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Performance Evaluation of Quality Metrics for Single and Multi Cell Admission Control with Heterogeneous Traffic in WCDMA Networks

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ABSTRACT

Call Admission Control (CAC) is one of the various radio resource management (RRM) congestion control functions in WCDMA systems. A lot of call admission control CAC algorithms are being used to keeping the interference below specific threshold level in order to improve the quality of service (QoS) and performance of the system . This paper performs deep analysis and evaluates the comprehensive differences between Single and Multi Cell Call Admission Control (SC-CAC and MC-CAC) algorithms in Wireless Coded Division Multiple Access (WCDMA) networks. MATLAB simulation model of a simple WCDMA system with CAC is implemented and analyzed to make a clear comparison between the two CAC algorithms in terms of outage probability, bit error rate (BER) and channel capacity which does not have an exact limit in WCDMA technique. Optimal power allocation water-filling formula is considered to calculate the maximum Shannon capacity over the fading channel. The simulation results show that MC-CAC has better performance scenario than the SC-CAC, therefore a lot of maximum values of capacity of Shannon's channel as well as minimum values of outage probability can be achieved by performing MC-CAC into the network. As a result this will improve the QoS. Three traffic classes (voice, multimedia and video) have been considered along different outage signal-to-interference ratio (SIR) thresholds. This paper shows that Multi Cell CAC has better features than Single Cell CAC in WCDMA networks.

Keywords—*WCDMA; QoS; Admission Control; Interference; Outage Probability; Capacity.*

1. INTRODUCTION

Wideband Coded Division Multiple Access WCDMA technology has been involved in the communication industry as the most dynamic adopted 3G (third generation air interface). Within the third generation partnership project, WCDMA has the name of Universal Terrestrial Radio Access UTRA. WCDMA supports the concept of Bandwidth on Demand. Frequency division duplex FDD and time division duplex TDD are the modes operation that WCDMA supports. The base station synchronization is asynchronous so there is no need for a Global Positioning System (GPS) to control the flow of traffic. The design of WCDMA is compatible with Global System for Mobile communication GSM, so the handovers between these two systems are considered seamless. (Toskala and Holma, 2004).

The interference in WCDMA system has to be managed by a threshold value condition. On the other side, the WCDMA system can accept a huge number of calls so it has a soft capacity and this may affect the interference level. Therefore, it is important for the WCDMA system to create a mechanism for controlling the new call admissions to stop degrading the QoS of other customers. (Patachaianand and Sandrasegaran, 2007).

WCDMA users transmit and receive on the same radio channel, if some new users are added to the total users a new interference will be created into the radio channel and with every new user the signal to interference ratio (SIR) will be decreased which means that the Bit Error Rate (BER) will take worst values as well as the Quality of Service (QoS). Fig. 1 (Alwis P., 2005), shows the interference that may occurred at the base station and the mobile equipments.

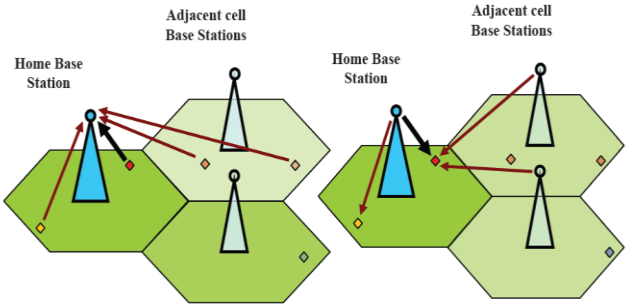

Figure 1.Interference at base station and mobile equipment.

It is important to remember the mechanism of power control in WCDMA. In closed loop transmission power control, the base station makes predictions in a regular way on the received signal to interference ratio SIR and it uses these predictions to perform a comparison between the estimated values and a target SIR value. Consequently, two cases will need a decision from the base station; the first case is if the recorded SIR values are bigger than the target SIR value then the base station will instruct the mobile station (MS) to decrease the power. While if the recorded SIR values are low then the base station will instruct the MS to increase the power. The mobile stations that work on the same frequency with different codes should be power controlled with a same strategy on mobile station by a certain mechanism to avoid over-shouting between mobile station and blocking some area of the cell (Toskala and Holma, 2004). Fig. 2 (Toskala and Holma, 2004, p.56), shows the mechanisms of fast closed loop transmission power control in WCDMA.

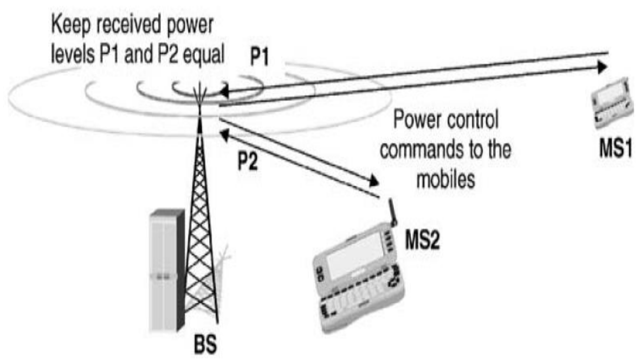

Figure 2. Closed loop transmission power control in WCDMA.

Call admission Control CAC is a supplying approach to determine the number of call connections into the network for the purpose of decreasing call dropping and jamming. The interference of Wideband code division multiple access WCDMA system is limited. The system stability will be affected by a new user in the case that WCDMA is operated with his full capacity (El-Samie, et al., 2008).

One of the effective strategies which can be used to improve the quality of service of the communication system is the call admission control. Coverage and capacity are examples of the problems that may face mobile telecommunication systems. The third generation of mobile communication change the way of communication due to the dynamic use of the capacity and network coverage (Zreikat, 2003).

By controlling the number of accepted calls, the call admission control CAC improves the performance and yields to high throughput in the system, also the CAC should be capable to accept new users without any effects on the other connected users (Catrein, et al., 2009).

In all cases the target is to increase the performance of the system, by decreasing the blocking probability, dropping probability, outage probability and increasing the quality of the service QoS.

In Code Division Multiple Access (CDMA), radio resources are limited quantities. Each user is got a code, which is spread out to the accessible frequency. The user's assigned code needed to be orthogonal to the codes of other users. As the number of users increases, interference between users' goes up due to which the quality can get worse. Hence, a standard should be maintained for providing a fine service to the users. This standard is known as Quality of Service (QoS). Call Admission Control (CAC) is one of the techniques for radio resource management RRM of wideband CDMA. The call is not accepted if the received SIR is less than the threshold. In order to contain large number of mobile users, cells (area covered by one Base Station) have micro and Pico cellular formation to make easy the user movement from one cell to another cell. This demands handing over of ongoing call from one cell to another, which is called handoff (Alwis P., 2005).

