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Faculty of Engineering

Electrical & Electronic Engineering

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M.Sc. Thesis

UMTS Multi-Services Capacity Evaluation for Uniform & Normal User Distributions

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Communications Engineering

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M.Sc. ***Thesis Title:***

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UMTS MULTI-SERVICES CAPACITY EVALUATION FOR UNIFORM & NORMAL USER DISTRIBUTIONS

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Lastly, I acknowledge the support and inspiration given by my family in pursuing and achieving this work.

Abstract

UMTS is a 3G system that uses WCDMA as a radio access technology which allows handover with the existing GSM system. This feature among others makes UMTS one of the most prominent 3G systems.

WCDMA specifications are issued in phases called releases, the first release implemented commercially is release 99 (R99). Later, WCDMA specifications have been evolved with the addition of a new feature called HSDPA (High Speed Downlink Packet Access) in Release 5. The goal of HSDPA is to increase the system capacity by increasing the data rate and reduce the round trip delay.

In WCDMA systems the capacity is interference limited, i.e. the maximum capacity is determined by the level of interference in the cell. Two main sources of interference are assumed, the intra-cell interference caused by the users of the same cell, and the inter-cell interference caused by the adjacent cells.

In this thesis, system capacity of both 3GPP R99 and HSDPA network are examined through system level simulations with focus on the downlink capacity as it is more likely to be the bottleneck of the system capacity because of the asymmetric nature of new services, such as Internet traffic.

The capacity results for voice only system, mixed voice and data system are analyzed and compared. Further, the capacity influence by the type of users' distribution in the cell is designed through simulation and later discussed. The effect of the cell isolation on the system capacity also studied. Conclusion of this work with some recommendation are also presented

تقييم سعة نظام UMTS متعدد الخدمات وفق التوزيع الطبيعي والتوزيع المنتظم للمشتركين

إعداد : عبدالكريم يوسف غريب
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ملخص:

نظام UMTS هو أحد أنظمة الجيل الثالث للهاتف النقال و يستخدم تقنية WCDMA التي تسمح بالتسليم والاستلام مع نظام GSM المنتشر حاليا. هذه الميزة بالإضافة لمزايا أخرى تجعل نظام UMTS أحد أهم أنظمة الجيل الثالث للهاتف النقال.

يتم إصدار مواصفات تقنية WCDMA على مراحل وتسمى إصدارات، أول إصدار تم تنفيذه بشكل تجاري هو (R99) . مواصفات WCDMA تم تطويرها لاحقا لتشمل تقنية الحزم ذات السرعة العالية في الوصلة الهابطة (HSDPA) في الإصدار R5. تهدف هذه الميزة لزيادة سعة النظام بزيادة معدل تدفق البيانات وتقليل وقت الإرسال والاستقبال في حزم البيانات.

تكون سعة النظام في تقنية WCDMA محددة بمستوى التداخل. أي أن معدل التداخل في الخلية يحدد السعة القصوى لها، حيث يوجد بشكل رئيسي مصدرين للتداخل في الخلية وهما التداخل الناشئ بسبب مستخدمي الخلية نفسها، والتداخل الناشئ من الخلايا المجاورة.

يتطرق هذا البحث لدراسة شبكات R99 وشبكات HSDPA عن طريق محاكاة على مستوى النظام مع التركيز على الوصلة الهابطة لأنها العامل الأهم في تحديد سعة النظام بسبب طبيعة البيانات غير المتماثلة في الخدمات الجديدة مثل الانترنت.

تم تحليل السعة لنظام المكالمات الصوتية فقط ونظام المكالمات الصوتية مع خدمات البيانات و مقارنتها. كذلك تم دراسة تأثر السعة بكيفية توزيع المستخدمين في الخلية. كما تم دراسة السعة للخلايا المعزولة، وفي نهاية البحث تم تقديم ملخص لنتائج البحث مع بعضاً من التوصيات.

Table of Content

I. INTRODUCTION

II. OVERVIEW OF MOBILE COMMUNICATION SYSTEMS

III . WCDMA FOR UMTS

IV. ANALYTICAL MODLEING & SIMULATION ALGORITHM

V. RESULTS AND DISCUSSION

VI. CONCLUSIONS & RECOMMENDATIONS

APPENDICES

List of Figures appendices

List of Tables:

List of Abbreviations

2G	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
ACK	Acknowledgement
AMC	Adaptive Modulation and Coding
ARQ	Automatic Repeat Request
BS	Base Station
BER	Bit Error Rate
BLER	Block Error Rate
CDMA	Code Division Multiple Access
CN	Core Network
CQI	Channel Quality Indicator
DL	Downlink
DS-CDMA	Direct-Sequence Code Division Multiple Access
EDGE	Enhanced Data Rates for GSM Evolution
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FTP	File Transfer Protocol
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat Request
HCS	Hierarchical Cell Structure
HHO	Hard Handover
HO	Handover
HSCSD	High Speed Circuit Switched Data
HSDPA	High Speed Downlink Packet Access
HTTP	Hypertext Transfer Protocol
IMT-2000	International Mobile Telecommunications - 2000
IP	Internet Protocol
ITU	International Telecommunications Union
LOS	Line-of-Sight
MCS	Modulation and Coding Scheme
MS	Mobile Station
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RNC	Radio Network Controller

RRC	Radio Resource Control
RRM	Radio Resource Management
SF	Spreading Factor
SHO	Soft Handover
SIR	Signal to Interference Ratio
TBS	Transport Block Size
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TPC	Transmit Power Control
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication Services
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband Code Division Multiple Access
WWW	World Wide Web

CHAPTER 1

INTRODUCTION

1.1 Background

The goal for the next generation of mobile communications system is to seamlessly provide a wide variety of communication services to anybody, anywhere, anytime. The intended services for next generation mobile phone users include services like transmitting high speed data, video and multimedia traffic as well as voice signals. The technology needed to tackle the challenges to make these services available is popularly known as the Third Generation (3G) Cellular Systems. The first generation systems are represented by the analog mobile systems designed to carry the voice application traffic. Their subsequent digital counterparts are known as second generation cellular systems. Third generation systems mark a significant jump, both in applications and capacity, from the current second generation standards. Whereas the current digital mobile phone systems are optimized for voice communications, 3G communicators are oriented towards multimedia message capability.

The introduction of multimedia services in third generation networks implies an increase in the bandwidth requirements. In order to accommodate the growth in capacity and bandwidth needs, the World Administrative Radio Conference (WARC) of the ITU (International Telecommunications Union) has identified extended spectrum for 3G, around the 2GHz band. Additionally, the third generation technology proposals, known within the ITU as IMT-2000, use improved, more sophisticated modulation schemes, so as to maximize the new spectrum allocation. First, the goal of ITU was the standardization of on global 3G system, but for different reasons this did not happen and more than 3G standard emerged. In Europe and most of the middle east 3G system is referred to as UMTS (Universal Mobile Telecommunication System).

UMTS uses WCDMA as a radio access technology and standardized by 3GPP (Third Generation Partnership Project). 3GPP issues its standard in release started by Release 99 (R99)

The WCDMA specifications up to Release 99 support data rates up to 2 Mb/s in indoor/small-cell-outdoor environments and up to 384 Kb/s with wide area coverage for packet-switched data. However, this figure has been felt as insufficient in the near future considering the upcoming growing-demands for packet-data services, primarily in the downlink. There-fore, the WCDMA specifications have been evolved in two stages within 3GPP in order to enhance higher packet-data rate. The first step has been to improve the downlink capacity and the second step targets for the uplink. The enhancement of downlink capacity of WCDMA system has been described as a feature known as **High Speed Downlink Packet Access** (HSDPA) in Release 5 of 3GPP specifications. The main goal of HSDPA has been to allow WCDMA to support downlink peak data rate in the range of approximately 10-14 Mb/s for best effort packet-data services. In addition to this, HSDPA targets to achieve lower round-trip delay and increased capacity. This enhancement has been based on the principle of sharin ra transmission channel, where a certain amount of power and code resource has been dynamically shared between different users, mainly in the time domain. Through this technology, both users and operators will get benefited; the users will achieve better user experience by shorter download times due to higher bit rates and operators will get greater system capacity.

1.2 Motive

The air interface capacity of a WCDMA cell is not pre-determined from the available spectrum amount and thus it cannot be planned very accurately. That is, the capacity is dependent on the performance of the receivers in a time varying environment and also on the interference within its own network and the spectrally adjacent network. The capacity might also be limited by the maximum available number of spreading codes and hardware resources. One of the most challenging parts of radio network planning is the estimation of the required traffic since the radio network planner has to know, at least approximately, what kind of services are going to be used, the likely user locations and hot-spot areas. It is also crucial to know the degree of asymmetry in multimedia services. In web-browsing, for example, the downlink traffic is larger than the uplink traffic and this has to be taken into account during network planning as well.

In most cases the WCDMA network capacity is interference limited and thus the radio network planning can be considered as being the control of the interference throughout the system. When the number of users or user bit-rates increases, the interference level rises, subsequently increasing the coverage threshold (Required received power) requiring the MS and BS to raise their transmission power in order to achieve the required performance. When a MS transmits at maximum Tx power, then it's on the edge of the cell. In this case, any rise in the interference level will result in dropping the edge user from the cell. That means when the load of the cell and therefore the interference increases, the coverage area shrinks. The change of the cell range due to change of the load of the cell is usually referred as "cell breathing". i.e. more cell load lead to lower coverage area and vice versa.

1.3 Research Objective

The primary source of interference in WCDMA network is the intra-cell and the inter-cell interference. Intra-cell (own cell) interference is caused by the users of the same cell where the reuse factor is 1, and depends on the orthogonality factor of the cell which indicates the degree of orthogonality between user codes. Inter-cell (adjacent cell) interference is caused by the adjacent cells working on the same frequency band (the same layer), and reflects the degree of cell isolation from the surrounding cells.

The effect of both inter-cell and intra-cell interference will be studied beside other important factor affecting the system capacity which is the user locations distribution in the cell. In WCDMA where fast power control is involved, the user locations affect the interference level and consequently the system capacity.

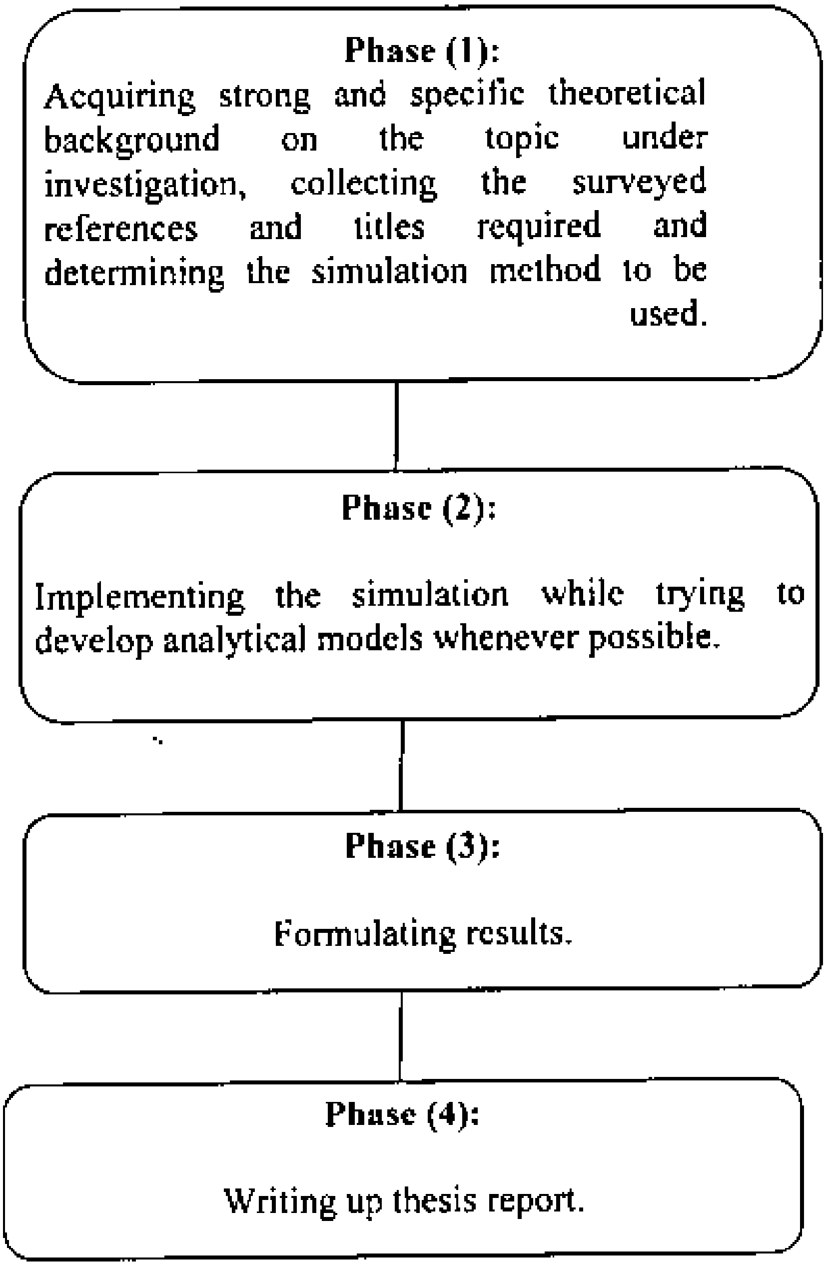
The goal of this thesis is to develop a simulation tool to study:

- The performance of UMTS networks in terms of system capacity in an interference limited environment, emphasizing the effect of orthogonality, cell isolation and the users distribution.

