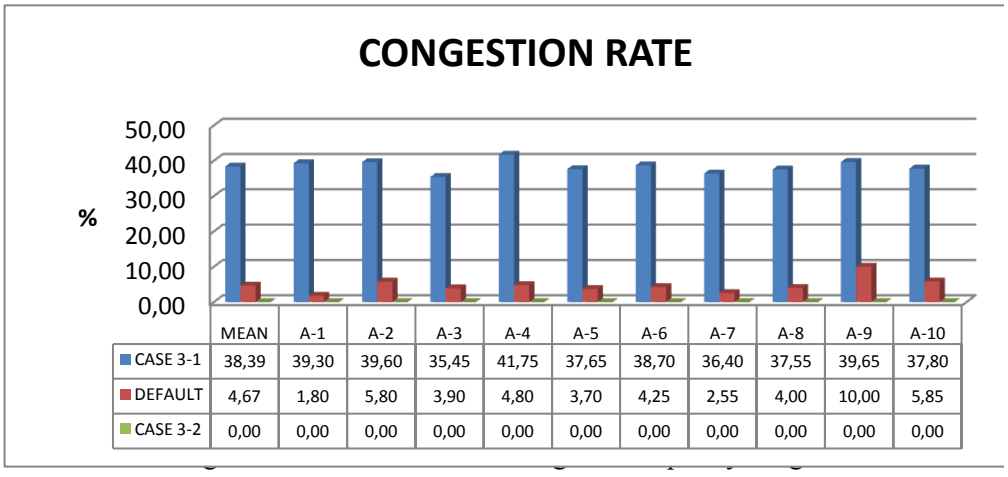


Table 4.35. D2 Case 3- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,02	4,85	3,25	5,95	3,35	4,65	4,55	4,00	4,55	3,25	1,80
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 3-2	26,16	26,90	27,20	27,65	24,50	27,10	25,20	26,30	26,90	25,50	24,30
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,02	4,85	3,25	5,95	3,35	4,65	4,55	4,00	4,55	3,25	1,80
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 3-2	26,16	26,90	27,20	27,65	24,50	27,10	25,20	26,30	26,90	25,50	24,30

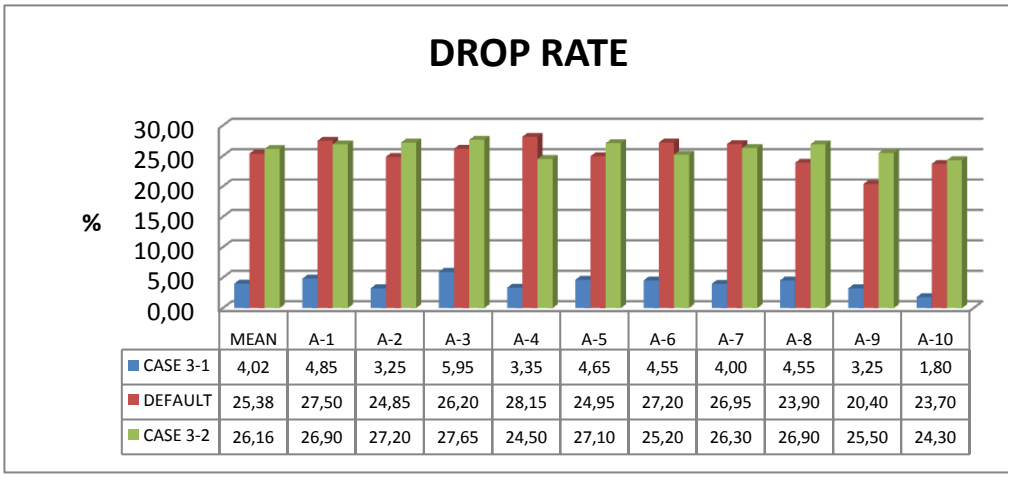
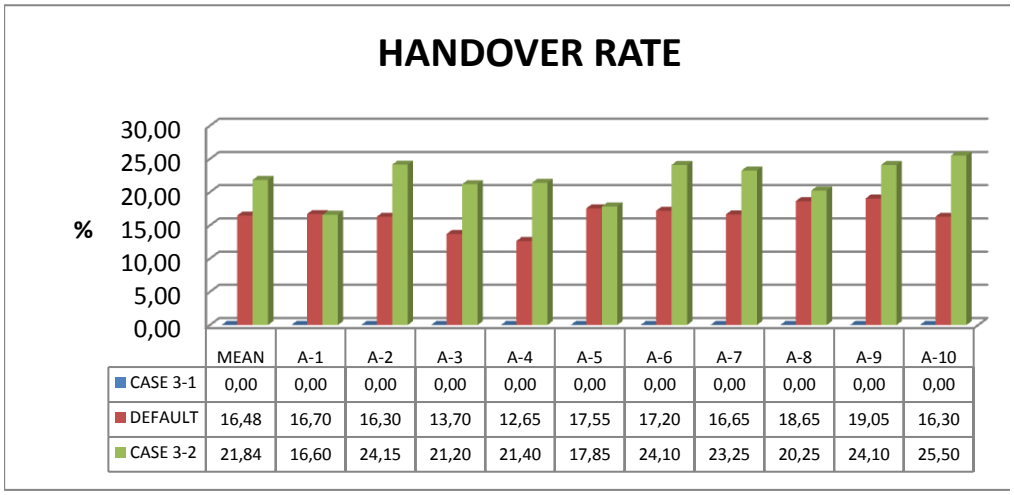


Table 4.36. D2 Case 3- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 3-2	21,84	16,60	24,15	21,20	21,40	17,85	24,10	23,25	20,25	24,10	25,50
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 3-2	21,84	16,60	24,15	21,20	21,40	17,85	24,10	23,25	20,25	24,10	25,50



4.2.2.4 D2-Case 4

Table 4.37. D2 Case 4- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	84,88	87,52	86,74	85,32	81,09	83,43	81,73	85,86	84,97	89,96	82,18
DEFAULT	87,10	87,80	86,17	86,81	83,30	88,09	85,67	87,56	89,01	88,56	88,03
CASE 4-2	89,32	93,02	90,68	90,25	87,28	90,22	88,27	88,77	87,55	87,44	89,75
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	7,64	7,88	7,81	7,68	7,30	7,51	7,36	7,73	7,65	8,10	7,40
DEFAULT	7,84	7,90	7,75	7,81	7,50	7,93	7,71	7,88	8,01	7,97	7,92
CASE 4-2	8,04	8,37	8,16	8,12	7,85	8,12	7,94	7,99	7,88	7,87	8,08

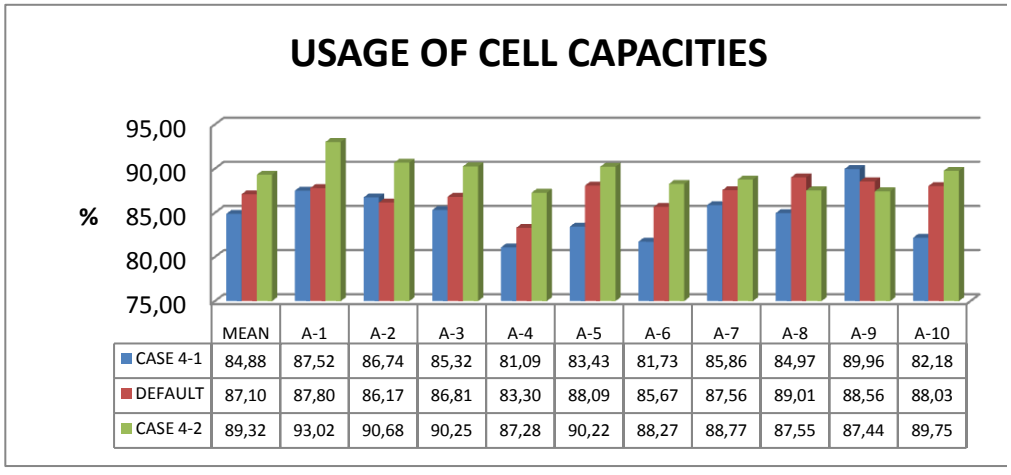


Table 4.38. D2 Case 4- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	78,81	79,13	79,85	79,85	78,73	78,09	78,18	78,97	77,60	79,62	78,04
DEFAULT	80,03	79,49	80,67	80,28	78,97	81,27	80,59	80,28	79,13	79,69	79,93
CASE 4-2	81,67	82,12	81,98	81,22	80,94	81,15	81,78	80,58	82,09	81,76	83,05
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	78,71	78,47	79,14	79,68	80,02	77,96	78,00	77,64	78,94	77,92	79,32
DEFAULT	80,51	81,12	80,76	79,94	80,28	80,93	80,95	80,50	79,44	81,04	80,17
CASE 4-2	82,03	80,99	81,47	82,55	82,55	82,27	81,77	82,92	82,52	82,18	81,07

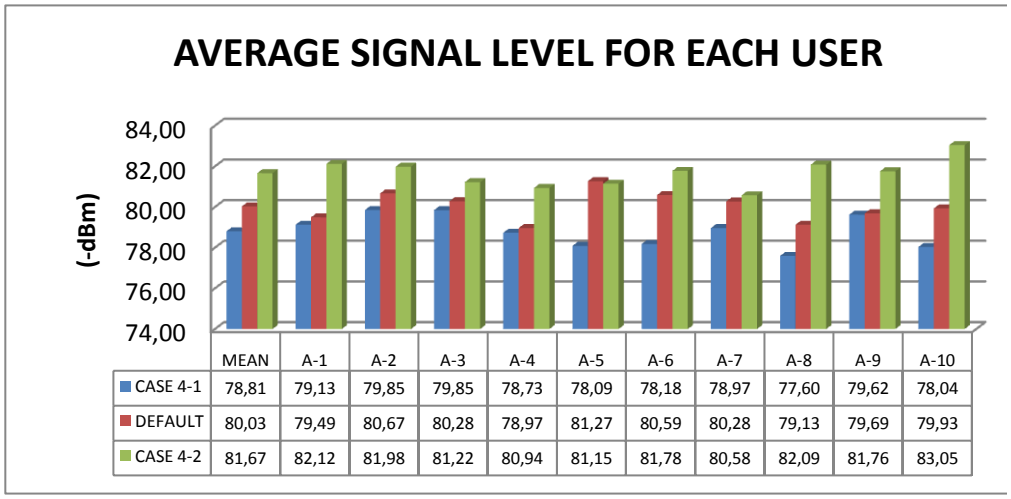


Table 4.39. D2 Case 4- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	2,92	3,55	4,50	1,20	4,15	2,05	0,80	2,10	0,70	6,20	3,90
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 4-2	4,56	5,45	4,55	7,00	3,75	2,75	3,85	3,85	6,05	5,20	3,15
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	2,92	3,55	4,50	1,20	4,15	2,05	0,80	2,10	0,70	6,20	3,90
DEFAULT	4,67	1,80	5,80	3,90	4,80	3,70	4,25	2,55	4,00	10,00	5,85
CASE 4-2	4,56	5,45	4,55	7,00	3,75	2,75	3,85	3,85	6,05	5,20	3,15