In this paper, we propose a CAC algorithm including single cell SC and multi cell MC CAC in WCDMA network to evaluate the performance and QoS of CAC in that network. Probability of Outage, maximum Shannon capacity of the channel and water-filling formula are used to evaluate the performance of the proposed CAC algorithm. The rest of paper is organized as follows. In section 2, some theoretical information and background of SC and MC-CAC are presented. The system model and the theoretical assessments and analysis that are essential to perform the simulation environment are introduced in section 3. The simulation model including the network topology, propagation model and traffic model is described in section 4. Section 5 describes the simulation methodology. The simulation results and the discussion as well as a comparison are presented in section 6. Finally, section 7 contains the concluding remarks.

2. Call Admission Control (CAC)

A. Single Cell Call Admission Control SC-CAC

In single cell call admission control scheme the handoff calls are occupying a part of the fixed link capacity. Therefore, the handoff calls were being obtain the priority over the other calls. The capacity of all channels into the SC-CAC should be less than a threshold value (which is adjusted by the algorithm) to accept new calls by the cell. In the single cell CAC, the type of modulation is one of the important requirements of the system and in some cases two or more types of modulation can be used such as M-QAM and QPSK. The call requests which the single cell receives are of three types, new user call, modulation switched call and handoff call. When the connection is not idle and the channels are doing the process of handoff or modulation switching, then the new user's request call will be dropped (Kwon, et al., 2005).

Fig. 3 (Catrein D., 2009), shows a single cell network with a specific number of users, new user's call request from mobile station *i* to the base station. The SC-CAC algorithms are used to measure the performance of the system based on some points such as the outage probability that affects the quality of service, the outage probability is related to the bit error rate BER.

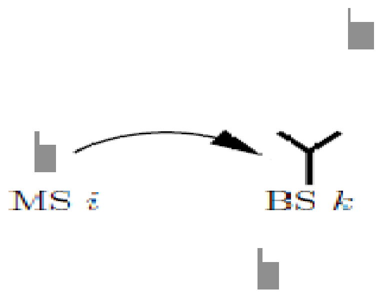

Figure 3.Single cell-new call request.

A multiple power scheme thresholds for multiple services was one of the CAC algorithms , another scheme works by estimating the power change that may results due to accept a new user either the power of the servicing cell or the power of the nearing cells.

One of the single cell CAC schemes gives the availability of reserving channels for multimedia, video and voice. An upper limit of the channel is determined by the cell and a new voice call is rejected if the channel limit is exceeded; a queuing system can be used in order to deal with the handoff calls (Sindal, 2009).

B. Multi Cell Call Admission Control MC-CAC

The user is connected to more than one base station if the system is working based on CDMA technology. The radio network controller RNC transfers calls between base stations in 3G networks and there is no disconnection, then RNC moves the user to another base station if the base station does not have the ability to accept it and this will increase the quality of service and minimize dropping and blocking probabilities (Zreikat, 2003).

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Fig. 4 (Zreikat A., 2003), shows the procedure to move the mobile station from one node B (base station) to other one, but the user is connected to one node B at a specific time.

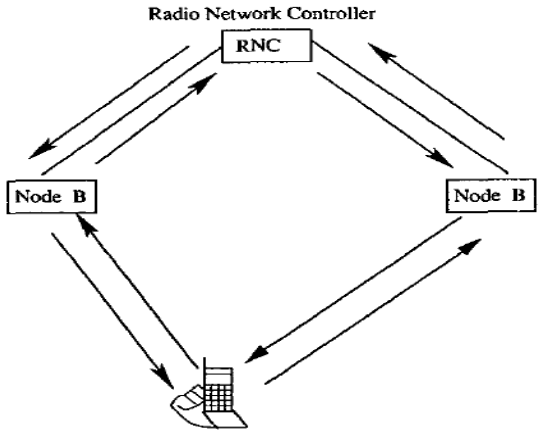

Figure 4.Moving the user between base stations.

The total received power equals the summation of the received power from the mobile users in the centre cell and nearing cells plus the background noise, this is applied in uplink WCDMA system with certain number of base stations service classes. Fig. 5 (Pires G., 2006), shows an example of a multi cell MC network.

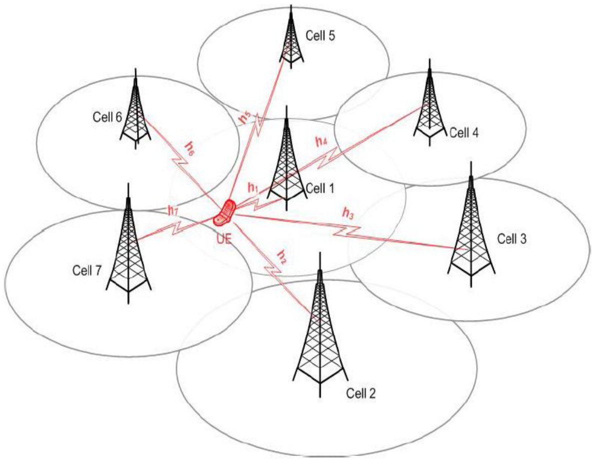

Figure 5. Seven cell scheme (multi-cell scheme).

Many types of load can exist in a multi cell network such as the homogenous load where the users have the same probability to be in any cell of the environment. Fig. 6 (Pires G., 2006), shows an example of the homogenous load type. Another load case is the heterogeneous where the load in the center cell is different than the load in the surrounding cells at the same multi cell environment (El-Dolil, et al., 2008).

Fig. 7 (Pires G., 2006), shows an example of heterogeneous load case, in this load case the central cell's load is 50% or 75% of the load in any of the nearing cell. There are a set of factors or parameters and QoS metrics that may considered as a very important issues to design a CAC algorithm such as the soft capacity of CDMA system, handoff call priority, mobility modeling, dynamic bandwidth reservation technique, the impact of performance power control technique, the effect of dynamic bit rate technique, base station maximum power and mobile station transmitting power (Mahmoudi, et al., 2005).

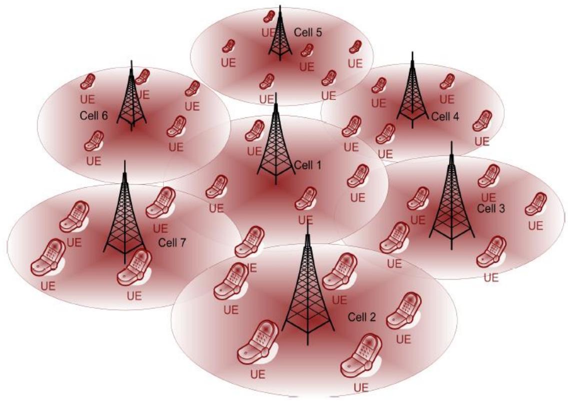

Figure 6.Example of Homogenous load type.