- The improvement of system capacity when introducing HSDPA (R5 feature) as compared to R99 system.

1.4 Scope of work

This work is divided into 4 phases as in the following flow chart:



Phase (1):

Acquiring strong and specific theoretical background on the topic under investigation, collecting the surveyed references and titles required and determining the simulation method to be used.

Phase (2):

Implementing the simulation while trying to develop analytical models whenever possible.

Phase (3):

Formulating results.

Phase (4):

Writing up thesis report.

1.5 Previous work

UMTS networks are designed to support both voice and data services. High-speed downlink packet access (HSDPA) is included in Release 5 of the WCDMA specifications to increase downlink capacity and bitrates. There is much research on the mixed traffic performance in UMTS Release 99 and HSDPA [1,2,3].

Study [1] provides an overview of the physical layer aspects of HSDPA and discusses the improvements in sector and user throughput (with respect to Release-99 UMTS) resulting from HSDPA with joint scheduling and resource allocation.

Study [2] considers performance aspects of streaming applications over HSDPA in a mixed streaming and best-effort service scenario. Different scheduling algorithms are evaluated with the aim of providing sufficient quality-of-service for streaming.

Study [3] provides packet scheduler design and performance simulations for running VoIP (Voice over IP) services over high-speed downlink packet access (HSDPA) in WCDMA. VoIP capacity results for HSDPA have been presented for different scheduling algorithms and delay budget parameter settings. It has been demonstrated that HSDPA is also attractive for transmission of VoIP, as it provides higher voice capacity compared to Release'99 DCH.

1.6 Chapters description

The second chapter of the thesis is a general overview on the mobile communication technology and mobile system evolution

Chapter 3 is dedicated to the 3G systems starting with the standardization of 3G system describing the features and structure of UMTS system ending with HSDPA description

Chapter 4 illustrates how the system parameters are modeled and the derivation of equations necessary to develop a simulation algorithm for downlink capacity as it's the limiting factor in the case of asymmetric data traffic.

In Chapter 5 different system scenarios are simulated with a discussion of the results.

The conclusion of the thesis is presented in chapter 6 followed by some recommendations for future work.

CHAPTER 2

OVERVIEW OF MOBILE COMMUNICATION SYSTEMS

2.1 CONCEPTS OF CELLULAR SYSTEM

In the beginning, mobile systems were developed much like radio or television broadcasting (i.e., a large area was covered by installing a single, high-power transmitter in a tower situated at the highest point in the area). A single high-power transmitter mobile radio system gave good coverage with a small number of simultaneous conversations depending on the number of channels

To increase the number of simultaneous conversations, a large area can be divided into a large number of small areas. Each small area is called a cell. To cover a cell, a single low-power transmitter is required. Cells in real life are more or less circular, but unfortunately circular cells do not "tessellate." (A shape is said to tessellate if copies of it can be placed side by side across a piece of paper without leaving any gaps and without any overlap.) A hexagon is quite close in shape to a circle and does tessellate and so most cells are drawn as hexagons to ease understanding [9].

Based on the radius of the cells, there are three architectures of cellular networks [8]:

1. Macrocells;
2. Microcells;
3. Picocells.

2.1.1 Macrocellular Radio Networks

Macrocells are mainly used to cover large areas with low traffic densities. These cells have radius between 1 and 10 km. A distinction between large macrocells and small macrocells should be made. Large macrocells have radius between 5 and 10 km or even higher. They are used for rural areas. Small cells have radii between 1 and 5 km. These cells are used if the traffic density in large cells is so high that it will cause blocking of calls.

2.1.2 Microcellular Radio Networks

Microcellular radio networks are used in areas with high traffic density, like urban areas. The cells have radius between 200m and 1 km [8]. For such small cells, it is hard to predict traffic densities and area coverage. Models for such parameters prove to be quite unreliable in practice. This is because the shape of the cell is time dynamic (i.e., the shape changes from time to time) due to propagation characteristics. Antennas are placed at street lamp elevations, surrounding buildings block signals propagating to adjacent cochannel cells. This improves the ability to reuse frequencies, as cochannel interference is reduced drastically by the shadowing effect caused by the infrastructure.

2.1.3 Picocellular Radio Networks

Picocells or indoor cells have cell radius between 10 and 200m. For indoor applications, cells have three-dimensional structures. Today, picocellular radio systems are used for wireless office communications. Various propagation characteristics of these types of networks are given in Table 2.1.

Table 2.1 Cellular network types [8]

Cell type	Size	Transmission power	Antenna height/ location	Path loss exponent	Signal characteristics	Rms Delay spread	Use
Macrocell	2-20km diameter	0.6-10W	>30m, top of tall building	2-5	Rayleigh fading and lognormal shadowing	< 8 μs	Large area coverage – reduce infrastructure cost
Microcell	0.4-2km diameter	<20mW	<10m street lamp elevation	Dual path – Low	Rician fading and lognormal shadowing	<2μs	Urban area coverage
Picocell	20-400m diameter	On the order of few milliwatts	Ceiling / top of book shelf	1.2-6.5	Rician fading	50-300ns	Mainly for indoor areas with high terminal capacity

2.2 Evolution of Mobile Networks

In 1980 the mobile cellular era had started, and since then mobile communications have undergone significant changes and experienced enormous growth.

2.2.1 First-generation analogue mobile systems

First-generation mobile systems used analogue transmission for speech services. In 1979, the first cellular system in the world became operational by Nippon Telephone and Telegraph (NTT) in Tokyo, Japan. The system utilized 600 duplex channels over a spectrum of 30 MHz in the 800 MHz band, with a channel separation of 25 kHz. In Europe the two most popular analogue systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). In 1981, the NMT-450 system was commercialized by NMT in Scandinavia. The system operated in the 450 MHz and 900 MHz band with a total bandwidth of 10 MHz. TACS, launched in the United Kingdom in 1982, operated at 900 MHz with a band of 25 MHz for each path and a channel bandwidth of 25 kHz. Extended TACS was deployed in 1985. Other than NMT and TACS, some other analogue systems were also introduced in 1980s across the Europe. For example, in Germany, the C-450 cellular system, operating at 450 MHz and 900 MHz (later), was deployed in September in 1985. All of these systems offered handover and roaming capabilities but the cellular networks were unable to interoperate between countries. This was one of the inevitable disadvantages of first-generation mobile networks. In the United States, the Advanced Mobile Phone System (AMPS) was launched in 1982. The system was allocated a 40-MHz bandwidth within the 800 to 900 MHz frequency range. In 1988, an additional 10 MHz bandwidth, called Expanded Spectrum (ES) was allocated to AMPS[7].

2.2.2 Second-generation mobile systems

Second-generation (2G) mobile systems were introduced in the end of 1980s. Low bit rate data services were supported as well as the traditional speech service. Digital transmission rather than analogue transmission was used by these systems. Consequently, compared with first-generation systems, higher spectrum efficiency, better data services, and more advanced roaming were offered by 2G systems. In Europe, the Global System for Mobile Communications (GSM) was deployed to provide a single unified standard. This enabled seamless services through out Europe by means of international roaming. The earliest GSM system operated in the 900 MHz frequency band with a total bandwidth of 50 MHz. During development over more than 20 years, GSM technology has been continuously improved to offer better services in the market.

New technologies have been developed based on the original GSM system, leading to some more advanced systems known as 2.5 Generation (2.5G) systems. So far, as the largest mobile system worldwide, GSM is the technology of choice in over 190 countries with about 787 million subscribers [7].

In the United States, there were three lines of development in second-generation digital cellular systems. The first digital system, introduced in 1991, was the IS-54 (North America TDMA Digital Cellular), of which a new version supporting additional services (IS-136) was introduced in 1996. Meanwhile, IS-95 (cdmaOne) was deployed in 1993. The US Federal Communications Commission (FCC) also auctioned a new block of spectrum in the 1900 MHz band (PCS), allowing GSM1900 to enter the US market.

In Japan, the Personal Digital Cellular (PDC) system, originally known as JDC (Japanese Digital Cellular) was initially defined in 1990. Commercial service was started by NTT in 1993 in the 800 MHz band and in 1994 in the 1.5 GHz band.

Second-generation digital cellular systems still dominate the mobile industry throughout the whole world. However, they are evolving towards third generation (3G) systems because of the demands imposed by increasing mobile traffic and the emergence of new type of services. The new systems, such as HSCSD (High Speed Circuit Switched Data), GPRS (General Packet Radio Service), and IS-95B, are commonly referred as generation 2.5 (2.5G). HSCSD, GPRS and EDGE are all based on the original GSM system. HSCSD is the first enhancement of the GSM air interface: it bundles GSM timeslots to give a theoretical maximum data rate of 57.6 kbit/s (bundling 4×14.4 kbit/s timeslots). HSCSD provides both symmetric and asymmetric services and it is relatively easy to deploy. However, HSCSD is not easy to price competitively since each timeslot is effectively a GSM channel.

Following HSCSD, GPRS is the next step of the evolution of the GSM air interface. Other than bundling timeslots, 4 new channel coding schemes are proposed. GPRS provides "always on" packet switched services with bandwidth only being used when needed. Therefore, GPRS enables GSM with Internet access at high spectrum efficiency by sharing time slots between different users. Theoretically, GPRS can support data rate up to 160 kbit/s. Deploying GPRS is not as simple as HSCSD because the core network needs to be upgraded as well.

EDGE uses the GSM radio structure and TDMA framing but with a new modulation scheme, 8QPSK, instead of GMSK, thereby increasing by three times the GSM throughput using the same bandwidth. EDGE in combination with GPRS will deliver single user data rates of up to 384kbit/s.

2.2.3 Third-generation mobile systems and beyond

The massive success of 2G technologies is pushing mobile networks to grow extremely fast as ever-growing mobile traffic puts a lot of pressure on network capacity. In addition, the current strong drive towards new applications, such as wireless Internet access and video telephony, has generated a need for a universal standard at higher user bitrates. Figure 2.1 shows the bit rate requirements for some of the applications that are predicated for 3G networks. Most of the new services require bitrates up to 2 Mbit/s.

