



TRIBHUVAN UNIVERSITY  
**INSTITUTE OF ENGINEERING**  
PULCHOWK CAMPUS

Thesis No.: 065/MSI/605

A THESIS REPORT ON  
**CALL BLOCKING ANALYSIS IN**  
**WCDMA CELL**

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(065/MSI/605)

Thesis Report

Submitted to:

Masters of Science in Information and Communication Engineering,  
Department of Electronics and Computer Engineering

November, 2012

# **CALL BLOCKING ANALYSIS IN WCDMA CELL**

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A thesis submitted in partial fulfillment of the requirements for the  
degree of Master of Science in Information and Communication  
Engineering

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November, 2012

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The undersigned certify that they have read and recommended to the Department of Electronics and Computer Engineering for acceptance, a thesis entitled “**Call Blocking Analysis in WCDMA Cell**” submitted by Kirit Giri in partial fulfillment of the requirement of for the award of the degree of “Master of Science in Information and Communication Engineering”.

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## ACKNOWLEDGMENT

This is my pleasure to submit the thesis report on “**Call Blocking Analysis in WCDMA Cell**” to department of Electronics and Computer Engineering for the partial fulfillment of the requirements for the degree of Masters of Science in Information and Communication Engineering.

Firstly, I would like to express my sincere gratitude to Assistant Professor Sharad Kumar Ghimire, my thesis supervisor, for his valuable advice, encouragement and kind support for carrying out this thesis.

I would also like to express my sincere gratitude to Head of Department of Electronics and Computer Engineering for giving me the opportunity to carry out this thesis. I would also like to extend my gratitude to my teachers of MSICE Committee and my friends for their encouragement and cooperation in carrying out the thesis. Last but not least, my gratitude to my friend Aashish Poudel, Jeewan Shrestha and Kabin Shrestha for helping me to get IEEE journal and providing me valuable suggestions which was very helpful to me to carry out my research.

## **ABSTRACT**

WCDMA is the air interface for UMTS which is a 3G standard technology. When traffic offered to the system increases there would come a situation that the system cannot handle any more call, this is known as call blocking. Analysis of call blocking is very necessary to plan new network as well as for the upgrade of existing network.

In WCDMA, different services like emergency call, voice call, video call and data are categorized in different service classes with different priorities. In this study three classes of traffic is taken into consideration. Blocking analysis in terms of probability has been done in this research by introducing a term known as BBU (Basic Bandwidth Unit) which is the basis for dimensioning of traffic as well as capacity of the system. In this thesis “**Call blocking analysis in WCDMA cell**”, change in blocking probability has been studied by fully-availability group approximation of WCDMA cell with change in offered traffic per BBU. The result shows that FAG approximation of WCDMA cell is an easy tool to analyze the capacity of a WCDMA cell.

**Keywords:** *WCDMA, FAG, BBU*

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## LIST OF SYMBOLS

<b>A</b>	total offered traffic per BBU
<b><math>a_i</math></b>	Offered traffic in Erlang by 'i' class of traffic
<b><math>b(i)</math></b>	Blocking probability for class 'i' class of traffic
<b><math>E_b/N_0</math></b>	Energy bit to Noise Spectral Density
<b><math>I_{total}</math></b>	Total received wideband power including thermal noise
<b>ksps</b>	kilo symbols per seconds
<b><math>L_i</math></b>	Load factor for a user of class 'i' service
<b>M</b>	No. of class of traffic
<b>Mcps</b>	Mega chips per seconds
<b><math>P_i</math></b>	Signal Power received from user of class 'i' service
<b><math>P(n)</math></b>	Probability of 'n' BBU being occupied
<b><math>R_i</math></b>	bit rate of the user of class 'i' service
<b><math>t_i</math></b>	Number of BBU required by class 'i' service
<b>V</b>	Capacity of the FAG in BBU
<b><math>v_i</math></b>	activity factor of a user of class 'i' service
<b>W</b>	Chip rate of spreading signal ( WCDMA W=3.8Mcps)
<b><math>\lambda_i</math></b>	Mean value of offered traffic if class 'i' service
<b><math>\Omega</math></b>	micro state of a Markovian System
<b><math>\mu_i</math></b>	mean holding time of a user of class 'i' service

## **ABBREVIATIONS**

AuC:	Authentication Center
BBU:	Basic Bandwidth Unit
BSC:	Base Station Controller
CAC:	Call Admission Control
CDMA:	Code Division Multiple Access
CBR:	Constant Bit Rate
CS:	Circuit Switched
EIR:	Equipment Identity Register
FAG:	Fully Availability Group
FDD:	Frequency Division Duplex
FEC:	Forward Error Correction
FTP:	File Transfer Protocol
GMSC:	Gateway MSC
GoS:	Grade of Service
GGSN:	Gateway GPRS Support Node
GSM:	Global System for Mobile communications
HLR:	Home Location Register
IP:	Internet Protocol
ISDN:	Integrated Services Digital Network
LTE:	Long Term Evolution
MSC:	Mobile Switching Center
PS:	Packet Switched
PSTN:	Public Switched Telephone Network
OVSF:	Orthogonal Variable Spreading Factor
QoS:	Quality of Service
RNC:	Radio Network Controller
SCP:	Service Control Point
SGSN:	Serving GPRS Support Node
TB:	Throughput Based
TDD:	Time Division Duplex

TDMA:	Time Division Multiple Access
TFI:	Transport Format Indicator
TFCI:	Transport Format Combination Indicator
UE:	User Equipment
UMTS:	Universal Mobile Telecommunications System
UTRA:	UMTS Terrestrial Radio Access
UTRAN:	UMTS Terrestrial Radio Access Network
VBR:	Variable Bit Rate
VLR:	Visitor Location Register
WPB	Wideband Power Based
WCDMA:	Wideband Code Division Multiple Access

**CHAPTER 1**  
**INTRODUCTION**

## **1.1 Background**

Third-generation mobile services are now widely being deployed. Multiplexing different services like speech, video and packet data on a single connection is a challenging task to perform. Universal Mobile Telecommunications System (UMTS) technology is an excellent framework for providing these services and Wideband Code Division Multiple Access (WCDMA) is its underlying air interface which had made it possible to meet the performance demands of the mobile Internet, including Web access, audio and video streaming, and video and IP multimedia calls.

The dimensioning and performance analysis of WCDMA cell is an important factor to perform on regular basis which helps in the upgrade of the current network as well as planning of the network expansion on new geographical regions. One of the methods for such analysis is to have analytical values of blocking probabilities of different classes of call when offered to the system on various scenarios.

With the feature of WCDMA categorizing the services like voice call, video call and data in different classes with different priorities, such analysis involves taking into consideration of numerous parameters. An efficient and effective way to perform such analysis is to use Fully Availability Group (FAG) approximation of WCDMA cell [3].

## **1.2 Problem Definition**

Increasing demand of cell phone uses not only have been a boon for telecom operators but also has presented different challenges to them. The proper planning of new network deployment or to upgrade the capacity of current network requires extensive research. The qualities of services that network operator present to their subscribers largely determine their current business and even their future existence. Though the 4G technology have started its deployment, existence of 3G technology is not going to cease in near future. The most popular 3G

technology that has been deployed so far is UMTS whose underlying physical interface is WCDMA.

The actual dimensioning of the system and analytical call blocking probability of WCDMA cell required consideration of various factors including transmitting power of a cell, gain of antenna, interferences for neighboring cell, no. of users, ratio of data users and more. Also that, WCDMA supports different classes of services with different priorities. So, this makes the channel modeling even more complex, but if this is can also be taken into consideration, it will be beneficial for effective WCDMA resource management in 3G mobile networks.

Thus, in order to prevent coverage holes as well as the over dimensioning of the network architecture it is very much necessary to have proper modeling of expected traffic for the WCDMA cell. If an easy and effective analytical method can approximate the WCDMA cell by calculating blocking probability of various classes of traffic, it will be very beneficial for network operators to deploy new network and also to upgrade currently deployed network. The Fully-availability approximation can be considered to be one the method which is effective yet less extensive to perform analytical calculation of call blocking probabilities of a WCDMA cell.

### **1.3 Objectives**

Modeling a WCDMA cell for call blocking analysis have always been a challenging task. Proper modeling can help the telecom operators to analyze the capacity of their existing network and also helps for network upgrade. The objective of the study is to model the WCDMA cell using Fully-Availability Group (FAG) approximation. Then using FAG approximation, the call blocking probability calculation for offered traffic of various class shall be done. Mainly, three classes of traffic will be taken into consideration, voice, video and data. The result then obtain shall be validate with the work done in [3].

## **1.4 Scope of the thesis**

In this thesis, the call blocking analysis of WCDMA cell has been done by calculating the blocking probability of the call. The call blocking probability has been calculated using the FAG approximation of the cell. The simulation has been done using C++ and Matlab has been used for the purpose of graph representation of the result. Only three classes of traffic has been taken into consideration which are voice call, video call and data traffic of 144kbps. Other variables that affect the blocking probability such as mobility of users, terrain structures, transmission powers etc. have not been taken into consideration directly. It has been assumed that cumulative effects of all of such activities are incorporated while assuming the value of load-factor of each class of traffic. The priority of certain class of traffic been used while calculating the blocking probability

## **1.5 Organization of thesis**

The thesis has been organized in six chapters. First chapter is the introduction, which provides brief introduction of the thesis. Followed by second chapter, “Literature Review”, where the brief introductions of works done previously which are related to this thesis work have been summarized. Along with that a brief introduction of Fully Availability Group (FAG) is also presented in this chapter. Chapter 3 presents the concept of UMTS/WCDMA which gives the technical background to understand the study work. This is followed by the Chapter-4, “Methodology”, where the diagnosis of the analytical method to calculate the blocking probability of WCDMA cell, which have been used in this study, has been presented. Chapter 5 presents all the simulation results their discussion. In the final chapter, “Conclusion and Future Enhancement”, the summary and conclusion of the thesis with further enhancement has been described followed by different references that have been used for the study purpose.

**CHAPTER 2**  
**LITERATURE REVIEW**

## 2.1 Related Work

Various works have been carried out for the call blocking analysis of in cellular communication. Following section summarizes the work done by various people which were taken as reference in due course of this research study.