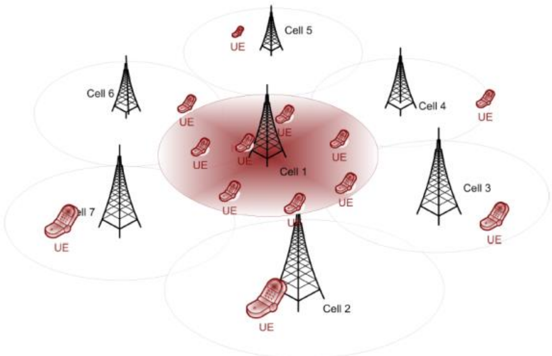

Figure 7.Example of Heterogeneous load type.

In the case of MC-CAC algorithm that is based on the power, a new user is accepted if the noise value of the home cell after admitting this user is less than a noise value threshold; this admission control is called power based admission control scheme.

In the case of power-based MC-CAC, the network transfers a mixed type of data and voice (service classes) and each class requires a specific value of bit rate. When a new user with a certain class of service transmits, an important factor should be taken in consideration which is the ratio between the received power from the mobile station to the total value of the interference. The values of BER are obtained from the link level measurements (El-Dolil, et al., 2008).

Multi cell call admission control algorithms minimize the noise probability in the nearing or neighboring cells around the center cell, which provides a progress increase in the process of admission control. In order to minimize the probability of blocking and then keep high quality of service QoS level. Multi cell CAC accepts amounts of calls less than the single cell SC in some cases. In other words, multi cell CAC rejects more amounts of calls than SC-CAC.

One of the multi cell CAC schemes is the CAC power control based. In this scheme the algorithm sets a target value for the SIR, and it makes a decision by comparing the SIR received value with the target value, then if it is less than the target value there will be an increasing in the transmitter's power. On the other hand, the transmitter's power is decreased if target value was exceeded (Pires, 2006).

3. System Model

C. Power Assumptions

The paper considers a WCDMA cellular radio system with B base station and K service classes, a three cell scheme has been used. In the case that the number of cells is one the SC-CAC algorithm will take place, while if the number of cells is two, three or more the MC-CAC will take place. The system model considers the effect of Additive White Gaussian Noise AWGN and the effect of Rayleigh and/or Nakagami multi path fading.

The system considers the transmitted power vector of the travelling users of any class and it is written as:

$$P_t = [p_1, p_2, p_3, \ldots\ldots\ldots\ldots p_M] \tag{1}$$

Where, $_M$ is the number of active users in the cell. The model represents the attenuation that the propagated signal will face through the medium by the path gain H, the path gain is the ratio between the received signal power to the transmitted signal power, and it is obtained from the mobile station records that are sending to the cell and the measurement at the base station. Path gain can be written as in the following matrix (Goldsmith, 2005):

$$H = \begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,B} \\ \vdots & \ddots & \vdots \\ h_{m,1} & \cdots & h_{m,B} \end{bmatrix} \tag{2}$$

Where $h_{i,B}$ is the path gain between the user *i* and base station B in the uplink direction.

The total received power at base station B is written as matrix notations:

$$P_{tot,B} = P_t.\ H + P_N \tag{3}$$

Where, P_{total}, Pt and H are all matrixes. P_N is the background noise. Therefore, the total received signal can be written as:

$$P_{tot,B} = P_{own,B} + P_{neigh,B} + P_N \tag{4}$$

Where $P_{own,B}$ is the received power from the mobile station in the serving cell, and $P_{neigh,B}$ is the received power from mobile station in the neighboring cells. The algorithm makes the decision based on the threshold value of signal to interference noise ratio SIR, the SIR is written as:

$$SIR = \frac{P_r}{N_o\, B + P_I} \tag{5}$$

Where P_r is the received power, N_o is the noise power, B is the bandwidth, P_I is the average power of the interference (Goldsmith, 2005).

The transmitted power after the CAC has accepted a new user can be expressed as (Proakis J., 2001):

$$P_{t,NEW} = P_t \frac{SINR_O}{SINR_i} \tag{6}$$

Where P_t is the old transmitted power prior to accept the new users, $SINR_o$ is the target value of the SINR, and $SINR_i$ is the current value of the signal to interference noise ratio.

The system considers a control admission criteria based on the outage probability after admitting new users in the both case of SC-CAC and MC-CAC, beside the calculated capacity of the system based on Shannon capacity theory as a target to measure the performance of the system and the quality of service QoS.

D. Probability of Outage

The outage probability is described as the probability that the signal to noise ratio SNR at the output is being below an outage threshold value (Γ_{th}). The outage threshold is a limit value for the SNR to measure the quality of service QoS (Sekulovic, 2010).

The outage probability as a mathematical expression is the integration of the probability density function PDF of the communication channel with limits of integration from zero to the value (Γ_{th}) (Goldsmith, 2005).

In the system model of this paper the diversity techniques are used to avoid the effects of multi path fading in order to increase the quality of service of the system. The system model considers a Nakagami-M distribution channel, the distribution or probability density function of this channel is written as:

$$P_{Z\,(Z)} = \frac{2\, m^m\, z^{2m-1}}{\Gamma(\mathrm{m})\ \mathrm{P_r}^{\mathrm{m}}}\ e^{\left[-\frac{mZ^2}{P_r}\right]} \tag{7}$$

P_r: is the average received power.

Γ ( ): Gamma function.

M: Nakagami fading parameter.

Now let $x = z^2$, and x is a random variable then equation (7) can be written as:

$$P_{z^2\,(x)} = \frac{m^m}{\mathrm{P_r}^{\mathrm{m}}}\ \frac{x^{m-1}}{\Gamma(\mathrm{m})}\ e^{\left[\frac{-mx}{P_r}\right]} \tag{8}$$

The outage probability is calculated for the channel with Nakagami fading parameter m=1, then the distribution represents Rayleigh fading and the outage probability P_{out} is written as:

$$P_{out} = \int_0^{\Gamma th} \mathrm{Pz(x)}\, dx \tag{9}$$

E. Channel Capacity

Determining the capacity of the communication channel is very important in order to satisfy the quality of service requirements. Capacity determines the maximum limit of data that can be transmitted over the channel. As in (Goldsmith, 2005, p.91): ‘‘*Shannon defined capacity as the mutual information maximized over all possible input distributions*’’.