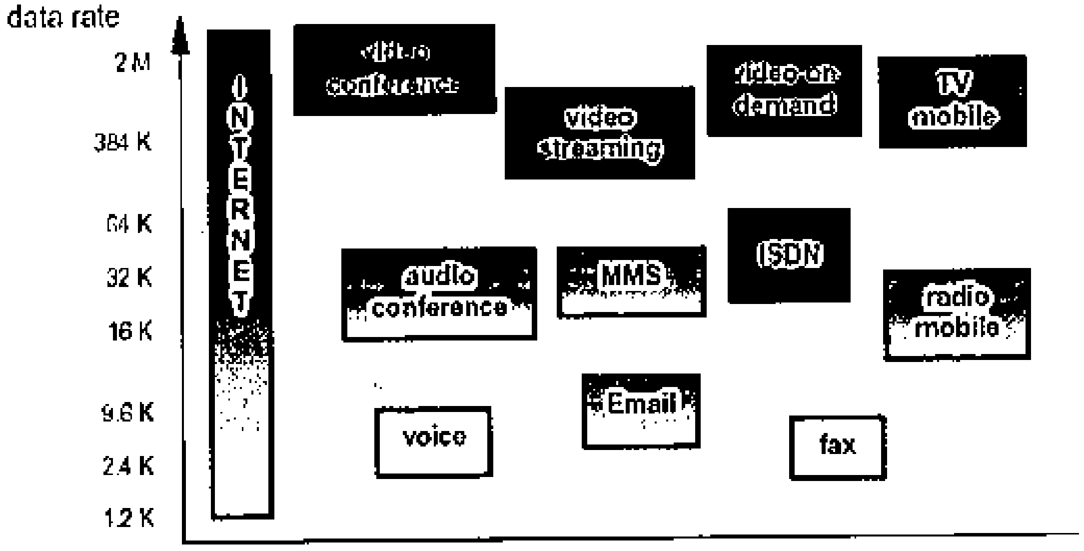


Figure 2.1 Bit rate requirements for 3G applications.

Because of these drivers, the International Telecommunications Union (ITU) has been developing 3G since 1985. 3G networks are referred to as IMT-2000 within ITU and UMTS (Universal Mobile Telecommunications Services) in Europe [7]. UMTS system performance evaluation is the subject of our thesis with a focus on the air interface capacity that uses WCDMA technology.

2.3 Mobile propagation channel

2.3.1 Introduction

The propagation loss is caused by the fact that the signal spreads out from the transmitter as if on the surface of a sphere. This is the so-called "free space propagation." The area of the surface is proportional to the radius squared, and hence the signal strength is inversely proportional to the distance squared from the transmitter to the receiver. This is written mathematically as $1/d^2$, where d is the distance from the transmitter.[9]

Measurements of mobile radio channels have found that, in practice, the signal strength decreases more quickly than $1/d^2$. Most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver, and where the presence of high buildings causes severe diffraction loss. Due to multiple reflections from various objects, the electromagnetic waves travel along different paths of varying lengths. The interaction between these waves causes multipath fading at a specific location.

For mobile channel a propagation models have been set to be used in coverage calculations in network planning. Of the available propagation models the Okumura–Hata model is most frequently referred to.

2.3.2 Okumura–Hata Model

The Okumura–Hata model is widely used for coverage calculation in macro-cell network planning. Based on measurements made by Y. Okumura in Tokyo at frequencies up to 1920 MHz, these measurements have been fitted to a mathematical model by M. Hata.

In the original model path loss was computed by calculating the empirical attenuation correction factor for urban areas as a function of the distance between the BS and the MS and the frequency. This factor was added to the free space loss. The result was corrected by the factors for BS antenna height and MS antenna height. Further correction factors were provided for street orientation, suburban and open areas, and irregular terrain.

Hata's formulas are valid when the frequency is 150–1000 MHz, the BS height is 30–200 m, the MS height is 1–10m and the distance is 1–20 km. The BS antenna height must be above the rooftop level of the buildings adjacent to the BS. Thus, the model is proposed to be used in propagation studies of macro-cells. Owing to frequency-band limitation, the original model was tailored by COST231, resulting in a COST231–Hata model with a range of 1.5–2.0 GHz, which is also applicable to 3G radio networks[6].

Based on this model the path loss in the 2GHz range for urban macrocellular environment given by:

$$L_p = 138.8 + 35.2\log(d)\ \text{dB} \quad \ldots\ldots\ldots\ldots (2.1)$$

And for suburban areas:

$$L_p = 129.4 + 35.2 * \log10(d)\ \text{dB} \quad \ldots\ldots\ldots\ldots (2.2)$$

2.4 multiple access techniques

Mobile cellular systems use various techniques to allow multiple users to access the same radio spectrum at the same time. In fact, many systems employ several techniques simultaneously. This section introduces the most important three techniques[3]:

- *Frequency-division multiple access* (FDMA);
- *Time-division multiple access* (TDMA);
- *Code-division multiple access* (CDMA);

An FDMA system divides the spectrum available into several frequency channels (Figure 2.2). Each user is allocated two channels, one for uplink and another for downlink communication. This allocation is exclusive; no other user is allocated the same channels at the same time.

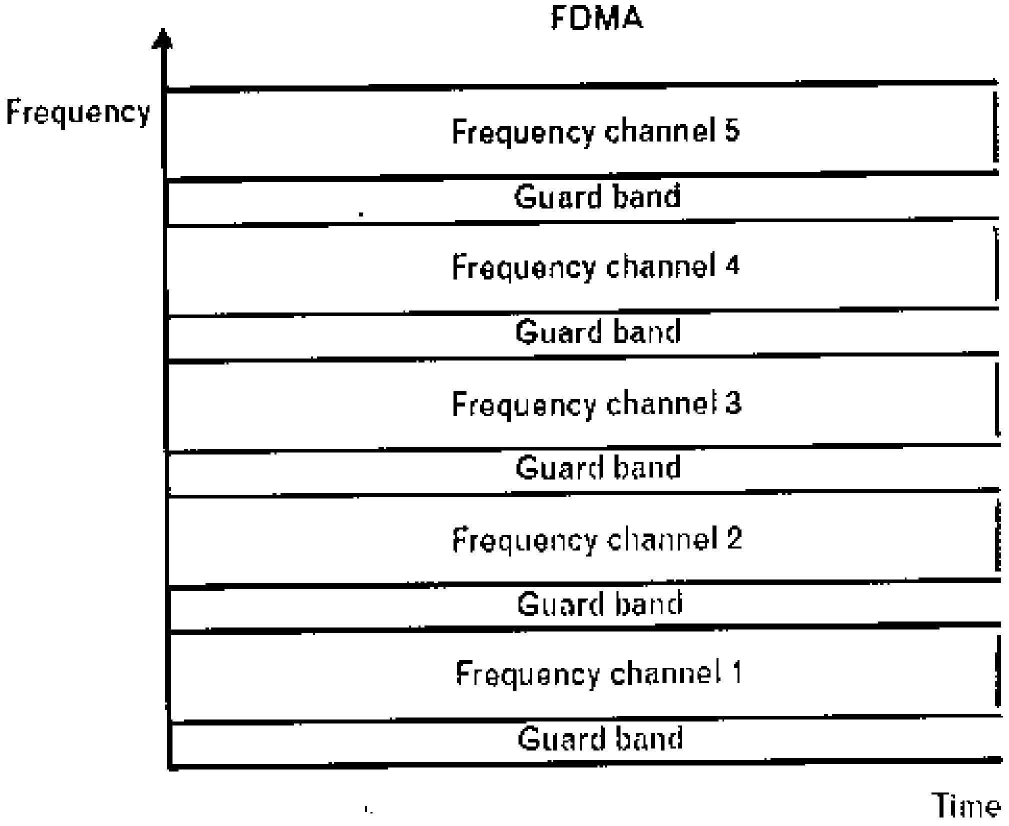


Figure 2.2 Time-frequency space allocation FDMA system

In a TDMA system (Figure 2.3), the entire available bandwidth is used by one user, but only for short periods at a time. The frequency channel is divided into time slots, and these are periodically allocated to the same user so that other users can use other time slots. Separate time slots are needed for the uplink and the downlink. GSM is based on TDMA technology. In GSM, each frequency channel is divided into several time slots (eight per radio frame), and each user is allocated one (or more) slot(s). In a TDMA system, the used system bandwidth is usually divided into smaller frequency channels. So in that sense GSM is actually a hybrid FDMA/TDMA system, as are most other 2G systems.

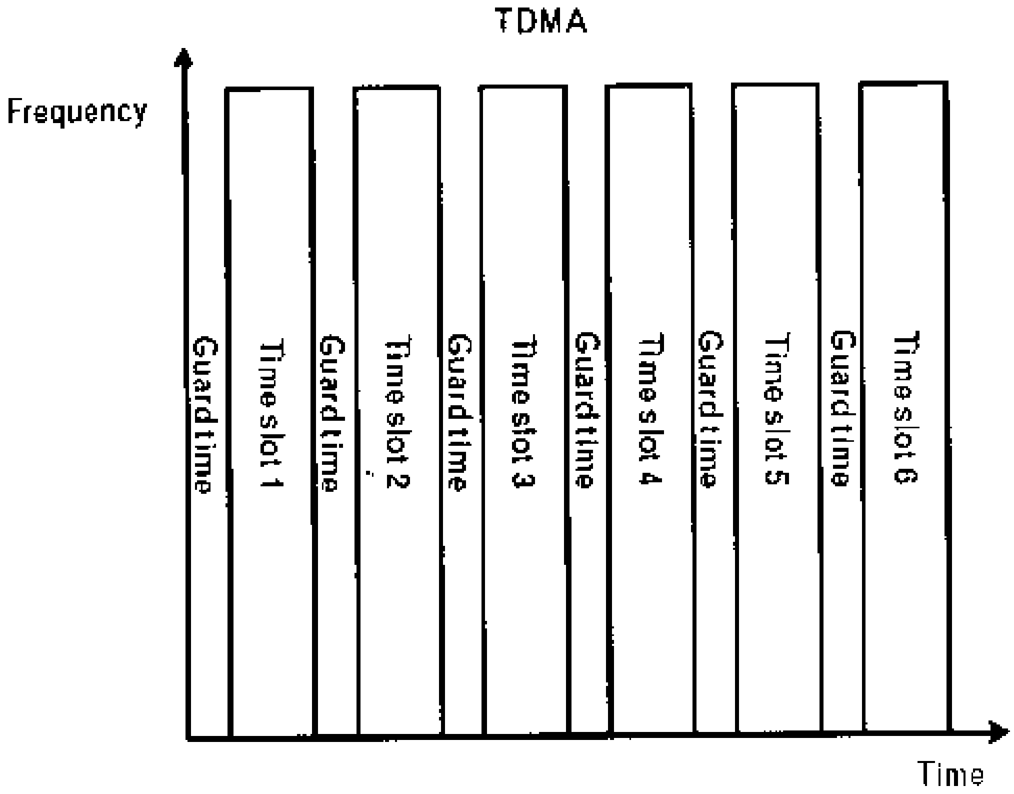


Figure 2.3 Time-frequency space allocation for TDMA system

In a CDMA system all users occupy the same frequency at the same time, no time scheduling is applied, and their signals are separated from each other by means of special codes (Figure 2.4). Each user is assigned a code applied as a secondary modulation, which is used to transform a user's signals into a spread-spectrum-coded version of the user's data stream. The receiver then uses the same spreading code to transform the spread-spectrum signal back into the original user's data stream. The following section gives more details on spread spectrum and CDMA.