D. Staehle in [1] has focused his work to study the capacity in UMTS network with heterogeneous traffic. The study has been carried out by calculating the blocking probability for varying the cell load. A cell load equal to one is considered to be the pole capacity of WCDMA cell. He too had used the Kaufman-Roberts Recursion formula for the calculation of call blocking probability.

K. Subramaniam and A. A. Nilsson have worked in call admission control schemes in [2]. The effect on call blocking probability with variation of uplink load factor has been studied in the paper. The investigation on two main call admission control schemes, Wideband Power Based (WPB) and Throughput Based (TB) in this paper shows that Wideband Power Based call admission control scheme works efficiently when data traffic is dominating in the network and Throughput Based call admission control scheme works efficiently when voice traffic is prevalent in the network. And user proposes to use Adaptive Call Admission Control (ACAC) scheme according to which the choice of WPB or TB should depend on the condition of the network by calculating the no. of active voice and data users periodically.

M. Stasiak and et al in [3] have presented the use of Fully Availability Group approximation of the WCDMA cell. This method introduces the concept of Basic Bandwidth Unit (BBU) to measure the capacity of a WCDMA cell as well the demand of resource by each group of traffic that is offered to the cell. He has calculated the call blocking probability to measure the capacity of a WCDMA cell. In his research he have shown that FAG approximation can be used to approximate the WCDMA cell and have verified his analytically obtained result with the values obtained by simulation done using Monte Carlo method.

The work done by G.A. Kallos in [4] is also based on Kaufman-Roberts Recursion method. Here too the call blocking probability has been calculated with varying the load into the system. In his work, there are fixed number of sources that are offering the traffic to the system. He has also proposed to add a new factor in the recursion formula to incorporate the soft-blocking to the system. He too has verified his analytical method with the simulation result like in [3].

Work done in [5] is again the work by M. Stasiak and et al where he has again presented the use of Kaufman-Roberts recursion formula to be used to model a WCDMA cell to calculate the call blocking probability incorporating hand-offs between the cell. There is no change in the process for calculating the blocking probability, but the only change was in calculating the offered traffic to the system. In his previous work at [3] the offered traffic was directly offered to the cell whereas in this paper the offered traffic due to handoff was also taken into consideration.

In [6] M. Glabowski and et al also have used Kaufman-Roberts recursion formula. M.Stasiak is also one of the co-author of this paper, so the approach is similar but only the process of calculation of offered traffic has a little difference. In order to incorporate the effect of the neighboring cell, the value of loading factor in any cell is calculated as the sum of the load factor due to the offered traffic in the cell and factor of load factor of a call in neighbor cell.

## **2.2 Poisson Distribution**

In our study, we have assumed that the call is offered to the system with the Poisson's distribution around its mean value. The Poisson distribution is a discrete probability distribution that expresses the probability of a given number of events occurring in a fixed interval of time and/or space if these events occur with a known average rate and independently of the time since the last event.

Some of the situation where it is used are,

- The number of cases of a particular disease in different towns.

- The number of particles emitted by a radioactive source in a given time.
- The number of births per hour during in a day
- The number of telephone call made during a given hour of a day.

Let  $X$  = The number of events in a given interval,

Then, if the mean number of events per interval is ' $\lambda$ '

The probability of observing  $x$  events in a given interval is given by

$$P(X=x) = e^{-\lambda} (\lambda^x / x!) \quad (2.1)$$

$x=0, 1, 2, 3, \dots$

Where, 'e' is a mathematical constant with approx. value of 2.718282

Also, the standard deviation ( $\sigma$ ) and variance ( $\sigma^2$ ) are given by

$$\sigma = \sqrt{\lambda} \quad (2.2)$$

$$\sigma^2 = \lambda \quad (2.3)$$

### 2.3 Markovian Model

In the work done in [1] and [3] have mentioned the behavior of the system when the call following Poisson's distribution is offered, can be explained using Markovial Model. A Markov chain is collection of random variables  $\{X_t\}$  (where  $t$  is 0, 1, ...) having the property that, given the present, the future is conditionally independent of the past. Which means future does not depends on the past but only on the present situation.

If a Markov sequence of random variables  $X_n$  take the discrete values  $a_1, \dots, a_N$ , then

$$P(X_n = a_i | X_{n-1} = a_{i_{n-1}}, \dots, X_1 = a_{i_1}) = P(X_n = a_i | X_{n-1} = a_{i_{n-1}})$$

And the sequence  $x_n$  is called a Markov chain.

## 2.4 Fully Availability Group

The Fully Availability Group (FAG) is a discrete link model that uses complete sharing policy. This system is an example of state-independent system in which the passage between two adjacent states of the process associated with a given-class stream does not depend on the number of busy bandwidth units in the system.

Increasing requirements of modern bandwidth-consuming multimedia applications, the time-effective methods of analysis and designing of switching networks has become crucial. Determining traffic characteristics of multi-service multi-stage switching systems is a complex problem. The classification of traffic sources in a broadband network is reduced to distinguishing the CBR (Constant Bit Rate) sources and the VBR (Variable Bit Rate) sources. The CBR sources have the defined values of emission rate, while the VBR sources require a greater number of parameters to describe the emitted streams.

In multi-rate models resources required for the connections of particular classes are the multiplicity of certain value of bandwidth, the so-called **Basic Bandwidth Unit (BBU)**. In circuit-switched systems, the bandwidth unit is well defined as time slot or channel. While constructing multi-rate models for broadband systems, it is assumed that BBU is the greatest common divisor of the equivalent bandwidths of all call streams offered to the system. The multi-rate systems can be investigated with the method of statistic equilibrium. In the case of the full-availability group carrying multi-rate traffic streams (basic link model), the multi-dimensional process can be exactly reduced to one-dimensional Markov chain. The calculation algorithm of these systems consists in approximating a multi-dimensional service process by the one-dimensional Markov chain, which is characterized by a product form solution.

This leads to a simple formula for recurrence calculation of the occupancy distribution in multi-rate systems. This formula is a generalization of the

Kaufman-Roberts recursion. The generalization consists of the introduction of relevant conditional (state dependent) probabilities of passing between the adjacent states of the system into the Kaufman-Roberts recursion. A decision to admit a new call is determined by the controlling function of the call admission CAC (Call Admission Control) on the basis of traffic parameters and demanded QoS (Quality of Service) parameters of both new and already serviced calls. The effectiveness of the CAC function depends on the adopted algorithm of the assignment of the network resources to individual calls of different traffic classes

### 2.4.1 Model of a Fully Availability Group

Let us consider a multi-rate system with a capacity of ‘V’ basic bandwidth units (BBU) which is serving ‘M’ independent classes of traffic with mean value of intensities as  $\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_M$ . and having Poissons distribution.

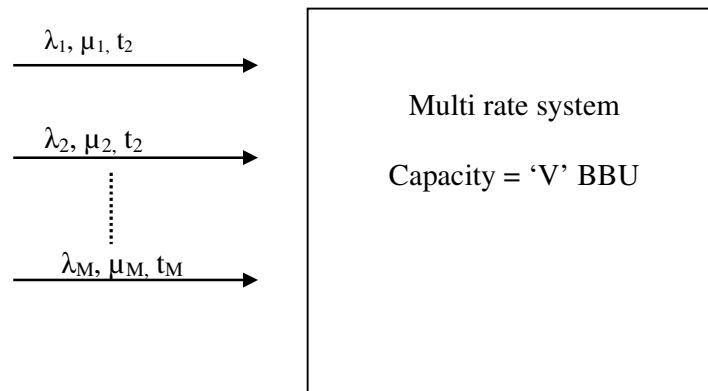


Fig2.1: Example of multi rate system for FAG

Now, if the holding time for the calls of particular class has an exponential distribution with the parameters:  $\mu_1, \mu_2, \mu_3, \dots, \mu_M$ . Then the mean traffic offered to the system by the class ‘i’ traffic stream is given by,

$$a_i = \lambda_i / \mu_i \tag{2.4}$$

Since there is more than one class of traffic, let ‘t<sub>i</sub>’ be the basic bandwidth unit (BBU) required for class ‘i’ traffic to set up a connection.

The micro-state of the system is determined by an ordered set:

$$\Omega = \{x_1, x_2, x_3, \dots, x_M\} \quad (2.5)$$

### 2.4.2 Example of a FAG

In a case with the number of offered traffic classes of 4 i.e., ( $M=4$ ), demanding  $t_1=2$ ,  $t_2=3$ ,  $t_3=1$ ,  $t_4=10$  BBU's respectively, then the state  $\Omega = \{2,0,2,3\}$  means that the system at that state have one call of first class which occupies 2 BBU, 3 calls of second class which occupies 3 BBU each, zero call for third class and 3 calls of 4 class which occupies 10 BBU each. Thus total of

$$2 \times 2 + 0 \times 3 + 2 \times 1 + 3 \times 10 = 36 \text{ BBU}$$

Now if the total capacity of the system was only 40 BBU then it could accommodate 2 more calls of First class of traffic can further be accommodated. Similarly, only 1 more call of second class be accommodated or 4 more call of third class can be accommodated but none of further call from fourth class can be accommodated. Thus, when further call cannot be accommodated and we say the call has been blocked.

### 2.4.3 Total number of Occupied BBU in a FAG system

Each micro-state is related to an appropriate macro-state that determines the number of busy BBU's in the system under consideration, irrespective of the number of serviced calls of particular traffic classes. The total number of busy BBU in the system is equal to

$$n = \sum_{i=1}^M a_i t_i \quad (2.6)$$

### 2.4.4 State Probability in a FAG system

Since, weather a call is blocked or not depends on the capacity of the system which is expressed as 'V' BBU and the number of BBU that have has been occupied, in our case, 'n', the important parameter which play a significant role is to calculate the probability of 'n' BBU being occupied. But for the calculation of

probability of macro state of 'n' number of to be occupied, the summation of probability of different micro state should be done which can be expressed at

$$P(n) = \sum p(x_1, x_2, x_3, x_4, \dots, x_M) \quad (2.7)$$

Now after solving this equation [5] we will finally obtain a recurring expression for the calculation of the probability know as Kaufman-Roberts recursion.

$$nP(n) = \sum_{i=1}^M a_i t_i P(n - t_i) \quad (2.8)$$

This formula helps to determine the occupancy distribution in the full-availability group with different multi-rate traffic stream.