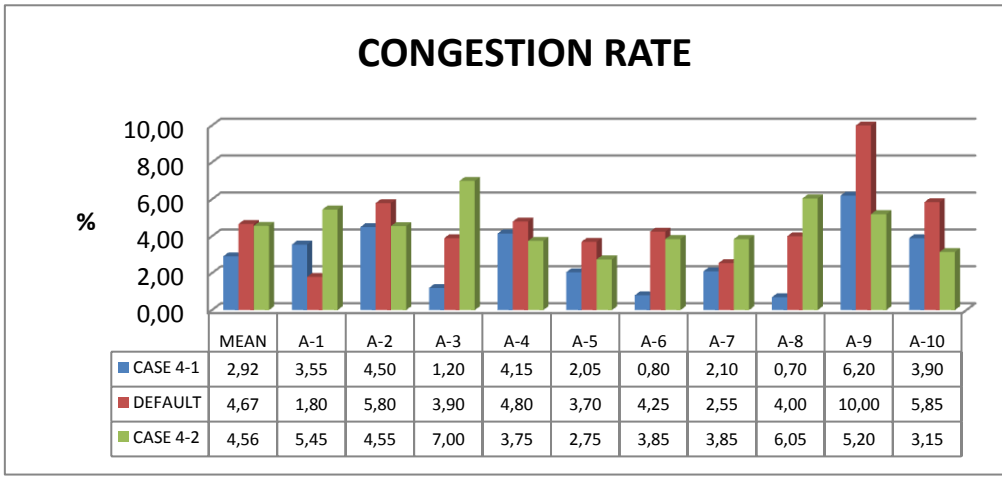


Table 4.40. D2 Case 4- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	29,37	26,00	27,35	30,55	32,95	32,00	33,00	28,35	30,90	21,80	30,75
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 4-2	23,70	21,00	22,00	21,65	26,40	25,05	24,65	24,25	23,45	24,40	24,15
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	29,37	26,00	27,35	30,55	32,95	32,00	33,00	28,35	30,90	21,80	30,75
DEFAULT	25,38	27,50	24,85	26,20	28,15	24,95	27,20	26,95	23,90	20,40	23,70
CASE 4-2	23,70	21,00	22,00	21,65	26,40	25,05	24,65	24,25	23,45	24,40	24,15

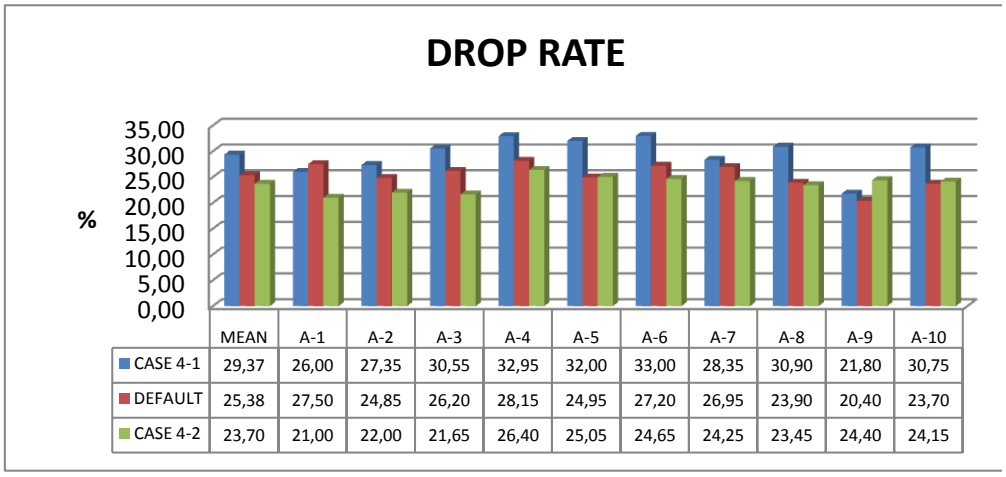
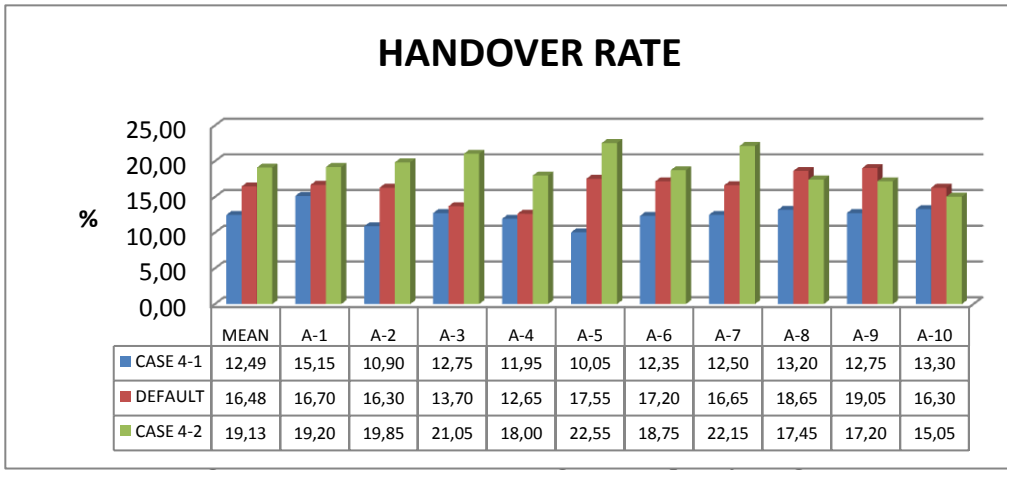


Table 4.41. D2 Case 4- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	12,49	15,15	10,90	12,75	11,95	10,05	12,35	12,50	13,20	12,75	13,30
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 4-2	19,13	19,20	19,85	21,05	18,00	22,55	18,75	22,15	17,45	17,20	15,05
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	12,49	15,15	10,90	12,75	11,95	10,05	12,35	12,50	13,20	12,75	13,30
DEFAULT	16,48	16,70	16,30	13,70	12,65	17,55	17,20	16,65	18,65	19,05	16,30
CASE 4-2	19,13	19,20	19,85	21,05	18,00	22,55	18,75	22,15	17,45	17,20	15,05



4.2.2.5 D3-Case 1

Table 4.42. D3 Case 1- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	61,59	61,91	60,31	64,18	60,20	58,48	61,27	61,63	65,76	61,60	60,52
DEFAULT	86,25	87,35	86,23	84,26	83,95	91,79	83,08	84,88	88,33	90,05	82,59
CASE 1-2	99,89	100,00	100,00	100,00	100,00	99,81	99,63	99,57	99,88	100,00	100,00
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	5,54	5,57	5,43	5,78	5,42	5,26	5,51	5,55	5,92	5,54	5,45
DEFAULT	7,76	7,86	7,76	7,58	7,56	8,26	7,48	7,64	7,95	8,10	7,43
CASE 1-2	8,99	9,00	9,00	9,00	9,00	8,98	8,97	8,96	8,99	9,00	9,00

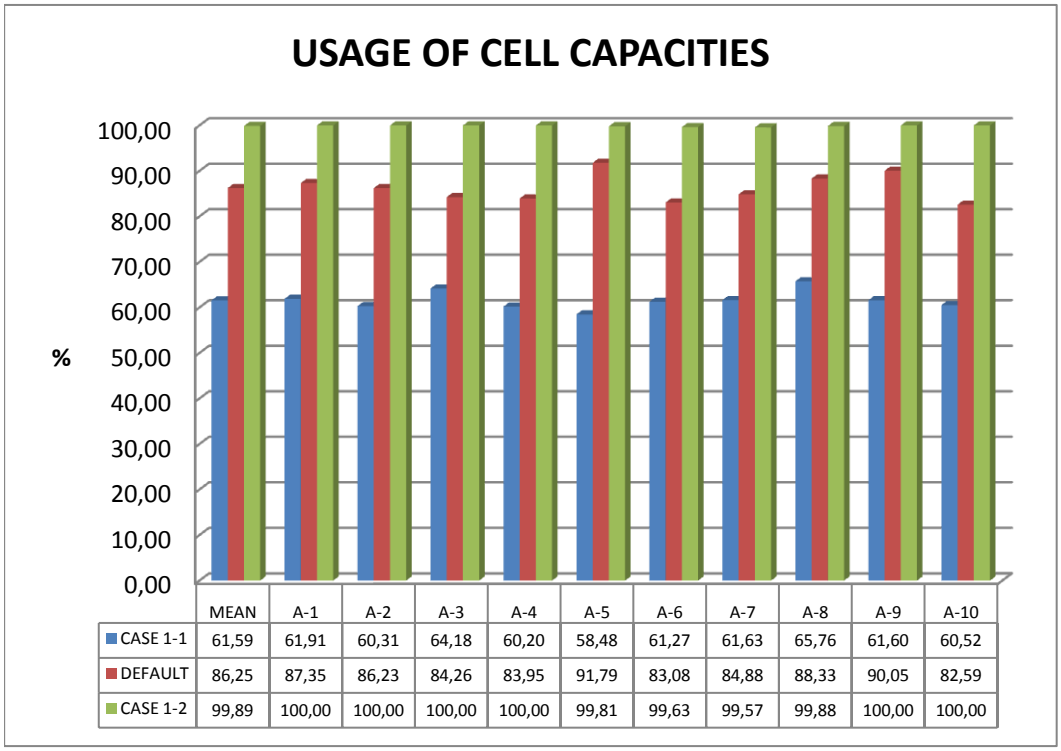


Figure 4.42. D3 Case 1- Average cell capacity usage

Table 4.43. D3 Case 1- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	79,99	79,42	79,67	78,46	80,05	80,18	80,31	80,13	79,79	81,77	80,14
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 1-2	80,52	80,36	81,41	80,49	79,56	81,24	81,03	80,90	80,48	79,89	79,88
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	79,99	79,42	79,67	78,46	80,05	80,18	80,31	80,13	79,79	81,77	80,14
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 1-2	80,52	80,36	81,41	80,49	79,56	81,24	81,03	80,90	80,48	79,89	79,88

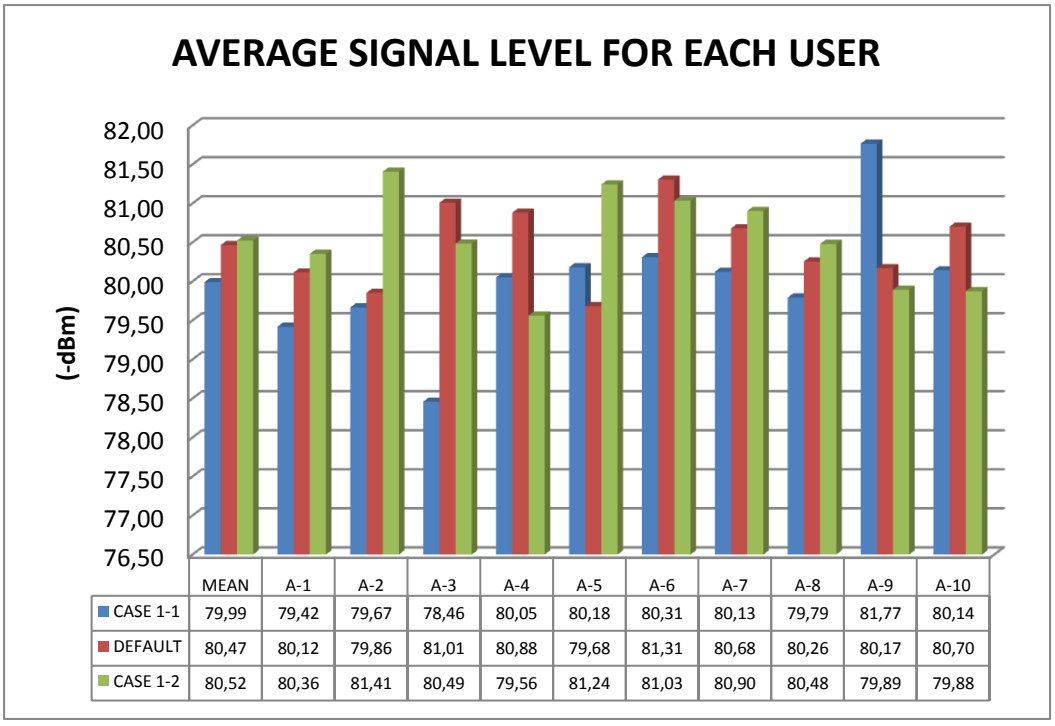


Figure 4.43. D3 Case 1- Average signal level per user

Table 4.44. D3 Case 1- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,04	0,30	0,00	0,00	0,00	0,00	0,00	0,10	0,00	0,00	0,00
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 1-2	46,46	47,10	52,48	50,34	46,86	40,72	46,84	35,06	46,02	48,90	50,26
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	0,02	0,15	0,00	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,00
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 1-2	116,15	117,75	131,20	125,85	117,15	101,80	117,10	87,65	115,05	122,25	125,65