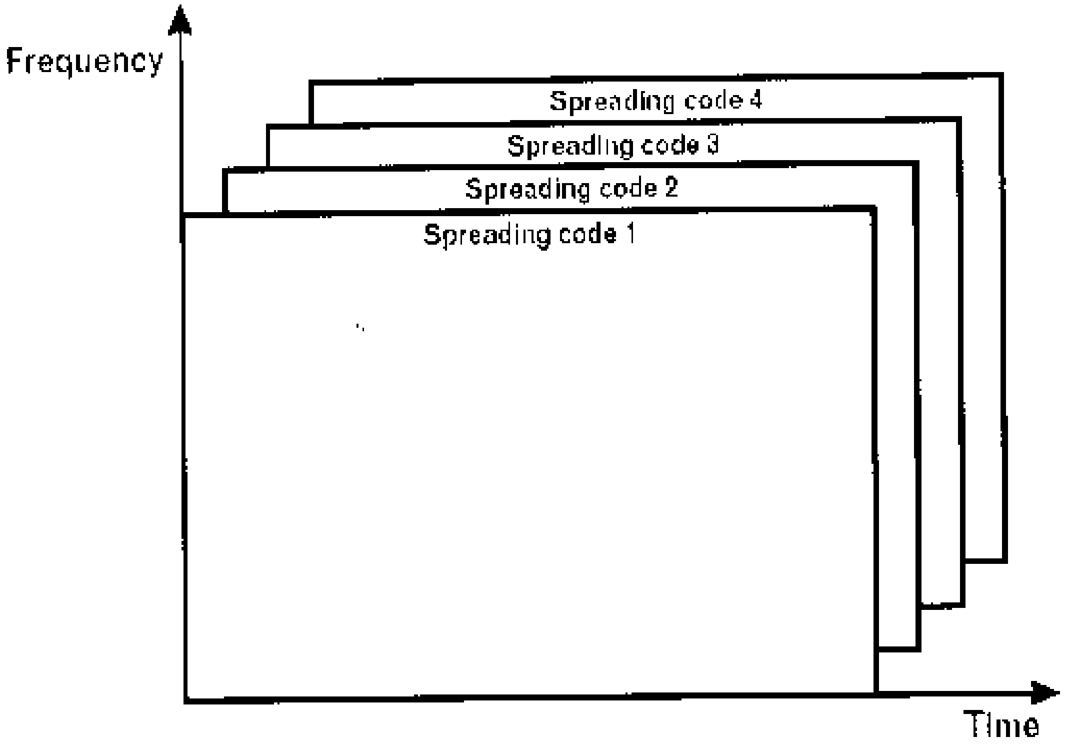


Figure 2.4 Time-frequency-code space allocation for CDMA system

2.5 spread spectrum and CDMA

2.5.1 Basic Principles of Spread Spectrum

The basic concept of spread spectrum communications is to transmit a signal using a bandwidth that is much wider than the signal bandwidth. Several modulation and coding schemes, such as wideband frequency modulation and Forward Error Correction (FEC) coding, result in increased transmission bandwidth but are not considered spread spectrum.

The following criteria are necessary for a system to be classified as spread spectrum system [12]:

i. The transmitted signal energy must occupy a bandwidth which is much larger than the information bandwidth and which is approximately independent of the information bandwidth.

ii. Demodulation must be accomplished, in part, by correlation of the received signal with a replica of the signal used in the transmitter to spread the information signal.

The purpose of transmitting a signal with a bandwidth wider than required is to improve the communications system performance. Spread spectrum systems have the following properties, which are utilized to improve performance relative to narrow band communications systems.

- ***Multiple access.*** A spread spectrum system allows multiple users to transmit simultaneously in the same transmission bandwidth. This is accomplished by assigning each user a unique code from a set of codes with low cross-correlation properties. Codes with low-cross correlation properties are also termed orthogonal spreading codes. Demodulation by correlating the received signals with the desired code will recover the desired signal. The undesired signals will remain spread over the transmission bandwidth and will contribute noise power to the desired signal-to-noise ratio (S/N). This is illustrated in Figure 2.5. Unlike TDMA or FDMA schemes, Spread Spectrum Multiple Access (alternatively CDMA) do not have a hard limit on the maximum number of users. Increasing the number of users both decreases the S/N ratio for existing users, and increases BER for all users.

- ***Multipath interference reduction.*** A spread spectrum system is capable of reducing multipath interference. This interference produces frequency selective fading of the received signal. Multipath interference is reduced by correlating the received signals with the spreading code to recover the desired signal.

Multipath signals with large distortions in amplitude, phase or time delay will appear uncorrelated with the spreading code and will remain spread.

- ***Privacy***. A spread spectrum system offers some degree of privacy because the spreading code is required to recover the transmitted signal.
- ***Anti-jamming***. A spread spectrum system is capable of reducing the effects of narrowband jamming. This is possible because correlating the jamming signal with the spreading code in effect spreads the jamming signal while despreading the desired signal.
- ***Low Probability of Intercept (LPI)***. Spread spectrum signals are difficult to detect, a characteristic termed Low Probability of Intercept, because the signal power is dispersed over a wide bandwidth. The transmitted signal is then difficult to distinguish from noise.

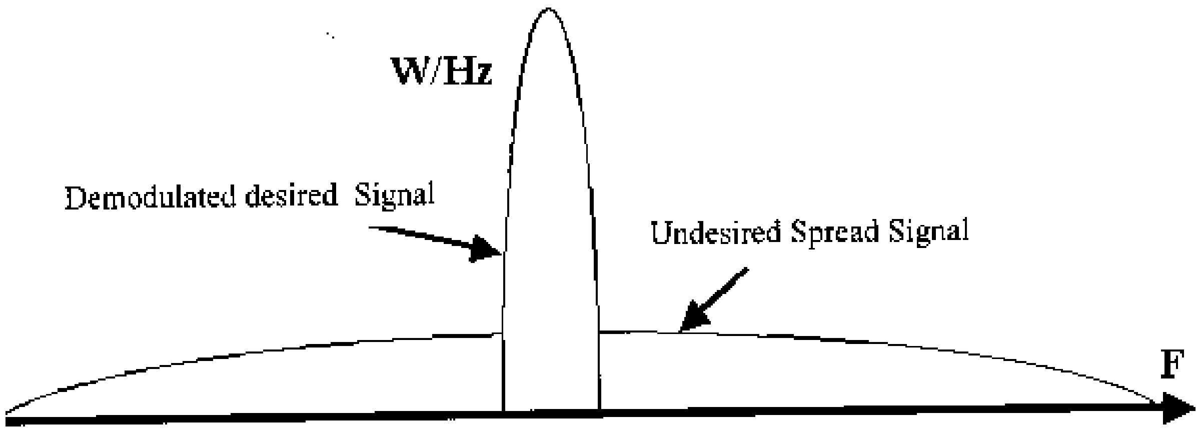


Figure 2.5 Demodulation in CDMA system

2.5.2 Types of Spread Spectrum Multiple Access

There is several modulation techniques used to generate spread spectrum signals. A Pseudorandom Noise (PN) sequence is typically used as a spreading code to convert a narrowband signal into a wideband, noise-like signal. Two types of spread spectrum exists, Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS), the latter is used in UMTS systems and explained below.

In DSSS the data signal is modulated by a PN code sequence that effectively spreads the signal power over a wide bandwidth. The block diagram of a DSSS transmitter is shown in Figure 2.6. The PN spreading code is a digital signal that takes on values of +1and -1, and the number of code bits (chips) per second is commonly called the chip rate (R_c). The chip rate is typically much larger than the data symbol rate (R_s), which results in the desired spreading in the frequency domain. The Spreading Factor (SF) of a DSSS system is the ratio of R_c to R_s.

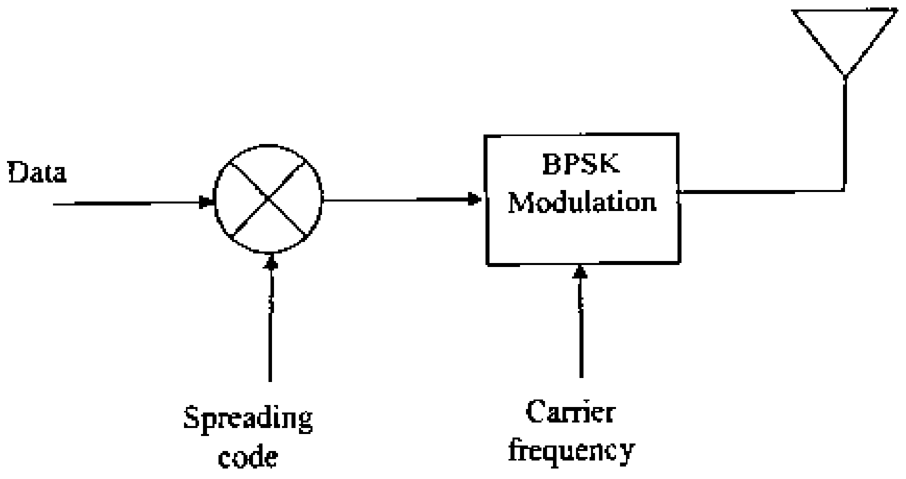


Figure 2.6 Block diagram of DSSS transmitter

During despreading, the spread user data (chip) sequence is multiplied bit by bit with the same code chips as used during the spreading process. As shown in figure 2.7, the original user data is recovered perfectly.

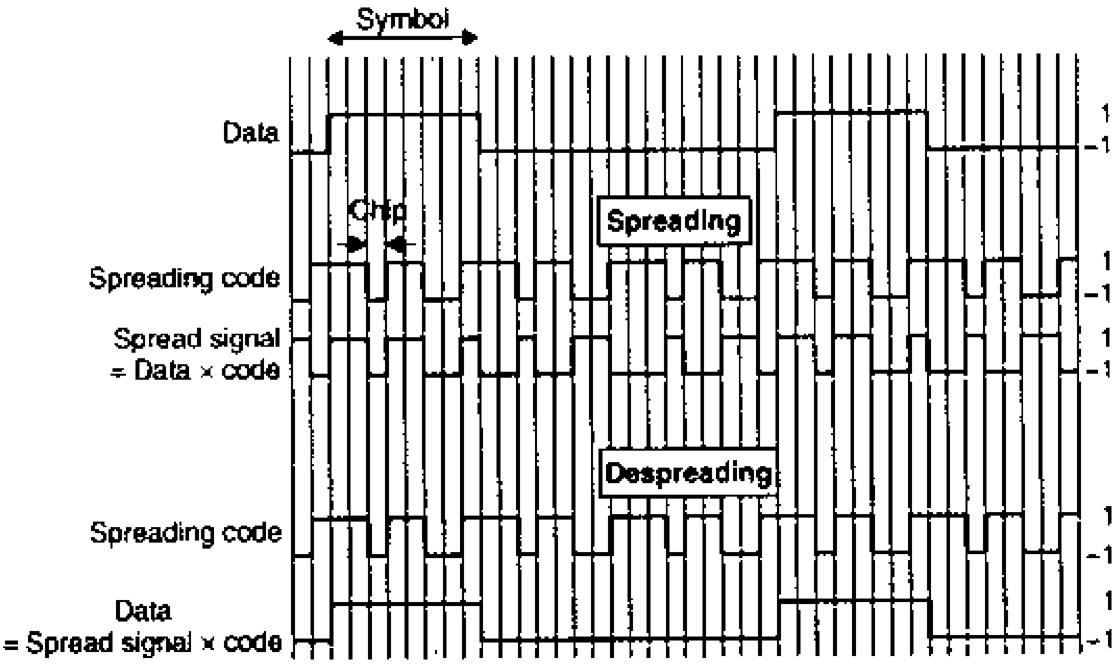


Figure 2.7 Spreading and despreading operation

Multiple access is accomplished by assigning each user a unique spreading code from a set of codes with low cross correlation properties. The receiver recovers a desired signal from a group of spread signals by correlating with the correct spreading code. This demodulates the desired signal but not the signals of other users. The spread signal of each user has properties similar to Additive White Gaussian Noise (AWGN). So, increasing the number of users effectively decreases the signal to noise ratio (S/N), and increases the BER, for all users. Multipath interference rejection is possible if the spreading codes have good autocorrelation properties.

2.5.3 Multiple Access Interference and Capacity

In an CDMA system multiple access interference (MAI) arises because all the users are transmitting in the same frequency band and although ideally the spreading codes are supposed to be orthogonal, there are however non-zero cross correlations between the spreading codes, causing the signals mutually interfere to some degree. In addition due to channel impairments, multipath propagation and Doppler shifts, the orthogonality is difficult to maintain. Thus the capacity in a CDMA system is interference limited and the performance degrades for all the users as new users are added.

It is much more difficult to determine cell capacity in CDMA networks than in their GSM counterparts. The problem is evident in the term 'soft capacity' that is often used to describe CDMA cells. This is because in a CDMA network, capacity is dependent on the average level of interference between users. As more connections are made into the network the overall level of interference increases; this in turn affects the call quality of every user connected to the network. Those users furthest from the base station tend to receive the greatest amount of interference and, at some point, could be forced below a signal-to-noise threshold that would normally guarantee acceptable service.