#### 2.4.5 Blocking probability in a FAG

The blocking state in the full-availability group for class 'i' calls occurs only when the group has less than 't<sub>i</sub>' free BBU's required for setting up a connection. The blocking probability for the class 'i' stream, b(i), can be expressed as

$$b(i) = \sum_{n=v-t_i+1}^V P(n) \quad (2.9)$$

#### 2.4.6 Total offered traffic in a FAG system

The different classes of traffic have different intensity of offered traffic. The no. of BBU being occupied depends on the offered traffic of each classes of traffic that is being offered to the system. This in turn determines the state probability of the system and hence governs the blocking probability of a particular class of traffic.

As the total capacity of the system is expressed in terms of BBU, the total traffic in a system is expressed as offered traffic per BBU and given by the equation,

$$A = \frac{\sum_{i=1}^M a_i t_i}{v} \quad (2.10)$$

The unit is Erl/BBU.

**CHAPTER 3**  
**UMTS/WCDMA**

### **3.1 Introduction**

UMTS (Universal Mobile Telecommunications System) is a third generation mobile cellular technology for network based on GSM standard and WCDMA is an air interface for it. UMTS networks are designed from the beginning for flexible delivery of any type of service, where each new service does not require particular network optimization. WCDMA radio solution brings advanced capabilities that enable new services like:

- High bit rates theoretically up to 2 Mbps in 3GPP Release '99, and beyond 10 Mbps in 3GPP Release 5. Practical bit rates are up to 384 kbps initially, and beyond 2 Mbps with Release 5;
- Low delays with packet round trip times below 200 ms;
- Seam less mobility also for packet data applications;
- Quality of Service differentiation for high efficiency of service delivery
- Simultaneous voice and data capability;
- Interworking with existing GSM /GPRS networks.

WCDMA is a Direct Sequence spread CDMA system, where user information bits are spread & sent 3.84 million chips per second over 5MHz radio channel. WCDMA technology allows multiple users to simultaneously use the spectrum where, each user's transmission is separated using orthogonal codes. It allows multiple information streams to be transmitted simultaneously, unlike TDMA (used by GSM), where users are separated by frequency & codes. This technology was developed for bandwidth on demand & concurrent services. [7]

### **3.2 Core network in UMTS**

The Release '99 core network has two domains: Circuit Switched (CS ) domain and Packet Switched (PS) domain, to cover the need for different traffic types WCDMA technology in radio access network is major evolution from GSM

network to 3G. But UMTS core network share the same core network as of GSM as shown in figure.

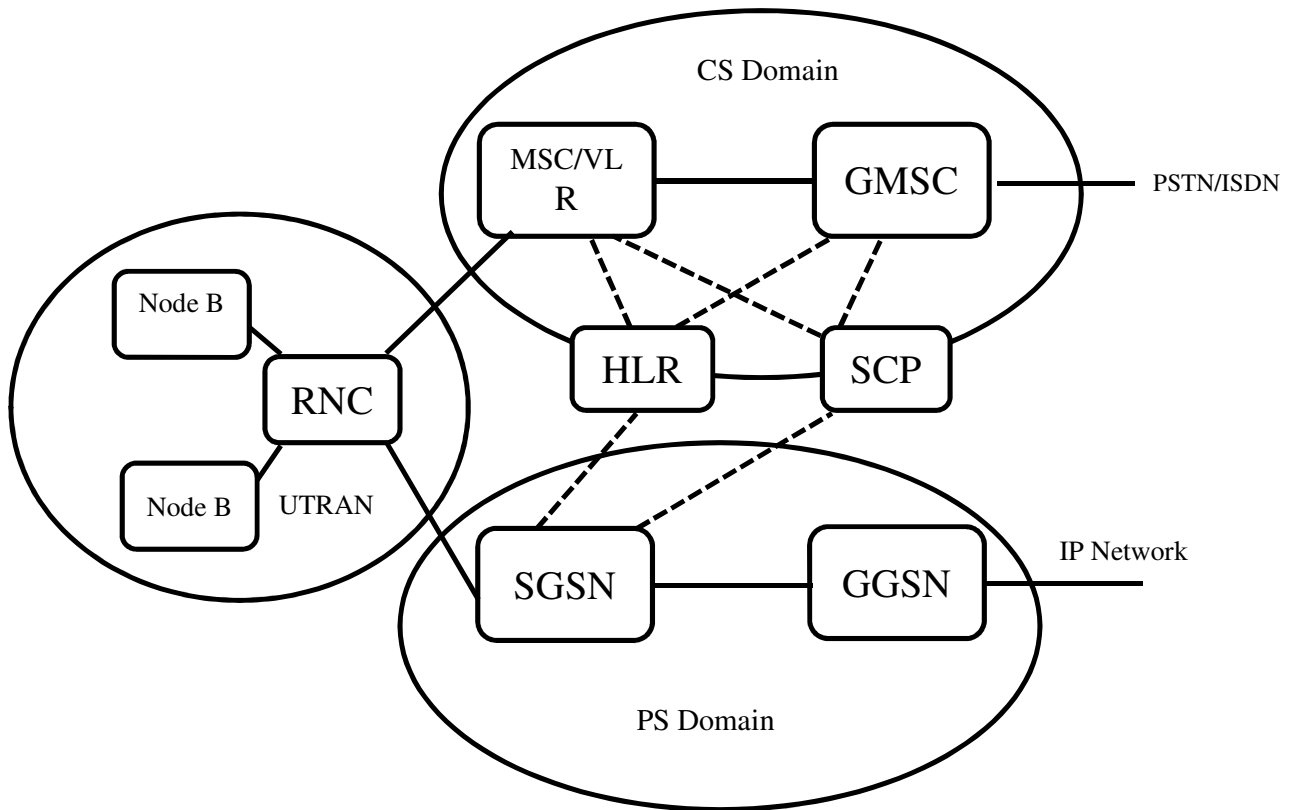


Fig: 3.1 Release '99 UMTS core network structure

The UTRAN is comprised of the User Equipment (UE) which is the handheld equipment carried by the user, Node B which is equivalent to Base Transceiver Station (BTS) of GSM and the Radio Network Controller (RNC) which is equivalent to Base Station Controller (BSC) of GSM. The UTRAN provides transmission paths between the Mobile Stations (MSs) and the NSS, and manages the transmission paths. The Network Sub-System is the brain of the entire UMTS network and is comprised of the Mobile Switching Center (MSC) and four intelligent network nodes known as the Home Location Register (HLR), Visitor Location Register (VLR), Equipment Identity Register (EIR), and the Authentication Center (AuC).

Network elements of core network are mainly divided into two main domains, Circuit Switched (CS) and Packet Switched (PS) domain. The main network elements of these domain are:

- MSC/VLR (Mobile Switching Center/Visitor Location Register):
- GMSC (Gateway MSC)
- HLR (Home Location Register)
- SCP (Service Control Point)
- SGSN (Serving GPRS Support Node)
- GGSN (Gateway GPRS Support Node)

### **3.3 Modes of Operation in WCDMA**

There are two modes of operation defined for the WCDMA air interface. The first mode is **Frequency Division Duplex (FDD)** where there are two separate 5MHz radio-channels- one for uplink (from UE to Node B) & one for downlink (from node B to UE). FDD is used in many 2G systems such as GSM, IS-136 & IS-95 CDMA. FDD requires a 5MHz channel for both the uplink and downlink; it uses the terrestrial paired band portion of UMTS spectrum allocation.

Another mechanism is **Time Division Duplex (TDD)**, where there is only one 5MHz carrier. The single carrier is time shared by both the uplink & downlink. The base station or Node B and the mobile or UE operate on the same 5MHz radio channel & work with each other to coordinate which direction the information is sent at any given time. TDD requires only one channel, therefore it uses terrestrial unpaired band portion of UMTS spectrum. TDD allows the radio interface to be optimally used for asymmetric packet data services. [7]

### **3.4 Classes of services in WCDMA**

Different services that WCDMA provides are grouped as four quality of service classes and are defined as follows: The most delay sensitive real-time applications such as voice or video conversation are in **conversational class**; streaming of audio or video in unidirectional way comes in **streaming class**; application that

are more tolerant to delay and are characterized by a request and response interaction such as web browsing or m-commerce are in **interactive class**; application that do not have strict delay requirements like email or FTP, are grouped into **background class**.

### **3.5 WCDMA a Physical Layer**

WCDMA is the underlying physical layer for the 3G UMTS network. Physical layer is directly related to the achievable performance issues when observing a single link between a terminal station and a base station. The physical layer has a major impact on equipment complexity with respect to the required baseband processing power in the terminal station and base station equipment. As well as the diversity benefits on the performance side, the wideband nature of WCDMA also offers new challenges in its implementation from the service point of view as well, the physical layer cannot be designed around only a single service, such as speech; more flexibility is needed for future service introduction.

The physical layer is required to support variable bit rate transport channels to offer bandwidth-on-demand services, and to be able to multiplex several services to one connection. Data generated at higher layers is carried over the air with transport channels, which are mapped in the physical layer to different physical channels.

The major functions of physical Layer of are

- Protection of the data sent over the air interface
- Channel Separation
- Source Identification

#### **3.5.1 Data Protection:**

Digital coding techniques such as convolutional coding or turbo coding are used to protect the data sent over-the-air interface. Those are known as forward error correction (FEC) because they add information to the data stream to enable the

receiver to correct errors during the decoding process. Interleaving is also used to reorder the coded bit stream to improve the effectiveness of the forward error correction provided by digital coding.

### **3.5.2 Channel Separation:**

Since node-B is transmitting to many users on the same 5MHz channel, channel separation utilizes Orthogonal Variable Spreading Factor (OVSF) codes to identify each user's data stream (or streams). Likewise, the UE uses the same OVSF codes to uniquely identify its data streams sent to the UTRAN. In the process of applying the OVSF codes, the use data stream is spread over the 5MHz Channel.

### **3.5.3 Source Identification:**

In any network there are many node B and UE transmitting simultaneously. In order to detect & decode data from the proper source, scrambling codes are used to uniquely identify a UE in the uplink & a node B in the downlink.