The Shannon capacity formula of the channel in AWGN is

$$C = B \log_2 (1 + \gamma) \tag{10}$$

The model is assuming that the channel is side information at the transmitter and receiver, i.e. perfect estimation case at the receiver side, and then Shannon capacity C of the fading channel is written as:

$$C = \int_0^{\infty} B \log_2 (1 + \gamma)\, p(\gamma)\, d\gamma \tag{11}$$

Where γ is the received SNR of the channel and B is the bandwidth of the channel. Another expression of the capacity that could be used is the capacity with outage.

The system model considers the formula of the fading channel capacity with average power constraint that achieves the optimal power adaptation to maximize Shannon capacity, this formula is called *water-filling* formula and it is written as in (Goldsmith, 2005):

$$C = \int_{\gamma_o}^{\infty} B \log_2 \left(\frac{\gamma}{\gamma_o}\right) p(\gamma)\, d\gamma \qquad (12)$$

The optimal power adaptation that maximizes the fading channel capacity is written as:

$$\frac{P(\gamma)}{\bar{P}} = \begin{cases} \frac{1}{\gamma_o} - \frac{1}{\gamma} & \gamma \geq \gamma_o \\ 0 & \gamma < \gamma_o \end{cases} \qquad (13)$$

Where *P(γ)* is the transmitted power and $\bar{P}$ is the average power limits, γ_o is a cutoff value, at a given time if the value of γ is less than this cutoff then there is no transmission at this time . The value of γ_o must achieves the following condition:

$$\int_{\gamma_o}^{\infty} \left(\frac{1}{\gamma_o} - \frac{1}{\gamma}\right) p(\gamma)\, d\gamma = 1 \qquad (14)$$

The concept of achieving the cutoff value in water-filling formula that maximizes the channel capacity is shown in fig. 8 (Kalyanarman S., 2011).

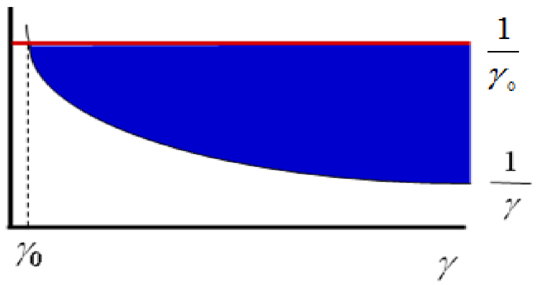

Figure 8. Water-filling optimal power.

The system model makes the decision of admission or rejection based on previous conditions which are the outage probability and the resulting capacity.

4. Simulation Model

The simulation model in this paper discusses the performance of the system for the above call admission control methods using MATLAB software. The simulation aims to study and compare the QoS for the SC-CAC and the MC-CAC under three service classes based on the calculated outage probability and channel capacity.

F. Network Topology

A three cells model is considered in the following simulation, omnidirectional antennas are implemented on the center base station of each cell. Single cell SC is the dominant CAC algorithm of the network if the number of cells (m) equals 1; Multi cell is the CAC algorithm for other cases.

G. Propagation Model

The effects of Gaussian noise as well as multipath fading are considered in the propagation channel, we assume the impact of Rayleigh fading and AWGN. The attenuation factor has been taken in consideration through the previous equation of path gain *H*. Regarding the AWGN, suppose the transmitted signal is s(*t*) and the noise is n(*t*), then the received signal r(*t*) can be written as (Harrad H., et al., 2002) :

$$r(t) = n(t) + s(t) \qquad (15)$$

The transmitted signal is propagated through the path and three issues will affect the propagation of the radio wave due to the obstacles, the reflection, refraction, and scattering. The direct path signal and the refracted, reflected, and scattered paths are combined at the receiver side and this will affect the signal to noise ratio of the received signal. This phenomenon is called multi path fading. Fig. 9 (Harrad H., et al., 2002, p.56), shows the affect of multi path fading.

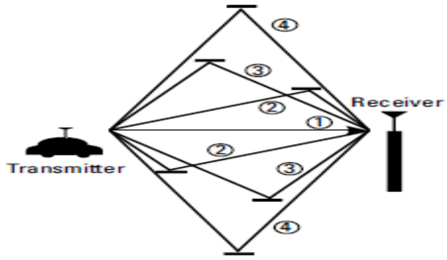

Figure 9.Multi path fading effect.

Fig. 10 (Kalyanarman, 2011), shows a base station that transmits to multiple mobile users /multiple outputs through a fading channel.

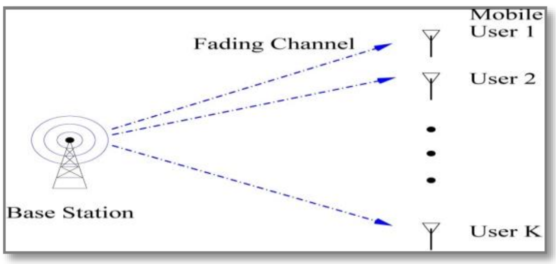

Figure 10.Multi user fading channel.

H. Traffic Model

Real-time services and non-real time services are the two main types of services in WCDMA system. Real-time services have the highest priority over non-real time services due to saving reserve a part of the channel capacity as WCDMA is limited capacity system. Three types of service classes are assumed in our simulation, which are voice calls, multimedia and video and each service class has a unique outage threshold value in dB. Table 1 shows the outage threshold values for each service class.

Table I: Service Classes

Service Class	***Outage Threshold (dB)***
Class 1 : Voice	-19.9
Class 2 : Multimedia	-13.7
Class 3 : Video	-11.57

Where, the outage threshold is the outage signal-to-interference ratio SIR threshold. In the simulation, if the value of SIR is lower than SIR required for any service class then the user’s call is in an outage condition. In the case that more than two outages were occurred the call will be dropped. The threshold values in the above table take in consideration a compensation for the power control errors as in (Ahmed and Yanikomeroglu 2005, Redana and Capone 2002). Table 2 summarizes the input parameters in the simulation model.

Table II: Simulation Input Parameters

Parameter	*Value*
Cellular Layout	3 cells
Noise power	1x 10^{-5}
Bandwidth (BW)	10 Mbps
Iteration	100
Signal-to-noise ratio (SNR)	0:1:20 dB
Γ (Gamma)	0:1:35 dB
Bit Error Rate (BER)	1x10^{-3}, 1x10^{-6}
Base station Antenna	Omnidirectional antenna
Average SNR	0:1:35 dB

5. Simulation Methodology

The performance evaluation is done using MATLAB simulation. This paper focuses on a comparison between the performances of two call admission control approaches: single cell call admission SC-CAC's approach and multi cell call admission control MC-CAC's approach. The comparison was made under the condition of multi-traffics WCDMA system.