This is a feature of CDMA networks known as 'cell breathing'; the effective service area expands and contracts according to the number of users connected.

2.6 Hierarchical Cell Structure:

In most UMTS frequency allocations done until today, operators have been allocated two or more Frequency Division Duplex (FDD) carriers
In principle, an allocation of one pair of FDD carriers allows the operation of network with only a single network layer like in figure 2.8. In hotspot areas highly loaded cells can be given extra capacity by adding another carrier to the cell, which would be more effective than increasing the BS transmission power. Operators with two paired carriers will be able to use two-layer structure, such as a macrocell layer together with a microcell or picocell layer. Such an approach is known as a *hierarchical cell structure* (HSC) and illustrated in figure 2.9 where microcells are added at selected high traffic areas. In this case the cell can be assumed isolated and the intercell interference is neglected.

If new capacity is needed in a WCDMA network, it is most probable that it cannot be accommodated just by adding new base station sites to the network. Once a new base station is added to the network, its influence will reach even distant base stations. The parameters in the nearest base stations, because of intercell interference, must be changed a lot, which triggers changes in the neighboring base stations. Hierarchical cell structures can help add new capacity without forcing a replanning of a large surrounding area. In WCDMA different frequencies are typically used for different levels of the network hierarchies; for example, one frequency for macrocells, another for microcells, and a third for picocells. So frequency planning is rather trivial in UMTS.

Figure 2.8 Continuous macro layer with frequency f1

Figure 2.9 continuous macro layer with frequency f1 and selected areas with micro cells with frequency f2

CHAPTER 3

WCDMA FOR UMTS

3.1 Introduction

In this chapter we introduce some UMTS-specific aspects, starting by the standardization process, then some features of the WCDMA air interface technology are discussed, followed by the UMTS system architecture and protocols; next, the different channel types in the system are explained with the modulation and coding techniques used. Finally, a presentation of HSDPA.

3.2 3G standardization and 3GPP releases

All modern public telecommunication systems are built to conform to some kind of standards. Standards define interfaces, reference points, and models that help to organize large and complicated systems into functioning networks.

It is important that the air interface is truly open, so that any mobile terminal works with any network in that system, regardless of the network equipment vendor. This requires that all equipment comply with the relevant specifications. For UMTS, these specifications are formulated by 3GPP (Third Generation Partnership Project). UMTS is a very complex system and the specifications must be very detailed to ensure error-free interoperability [5].

3GPP specifications are issued in phases called releases. Release 99 is the first release that is implemented in live networks and it's required to provide data rates of 384 kbps for wide area coverage and up to 2 Mbps for hot-spot areas. Release 4 is the first upgrade for 3GPP systems.

Release 4 only contained minor adjustment with respect to release 99 [4]. Many operators can also implement a Release 4 network as their first 3GPP system.

Release 5 contains several large and important enhancements for 3GPP systems. These enhancements include the following [5]:

- High Speed Downlink Packet Access (HSDPA)
- Wideband AMR (WB-AMR) codec
- IP-based multimedia services (IMS)
- Reliable end-to-end QoS for packet-switched domain

The most important among these enhancements is HSDPA, where this feature improves the end-user experience by increasing peak data rates to 10 Mbps (14 Mbps theoretically) in the downlink, reducing delay and increasing system capacity. With the advantages of HSDPA, Operators will be able to provide end-users with more advanced Wireless Broadband applications offering wide area coverage and mobility.
Further explanation of HSDPA is given in subsequent section of this chapter.

3.3 WCDMA Overview

3.3.1 WCDMA characteristics and features

WCDMA was chosen as the air interface for UMTS as it is capable of supporting the IMT-2000 3G wireless goals. WCDMA can support users with different BER requirements and data rates up to 2 Mbps. It has the capability to time multiplex streams, such as voice and data from the same source, over a single physical channel. WCDMA supports packet data transmission using both a shared access scheme and a dedicated access scheme.

By definition, the bandwidth of a WCDMA system is 5 MHz or more, some characteristics and features of WCDMA system are [4]:

- WCDMA is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, i.e. user information bits are spread over a wide bandwidth by multiplying the user data with pseudo-random bits (called chips) ***derived from CDMA spreading codes***. In order to support very high bit rates (up to 2 Mbps), the use of a variable spreading factor and multicode connections is supported.

- The chip rate of 3.84 Mcps leads to a carrier bandwidth of approximately 5 MHz. DS-CDMA systems with a bandwidth of about 1 MHz, such as IS-95, are commonly referred to as narrowband CDMA systems. The inherently wide carrier bandwidth of WCDMA supports high user data rates and also has certain performance benefits, such as increased multipath diversity. The network operator can deploy multiple 5 MHz carriers to increase capacity, possibly in the form of hierarchical cell layers. Figure 3.1 shows this feature.

- WCDMA supports highly variable user data rates, in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. The user data rate is kept constant during each 10 ms frame. However, the data capacity among the users can change from frame to frame. Figure 3.1 also shows an example of this feature. This fast radio capacity allocation will typically be controlled by the network to achieve optimum throughput for packet data services.

- WCDMA supports two basic modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, separate 5 MHz carrier frequencies are used for the uplink and downlink respectively, whereas in TDD only one 5 MHz is timeshared between the uplink and downlink. Uplink (reverse link) is the connection from the mobile to the base station, and downlink (forward link) is that from the base station to the mobile.
- WCDMA supports the operation of asynchronous base stations, so that, unlike in the synchronous IS-95 system, there is no need for a global time reference such as a GPS. Deployment of indoor and micro base stations is easier when no GPS signal needs to be received.

- WCDMA employs coherent detection on uplink and downlink based on the use of pilot symbols or common pilot. While already used on the downlink in IS-95, the use of coherent detection on the uplink is new for public CDMA systems and will result in an overall increase of coverage and capacity on the uplink.

- WCDMA is designed to be deployed in conjunction with GSM. Therefore, handovers between GSM and WCDMA are supported in order to be able to ***leverage*** the GSM coverage for the introduction of WCDMA.

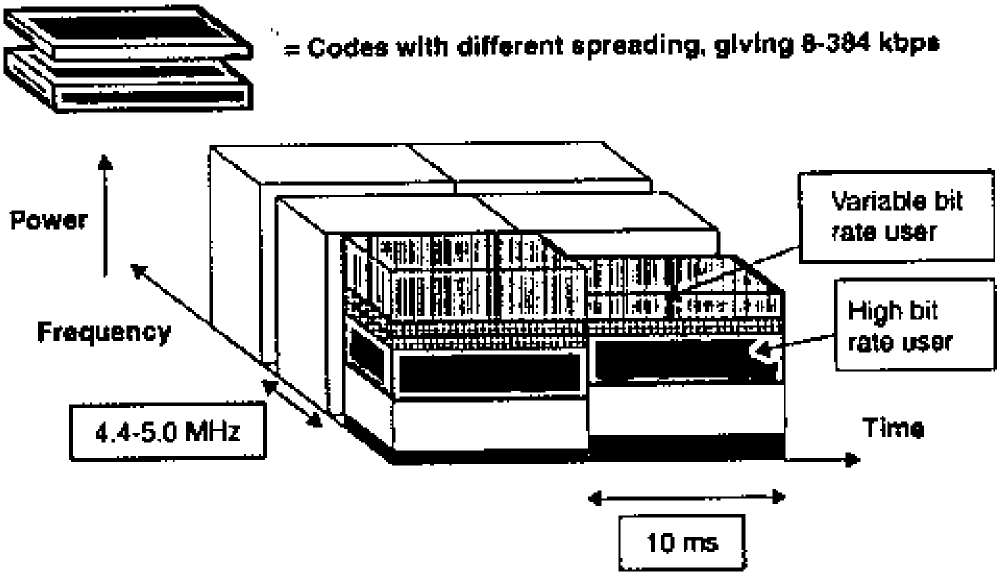


Figure 3.1 Allocation of bandwidth in WCDMA in the time-frequency-code space

- The WCDMA air interface has been standardized in such a way that advanced CDMA receiver concepts, such as multiuser detection and smart adaptive antennas, can be deployed by the network operator as a system option to increase capacity and/or coverage. In most second generation systems no provision has been made for such receiver concepts and as a result they are either not applicable or can be applied only under severe constraints with limited increases in performance.

3.3.2 Power Control

Power control is a necessary element in all mobile systems because of the battery life problem and safety reasons, but in CDMA systems, power control is essential because of the interference-limited nature of DS-CDMA where all signals are transmitted on the same frequency band in the same time. Power control is needed both in the uplink and in the downlink, although for different reasons.

In the uplink direction, all signals should arrive at the base station's receiver with the same signal power. The mobile stations cannot transmit using fixed power levels, because the cells would be dominated by users closest to the base station and faraway users couldn't get their signals heard in the base station. This phenomenon is called the near-far effect (Figure 3.2). In the worst case one over-powered MS could block a whole cell. The solution is to apply power control to guarantee that signals coming from different terminals have the same power when they arrive at the BS.

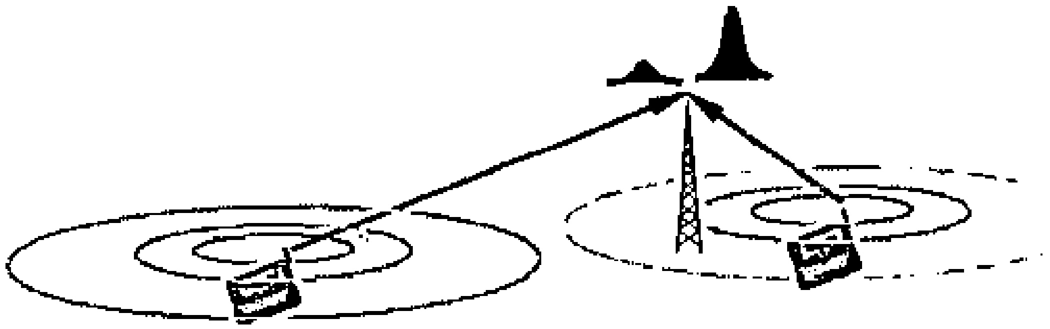


Figure 3.2 near-far effect in the uplink

The situation is different in the downlink direction. The downlink signals transmitted by one base station are mutually orthogonal i.e. ideally do not interfere with each other. However, it is impossible to achieve full orthogonality in typical usage environments. Signal reflections cause nonorthogonal interference even if only one base station is considered. Moreover, signals sent from other base stations are, of course, nonorthogonal and thus they increase the interference level especially when all BS use the same downlink frequency carrier, therefore, power control is also needed in the downlink. The signals should be transmitted with the lowest possible power level, which maintains the required signal quality [5].

3.3.3 Handover

Mobile networks allow users to access services while on the move so giving end users "freedom" in terms of mobility.

Handover is the essential component for dealing with the mobility of end users. It guarantees the continuity of the wireless services when the mobile user moves across cell boundaries.

There are four different types of handovers in WCDMA mobile networks. They are [6]

Intra-system HO:

Intra-system HO occurs within one system. It can be further divided into Intra-frequency HO and Inter-frequency HO. Intra-frequency occurs between cells belonging to the same WCDMA carrier, while Inter-frequency occurs between cells operate on different WCDMA carriers.