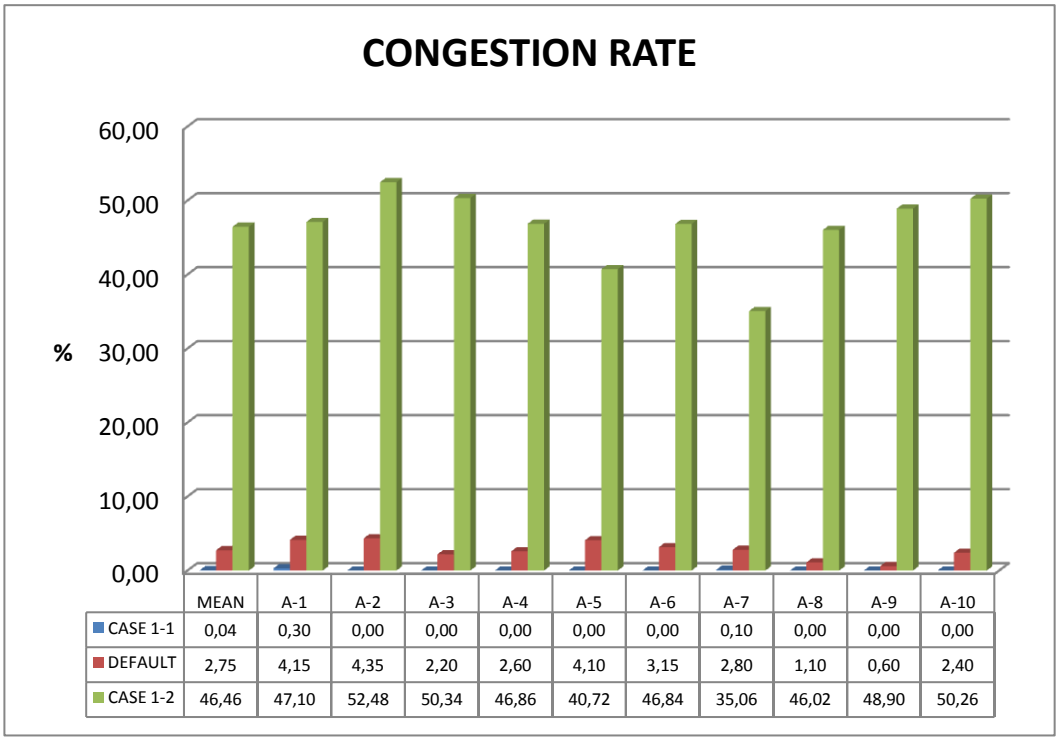


Figure 4.44. D3 Case 1- Congestion rate

Table 4.45. D3 Case 1-Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	9,57	11,00	8,60	7,20	9,80	10,40	9,50	8,80	5,30	12,60	12,50
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 1-2	21,18	20,50	15,12	17,26	20,74	26,94	20,88	32,68	21,62	18,70	17,34
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	4,79	5,50	4,30	3,60	4,90	5,20	4,75	4,40	2,65	6,30	6,25
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 1-2	52,95	51,25	37,80	43,15	51,85	67,35	52,20	81,70	54,05	46,75	43,35

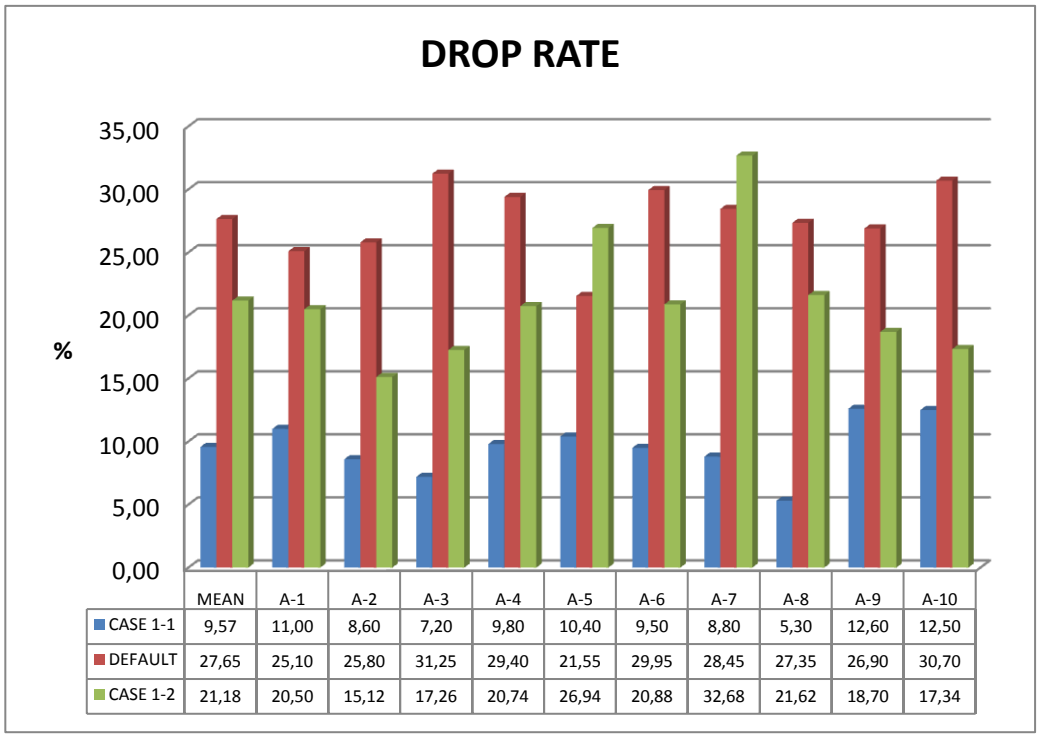


Figure 4.45. D3 Case 1- Drop rate

Table 4.46. D3 Case 1- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	8,20	6,80	12,80	11,00	6,50	5,10	7,30	11,60	5,90	6,70	8,30
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 1-2	10,32	11,58	10,18	9,40	8,88	10,68	11,26	10,44	12,44	9,16	9,22
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 1-1	4,10	3,40	6,40	5,50	3,25	2,55	3,65	5,80	2,95	3,35	4,15
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 1-2	25,81	28,95	25,45	23,50	22,20	26,70	28,15	26,10	31,10	22,90	23,05

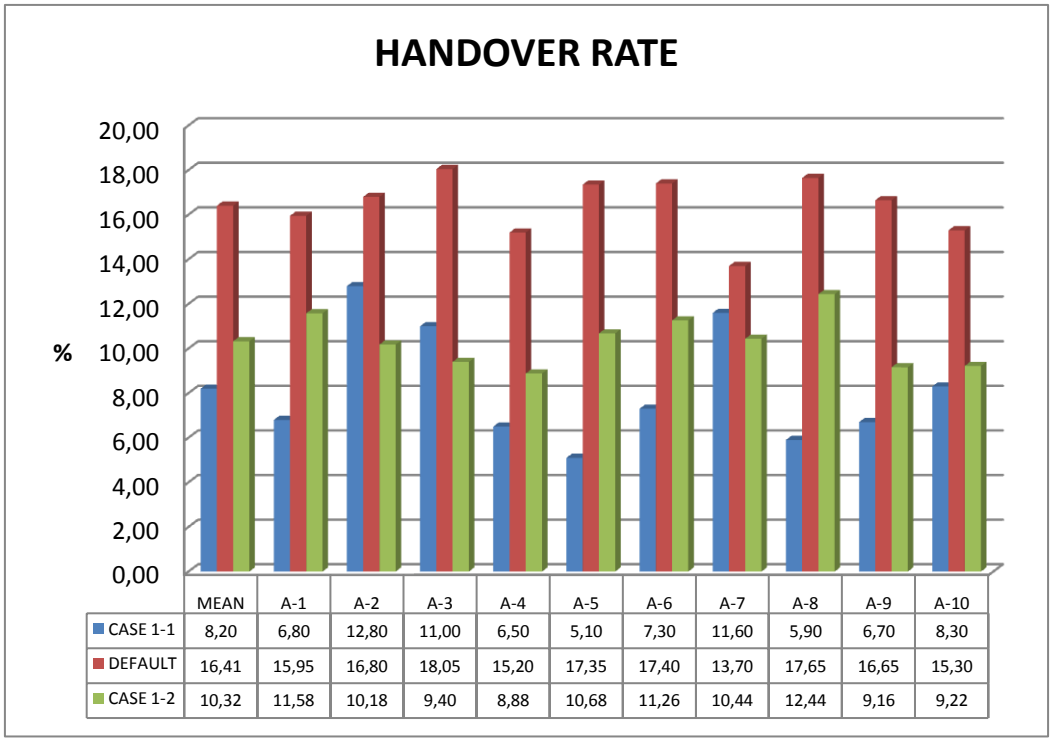


Figure 4.46. D3 Case 1- Handover rate

4.2.2.6 D3-Case 2

Table 4.47. D3 Case 2- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	94,55	94,91	95,19	92,59	95,28	94,91	94,91	97,69	93,06	95,28	91,67
DEFAULT	86,25	87,35	86,23	84,26	83,95	91,79	83,08	84,88	88,33	90,05	82,59
CASE 2-2	76,67	77,42	77,03	75,76	73,98	77,63	76,27	78,20	73,99	78,74	77,66
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	5,67	5,69	5,71	5,56	5,72	5,69	5,69	5,86	5,58	5,72	5,50
DEFAULT	7,76	7,86	7,76	7,58	7,56	8,26	7,48	7,64	7,95	8,10	7,43
CASE 2-2	9,20	9,29	9,24	9,09	8,88	9,32	9,15	9,38	8,88	9,45	9,32