The evaluation of the QoS and performance was done through a programming simulation to analyze the relationship between signal to noise ratio SNR and probability of outage in terms of bet error rate BER. Another simulation process is done to show the relationship between SNR and capacity of the network in the case of single cell traffic and multi cell traffic cases.
Control admission algorithm is generated to add or reject a new user based on certain policy into the network and this needs some analysis to evaluate the impact of the decision algorithm on the system performance.

In this paper there are a set of independent variables, the main independent variables are the single cell cellular layout, the multi cell cellular layout and the service traffic class with the corresponding outage threshold. There are another set of secondary parameters such as the noise power, interference, bandwidth, signal-to-noise ratio SNR and bit error rate BER. While the dependent research variables are the probability of outage (blocking or dropping) and total channel capacity after deciding to admit a new user depending on the call admission control algorithm that is in use.

The following chart – fig. 11 represents the Call Admission Control CAC algorithm that is used in this paper, where SC stands for Single Cell and MC is Multi Cell. The MATLAB simulation model and the algorithm enter the input parameters above and then set the outage SIR threshold that is mentioned in table 1. Based on the threshold value the algorithm starts the simulation for the desired service class *k;* the algorithms define two values of bit error rate BER. Using the equations — 7, 8, 9— the code calculates the threshold value of gamma (Γ).

Using equation 9 the simulation code will calculate the outage probability for the two choices SC and MC. To evaluate the performance and the QoS for each CAC algorithm the maximum capacity is calculated using Shannon capacity formula and water-filling formula. Finally, the CAC takes the decision to admit or reject the new user.

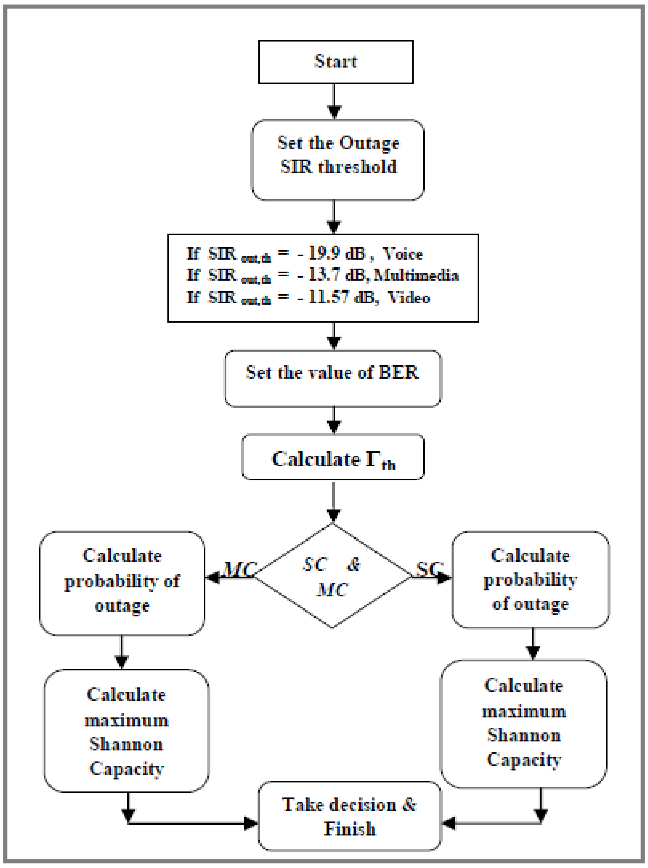

Figure 11. Call admission control CAC Algorithm flow chart.

6. Simulation Results

The simulation shows and evaluates the performance results of Single and Multi cell CAC for each service class, and calculates the probability of outage in presence of channel multipath fading channel for the two algorithms in terms of BER values. Shannon capacity formula is used to calculate capacity of the channel as a reference to meauser the performance of the selected admission control algorithms.

I. Voice Service Simulation Results

Voice service class simulation results are shown. The value of outage SIR threshold is -19.9 dB. The goal is to measure the quality of service for single and multi cell CAC, so the algorithm calculates the outage probability versus average SNR that is varying from 0 to 35 dB and BER is taking the values of 1x10^{-6} and 1x10^{-3} . Fig. 12 shows the fact that when SNR is 25 dB and if the dominant algorithm is single cell in presence of 1x10^{-3} bit error rate then outage probability P_{out} is close to 1x10^{-2}.

On the other hand, when the number of cells is two and in presence of the same values of bit error rate as well as average SNR, the outage probability is very close to 1x10^{-4}. While for the case of three cells the outage probability is near 1x10^{-6} taking in consideration the same varying factors. The figure also shows the results of P_{out} when BER is the ideal scenario (1x10^{-6}). From the figure especially after the average SNR of 15 dB, difference between the three cases in outage probability values has been noticed clearly.

The outage probability for the three cells case is approximately close to zero when the average SNR is 35 dB. Finally, the figure shows also a small possibility regarding output SNR for being less than the threshold value (-19.9 dB); this happens for voice traffic class and if the number of cells that are operating in the call admission control CAC is two or three cells. The result is a higher performance of quality of service over the case of single cell SC. The outage probability values have been displayed as a surface and fig. 13 shows that surface[1].

J. Multimedia Service Simulation Results

Low data rate services such as music, images, medium multimedia and movies all are combined in the expression: multimedia services. In multimedia simulation's part the value of outage SIR threshold is -13.7 dB. . The goal is to measure the quality of service for single and multi cell CAC, so the algorithm calculates the outage probability versus average SNR that is varying from 0 to 35 dB and BER is taking the values of $1x10^{-6}$ and $1x10^{-3}$. Fig. 14 shows the fact that when SNR is 25 dB and if the dominant algorithm is single cell in presence of $1x10^{-3}$ bit error rate then outage probability P_{out} is less than $1x10^{-2}$.

On the other hand, when the number of cells is two and in presence of the same values of bit error rate as well as average SNR, the outage probability is $1x10^{-5}$. While for the case of three cells the outage probability is very close to $1x10^{-8}$ taking in consideration the same varying factors. The figure also shows the results of P_{out} when BER is the ideal scenario $1x10^{-6}$ From the figure especially after the average SNR of 17 dB, difference between the three cases in outage probability values has been noticed clearly. Finally, the figure shows also a small possibility regarding output SNR for being less than the threshold value (-13.7 dB); this happens for multimedia traffic class and if the number of cells that are operating in the call admission control CAC is two or three cells. The result is a higher performance of quality of service over the case of single cell SC.