Inter-system HO:

Inter-system HO takes places between cells belonging to two different Radio Access Technologies (RAT) or different Radio Access Modes

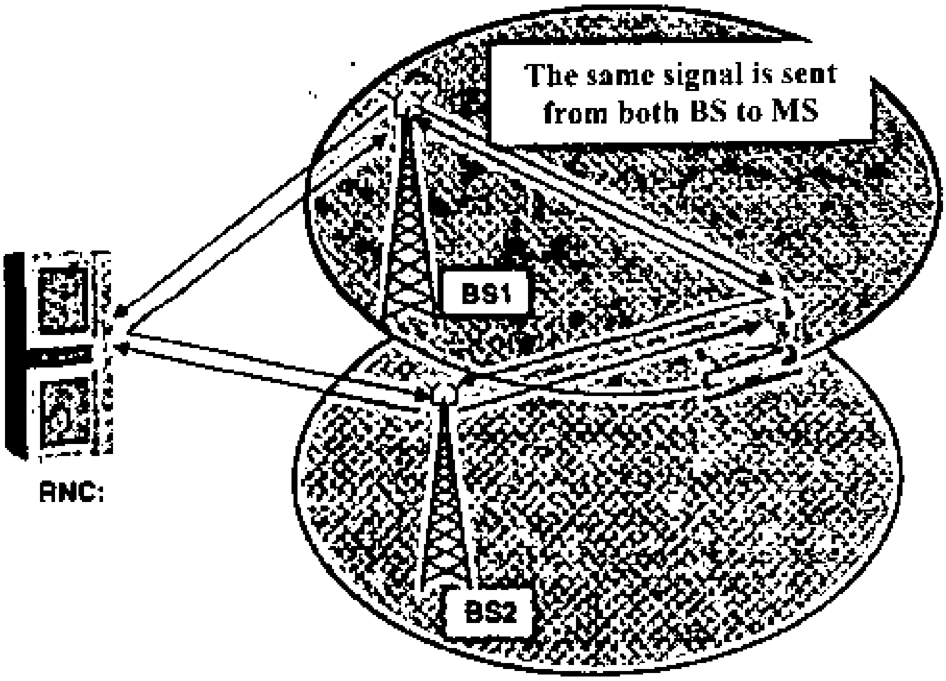
(RAM). The most frequent case for the first type is expected between WCDMA and GSM/EDGE systems.

Hard Handover (HHO)

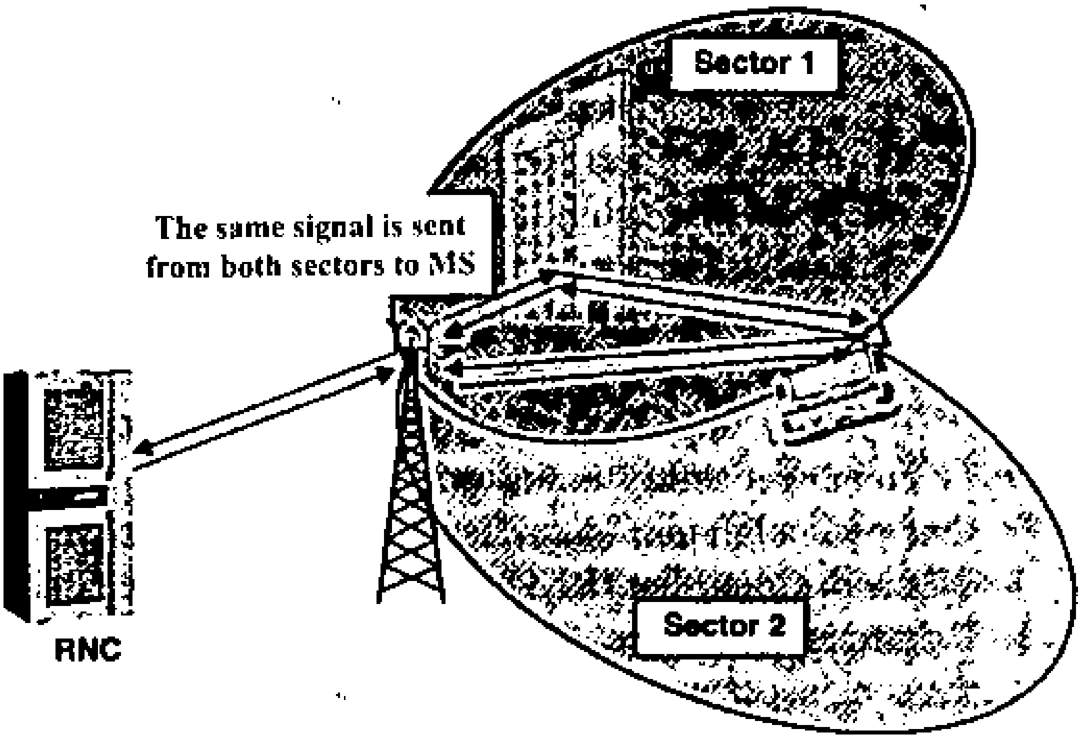
HHO is a category of HO procedures in which all the old radio links of a mobile are released before the new radio links are established. For real-time bearers it means a short disconnection of the bearer.

Soft Handover (SHO) and Softer HO:

During soft handover, a mobile simultaneously communicates with two (2-way SHO) or more cells belonging to different base stations. In the softer handover situation, a mobile is controlled by at least two sectors under one base station. SHO and softer HO are only possible within one carrier frequency and therefore, they are intra-frequency handover processes. Figure 3.3 illustrates soft and softer HO



(a)



(b)

Figure 3.3. (a) Soft handover, (b) softer Handover

3.4 UMTS System Architecture and Protocols

UMTS system is logically divided into the core network, UMTS Terrestrial Radio Access Network (UTRAN), and User Equipment (UE). The labels Uu and lu in figure 3.4 refer to the protocol interfaces between the UE and UTRAN, and UTRAN and core network respectively. This is illustrated in Figure 3.4. The core network contains the Mobile Switching Center (MSC), GGSN, and SGSN, which exist as part of the GSM and GPRS core network. In addition to switching and control functions, the core network provides access to the Public Switched Telephone Network (PSTN), and public data networks. UTRAN consists of the Radio network Controller (RNC) and Base stations (Node B). These components provide wireless access for the UE.

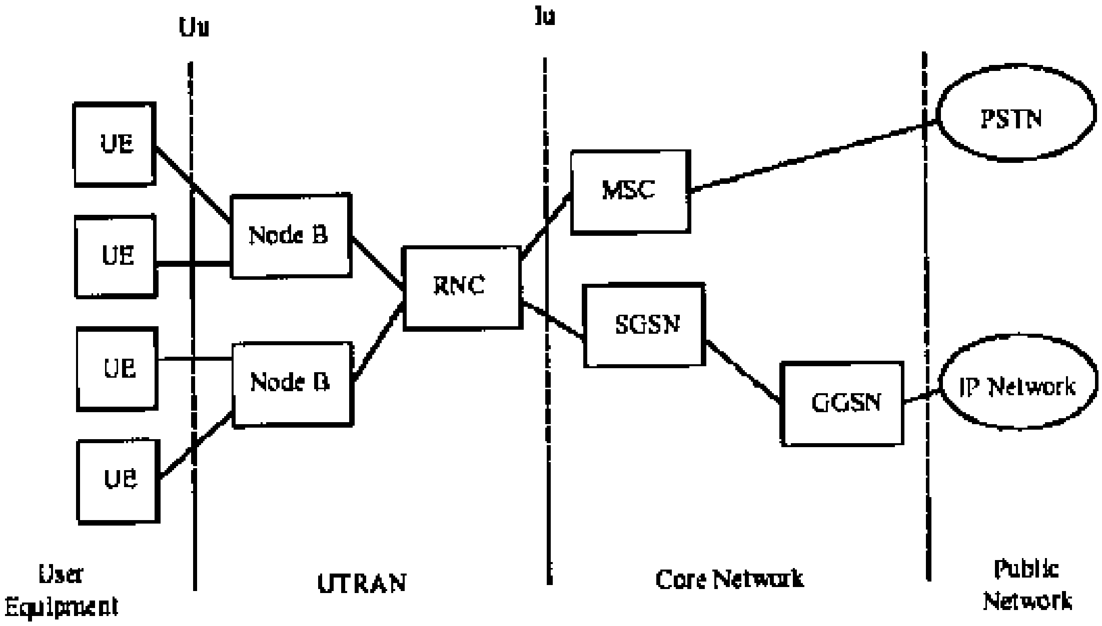


Figure 3.4 UMTS System Architecture

Following the OSI protocol model, radio interface protocols in the UTRAN system can be described by using a layered three-level protocol model. In Figure 3.5 the lowest layer in this interface is the physical layer L1. It has to handle slightly different tasks depending on whether it is in the UE or in Node B.

Layer 2 consists of the medium access control (MAC), the radio link control (RLC) and other functionalities. Layer 3 includes the following sublayers: RRC, mobility management (MM), GPRS mobility management (GMM), call control (CC), and other functionalities.

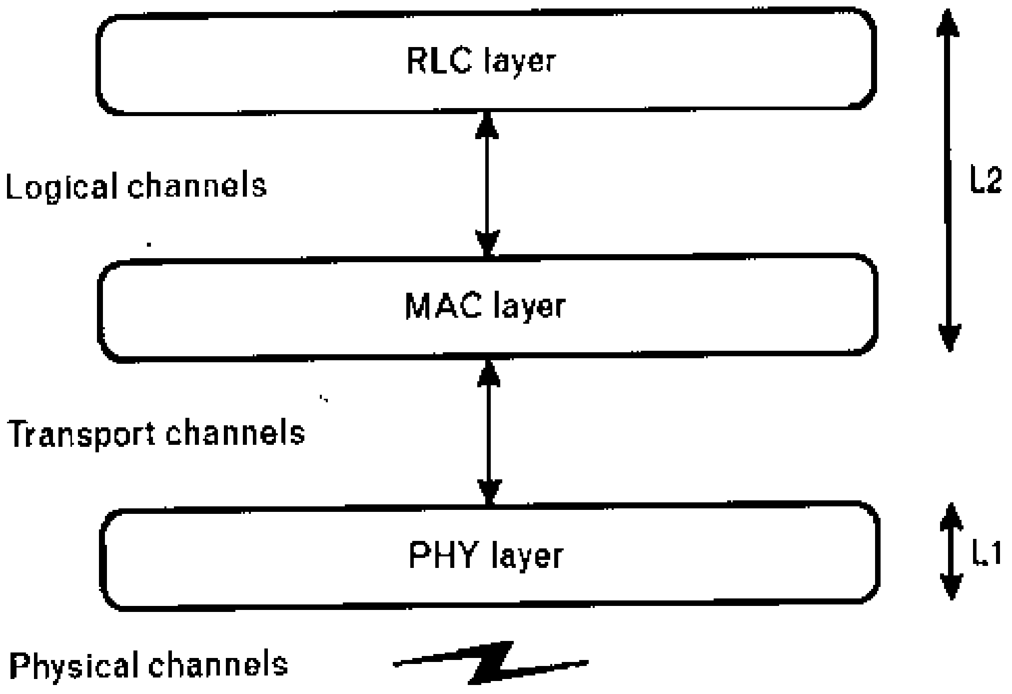


Figure 3.5 Channel types [5]

3.5 Transport and physical channels

There are three separate channel concepts in the UTRAN: logical, transport, and physical channels. Logical channels define what type of data is transferred. These channels define the data-transfer services offered by the MAC layer; that is, the concept of logical channels is used in the interface above the MAC.

Transport channels define how and with which type of characteristics the data is transferred by the physical layer. Transport channels constitute the interface by which the MAC communicates with the physical layer, see figure 3.5.

The basic data unit exchanged between PHY layer and the MAC is called **transport block (TB)**. It is possible to send several transport blocks via the same transport channel within one frame in parallel. A set of simultaneous transport blocks is called **the transport block set (TBS)**. The transmission time interval (TTI) is defined as the inter-arrival time of transport block sets. This is always a multiple of an L1 radio frame duration, the exact value being either 10, 20, 40, or 80 ms (in HSDPA this is 2 ms). Each transport channel can have its own TTI as indicated in Figure 3.6.