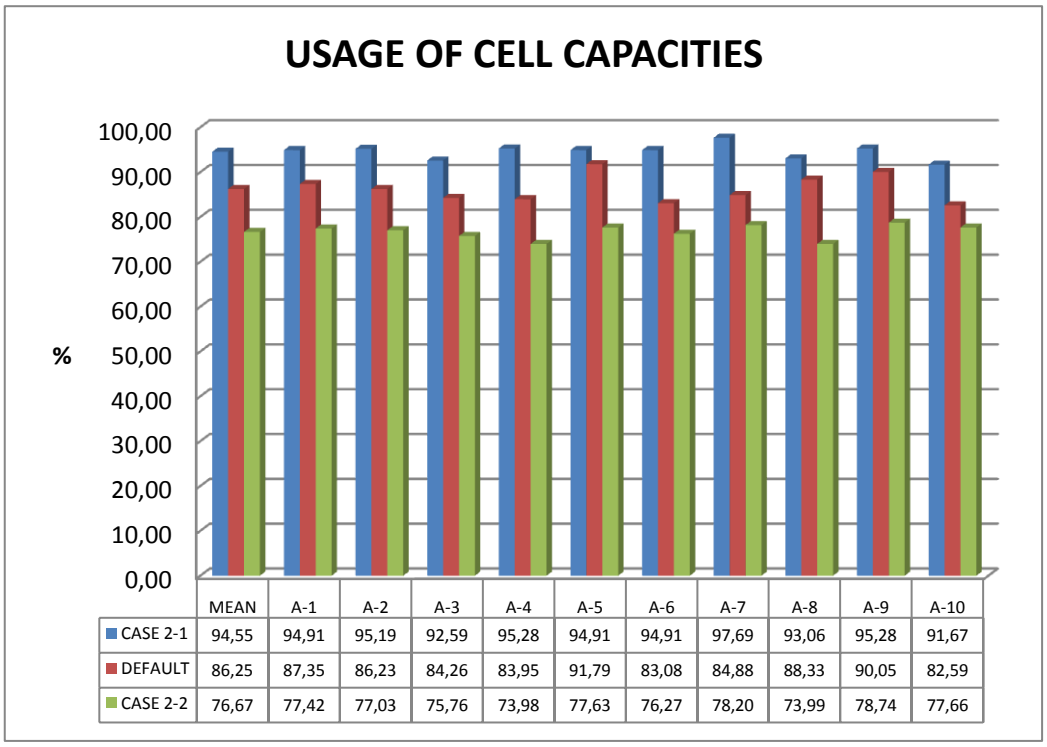


Figure 4.47. D3 Case 2- Average cell capacity usage

Table 4.48. D3 Case 2- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	80,56	78,99	81,15	80,67	79,96	79,99	80,95	81,37	81,70	79,75	81,05
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 2-2	80,06	80,77	79,52	80,09	79,35	79,11	80,10	80,15	80,69	80,65	80,11
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	80,56	78,99	81,15	80,67	79,96	79,99	80,95	81,37	81,70	79,75	81,05
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 2-2	80,06	80,77	79,52	80,09	79,35	79,11	80,10	80,15	80,69	80,65	80,11

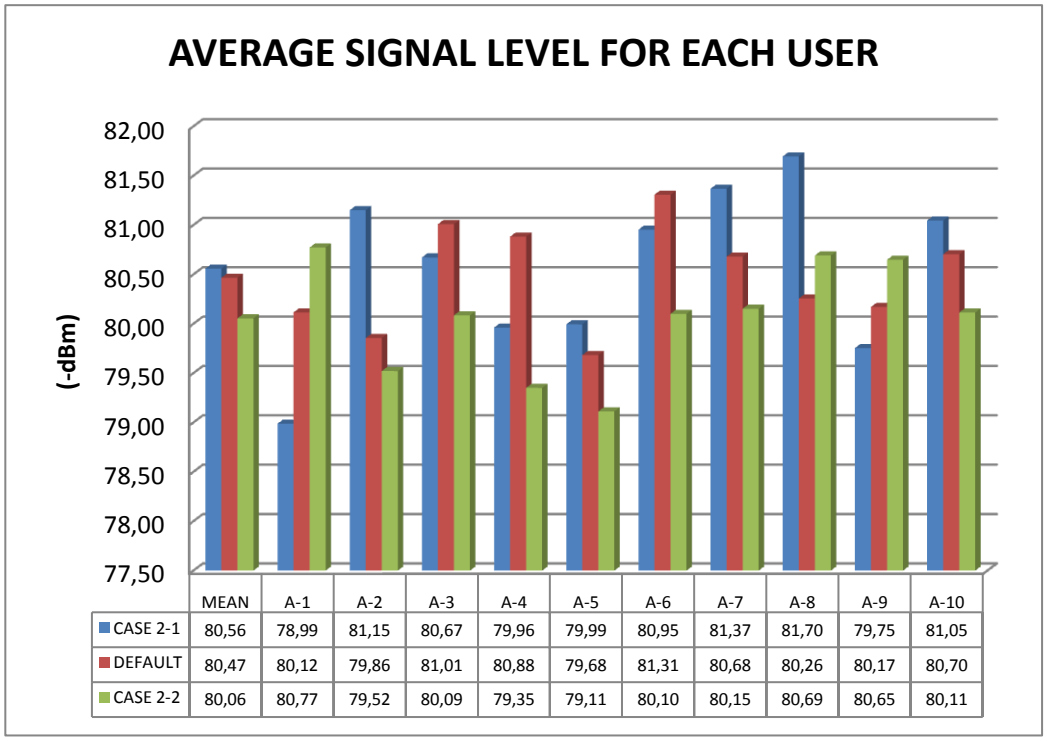


Figure 4.48. D3 Case 2- Average signal level per user

Table 4.49. D3 Case 2- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	17,80	18,00	15,30	14,85	18,75	20,60	16,95	20,65	15,80	21,35	15,75
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 2-2	1,53	0,25	0,35	0,85	0,00	1,45	2,05	5,95	0,10	1,90	2,40
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	17,80	18,00	15,30	14,85	18,75	20,60	16,95	20,65	15,80	21,35	15,75
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 2-2	1,53	0,25	0,35	0,85	0,00	1,45	2,05	5,95	0,10	1,90	2,40

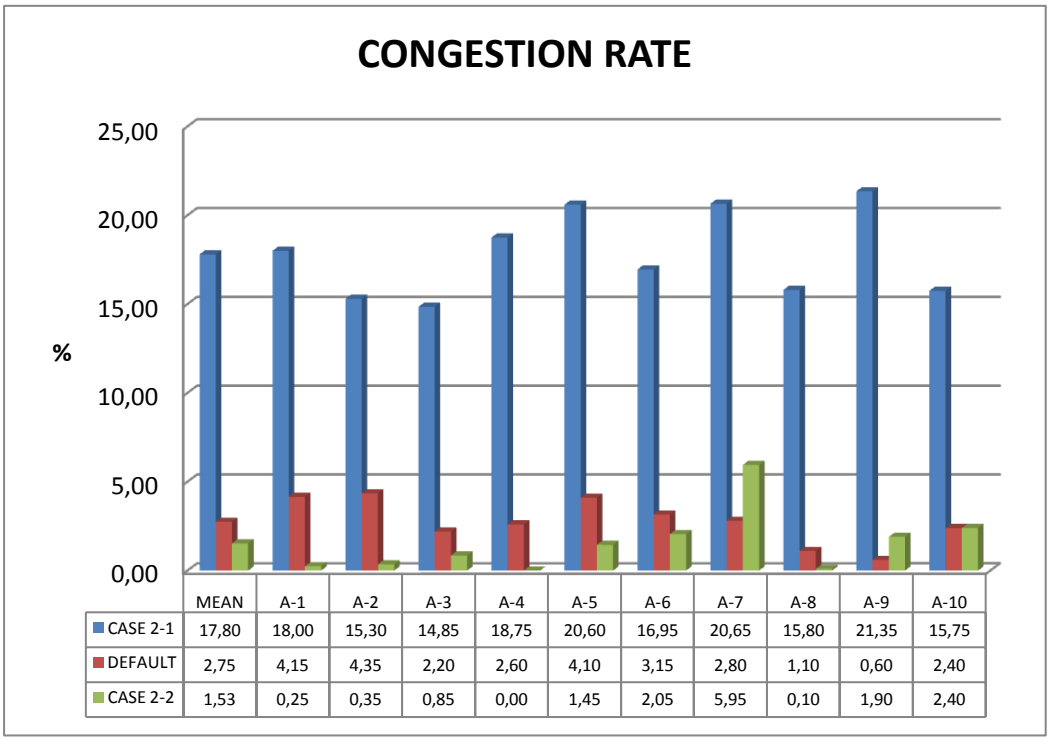


Figure 4.49. D3 Case 2- Congestion rate

Table 4.50. D3 Case 2- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	31,27	31,05	33,30	35,15	29,80	28,15	32,70	26,60	33,95	27,20	34,75
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 2-2	17,88	20,55	18,95	17,85	20,10	16,80	18,55	11,65	20,50	18,05	15,80
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	31,27	31,05	33,30	35,15	29,80	28,15	32,70	26,60	33,95	27,20	34,75
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 2-2	17,88	20,55	18,95	17,85	20,10	16,80	18,55	11,65	20,50	18,05	15,80

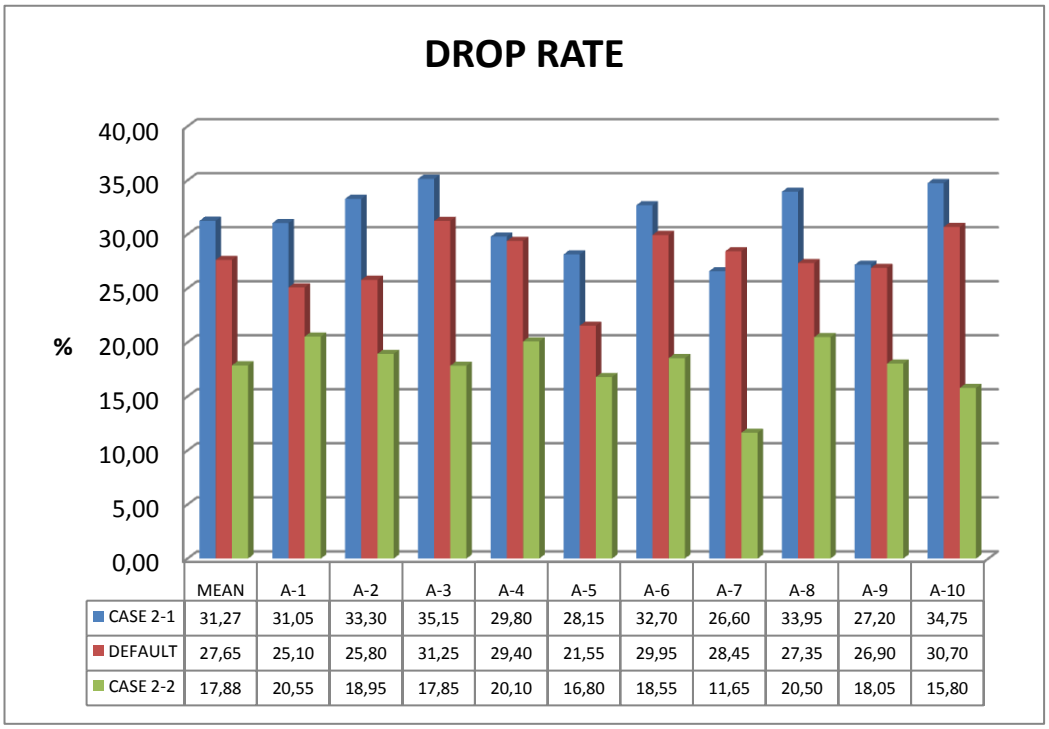


Figure 4.50. D3 Case 2- Drop rate

Table 4.51. D3 Case 2- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	14,88	14,60	15,70	14,00	15,25	12,95	14,70	16,75	15,05	15,25	14,55
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 2-2	13,12	13,20	10,80	12,35	12,75	13,45	13,05	15,65	14,80	11,30	13,80
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 2-1	14,88	14,60	15,70	14,00	15,25	12,95	14,70	16,75	15,05	15,25	14,55
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 2-2	13,12	13,20	10,80	12,35	12,75	13,45	13,05	15,65	14,80	11,30	13,80