Starting with the voice data stream, the physical layer receives data rate of let us say 7.5kbps (voice data rate is low). The digital coding techniques used to protect the data stream result in additional information in the stream say there is twice the amount of symbol versus bits, resulting into 15ksps data stream. Then this 15ksps (kilo symbols per seconds) data stream is channelized and spread to match the chip rate of UMTS 5MHz channel. The chip rate is fixed at 3.84Mcps (Mega chips per second), which is 256[since,  $15K \times 256 = 3.84M$ ] times the symbol rate in our example. The data rate is kept fixed. If the video call is taken into account, the physical layer receives data at higher rate but our final chip rate should be 3.84Mcps. So, the spreading factor will be less than 256.

## **3.6 Transport Channel and their Mapping to Physical Layer**

Each transport channel is accompanied by the Transport Format Indicator (TFI) at each time event at which data is expected to arrive for the specific transport

channel from the higher layers. The physical layer combines the TFI information from different transport channels to the Transport Format Combination Indicator (TFCI). The TFCI is transmitted in the physical control channel to inform the receiver which transport channels are active for the current frame; The TFCI is decoded appropriately in the receiver and the resulting TFI is given to higher layers for each of the transport channels that can be active for the connection.

### **3.6.1 Dedicated Transport Channel**

The dedicated transport channel carries all the information intended for the given user coming from layers above the physical layer, including data for the actual service as well as higher layer control information. The content of the information carried on the DCH is not visible to the physical layer. The dedicated transport channel carries both the service data, such as speech frames, and higher layer control information, such as handover commands or measurement reports from the terminal.

### **3.6.2 Common Transport Channels**

There are six different common transport channel types defined.

#### **3.6.2.1 Broadcast Channel**

The Broadcast Channel (BCH) is a transport channel that is used to transmit information specific to the UTRA network or for a given cell. The most typical data needed in every network is the available random access codes and access slots in the cell, or the types of transmit diversity method used with other channels for that cell. So, it is needed for a terminal to register in a cell.

#### **3.6.2.2 Forward Access Channel**

The Forward Access Channel (FACH) is a downlink transport channel that carries control information to terminals known to be located in the given cell. This is used, after a random access message has been received by the base station. It is also possible to transmit packet data on the FACH.

### **3.6.2.3 Paging Channel**

The Paging Channel (PCH) is a downlink transport channel that carries data relevant to the paging procedure, that is, when the network wants to initiate communication with the terminal like for example there is a call to the terminal. The identical paging message can be transmitted in a single cell or in up to a few hundred cells, depending on the system configuration.

### **3.6.2.4 Random Access Channel**

The Random Access Channel (RACH) is an uplink transport channel intended to be used to carry control information from the terminal, such as requests to set up a connection. It can also be used to send small amounts of packet data from the terminal to the network.

### **3.6.2.5 Uplink Common Packet Channel**

The uplink common packet channel(CPCH) is an extension to the RACH channel that is intended to carry packet-based user data in the uplink direction. The reciprocal channel providing the data in the downlink direction is the FACH.

### **3.6.2.6 Downlink Shared Channel**

The downlink shared channel (DSCH) is a transport channel intended to carry dedicated user data and/or control information; it can be shared by several users. In many respects it is similar to the forward access channel, although the shared channel supports the use of fast power control as well as variable bit rate on a frame-by-frame basis.

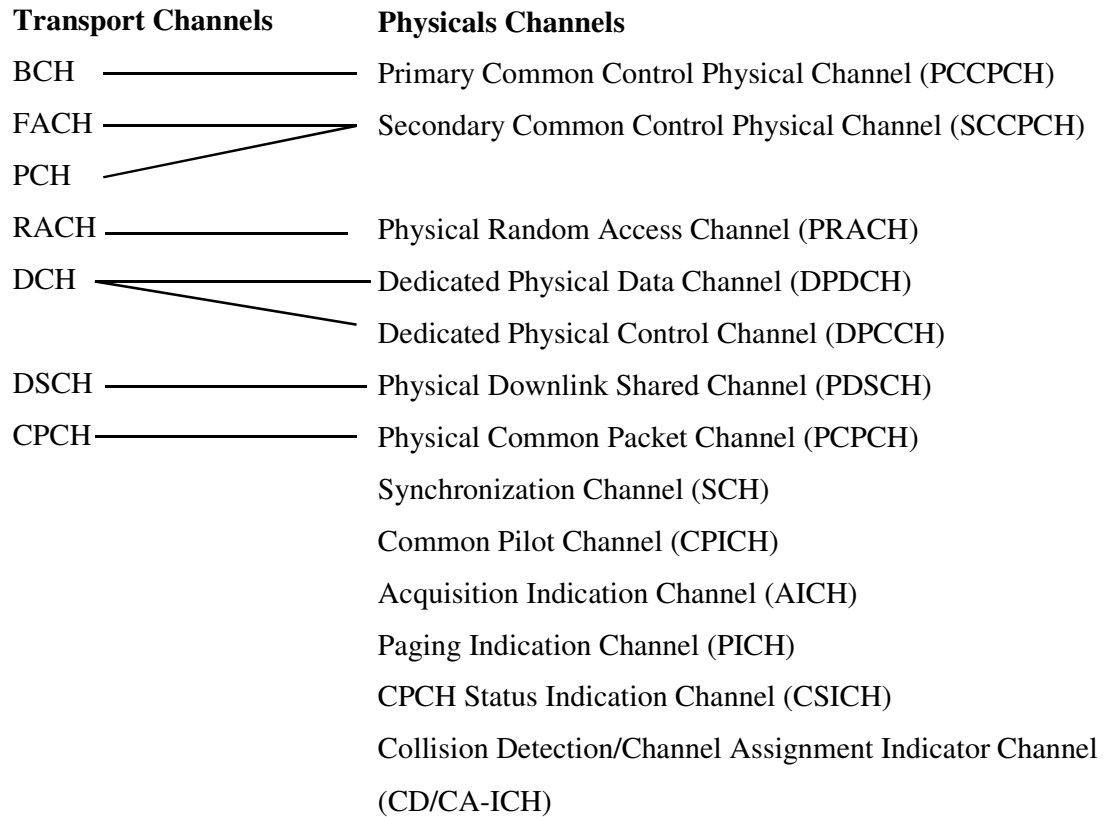


Fig 3.2 Transport Channel to Physical channel mapping

### 3.7 Interference in WCDMA

In WCDMA all users transmit in the same frequency band and their signals are separated by using orthogonal or pseudo-orthogonal codes. Except for the ideal case when real orthogonal codes are used and no multi-path propagation occurs, a user sees the other users' signal as interference. The interference grows with the number of users in the system and limits the uplink capacity. WCDMA admission control is performed on the basis of the measured noise rise. The noise rise is the ratio of the total interference ' $I_o$ ' to the interference of an unloaded system which corresponds to the thermal noise  $N_0$ . The total interference density comprises the own-cell interference  $I_{own}$ , the other-cell interference  $I_{other}$ , and also the thermal noise. The noise rise is then defined as [7]

$$\text{Noise rise} = \frac{I_o}{N_o} = \frac{I_{own} + I_{other} + N_o}{N_o} \quad (3.1)$$

In interference-limited CDMA systems, call admission control is viewed as the means of interference management and plays a key role to guarantee both the grade of service (GoS) and quality of service (QoS) for desired capacity and teletraffic performance. New calls are blocked when the total interference, which is the sum of same cell and other cell interference, is too high or if it reaches a fixed threshold value as defined in the system.

Some of the types of interference as described in [5] are:

i) **co-channel interference:**

It is the interference within a cell. In WCDMA, more than single user are using same frequency channel with the area of a given cell. This will result interference from one user's frequency to others.

ii) **Outer co-channel interference:**

It is the interference from the concurrent users of the frequency channel working within the area of adjacent cells

iii) **Adjacent channel interference:**

It is the interference from the adjacent frequency channels which can be of the very same operator or can be of difference telecom operator as well.

iv) **Other interferences:**

These are the noise and interferences from some other systems and sources than WCDM. It can be both narrowband and broadband.

### 3.8 Uplink Load Factor

Signal reception is possible only when the relation of energy per bit 'E<sub>b</sub>' to noise spectral density 'N<sub>o</sub>' is inside the given range. The theoretical spectral efficiency of a WCDMA cell can be calculated from the load equation.

By definition,

$$\left(\frac{E_b}{N_o}\right)_i = \text{processing gain of user 'i'} \frac{\text{signal of user i}}{\text{Total received power(exclusive of own signal)}}$$

This can be written as, [7]

$$\left(\frac{E_b}{N_0}\right)_i = \frac{W}{v_i R_i} \cdot \frac{P_i}{I_{total} - P_i} \quad (3.2)$$

Where,

$P_i$ : Signal power received from a user of the class 'i' connection

$W$ : chip rate of spreading factor, 3.84Mcps for WCDMA

$v_i$ : activity factor of a user of the class 'i' service

$R_i$ : bit rate of a user of the class 'i' service

$I_{total}$ : total received wideband power including thermal noise power

Solving equation 3.2 we can get,

$$P_i = \frac{1}{1 + \frac{W}{\left(\frac{E_b}{N_0}\right)_i v_i R_i}} I_{total} \quad (3.3)$$

To obtain the load factor  $L_i$  of one connection,  $P_i$  is defined as

$$P_i = L_i I_{total} \quad (3.4)$$

Thus,

$$L_i = \frac{1}{1 + \frac{W}{\left(\frac{E_b}{N_0}\right)_i v_i R_i}} \quad (3.5)$$

The total received interference, excluding the thermal noise  $P_N$ , can be written as the sum of the received powers from all  $N$  users in the same cell

$$I_{total} - P_N = \sum_{i=1}^N P_i = \sum_{i=1}^N L_i \cdot I_{total} \quad (3.6)$$

The noise is defined as the ratio of the total received wideband power to the noise power

$$\text{Noise rise} = \frac{I_{total}}{P_N} \quad (3.7)$$

and using equation 3.5 we can obtain

$$\text{Noise rise} = \frac{I_{\text{total}}}{P_N} = \frac{1}{1 - \sum_{i=1}^N L_i} = \frac{1}{1 - \eta_{UL}} \quad (3.8)$$

where we have defined the load factor  $\eta_{UL}$  as

$$\eta_{UL} = \sum_{i=1}^N L_i \quad (3.9)$$

When  $\eta_{UL}$  becomes close to 1, the corresponding noise rise approaches infinity and the system has reached its pose capacity.