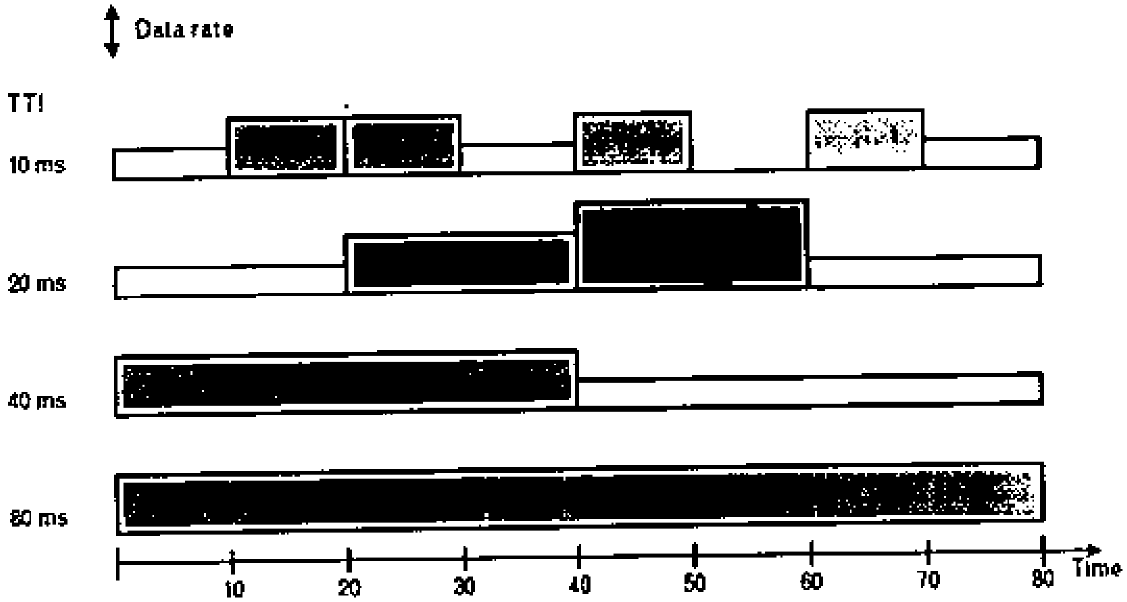


Figure 3.6 Transport channels with different TTI & TBS

Two types of transport channel exist: dedicated channels and common channels. The main difference between them is that a common channel is a resource divided between all or a group of users in a cell, they do not support soft/softer handover but some of them can have fast power control [6]. Dedicated channel, identified by a certain code on a certain frequency, is reserved for a single user only and characterized by features such as fast power control, fast data rate change on a frame-by-frame basis, and supports soft handover.

In R99 there exists one dedicated transport channel and six common cannel defined for FDD mode.

The only dedicated transport channel type is:

- Dedicated channel (DCH): For one UE only; Either uplink or downlink.

The common transport channels are:

- Broadcast channel (BCH): A downlink channel for broadcast of system and cell-specific information.

- Paging channel (PCH): A downlink channel used for transmission of paging and notification messages;

- Random access channel (RACH) : A contention-based uplink channel; Used for initial access or non-real-time dedicated control or traffic data;

- Common packet channel (CPCH): A contention-based uplink channel used for transmission of bursty data traffic;

- Forward access channel (FACH): A common downlink channel; May carry small amounts of user data.

- Downlink shared channel (DSCH): A downlink channel shared by several UEs; Used for dedicated control or traffic data; Associated with a DCH (does not exist alone).

The common transport channels needed for basic network operation are RACH, FACH and PCH, while the use of DSCH and CPCH is optional and can be decided by the network operator [4].

Mapping of Transport Channels onto the Physical Channels

Physical channels define the exact physical characteristics of the radio channels. These are the channels used below the PHY layer (L1); that is, in the radio interface. The different transport channels are mapped to different physical channels, The transport channel to physical channel mapping is illustrated in Figure 3.7

3.6 Physical Channel spreading and Modulation

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. The WCDMA physical layer uses DSSS (direct sequence spread spectrum) with variable spreading factor and constant chip rate of 3.84 Mcps.

WCDMA uses a 10 ms radio frame divided into 15 time slots of 0.667ms, this means that one time slot could transfer up to 2,560 symbols (SF=1). The rate one user channel can support depends on the spreading factor used in the channel.

In FDD the spreading factors are from 4 to 256 for the uplink and from 4 to 512 for the downlink. In TDD they are from 1 to 16 in both directions. thus for downlink FDD the maximum channel data rate available (SF=4) is 3.84Mcps/4 =960ksps which corresponds to 1.92Mbps for QPSK that's used in release 99 in 3GPP specifications.

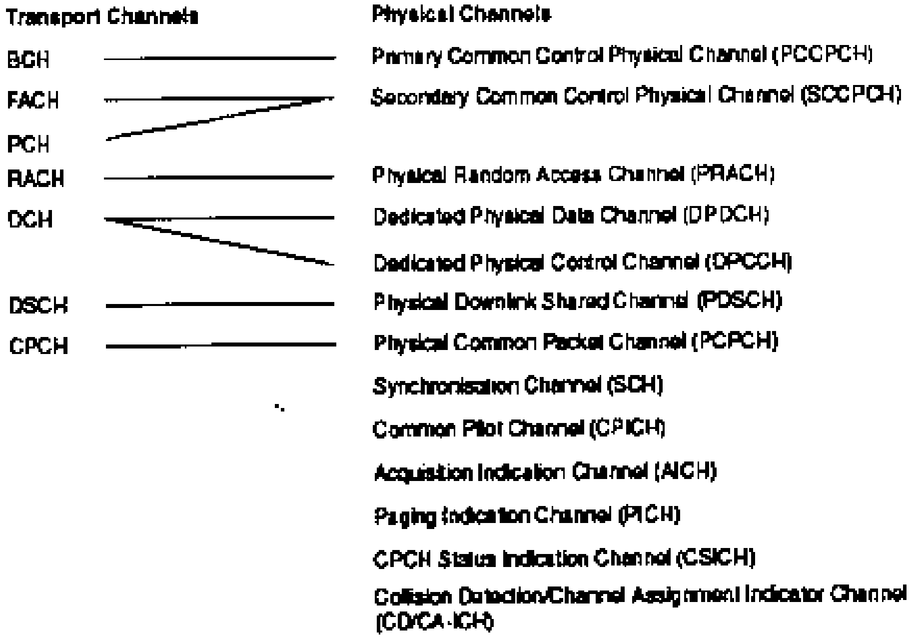


Figure 3.7 Transport channel to physical channel mapping

The spreading process in UTRAN consists of two separate operations or steps: channelization and scrambling as in Figure 3.8.

Orthogonal variable spreading factor (OVSF) codes, called channelization codes, are used to spread the data in each frame with the ability to change SF each 10 ms frame and allocate multiple codes (channels) for a single user. Channelization codes are used differently in both uplink and downlink. In the uplink these codes are used to separate channels for a single user, in downlink OVSF code used to separate different users within one cell.

On top of the channelization codes, another type of coding is used, called scrambling codes, which is used to separate users in the uplink and to differentiate downlink channels from adjacent cells In the downlink, pseudorandom scrambling codes are used to reduce inter-base-station interference where each Node B has only one unique primary scrambling code, and this is used to separate various base stations.

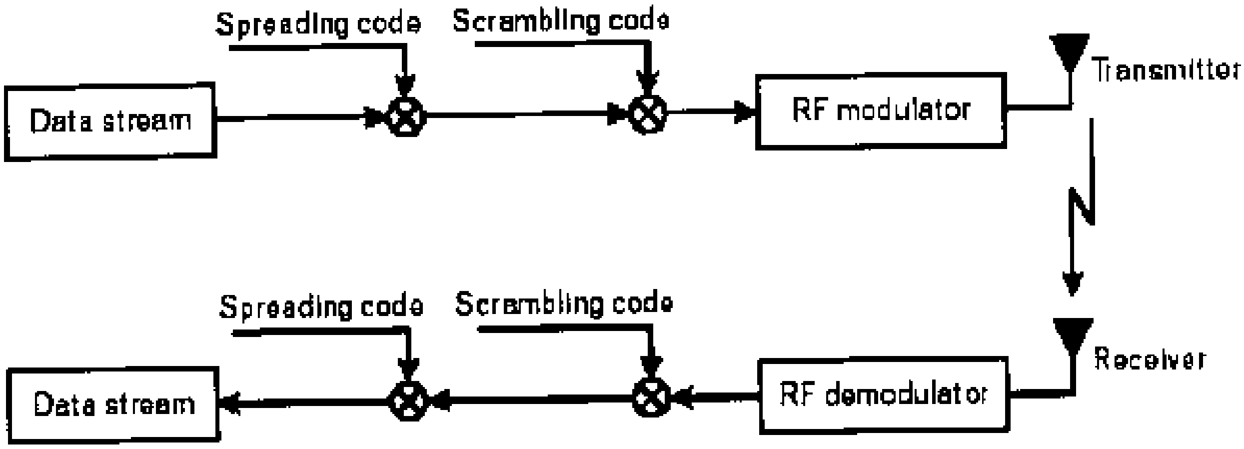


Figure 3.8 spreading and scrambling in UTRAN

3.7 HSDPA Concepts

In order to improve support for high data rate packet switched services, 3GPP developed an evolution of UMTS based on WCDMA known as High Speed Downlink Packet Access (HSDPA) which is included in the Release 5 specifications..HSDPA is targeting increased capacity, reduced round trip delay, and higher peak data rates up to 8–10 Mbps.

To implement the HSDPA feature, three new channels are introduced in the physical layer specifications [4]:

- HS-DSCH carries the user data in the downlink direction, with the peak rate reaching up to 10 Mbps range with 16 QAM
- High-speed Shared Control Channel (HS-SCCH) carries the necessary physical layer control information to enable decoding of the data on HS-DSCH and to perform the possible physical layer

combining of the data sent on HS-DSCH in the case of retransmission of an erroneous packet.

- Uplink High-Speed Dedicated Physical Control Channel (HS-DPCCH) carries the necessary control information in the uplink, namely, ARQ acknowledgements (both positive and negative ones) and downlink quality feedback information.

HSDPA achieves its aim by using the following techniques:

- Shared channel transmission
- Higher-order modulation
- Short transmission time interval (TTI)
- Fast link adaptation
- Fast scheduling
- Fast hybrid automatic-repeat-request (ARQ).

Fast link adaptation techniques enable the use of spectrally efficient higher order modulation (16QAM) when channel conditions permit, and revert to robust Quaternary Phase Shift Keying (QPSK) modulation for poor channel conditions. This technique also called AMC (Adaptive modulation and coding) where the shared channel transport format (i.e., the modulation scheme and the code rate) depends on the channel quality. This is monitored constantly, and the transport format used can be changed in every frame.

The quality information is transmitted to Node Bs via the uplink control channels. The UE signals information to the network about the highest data rate it can accept under the current channel conditions and still maintain a block error rate under 10%. This information is signaled in a field called CQI (Channel Quality Indication). The network uses this indicator in order to (re)configure the HS-DSCH format to be chosen for subsequent transmission to that UE. For example, if the CQI indicates that the quality is degrading, a less ambitious coding/modulation scheme is chosen to cope better with the poor conditions.

Fast Hybrid Automatic Repeat Request (HARQ) algorithms rapidly request the retransmission of missing data entities and combine the soft information from the original transmission and any subsequent retransmissions before any attempts are made to decode a message. The term "Hybrid ARQ" used to describe any combined FEC+ARQ scheme in which FEC scheme aims to fix as many errors as possible, and then the error-detection function checks whether the result was correct.

In Release 99, retransmission functionality is part of the RLC layer located in RNC. However, this kind of high-level retransmission scheme is too slow for high-speed data transmissions required for HSDPA, where the HARQ retransmission buffers are located closer to the physical layer: in the new MAC-hs logical entity that is located in Node-B just above the physical layer (see Figure 3.9). Moreover, a shorter frame length (TTI=2ms) is used to make HARQ more efficient

Two common method for HARQ can be used; Chase combining and incremental redundancy. ***Chase combining*** involves the retransmission by the transmitter of the same coded data packet. The decoder at the receiver combines these multiple copies of the transmitted packet. In the ***incremental redundancy*** method, instead of sending simple repeats of the coded data packet, progressive parity packets are sent in each subsequent transmission of the packet. The decoder then combines all the transmissions and decodes the packet at a lower code rate.

Fast scheduling shares the HS-DSCH among the users. This technique, which exploits multi-user diversity, strives to transmit to users with favorable radio conditions.