K. Video Service Simulation Results

Video services are high data rate services. In video simulation part the value of outage SIR threshold is -11.57 dB. . The goal is to measure the quality of service for single and multi cell CAC, so the algorithm calculates the outage probability versus average SNR that is varying from 0 to 35 dB and BER is taking the values of $1x10^{-6}$ and $1x10^{-3}$.

Fig. 15 shows the fact that when SNR is 25 dB and if the dominant algorithm is single cell in presence of $1x10^{-3}$ bit error rate then outage probability P_{out} is close to $1x10^{-3}$. On the other hand, when the number of cells is two and in presence of the same values of bit error rate as well as average SNR, the outage probability is very close to $1x10^{-6}$. Besides that outage probability for the three cells case and in presence of the same values of bit error rate as well as average SNR is, $1x10^{-8}$. The figure also shows the results of P_{out} when BER is the ideal scenario ($1x10^{-6}$). From the figure epically after the average SNR of 15 dB, difference between the three cases in outage probability values has been noticed clearly. Finally, the figure shows also a small possibility regarding output SNR for being less than the threshold value (-11.57 dB); this happens for video traffic class and if the number of cells that are operating in the call admission control CAC is two or three cells. The result is a higher performance of quality of service over the case of single cell SC.

L. Channel Capacity Simulation Results

The simulation model calculates the channel capacity based on Shannon capacity, the simulated noise power is $1x10^{-5}$ and the simulated bandwidth of the channel is 10 Mbps. This part of simulation finds the relationship between the SNR and capacity of the channel in both single cell case and multi cell case in order to measure the quality of service QoS for both SC-CAC and MC-CAC.

The simulation takes in consideration the effect of noise that is weighted by fading on the transmitted power with the assumption that the estimation is perfect between the transmitter and receiver. In fig. 16 SNR varies from 0 to 20 dB, the figure shows the calculated channel capacity for both single cell and multi cell cases. At 10 dB SNR the capacity of single cell channel is 1.3 Mbps, for two cells the channel capacity is 3 Mbps and for the case of three cells the capacity of channel is 4.2 Mbps.

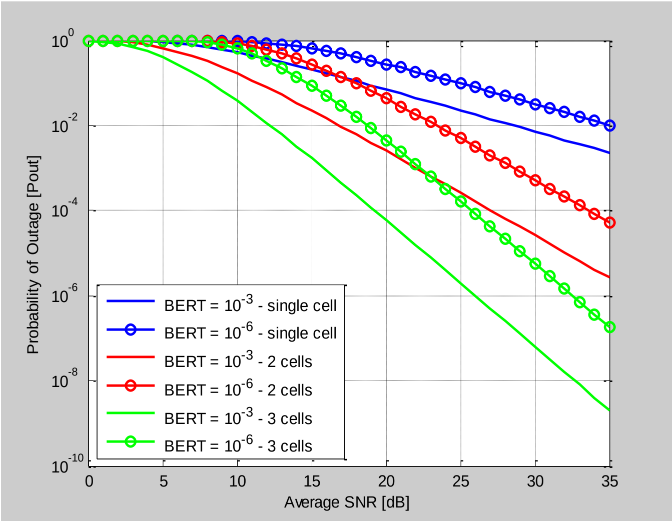

Figure 12. Probability of outage (P_{out}) results for class 1 (voice) service.

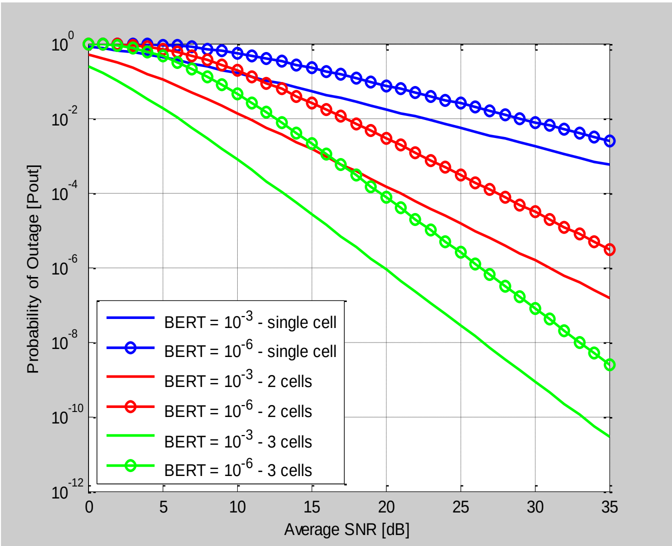

Figure 14. Probability of outage (P_{out}) results for class 2 (multimedia) service.

[1] *" Surf: display a matrix as a surface. Surf (Z) creates a 3-D shades surface from components in matrix Z using X=1:n and Y=1:m , Where [m,n] = size(Z), the height Z is a single-valued function defined over a geometrically rectangular grid''* (MathWorks, 2011).

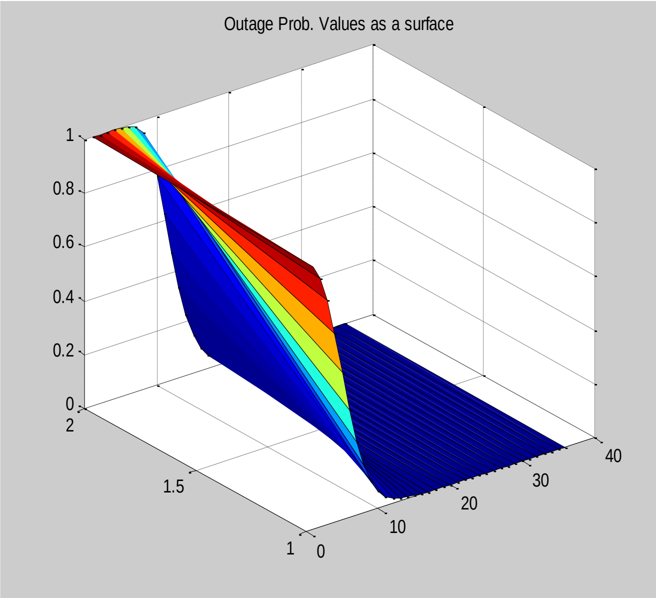

Figure 13. Outage probability values as a Surface for class 1 (Voice).