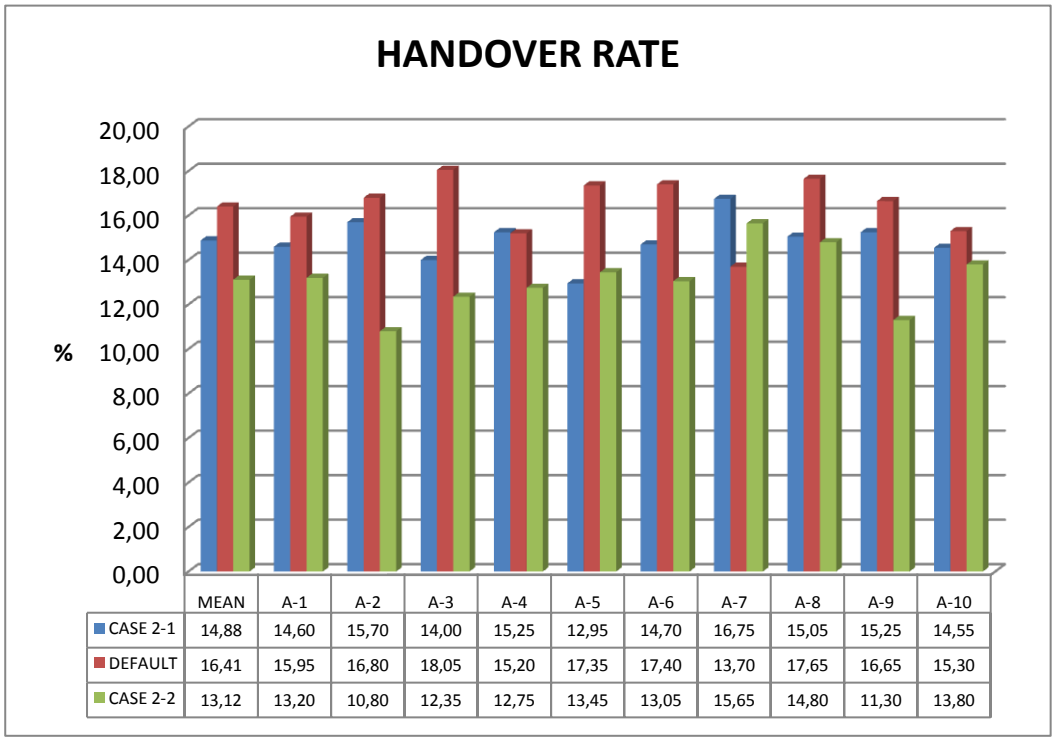


Figure 4.51. D3 Case 2- Handover rate

4.2.2.7 D3-Case 3

Table 4.52. D3 Case 3- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	75,21	74,24	77,28	77,44	72,99	74,69	76,49	75,66	75,38	72,97	74,99
DEFAULT	86,25	87,35	86,23	84,26	83,95	91,79	83,08	84,88	88,33	90,05	82,59
CASE 3-2	91,57	92,22	93,70	91,36	91,27	91,54	92,53	88,52	91,14	92,72	90,74
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	6,77	6,68	6,95	6,97	6,57	6,72	6,88	6,81	6,78	6,57	6,75
DEFAULT	7,76	7,86	7,76	7,58	7,56	8,26	7,48	7,64	7,95	8,10	7,43
CASE 3-2	8,24	8,30	8,43	8,22	8,21	8,24	8,33	7,97	8,20	8,34	8,17

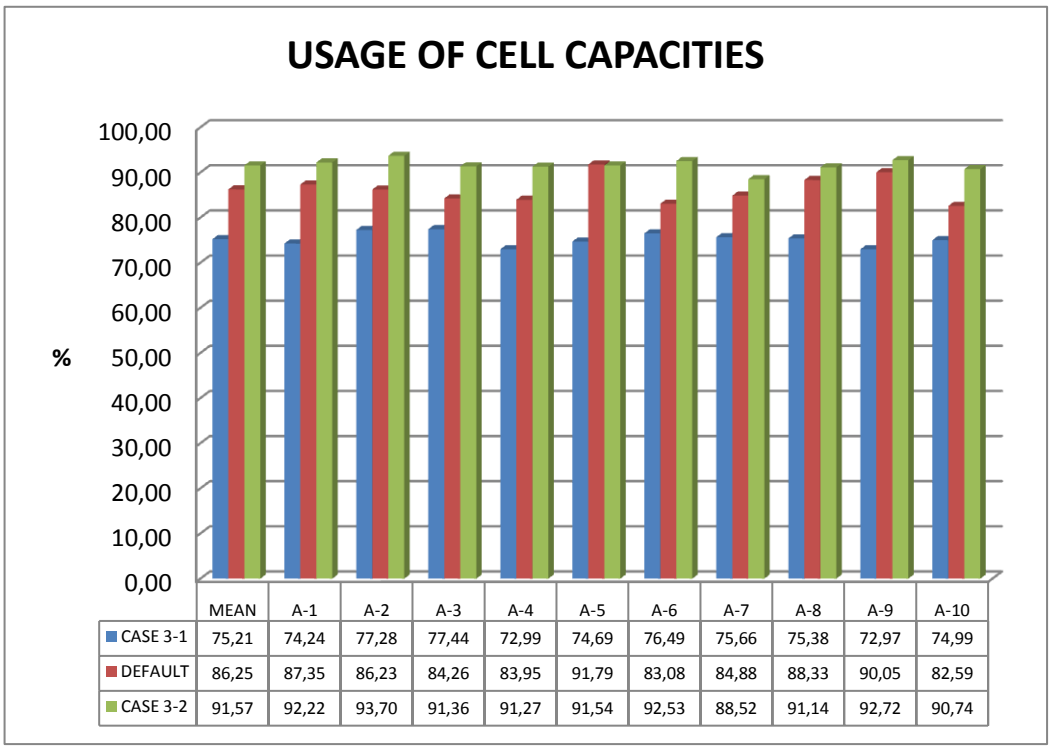


Figure 4.52. D3 Case 1- Average cell capacity usage

Table 4.53. D3 Case 3- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	78,90	79,21	78,87	77,72	78,78	78,39	78,57	78,76	80,66	79,56	78,47
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 3-2	80,83	80,65	80,00	80,42	80,79	79,46	80,97	80,67	82,95	80,03	82,37
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	78,90	79,21	78,87	77,72	78,78	78,39	78,57	78,76	80,66	79,56	78,47
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 3-2	80,83	80,65	80,00	80,42	80,79	79,46	80,97	80,67	82,95	80,03	82,37

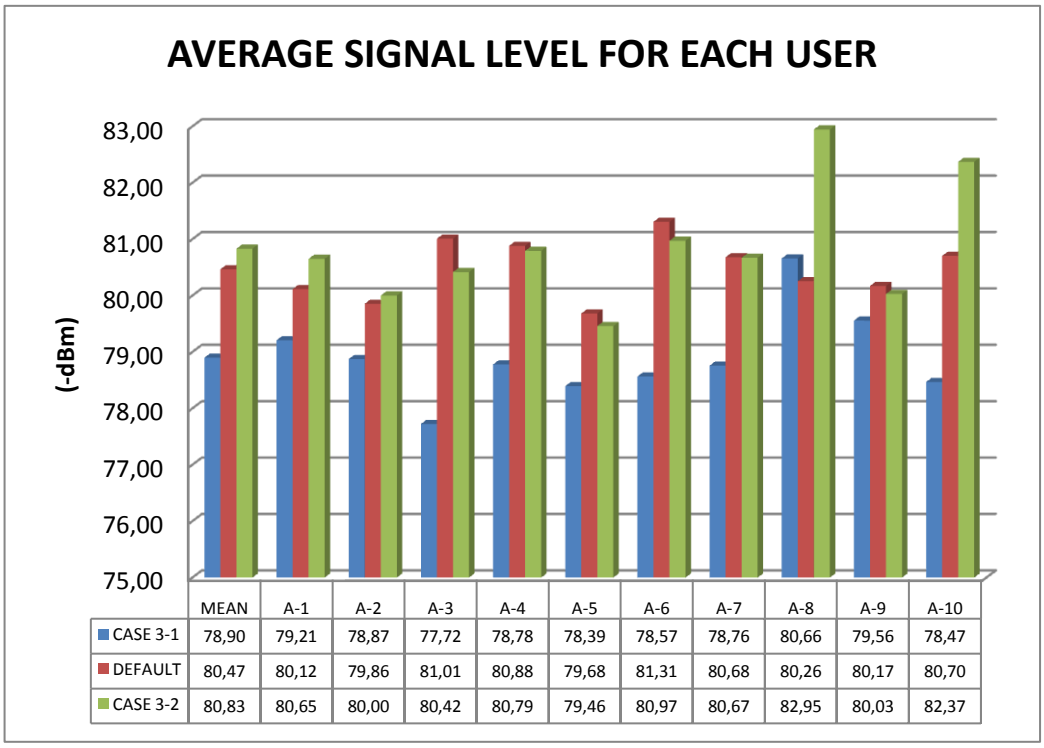


Figure 4.53. D3 Case 3- Average signal level per user

Table 4.54. D3 Case 3- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	37,28	37,75	36,65	35,00	41,15	37,60	36,70	37,00	33,10	41,15	36,65
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	37,28	37,75	36,65	35,00	41,15	37,60	36,70	37,00	33,10	41,15	36,65
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 3-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