The typical value for  $E_b/N_o$ ,  $v_i$ ,  $L_i$  for these service classes can be expressed as in the following table [7]:

<b>Class of service (i)</b>	<b>Voice call</b>	<b>Video call</b>	<b>Data</b>
W [Mchip per sec]	3.84		
$R_i$ [kbps]	12.2	64	144
$v_i$	0.67	1	1
$(E_b/N_o)_i$ [dB]	4	2	1.5
$L_i$	0.0053	0.0257	0.0503

Table 3.1: Table showing the typical value of  $E_b/N_o$ ,  $v_i$ ,  $L_i$  for different classes of service in WCDMA.

**CHAPTER 4**  
**METHODOLOGY**

The methodologies involve the following work shown in block diagram.

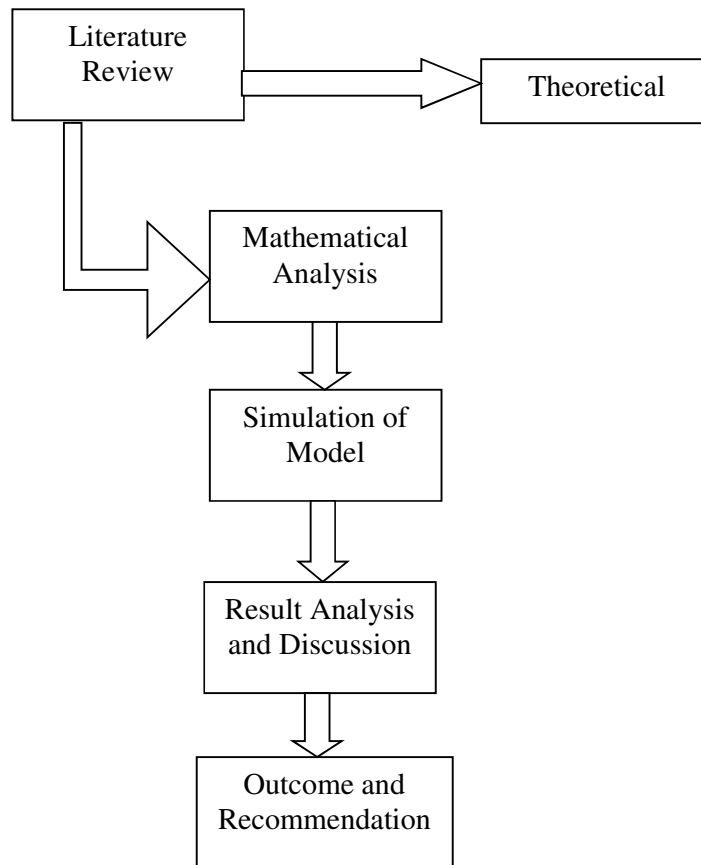


Fig4.1: Methodology flow diagram

The task of research starts with the reviewing of different literatures including IEEE journals. For the study purpose the Markovian model of the WCDMA cell have been taken into account. Mathematical modeling for this method is being studied. And for the single-dimensional approximation of this model Kaufman-Roberts Recursion formula have been used.

The study process includes the following steps:

1. Fully Availability Group approximation of WCDMA Cell.
2. Modeling of voice, video and data traffic in terms of BBU.
3. Capacity consideration of WCDMA cell for FAG approximation

4. Call blocking probability calculation for certain offered traffic.
5. Call blocking probability calculation for variation of total offered traffic.
6. Analysis on the basis of obtained values.

## 4.1 Model of the system

Three main types of traffic in a WCDMA cell are Voice call, Video call and Data. Thus the study focuses on the calculation of blocking probability of a WCDMA cell as a system of Fully Availability Group which serves each of these classes of traffic.

### 4.1.1 Modeling of traffic

The typical values of load factor for different classes of services are obtained from Table 3.1 are,

$$L_1 \text{ for Voice} = 0.0053$$

$$L_2 \text{ for Video} = 0.0257$$

$$L_3 \text{ for Data} = 0.0503$$

Now for BBU calculation,

$$L_{BBU} = \text{GCD} (L_1, L_2, L_3) \quad (4.1)$$

Thus,  $L_{BBU} = 0.0001$

The value of BBU for each class of service is calculated as,

$$t_i = \left[ \frac{L_i}{L_{BBU}} \right] \quad (4.2)$$

Therefore, obtained value of 't<sub>i</sub>' using equation 4.2 is,

$$t_1 \text{ (Voice)} = 53 \text{ BBU}$$

$$t_2 \text{ (Video)} = 257 \text{ BBU}$$

$$t_3 \text{ (Data)} = 503 \text{ BBU}$$

The study focuses on the study of blocking probability of the class of service with variation of load. Instead of taking into account of offered traffic of each class of service the study is carried out with varying overall load i.e., total Erl/BBU is varied across a given range.

#### 4.1.2 Modeling of WCDMA cell

WCDMA cell is considered as a fully availability group with its capacity expressed in BBU. The capacity of the system is determined by percentage of the allowable maximum load to the system. [3] The numerical value of the capacity of the system is given by the equation

$$V_{UL} = \left[ \frac{V}{L_{BBU}} \right] \quad (4.3)$$

where, 'V' is the percentage of maximum allowable traffic in up uplink direction to the theoretical capacity of the system.

Now, considering the maximum allowable traffic in uplink direction to be 30% of the theoretical capacity of the cell,

We obtain the capacity of the cell using equation 4.3 as,

$$V_{UL} = \left[ \frac{30\%}{0.0001} \right]$$

Thus,  $V_{UL} = 3000$  BBU

#### 4.2 Simplification of Kaufman-Roberts Recursion formula

The Kaufman-Roberts recursion formula is given be

$$nP(n) = \sum_{i=1}^M a_i t_i P(n - t_i) \quad (4.4)$$

In this formula we can see that, state probability of 'n' BBU being occupied depends on the state probability of 'n-t<sub>i</sub>' BBU being occupied. We also know that,

$P(k)$  equals to zero when 'k' is an negative number because there is no such case that negative number of BBU is being occupied in the system.

Now the problem with implementing this formula is we cannot directly tell what is the value of  $P(n)$  when ' $n \rightarrow 0$ ' or say the minimum possible value. The value of  $P(n)$  when ' $n \rightarrow 0$ ' is differs for different values of ' $a_i$ ' and ' $t_i$ '. It also depends on the number of classes of traffic that is being offered to the system.

Thus, in order to obtain find the convergence for this recursion formula,

Let us consider,

The probability of a 'k' BBU being occupied is expressed as

$$P(k)=X_k P(0) \tag{4.5}$$

Then,

$$P(0)= X_0 P(0);$$

$$P(1) = X_1 P(0);$$

$$P(2) = X_2 P(0);$$

:

:

$$P(k)=X_k P(0)$$

:

:

$$P(n)=X_n P(0)$$

We know that the summation of probability of all possible states in a system is equal to one.

Thus,

$$P(0) + P(1) + P(2) + \dots + P(k) + \dots + P(n) = 1$$

Using, equation 5.5,

$$P(0)\{X_0 + X_1 + X_2 + \dots + X_k + \dots + X_n\} = 1$$

Therefore,

$$P(0) = \frac{1}{\sum_{j=0}^n X_j} \quad (4.6)$$

Thus, using this equation we can obtain,

$$X_0 = 1 \text{ [Since, } P(0) = X_0 P(0) \text{ ]}$$

$$\text{And, } P(k) = \frac{X_k}{\sum_{j=0}^n X_j} \quad (4.7)$$

Using this very same deduction of the Kaufman-Roberts recursion formula the simulation has been carried out.

### **4.3 Tools Used:**

#### **4.3.1 Turbo C++ 3.0**

For the purpose of obtaining the blocking probability, coding has been done using **Turbo C++ 3.0**. Thus obtained values are then saved into a plain text file. The used of C++ was chosen so that, the deep understanding of each variables governing the calculation of blocking probability of FAG approximation of WCDMA cell could be obtained.

#### **4.3.2 Matlab V7.6.0.324**

For the purpose of plotting of graph, Matlab Version 7.6.0.324 has been used. Matlab was chosen because of the complexity involved in the graphical representation of data in C++. The choice of version of Matlab do not play major

role in the study because only the graph plotting feature of Matlab was used in the study.

**CHAPTER 5**  
**SIMULATION AND RESULTS**

Call blocking probability of the WCDMA cell was calculated with the help of program written in C++. Following are the assumptions under taken for the calculation of the blocking probability.

1. WCDMA cell behaves as a Fully Availability Group.
2. Services offered to the system falls in one of the three category; voice call, video call or data.
3. The percentage of maximum allowable traffic in uplink direction to be 30% of theoretical capacity of the system. Thus,  $V=3000\text{BBU}$
4. The value for Basic Bandwidth Unit for different class of traffic is taken as mentioned in 5.2.1 i.e., for voice call,  $t_1=53\text{BBU}$ ; for video call,  $t_2=257$ ; and for data traffic  $t_3=503$

This study was mainly based on the work done in [3] by M.Stasiak, P. Zwierzykowski, and J. Wiewiora. The authors have work on use of FAG to model the WCDMA cell. In their work in [3] and also in the work done in [6], the analytical value of blocking probability in WCDMA cell have been calculated. Which is then compared with the simulation values and it has been shown that use of FAG approximation for WCDMA cell and calculation of Blocking probability of a call using Kaufman-Roberts recursion formula verifies with the simulation value.

On the basis of their research, this study have been carried out where FAG approximation of WCDMA cell was done and the value of blocking probability for WCDMA cell have been calculated in presence of different classes of service being offered to the system.