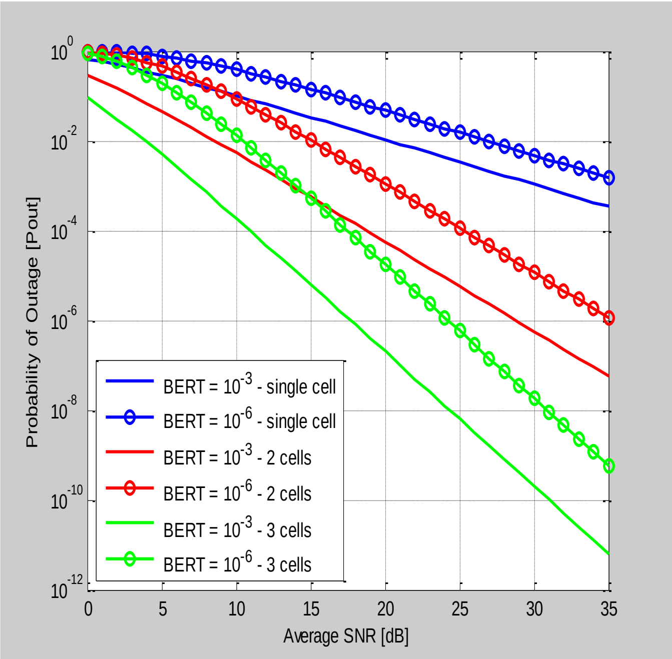

Figure 15. Probability of outage (P_{out}) results for class 3 (video) service.

Fig. 16 shows that as the SNR increases the capacity also increase, so at 20 dB SNR the capacity for three cells is 9.1 Mbps. The figure implies that the Shannon channel capacity for the multi cell case is higher than the case of single cell, which means that the network in multi cell case has more ability to admit new users without any disconnection in the service for the old users. The channel capacity difference between the three cases becomes larger after a 12 dB SNR, the figure also shows that at a lower SNR values the three curves is relatively close to each other.

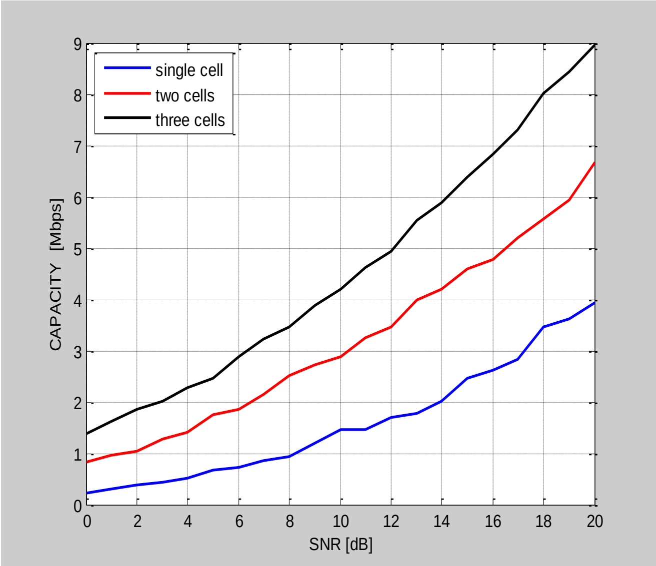

Figure 16. Channel Capacity (Mbps) results for single and multi cell CAC.

In this paper we are considering the case of 3-cell cellular layout of the Multi-Cell CAC, but we have used the 7-cell cellular layout just to study the impact of increasing the number of cells in the cellular layout on channel capacity. As fig. 17 shows the system capacity has increased as the number of cells increases, for example at 18 dB SNR the capacity is 16 Mbps for the 7-cells layout.

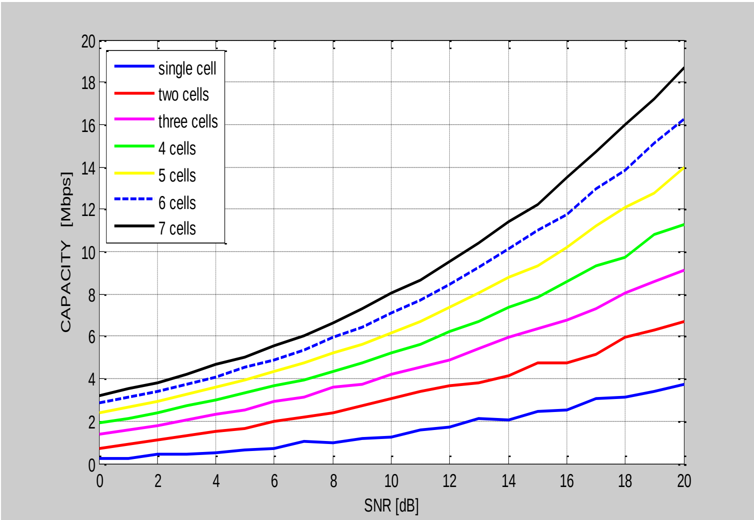

Figure 17. Simulation results for the 7-Cells layout capacity.

The values of the capacity in fig. 16 and fig. 17 are mean (average) values and the reason is that the simulated capacity is <21x100> double array with a minimum value of 0.6900 and Maximum value of 13.2064. Therefore, the capacity matrix values have been plotted as a surface (*surf*) as shown in fig. 18 and this figure describes the case of three cells layout.

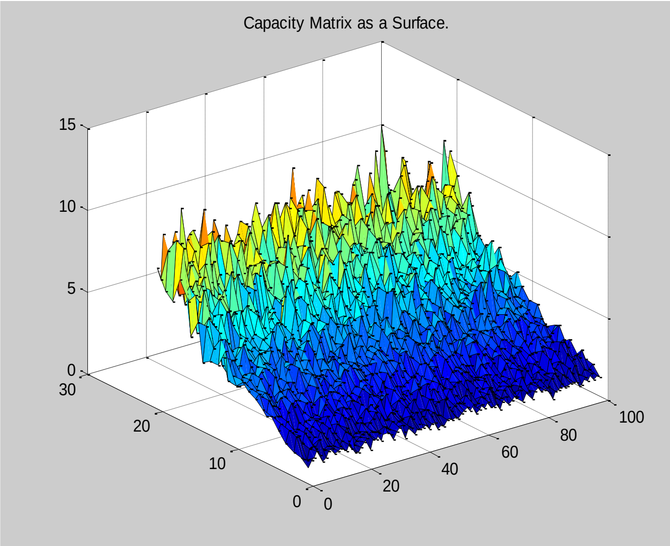

Figure 18. Capacity calculated values as a Surface.

Table 3 summarizes the simulation results of outage probability P_{out} in SC and MC for the three different class services at a fixed value of SNR and BER. Table 4 summarizes the capacity simulation results at a fixed value of SNR.