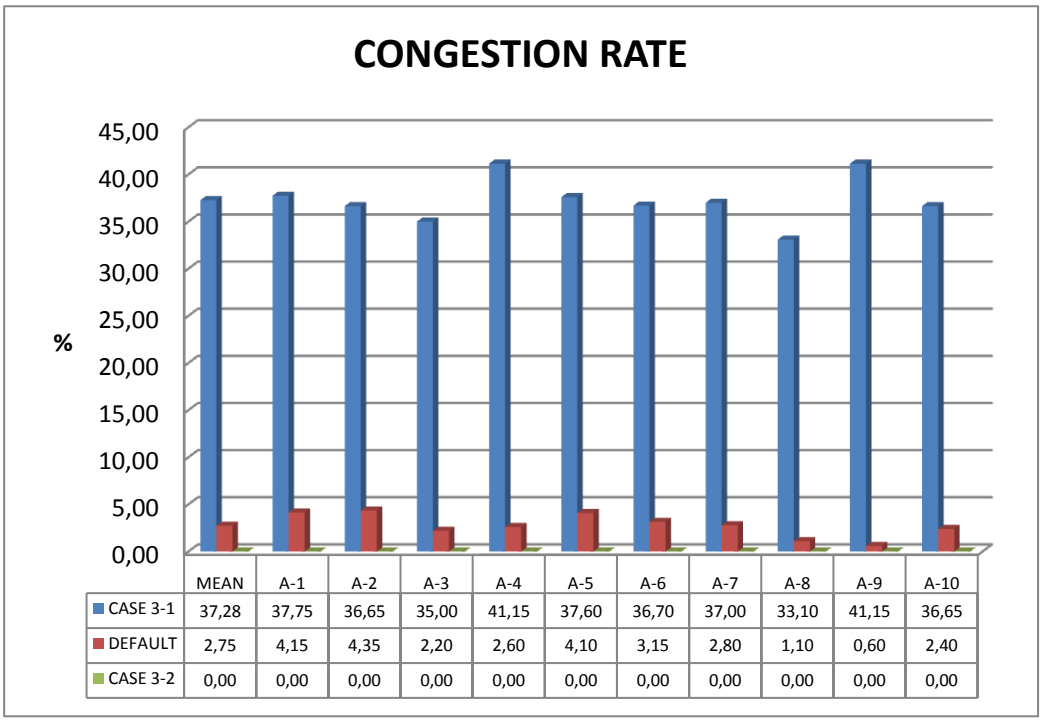


Figure 4.54. D3 Case 3- Congestion rate

Table 4.55. D3 Case 3- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,17	3,20	5,15	4,15	2,45	3,00	3,55	3,55	8,05	4,50	4,05
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 3-2	26,09	25,30	24,10	26,00	26,50	25,85	25,95	28,30	27,50	24,90	26,50
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	4,17	3,20	5,15	4,15	2,45	3,00	3,55	3,55	8,05	4,50	4,05
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 3-2	26,09	25,30	24,10	26,00	26,50	25,85	25,95	28,30	27,50	24,90	26,50

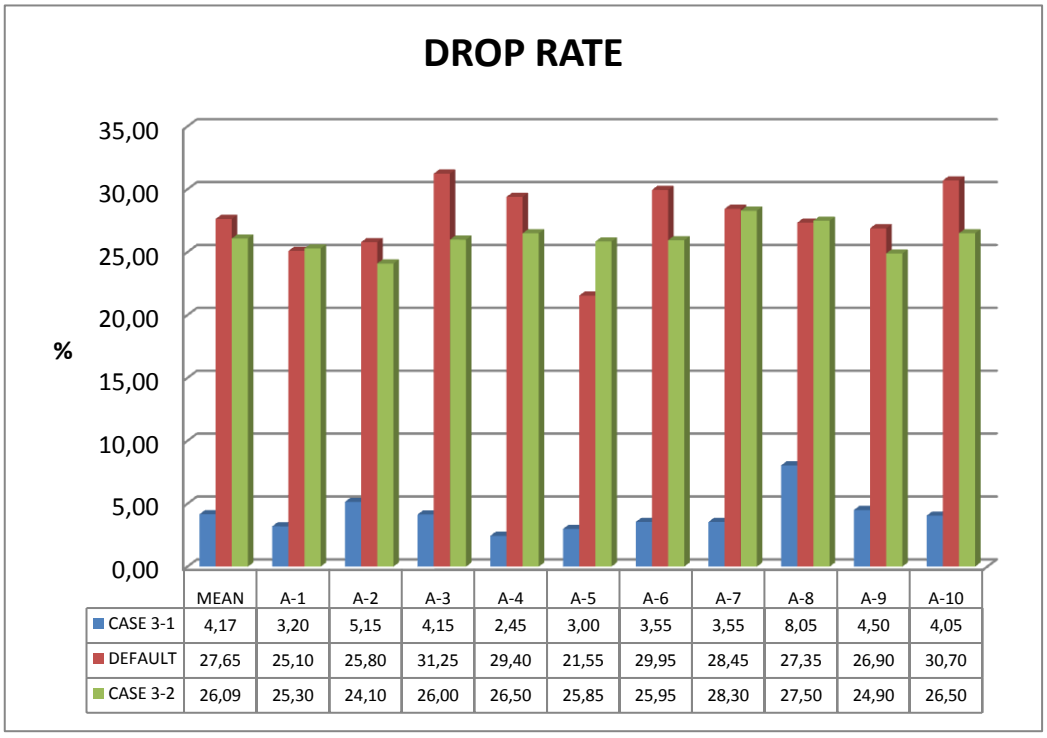


Figure 4.55. D3 Case 3- Drop rate

Table 4.56. D3 Case 3- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 3-2	20,81	19,00	22,20	20,10	21,25	20,20	20,30	17,90	24,35	22,10	20,70
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 3-1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 3-2	20,81	19,00	22,20	20,10	21,25	20,20	20,30	17,90	24,35	22,10	20,70

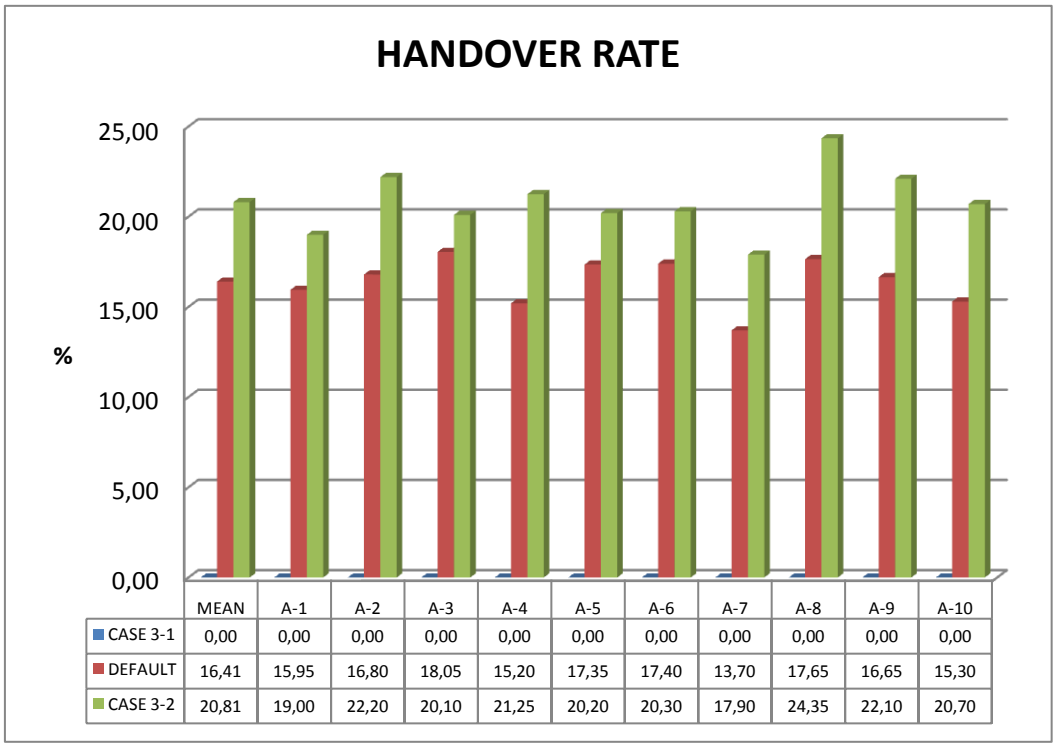


Figure 4.56. D3 Case 3- Handover rate

4.2.2.8 D3-Case 4

Table 4.57. D3 Case 4- Average cell capacity usage in percentages (upper) and numbers(below). Recall that a cell can take a maximum of 9 users.

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	82,60	77,53	84,76	79,81	81,23	84,94	85,12	83,73	83,72	81,37	83,78
DEFAULT	86,25	87,35	86,23	84,26	83,95	91,79	83,08	84,88	88,33	90,05	82,59
CASE 4-2	89,28	91,23	86,94	91,07	89,04	87,38	91,30	90,42	90,49	86,75	88,15
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	7,43	6,98	7,63	7,18	7,31	7,64	7,66	7,54	7,53	7,32	7,54
DEFAULT	7,76	7,86	7,76	7,58	7,56	8,26	7,48	7,64	7,95	8,10	7,43
CASE 4-2	8,04	8,21	7,83	8,20	8,01	7,86	8,22	8,14	8,14	7,81	7,93

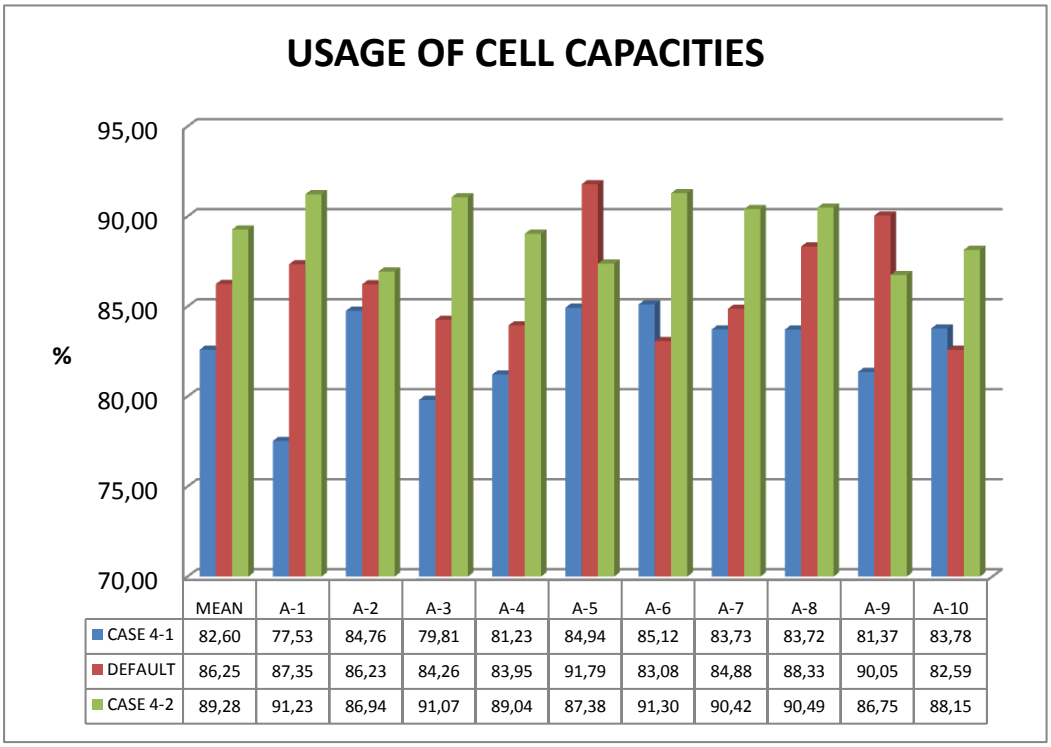


Figure 4.57. D3 Case 4- Average cell capacity usage

Table 4.58. D3 Case 4- Average signal level per user

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	78,99	79,83	78,52	79,84	79,23	78,79	78,61	77,99	79,27	78,89	78,98
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 4-2	82,40	80,76	83,35	82,73	82,85	82,37	82,58	82,86	82,79	81,78	81,95
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	78,99	79,83	78,52	79,84	79,23	78,79	78,61	77,99	79,27	78,89	78,98
DEFAULT	80,47	80,12	79,86	81,01	80,88	79,68	81,31	80,68	80,26	80,17	80,70
CASE 4-2	82,40	80,76	83,35	82,73	82,85	82,37	82,58	82,86	82,79	81,78	81,95