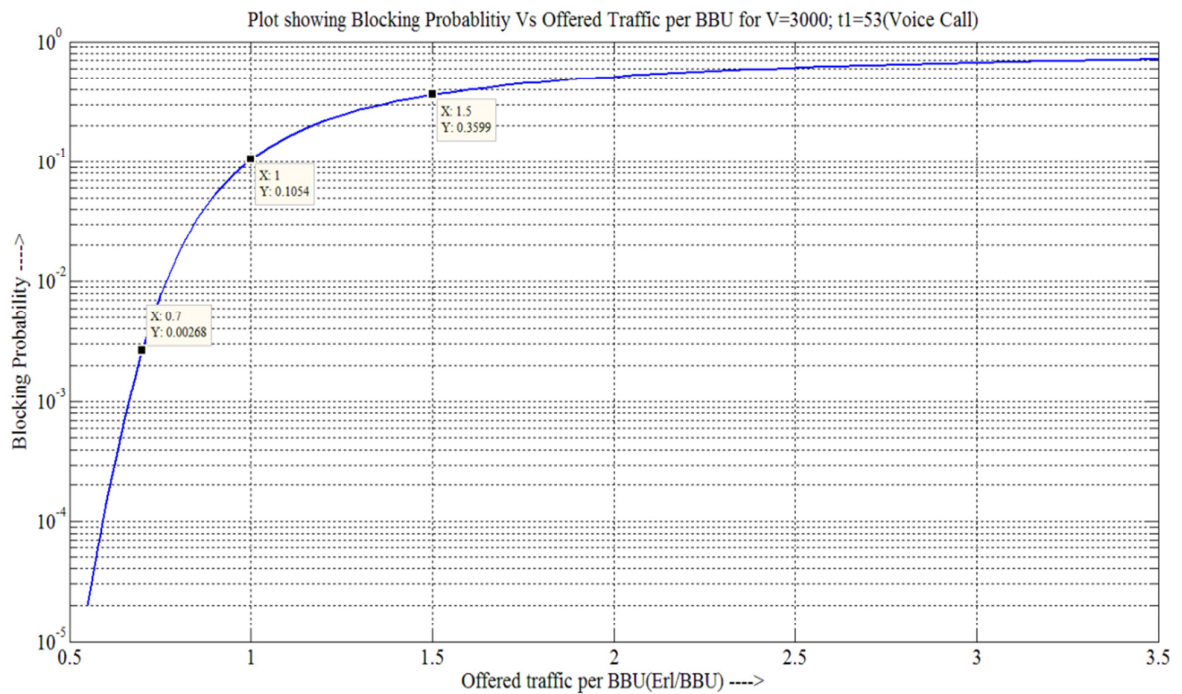


Fig 5.1 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for Voice call

The figure shows the blocking probability when voice call traffic is offered to the system. The value of blocking probability is very less when traffic per BBU is less than one. Rapid change in blocking probability is seen when offered traffic is varied from 0.55 to 1 Erl/BBU. In the graph we can see that for offered traffic is 0.7 Erl/BBU the blocking probability was just 0.2% but when the offered traffic reaches 1 Erl/BBU then the blocking probability was 10.5% which is a substantial amount. And when the offered traffic was 1.5 Erl/BBU a blocking probability of almost 36% indicates that the cell has already been overwhelmed with the traffic that it can handle.

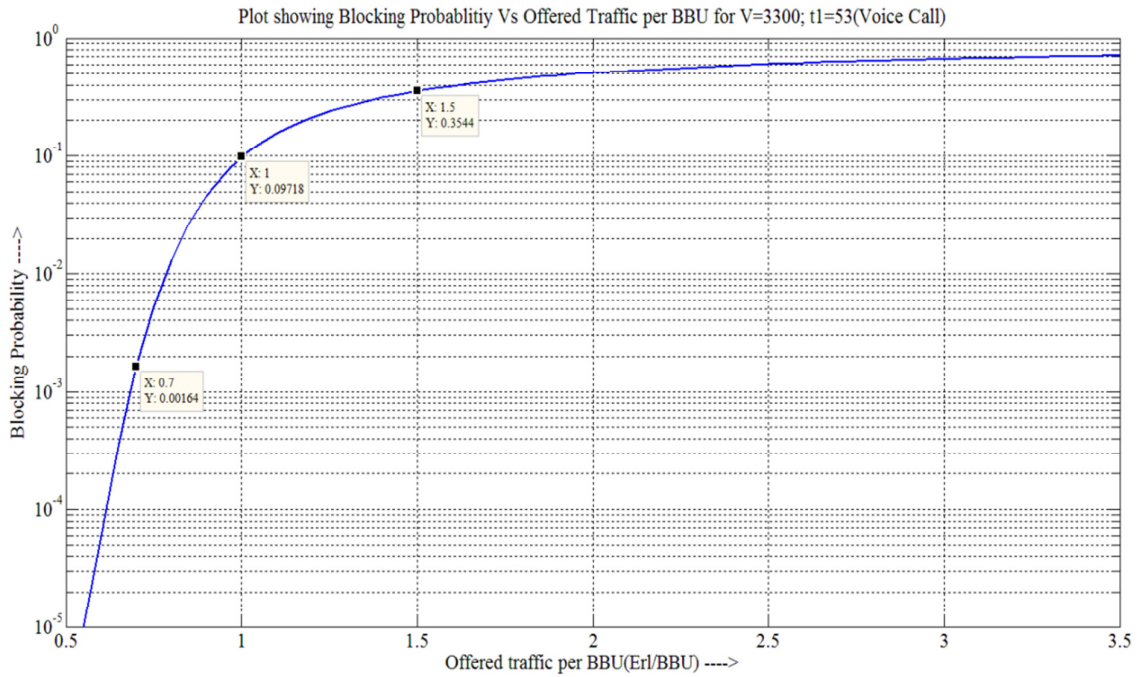


Fig 5.2 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for voice call when system capacity is increased by 10%

Fig 5.2 shows the result when the capacity of the system is increased by 10%. The offered traffic in this case is same as that in previous case. Only voice call was offered to the system. There was not much change in the value of blocking probability and response was also similar to that of the first case. Because of the increase in capacity, we can see slightly decrease in the value of blocking probability which is as expected.

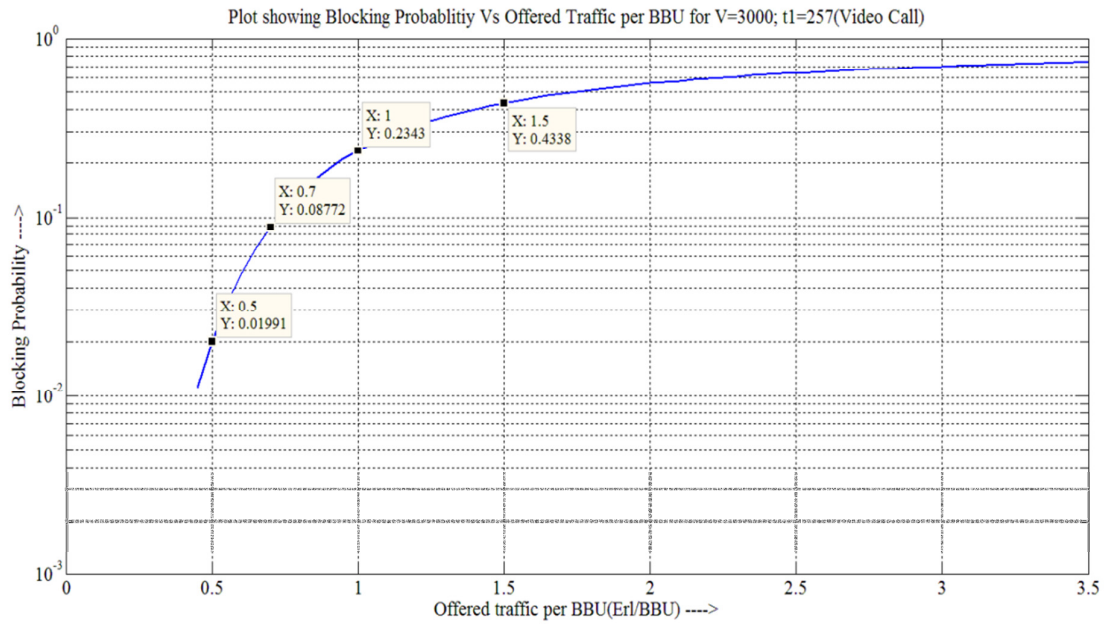


Fig 5.3 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for video call

Fig 5.3 shows the result when the system was offered with the video call traffic only. The blocking probability in this case is quite substantial compare to that of the voice call. Almost 2% blocking is observed even when the offered traffic is just 0.5Erl/BBU. And at offered traffic of 0.7Erl/BBU the blocking probability was 8.7% which was just 0.26% when it was the case with voice call traffic. This rise in call blocking probability was due to the fact that video call demands larger BBU compare to voice call. Here we can see, when the offered traffic was 1.5Erl/BBU the blocking probability was 43.38% which is very high. Thus this shows the capacity of the system should be increased.

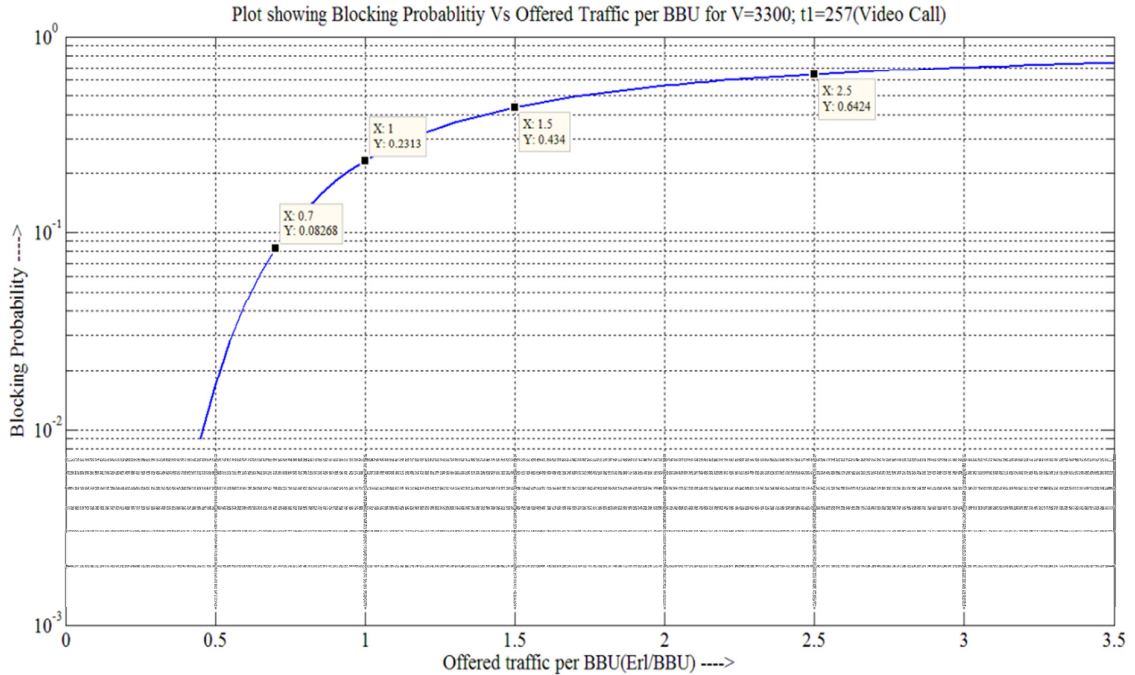


Fig 5.4 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for video call when system capacity was increased by 10 %