This paper performs the study by proposing and showing many scenarios of call admission control, the simulation results have reached to a set of conclusions controlling the performance of single and multi cell CAC. Accepting or refusing new call users is made based on some mechanisms and certain conditions in both single and multi cell AC algorithms. The traffic model in this paper expands the study with the three type of service classes the voice calls, multimedia, and video. The class services were categorized to real time and non real time services depending on the priority of the service.

Table III: Pout Simulation Results

CAC	***Class***	***BER***	***SNR***	P_{out}
SC	Voice	$1x10^{-3}$	25 dB	< $1x10^{-2}$
MC	Voice	$1x10^{-3}$	25 dB	$1x10^{-6}$
SC	Multimedia	$1x10^{-3}$	25 dB	< $1x10^{-2}$
MC	Multimedia	$1x10^{-3}$	25 dB	$1x10^{-8}$
SC	Video	$1x10^{-3}$	25 dB	$1x10^{-3}$
MC	Video	$1x10^{-3}$	25 dB	$1x10^{-8}$
SC	Voice	$1x10^{-6}$	25 dB	$1x10^{-1}$
MC	Voice	$1x10^{-6}$	25 dB	< $1x10^{-3}$
SC	Multimedia	$1x10^{-6}$	25 dB	< $1x10^{-1}$
MC	Multimedia	$1x10^{-6}$	25 dB	< $1x10^{-5}$
SC	Video	$1x10^{-6}$	25 dB	$1x10^{-2}$
MC	Video	$1x10^{-6}$	25 dB	< $1x10^{-6}$

The above results show that the values of the probability of outage at $1X10^{-6}$ BER is relatively larger than the values at $1x10^{-3}$ BER , that because the value of $1x10^{-6}$ is difficult to achieve (ideal) than the value of $1x10^{-3}$ and then the results agree with the meaning of the probability of outage.

Table IV: Capacity Simulated Results

CAC	***SNR***	***Capacity***
SC	10 dB	1.3 Mbps
MC (3 cells)	10 dB	4.2 Mbps
MC (7 cells)	10 dB	8 Mbps
SC	14 dB	2.2 Mbps
MC (3 cells)	14 dB	5.9 Mbps
MC (7 cells)	14 dB	11.7 Mbps
SC	20 dB	3.7 Mbps
MC (3 cells)	20 dB	6.4 Mbps
MC (7 cells)	20 dB	18.2 Mbps

7. CONCLUSIONS

In this paper we have used a system model that is based on the power adaptation mechanism in order to decrease the probability of outage and increasing the channel capacity by applying the water-filling formula. Furthermore, the simulation model takes in consideration the effect of multipath fading and signal to interference noise ratio that degrades the quality of service, and it shows that the diversity techniques are very important to deal with multi path fading channels. It is important to mention that the transmitted power and noise were weighted by fading assuming a perfect estimation between the transmitter and receiver. The channel simulation factor *m* is related to Nakagami distribution; and to Rayleigh (if and only if) it is equal 1.

The simulation results of the outage probability in presence of fixed value of average signal to noise ratio SNR and BER , multi cell CAC provides the smallest values of outage probability and this proves that this scheme of call admission control keeps the optimal SNR values that is required for a high quality of service. On the other hand, the SC-CAC shows high values of outage probability, therefore the quality of service is not as high as needed. For the voice service class traffic, the results show that the minimum outage probability is achieved with a 35 dB average SNR and $1x10^{-3}$ BER in the case of 3 cells (Multi cell), based on this result the optimal technique to deal with voice services in a high standers of quality of service QoS was tested in the case of three cell scenario and in a special case with 7-cells layout.

The outage probability difference between the SC and MC cases becomes larger as the number of cells increase. For the multimedia service class, the simulation results also show that the minimum outage probability is achieved with a 35 dB average SNR and $1x10^{-3}$ BER in the case of 3 cells (Multi cell). If a comparison between the results of voice and multimedia takes place, then at 25 dB SNR and $1x10^{-3}$ BER the value of outage probability is below the value of P_{out} of voice class, and because of the various demands on the real time (voice) service; the results show that QoS performance for multi cell scheme in case of multimedia service is better than the performance of voice call service.

For the video service class traffic, at 25 dB SNR the simulation results show that the probability of outage has minimum value for the case of three cells (Multi cell) , as the SNR increased the probability of outage decrease as minimum as possible. The results show that at small SNR values the difference between SC and MC in terms of probability of outage is not too large, but when the SNR is between 15 and 35 dB the difference becomes large.

Another issue has been shown from the simulation result which is capacity. The system model considers the water filling formula to maximize Shannon capacity over the fading channel based on the power adaptation technique; the simulation results show that the capacity of the fading channel can be maximized to high value by considering the MS-CAC power based scheme. At a fixed value of SNR, MC-CAC gives the highest value of capacity over the channel which means that the algorithm has the ability to admit new users without any effects on the total number of connected users. The results show that the capacity of the fading channel is increasing as the SNR is increased. At low SNR values the capacity difference between SC and MC is not too large. However, the MC has the better capacity.

It has been shown that the number of cells (cells layout) in CAC algorithm plays an important role in determining system capacity. Therefore, the cellular layout can be considered as one of factors to specify the performance and QoS in WCDMA networks. From the simulation results the MC-CAC has many advantages over the SC-CAC, in terms of minimum probability of outage, stability of the link, less error probability control admission mechanism, system throughput and QoS. In summary, this paper comes with the conclusion that our selected MC-CAC with specific cellular layout is more effective in WCDMA communication system than the SC-CAC as the simulated results of the outage probability and channel capacity have been implied; this means that the quality of service QoS and the overall performance of the network have improved by using the MC-CAC scheme as an algorithm for call admission control. Consequently, the network is performing handover process easily without dropping the calls or rejecting more users and dropping probability can be decreased without increasing the blocking probability into high levels.
Always the challenge is with the high bit rate services and achieving an enchantment of the network coverage for these services.

8. Future Work

We outline a few spotlights for future research in the field of call admission control CAC as follows:

- The proposed simulation work in this paper can be applied in two cases: homogeneous load and heterogeneous load, further works can be done with a focus on the mixed traffic load case at the downlink and uplink sides based on the simulation mechanism of this work in order to study the QoS differentiation.
- Further research may present two different signal-to-interference SIR thresholds for each class of the three traffic classes just to give the priority for handover calls over other types of new calls.
- New mechanism or techniques can be used in the simulation model to delay the data traffic such as queuing and packet scheduling in order to utilize the system's resource in an efficient way.

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