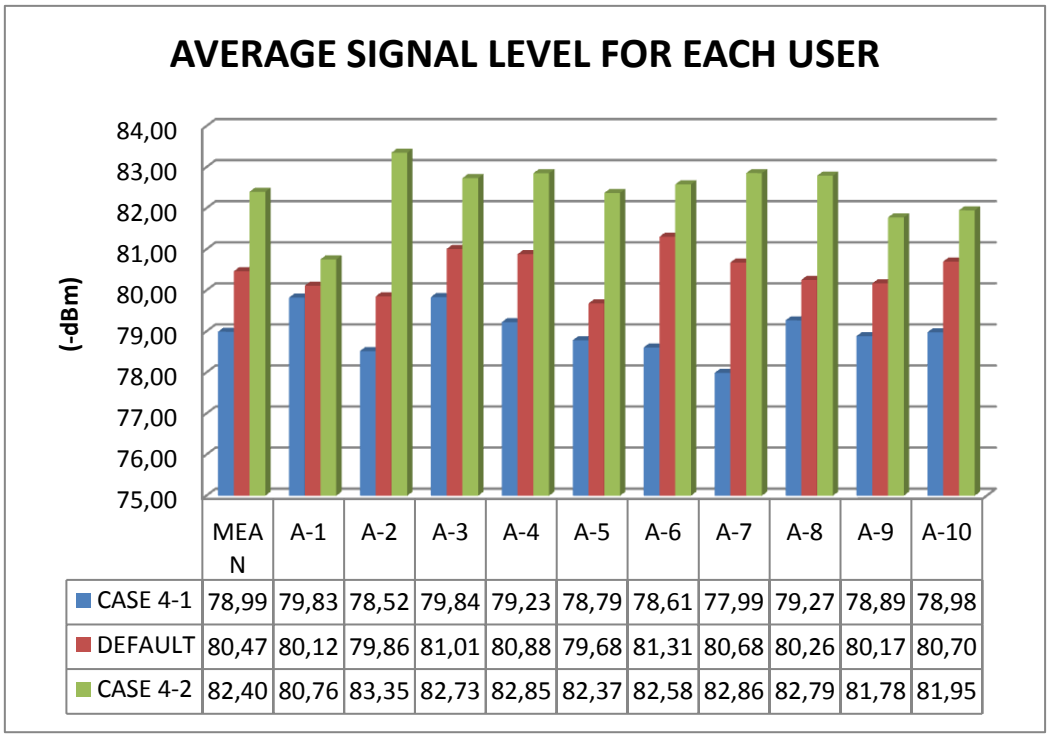


Figure 4.58. D3 Case 4- Average signal level per user

Table 4.59. D3 Case 4- Congestion rate (upper) and average number of congested users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	2,33	0,25	3,85	0,20	1,75	0,45	4,40	0,85	6,60	0,20	4,75
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 4-2	6,16	1,30	9,35	5,85	7,85	5,20	5,90	6,70	4,15	9,20	6,05
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	2,33	0,25	3,85	0,20	1,75	0,45	4,40	0,85	6,60	0,20	4,75
DEFAULT	2,75	4,15	4,35	2,20	2,60	4,10	3,15	2,80	1,10	0,60	2,40
CASE 4-2	6,16	1,30	9,35	5,85	7,85	5,20	5,90	6,70	4,15	9,20	6,05

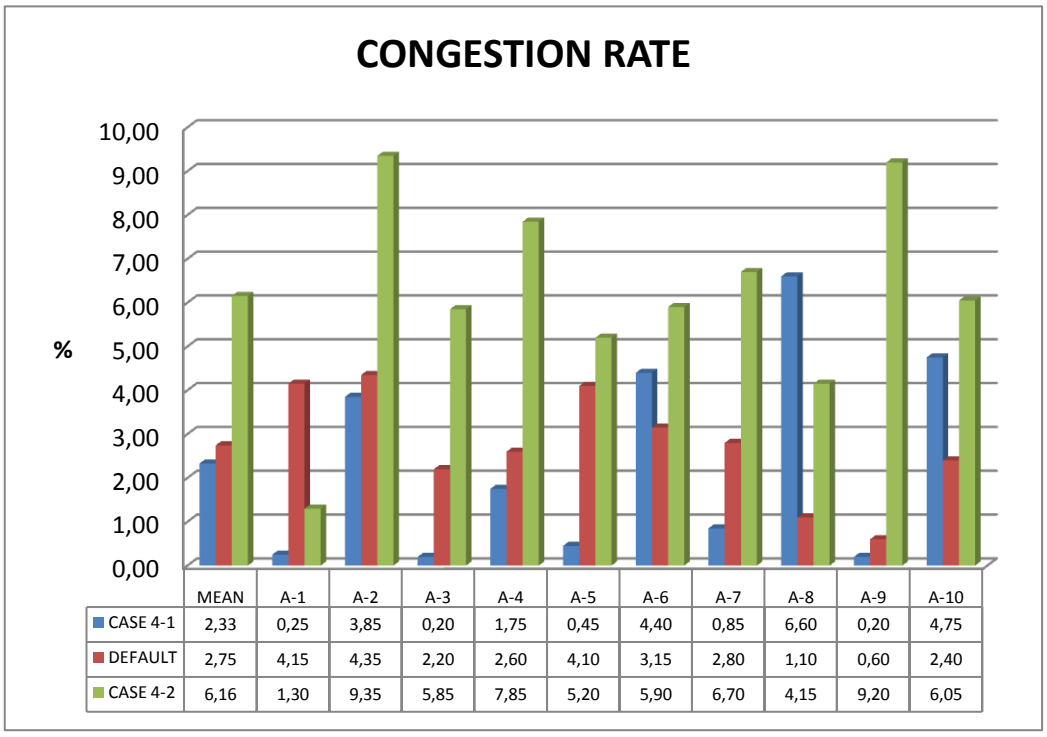


Figure 4.59. D3 Case 4- Congestion rate

Table 4.60. D3 Case 4- Drop rate (upper) and average number of dropped users (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	31,34	36,95	28,75	35,15	32,85	31,15	28,30	31,75	26,40	34,30	27,80
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 4-2	22,27	24,80	20,65	22,60	22,20	24,85	20,60	20,95	22,55	20,95	22,55
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	31,34	36,95	28,75	35,15	32,85	31,15	28,30	31,75	26,40	34,30	27,80
DEFAULT	27,65	25,10	25,80	31,25	29,40	21,55	29,95	28,45	27,35	26,90	30,70
CASE 4-2	22,27	24,80	20,65	22,60	22,20	24,85	20,60	20,95	22,55	20,95	22,55

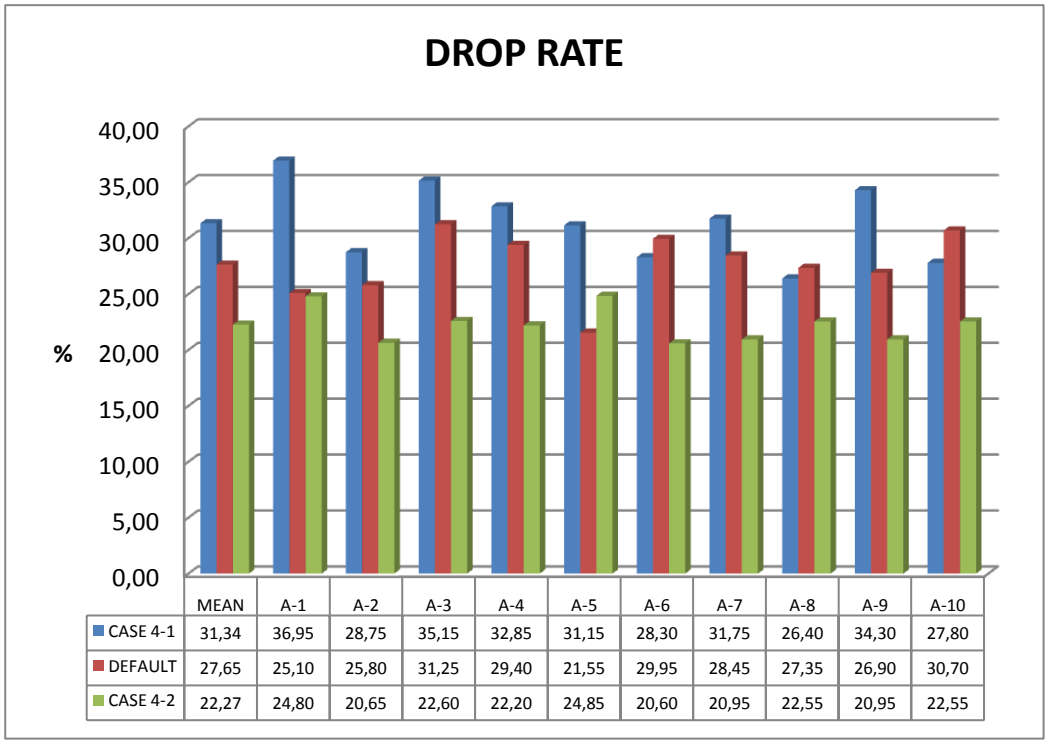


Figure 4.60. D3 Case 4- Drop rate

Table 4.61. D3 Case 4- Handover rate (upper) and the average number of users whose call is handed over (lower)

INPUT PARAMETERS						1		DEFAULT		2	
CASE 1 (Number Of User)						50		100		250	
CASE 2 (Capacity Of Cell)						6		9		12	
CASE 3 (Neighborhood)						0		Realistic		1	
CASE 4 (Signal Level)						-91 dBm		-94 dBm		-97 dBm	
(Number Of Step)						10		10		10	
CASE %	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	12,73	11,55	12,35	10,75	14,75	13,75	11,70	12,75	14,60	9,55	15,50
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 4-2	20,39	20,25	18,70	22,95	21,90	20,70	20,65	18,45	21,40	16,15	22,75
CASE	**MEAN**	**A-1**	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**A-9**	**A-10**
CASE 4-1	12,73	11,55	12,35	10,75	14,75	13,75	11,70	12,75	14,60	9,55	15,50
DEFAULT	16,41	15,95	16,80	18,05	15,20	17,35	17,40	13,70	17,65	16,65	15,30
CASE 4-2	20,39	20,25	18,70	22,95	21,90	20,70	20,65	18,45	21,40	16,15	22,75