Fig 5.4 shows the blocking probability when the system capacity was increased by 10%. The curve shows here shows similar pattern to that of previous one. When the offered traffic was low for example 0.7Erl/BBU there was slight decrease in blocking probability but in interesting fact was observed when offered traffic was 1.5Erl/BBU, the blocking probability instead of decreasing have shown a little increment. This is mainly because, with increase in capacity of the system by 10%, there was increment in one possible state. Here 10% increment in system capacity was addition of 300BBU to the system, whereas BBU of a video call as 257. When system capacity was 300BBU the call would be blocked when the system is serving 11 such calls which is equivalent to  $11 \times 257\text{BBU} = 2827\text{ BBU}$  being occupied. And with the system with increased capacity by 10% the call will be blocking when  $12 \times 257\text{BBU} = 3084\text{BBU}$  is being occupied. Here, using the Kaufman-Roberts recursion formula, for larger value of offered traffic the probability of 3084BBU being occupied in the system of 3300 BBU comes to be greater than 2087BBU being occupied in the system of 3000BBU.

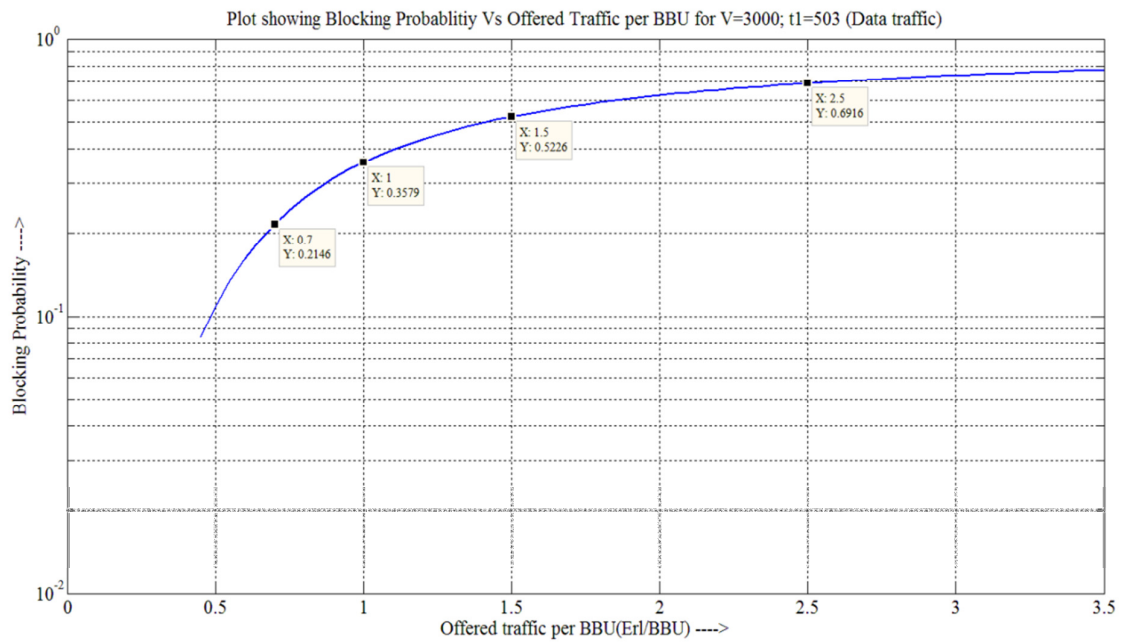


Fig 5.5 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for data traffic of 144kbps

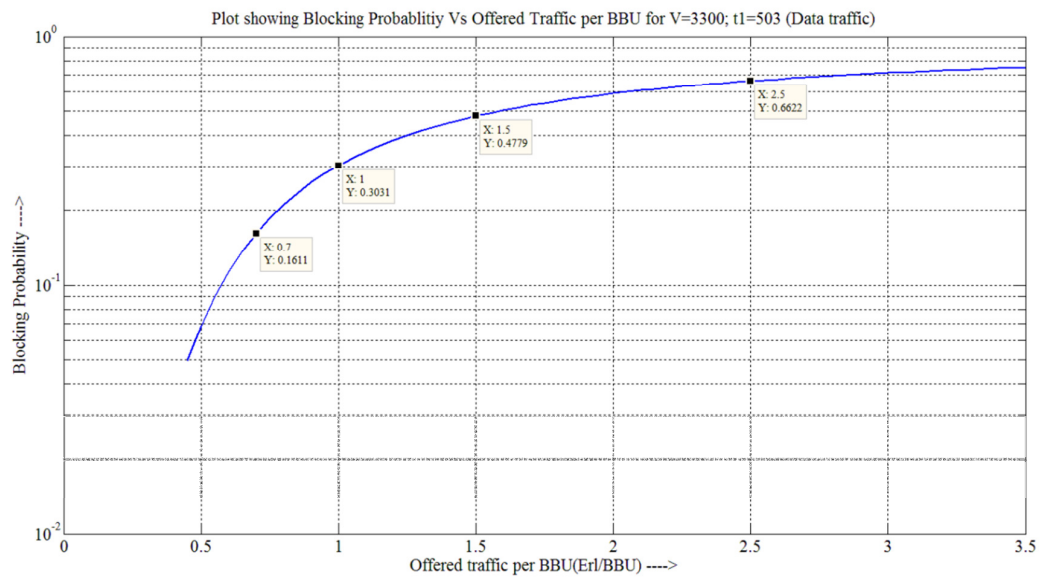


Fig 5.6 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) for data traffic of 144kbps for system capacity increased by 10 %

Fig 5.5 and Fig 5.6 shows the blocking probability with change in offered traffic per BBU. Blocking probability of more than 35% even when the offered traffic was 1Erl/BBU was very substantial. This indicates that system capacity is under dimensioned to handle the data traffic. Slightly improvement in call blocking probability is seen in later case which is in turn as expected because there has been increment to the system capacity.

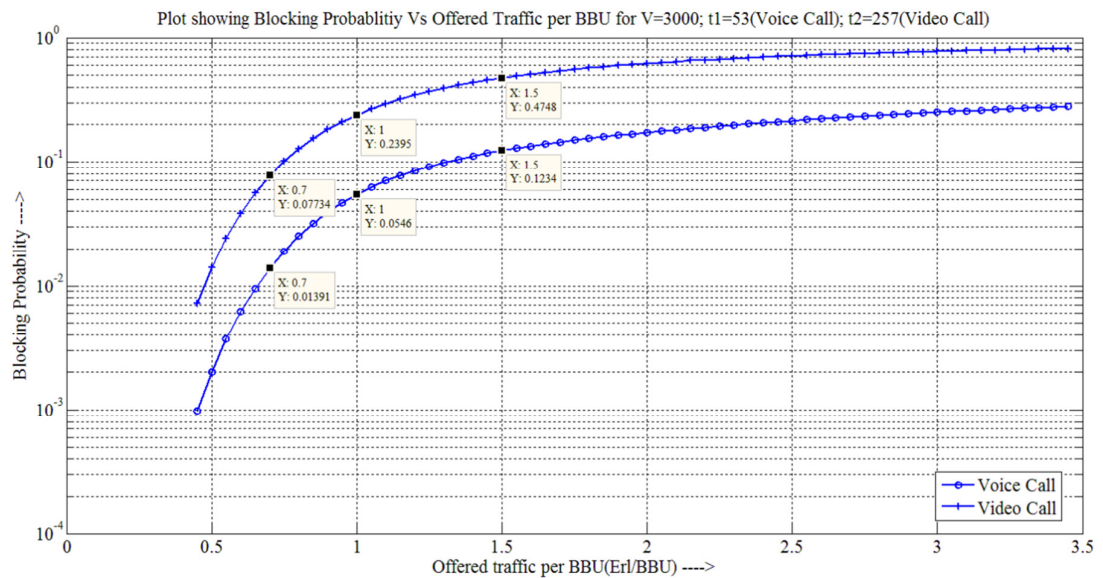


Fig 5.7 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) when both Voice and Video calls are offered to the system

Fig 5.7 shows the blocking probability when both voice and video calls are offered to the system. The result shows for same offered traffic to the system, the call blocking probability of a voice call is lower in later case. This is because, in our assumption, we have assumed that the ratio of offered traffic of voice and video is 1:1. And since the BBU of voice is larger in value, among the total offered traffic, video call is occupying the larger number of BBU. Thus in later case with increase in total offered traffic per BBU the blocking probability of voice will be lower than that when only voice is being offered. And just in opposite manner, blocking probability of voice when offered alone will be higher while compare to the case when both are being offered.