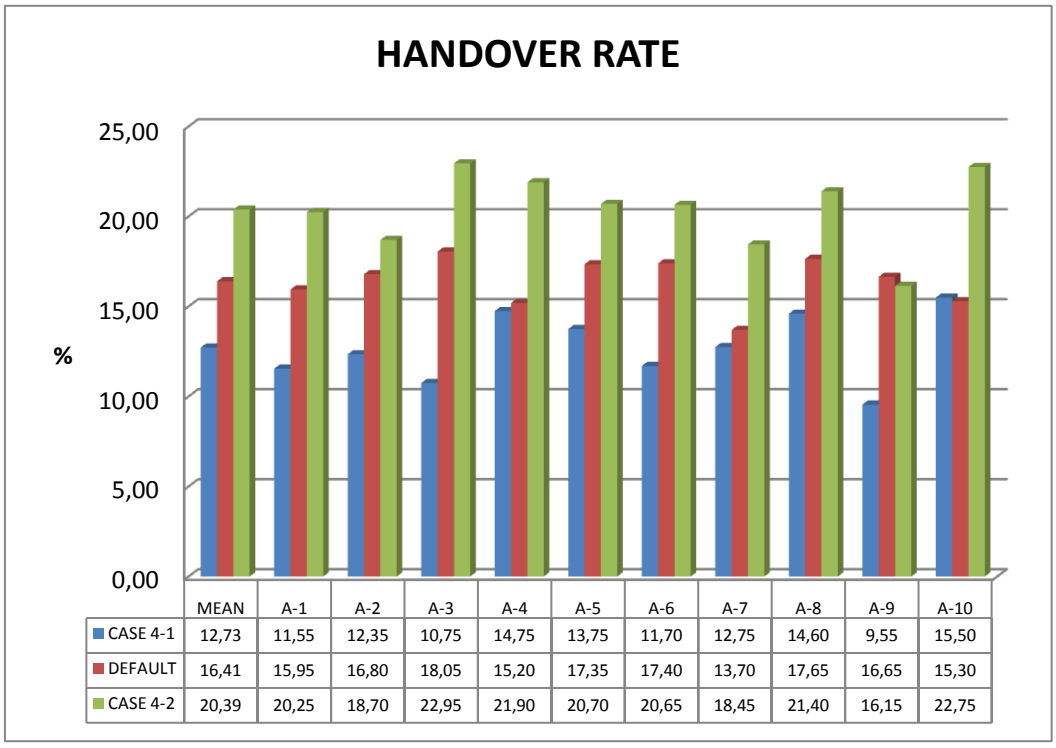


Figure 4.61. D3 Case 4- Handover rate

Table 4.62. Comparison of average cell capacity usage for D1, D2, D3

CASE	D1 MEAN VALUES	D2 MEAN VALUES	D3 MEAN VALUES	% COMPARISON D1-D2	% COMPARISON D1-D3
CASE 1-1	5,83	5,46	5,54	-0,06	-0,05
CASE 1-2	9,00	8,99	8,99	0,00	0,00
CASE 2-1	5,69	5,73	5,67	0,01	0,00
CASE 2-2	9,12	9,27	9,20	0,02	0,01
CASE 3-1	6,81	6,72	6,77	-0,01	-0,01
CASE 3-2	8,16	8,26	8,24	0,01	0,01
CASE 4-1	7,53	7,64	7,43	0,01	-0,01
CASE 4-2	8,21	8,04	8,04	-0,02	-0,02
DEFAULT	7,83	7,84	7,76	0,00	-0,01

Table 4.63. Comparison of average signal level per user for D1, D2, D3

CASE	D1 MEAN VALUES	D2 MEAN VALUES	D3 MEAN VALUES	% COMPARISON D1-D2	% COMPARISON D1-D3
CASE 1-1	80,37	80,25	79,99	0,00	0,00
CASE 1-2	80,43	79,89	80,52	-0,01	0,00
CASE 2-1	80,48	80,23	80,56	0,00	0,00
CASE 2-2	80,34	80,40	80,06	0,00	0,00
CASE 3-1	78,87	78,64	78,90	0,00	0,00
CASE 3-2	81,21	80,92	80,83	0,00	0,00
CASE 4-1	78,81	78,71	78,99	0,00	0,00
CASE 4-2	81,67	82,03	82,40	0,00	0,01
DEFAULT	80,03	80,51	80,47	0,01	0,01

Table 4.64. Comparison of congestion rate for D1, D2, D3

CASE	D1 MEAN VALUES	D2 MEAN VALUES	D3 MEAN VALUES	% COMPARISON D1-D2	% COMPARISON D1-D3
CASE 1-1	0,01	0,00	0,02	-1,00	1,00
CASE 1-2	113,93	112,48	116,15	-0,01	0,02
CASE 2-1	16,42	17,94	17,80	0,09	0,08
CASE 2-2	0,83	0,75	1,53	-0,09	0,85
CASE 3-1	38,11	38,39	37,28	0,01	-0,02
CASE 3-2	0,00	0,00	0,00	0,00	0,00
CASE 4-1	3,41	2,92	2,33	-0,15	-0,32
CASE 4-2	5,74	4,56	6,16	-0,20	0,07
DEFAULT	2,54	4,67	2,75	0,84	0,08

Table 4.65. Comparison of drop rate for D1, D2, D3

CASE	D1 MEAN VALUES	D2 MEAN VALUES	D3 MEAN VALUES	% COMPARISON D1-D2	% COMPARISON D1-D3
CASE 1-1	4,95	5,09	4,79	0,03	-0,03
CASE 1-2	55,10	56,59	52,95	0,03	-0,04
CASE 2-1	32,40	30,56	31,27	-0,06	-0,03
CASE 2-2	18,65	18,66	17,88	0,00	-0,04
CASE 3-1	4,12	4,02	4,17	-0,02	0,01
CASE 3-2	27,12	26,16	26,09	-0,04	-0,04
CASE 4-1	29,84	29,37	31,34	-0,02	0,05
CASE 4-2	20,14	23,70	22,27	0,18	0,11
DEFAULT	26,85	25,38	27,65	-0,05	0,03

Table 4.66. Comparison of handover rate for D1, D2, D3

CASE	D1 MEAN VALUES	D2 MEAN VALUES	D3 MEAN VALUES	% COMPARISON D1-D2	% COMPARISON D1-D3
CASE 1-1	3,38	4,53	4,10	0,34	0,21
CASE 1-2	24,97	24,01	25,81	-0,04	0,03
CASE 2-1	15,16	14,32	14,88	-0,06	-0,02
CASE 2-2	13,63	13,65	13,12	0,00	-0,04
CASE 3-1	0,00	0,00	0,00	0,00	0,00
CASE 3-2	22,14	21,84	20,81	-0,01	-0,06
CASE 4-1	12,55	12,49	12,73	0,00	0,01
CASE 4-2	19,57	19,13	20,39	-0,02	0,04
DEFAULT	17,03	16,48	16,41	-0,03	-0,04

5. DISCUSSION and CONCLUSION

A simulation of a GSM network with respect to GSM quality parameters was accomplished in this work. The developed model was demonstrated on an example that involved a realistic GSM system geography. The main approach of the model was its usage of random data for the initial location and the motion of the mobile users in an effort to capture the random nature of the actual GSM traffic. Possible differences in user mobility were analyzed by considering three different speed distributions of the users.

The increase in the number of active users caused an increase in the drop number. However, it was noticed that the drop rate did not increase proportionally to the user number. For a drop to occur a call should be initiated in the first place. If the cell capacity is too small (or number of users too large), there will be fewer initiated calls which lead to a decrease in the drop rate. As expected, an increase in cell capacity decreased the drop and congestion rates improving the overall quality of the communication. An improved neighborhood had a similar effect. We also observed that increasing the capacity had a similar effect as decreasing the number of users. When the capacity exceeded the number of users the congestion and drop parameters started to decline. These results seems to imply that the user number/total capacity ratio is the actual determining factor of the quality parameters and both quantities need not be studied independently.

An intense neighborhood of the cells had a positive effect on congestion since it allowed a higher capacity rate to be available to the users. However, more users successfully connecting brought with it an associated increase in the drop rate. It should be noted that for drop to occur, a call should be initiated in the first place. It is not possible for a congested user to experience a drop.

Allowing a lower quality signal partially eliminated the coverage problem. More users were covered which in turn lead to an increase in the congestion. A user that would experience a drop with a high-quality allowed signal, has a chance to continue with the connection in case of low-quality allowed signal through handover

process. Hence, a low-quality allowed signal decreased the drop rate and increased handover rate.

The average signal strength is a simple measure of service quality. Our analysis revealed that this measure was mostly related with the cell neighborhood and allowed signal level. The number of users and the cell capacity did not affect average signal strength significantly.

Constraining the user speeds to certain intervals to distinguish pedestrian and non-pedestrian users (D2 and D3 distributions) in the analysis remarkably produced very similar results to the analysis where this distinction is not made (D1 distribution). The users in D2 and D3 distributions had an average speed of 14.5 and 5.5 pixels/unit time, respectively, compared to 20 pixels/unit time of the users in D1 distribution. This significant change in the average speed produced less than 1% deviation in the service quality parameters obtained with the D1 distribution. It is clear that the conclusions mentioned above could have been drawn with any user speed distribution (i.e. with any chosen fraction of pedestrians and non-pedestrians in the user pool).

This observation can be explained with the fact that our analysis mainly focused on both time- and user-averaged values of quality parameters. In one sense, every time step represents a separate analysis in our approach. Although there might be differences in quality parameters from one time point to the other, time-averaging smoothens out these differences. Moreover, the distinction between service quality experienced by a pedestrian and non-pedestrian user disappears due to user-averaging. If a separate log were kept for each individual user, the service history of each user could be thoroughly analyzed. Although computationally inefficient, this approach would allow us not only to look at pedestrian and non-pedestrian users separately but also to study the service history of each user. For example, with this approach it would be possible to keep track of how many handovers or drops a specific user experiences in one analysis. That way, average parameter values associated with each individual user could be calculated which, in turn, would enable us to make a distinction between the service provided to a pedestrian and non-pedestrian user. It might be speculated that such an analysis will indicate non-

pedestrian with higher speed experiencing more frequent handovers and drops compared to slower-moving pedestrian.

Every model is an approximation to the modeled system that comes along with its assumptions and simplifications. Clearly, this fact holds for our model, too. We specified a relatively small number of mobile users (although large enough to see a truly random pattern). The same simulation could be performed with an increased number of mobile users and cell capacities although we are certain that the conclusions drawn in that case will mostly remain the same. The model utilized in the current study assumed that the users could be located anywhere in the problem domain. In reality, there will be certain spots in the simulation domain where the population is denser or more dilute compared to other parts of the considered geography. Similarly, there will be spots where certain speeds are more likely, i.e. where users move faster (e.g. along the highways) or slower (e.g. malls, pedestrian regions). The speed spectrum of mobile users is not uniform and this fact can be taken into consideration in our model. Speeds that are between walking speed and vehicle speeds are likely to be encountered less frequently among users which we tried to reflect to our model in D2 and D3 analyses. Other (e.g. nonuniform) speed spectrums can be chosen for the mobile users in the analysis, but this would only make sense if individual logs are kept for each user as outlined above.

The model proposed here seemed to produce meaningful results with respect to what is known about such systems. Although simple, the utilized approach can provide significant insight about the internal dynamics of cellular systems. With further refinement, the model has the potential to become a useful tool to be used in planning and partial optimization of such systems.

Some suggestions can be made about possible future studies along the same lines as the current one. The model can be further refined by relaxing some of the above mentioned assumptions. If the right statistical data about the above mentioned aspects are available, more realistic simulations can be performed. For example, the interference issue which is neglected in our model could be taken into consideration if relevant data is available. As already mentioned, keeping track of the service

history of individual users will enable us to study the effect of speed distribution with better effectiveness.

Another interesting future study could even include call durations and distinguish between active and passive users. Again, with the availability of the corresponding statistical data, this approach could bring a new dimension to the approach proposed in this work.

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