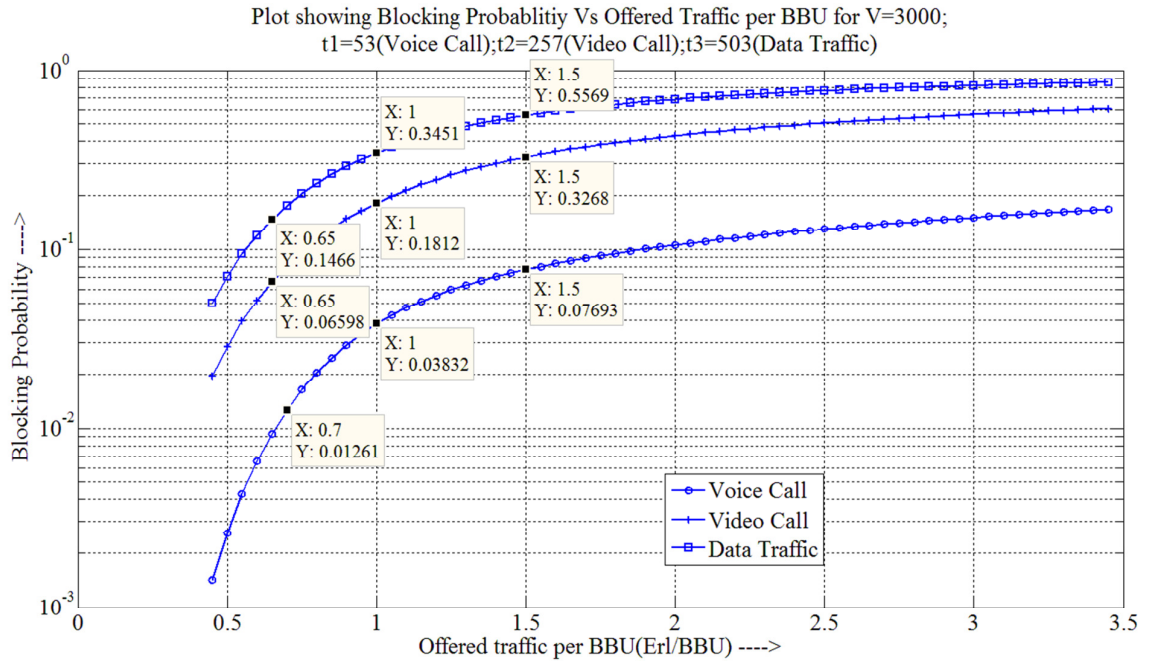


Fig 5.8 Graph Showing the Blocking probability with change in offered traffic per BBU (Erl/BBU) when all the service classes, i.e., Voice, Video and data traffic are offered to the system

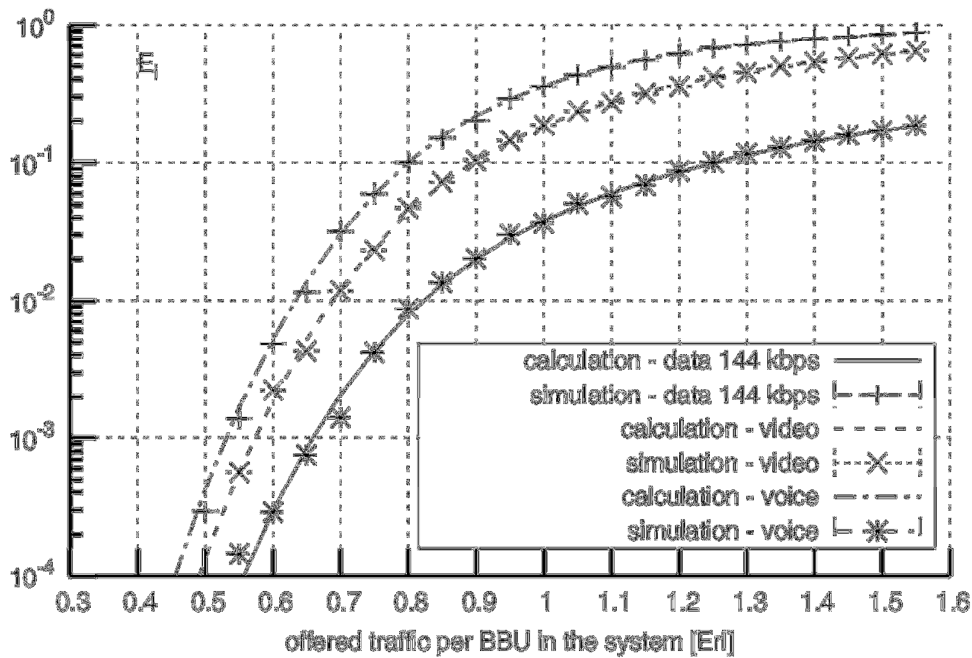


Fig 5.9 Graph obtained by M. Stasaik and et all in [3]

Fig 6.8 and Fig 6.9 show the graphs of blocking probability when all three classes of traffic were offered to the system. Fig 6.9 is the result obtained by M. Stasaik and et al in [3] with the dimensioning of capacity of system to be 800BBU. In his paper he have only mentioned about the possibility of FAG approximation on WCDMA cell which he have verified with the simulation result. In the same manner, I have also used the FAG approximation of WCDMA cell to study the behavior with change is capacity of the cell. The result obtained in Fig 6.8 in my study shows consistency with what is obtained in [3].

If we further look at the result, what we can see is when the offered traffic is further increased from 2Erl/BBU there is not much change in blocking probability and also that the blocking probability of one is not obtained even when the offered traffic is 3.5Erl/BBU. So, an important deduction can be made that the FAG approximation of WCDMA cell may not yield the exact scenario when the offered traffic is too high. In the result published in [3] and [5], the authors also have calculated blocking probability for maximum value of offered traffic of 1.5Erl/BBU but have not mentioned weather the FAG approximation holds true for larger value of offered traffic or not.

Following table shows the result of change in probability when capacity of system was increased by 10% i.e., 'V' incremented from 3000 to 3300.

Offered Traffic (Erl/BBU)	Voice Call		Video Call		Data		Change		
	V=3000	V=3300	V=3000	V=3300	V=3000	V=3300	Voice Call (%)	Video Call (%)	Data traffic (%)
<b>0.70</b>	0.00268	0.00164	0.08772	0.08268	0.21463	0.16112	38.81	5.75	24.93
<b>0.75</b>	0.00762	0.00529	0.11075	0.10577	0.24071	0.18586	30.58	4.50	22.79
<b>0.80</b>	0.01728	0.01322	0.13499	0.13025	0.26604	0.21044	23.50	3.51	20.90
<b>0.85</b>	0.03256	0.0268	0.15989	0.1555	0.29049	0.23461	17.69	2.75	19.24
<b>0.90</b>	0.0532	0.04611	0.18497	0.18101	0.31397	0.25819	13.33	2.14	17.77
<b>0.95</b>	0.07799	0.07009	0.20988	0.20637	0.33644	0.28105	10.13	1.67	16.46
<b>1.00</b>	0.10541	0.09718	0.23434	0.2313	0.35789	0.30311	7.81	1.30	15.31
<b>1.05</b>	0.13412	0.12589	0.25816	0.25557	0.37833	0.32433	6.14	1.00	14.27
<b>1.10</b>	0.16309	0.15504	0.2812	0.27905	0.39779	0.34467	4.94	0.76	13.35
<b>1.15</b>	0.19162	0.18387	0.30339	0.30164	0.41629	0.36414	4.04	0.58	12.53
<b>1.20</b>	0.21928	0.21187	0.32468	0.3233	0.43387	0.38276	3.38	0.43	11.78
<b>1.25</b>	0.24582	0.23876	0.34507	0.34402	0.45058	0.40053	2.87	0.30	11.11
<b>1.30</b>	0.27114	0.26442	0.36454	0.36379	0.46647	0.4175	2.48	0.21	10.50
<b>1.35</b>	0.29518	0.28879	0.38312	0.38265	0.48157	0.43369	2.16	0.12	9.94%
<b>1.40</b>	0.31796	0.31187	0.40084	0.40061	0.49594	0.44913	1.92	0.06	9.44%
<b>1.45</b>	0.33952	0.33371	0.41773	0.41771	0.50961	0.46387	1.71	0.00	8.98%
<b>1.50</b>	0.35991	0.35436	0.43382	0.4340	0.52263	0.47793	1.54	-0.04	8.55%

Table: 5.1: Table showing the call blocking probability with change in offered traffic for

This table shows the change in blocking probability of a call with change in offered traffic per BBU to the system. Here, we can also see that when the system capacity was increased by 10% there is substantial change in blocking probability of a call. The significant change in blocking probability was obtained when there was low offered traffic. This is because at that time the absolute value of call blocking probability was low in itself.

## **CHAPTER 6**

### **CONCLUSION AND FUTURE ENHANCEMENT**

## **6.1 Conclusion**

Here I have performed the call blocking analysis of WCDMA cell using FAG approximation and by using Kaufman-Roberts Recursion formula. The call blocking analysis has been performed by calculating the blocking probability of the call. The result shows the increase in blocking probability with offered traffic per Erlang. Also that, that for the same offered traffic it is observed that the call blocking probability for video call is higher than that of the voice call and blocking probability of data is higher than that of the voice call.

The most important part of the thesis was to realize the WCDMA cell as FAG system. This proposition was made in [3] and [6]. Thus, the realization of WCDMA cell as FAG was carried out. Such analytical process can be beneficial for both parties, equipment manufacturing vendors as well as telecom operators. The study was concise to the use of FAG approximation in WCDMA cell only, but with appropriate value of loading factors and system dimensioning, it can also be used for other networks as well. In this study it is also observed the blocking probability almost being constant after the offered traffic per Erlang reaches beyond 2.5Erl/BBU. So, it have been observed that this method can be beneficial and gives proper result only when the offered traffic is between certain range.

## **6.2 Limitation and Future Work**

There are various limitations in the study which opens the door for the future enhancement of the work. Some the limitations are mentioned as bellow:

- Only three classes of traffic have been taken into consideration.
- For calculating the loading factor of data traffic only 144kps data rate is taken into consideration
- Priority of certain class of traffic has not been taken into consideration while calculating the blocking probability

- When multiple classes of traffic are offered to the system, the ratio is taken to be 1:1 but in practical cases, voice call are more dominant in the network
- For the simulation purpose, Turbo C++ has been used, so the limitation associated with the tool is also inherited in the study process such as the size of variable. Some problems were faced when the system capacity was considerable higher compare to the BBU of offered traffic.

Future enhancement of the work mainly includes the remedy of the limitations mentioned above. The study presents the use of FAG approximation to perform the call blocking analysis by calculating the blocking probability of the call. The FAG approximation is an important tool thus it can further be explored to calculate the blocking probability in more complex cellular architecture like that of LTE. But this will require extensive research for system dimensioning and BBU approximation of the classes of traffic which would be served in the LTE cell.

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