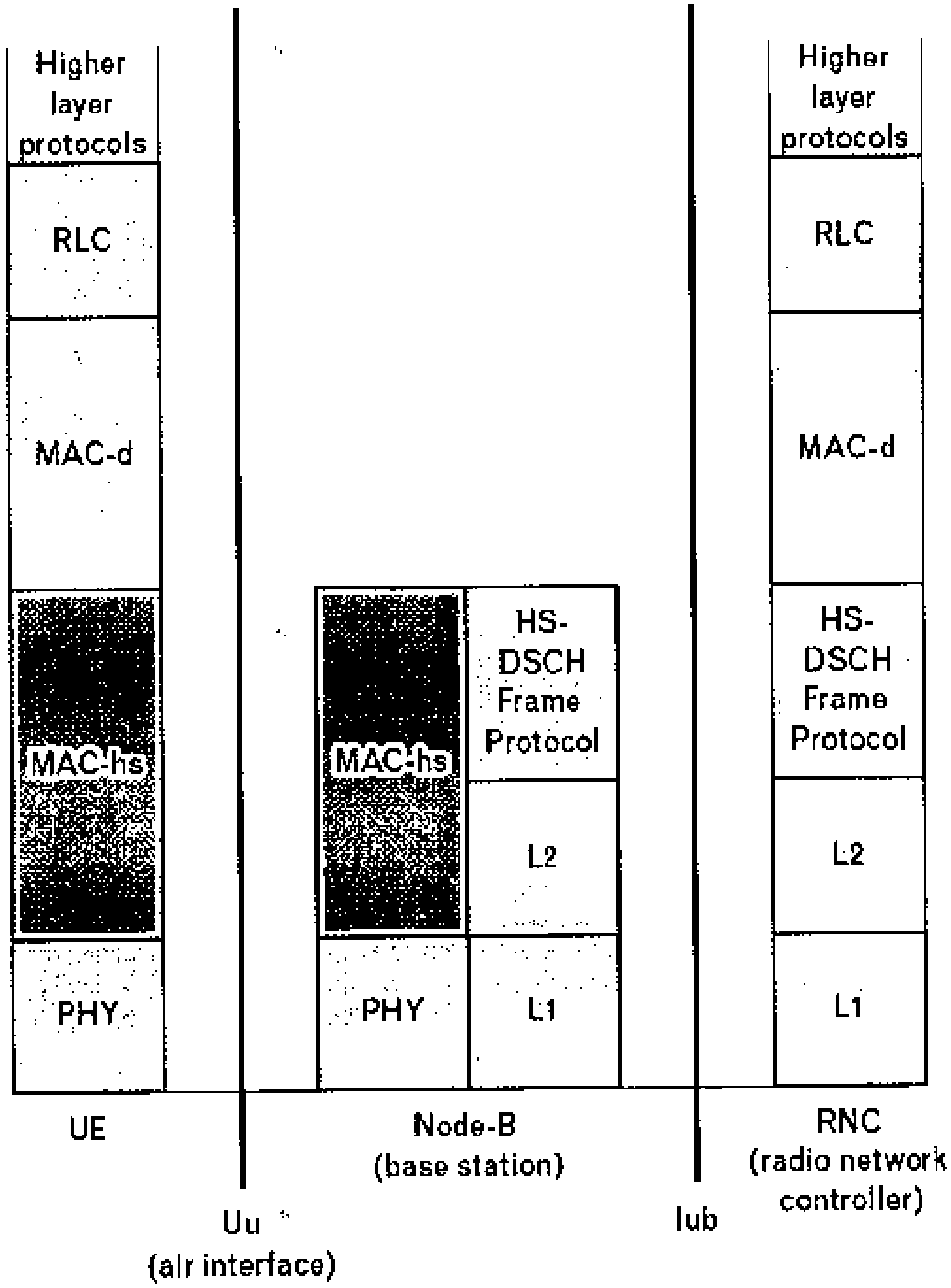


Figure 3.9 HSDPA protocol stack [5]

CHAPTER 4

ANALYTICAL MODLEING & SIMULATION ALGORITHM

4.1 Introduction

As the main target of 3G systems is to support data services such as voice and video streaming and web traffic, which are asymmetric in nature, the downlink capacity is the limiting factor of the cell capacity.

In this chapter, analytical model for downlink cell capacity is developed with some assumption and approximations to simplify the work. Based on this analytical model, a simulation algorithm is developed and implemented in MATLAB, the results are explained and discussed in the next chapter.

4.2 System Model

For the purpose of downlink capacity evaluation , the performance of a hexagonal macro cell will be estimated considering the interference caused by six surrounding cells, where the reuse factor is one and all cells use the same carrier frequency as in figure 4.1. Also assumed that all BS transmits at its maximum allowed transmit power P_{max} as the maximum cell capacity is to be evaluated. Depending on the 3GPP specification release used, there will be two scenarios.

In the first scenario, only R99 will be considered where the DCH (dedicated channels) will be simulated assuming each user allocated one DCH, the other common channel will be considered as a power overhead, and typically allocated 15% of the maximum BS transmit power P_{max}. Within this scenario, the sensitivity of different system parameter and its effect on the capacity will be investigated, also different service types will be considered.

In the second scenario, HSDPA feature will be simulated with the addition of HS-DSCH users besides R99 users with the same maximum transmit power P_{max} of BS as in the first scenario and the capacity will be compared. A percentage of P_{max} will be allocated to the HS-DSCH, this percentage is a network operator parameter; different allocations will be considered

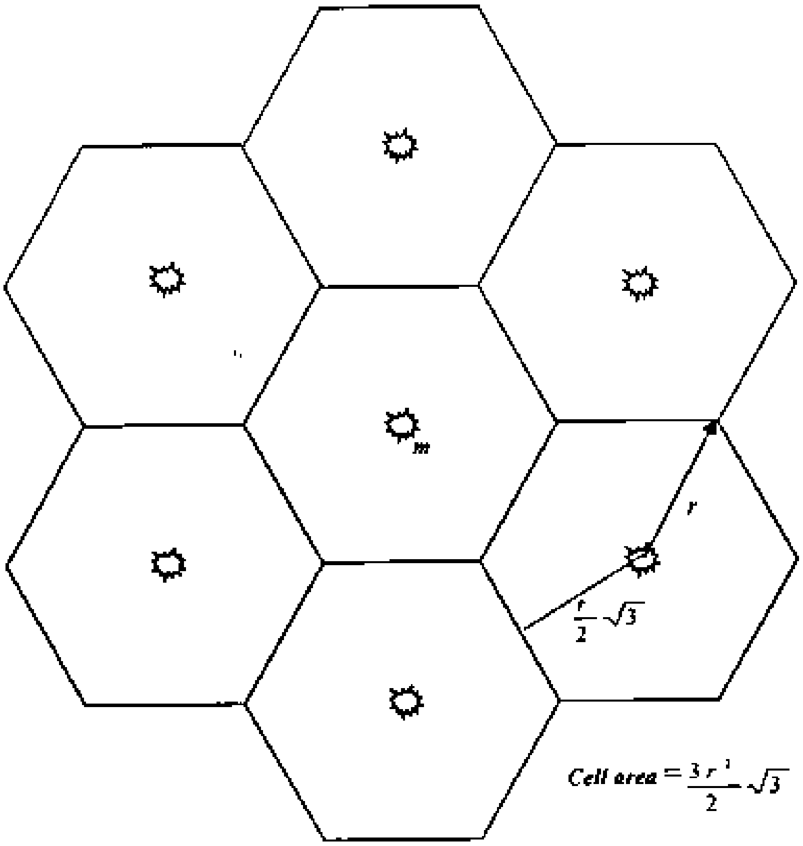


Figure 4.1 simulated model

4.3 Path-loss Model

A path loss model based on Okumura-Hata model will be used where the macrocell path loss is modeled for urban area as [6]:

$$L_p=25.9+35.2\log(d)+33.6\log(f) \quad \text{.................. (4.1)}$$

d is the distance in km
f is the carrier frequency in MHz. In UMTS the frequency band allocated for downlink FDD mode is (2110-2170)MHz the midrange value of 2140MHz will be used and then :

$$L_p=138.8+35.2\log(d) \quad \text{........................ (4.2)}$$

4.4 Multipath channel model

A set of reference measurement channels has been defined by 3GPP in [11], where the UE performance requirement has been defined for DCH in different multipath profiles; that is the E_b/N_o requirement is given for a certain BLER.

Appendix A shows propagation conditions that are used for the performance measurements in multi-path fading environment. The reference channel with 4 multipath components (case 3) is typical for the macrocell environment.

4.5 Downlink capacity equation (Interference model)

Assume ρ_i is *Eb/No* requirement for UE (User Equipment) *i* served by BS *m*, which is determined by BLER requirement.

where *No* is the thermal plus interference noise density.

$$\rho_i = \frac{W}{R_i}(SNR)_i \text{ .... } (4.3)$$

Where *W is the chip rate*

R_i is the service bit rate of UE i

$(SNR)_i$ is the received signal power over the total noise power of user i

$$\rho_i = \frac{W}{R_i} \cdot \frac{p_i / L_{m,i}}{I_{own} + I_{oth} + P_N} \text{ .... } (4.4)$$

p_i *the BS transmit power allocated for user i*

$L_{m,i}$ *is the path loss from the serving BS m to UE i*

I_{own} *the multiple access interference noise power caused by non-orthogonality of user codes in the own cell*

I_{oth} *is the multiple access interference noise power caused by other cells adjacent to BS m*

P_N *the thermal noise power received by MS i*

Equation (4.4)can be written in terms of the BS total transmit power as[13]:

$$\rho_i = \frac{W}{R_i} \cdot \frac{p_i / L_{m,i}}{\frac{P_m}{L_{m,i}}(1-\alpha) + \sum_{n=1}^{6} P_n / L_{n,i} + P_N} \ldots\ldots\ldots\ldots (4.5)$$

P_m	*the total transmitted power of BS m*
P_n	*the total transmitted power of adjacent BS n, n=1,2,. . .,6*
$L_{n,i}$	*is the is path loss from the BS n to UE i*
α	*Orthogonality factor (represents the degree of orthogonality between the user codes in the downlink. The users codes are completely orthogonal when α=1, i.e. the codes cross correlation=0)*

With uniform traffic distribution over all cells, the total transmit power of all cells is the same i.e. $P_m = P_n = P_t$, *and if the activity factor of user i is* v_i *we can write:*

$$\rho_i = \frac{W}{R_i} \cdot \frac{p_i}{P_t(1-\alpha_i) + P_t \sum_{n=1}^{6} \frac{L_{m,i}}{L_{n,i}} + P_N L_{m,i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.6)$$

Solving (4.6) for p_i *, the BS transmit power for UE i is:*

$$p_i = \frac{\rho_i R_i}{W}\left(P_t(1-\alpha_i) + P_t \sum_{n=1}^{6} L_{m,i} / L_{n,i} + P_N L_{m,i}\right) \ldots\ldots\ldots\ldots\ldots\ldots (4.7)$$

i=1,2, . . . ,I. whereI is the number of UEs served by BS m

Multiplying Eq.(4.7) by the activity factor v_i *for UE i and summing over all UEs served by BS m gives the total BS transmit power for traffic channels* P_{DCH}

$$\left.\begin{aligned} P_{DCH} &= \sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}\left(P_t(1-\alpha_i)+P_t\sum_{n=1}^{6}\frac{L_{m,i}}{L_{n,i}}+P_N L_{m,i}\right) \\ P_{DCH} &= P_t\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}\left((1-\alpha_i)+\sum_{n=1}^{6}\frac{L_{m,i}}{L_{n,i}}\right)+P_N\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}L_{m,i} \end{aligned}\right\} \text{........ } (4.8)$$

The total BS transmit power is the sum of the traffic channels power P_{DCH} and the power allocated for common channels denoted P_{CCH}

$$P_t=P_{DCH}+P_{CCH} \text{ ....} (4.9)$$

P_{CCH} is typically allocated 15% of the maximum BS transmit power P_{max}[4], this percentage will be used in our simulation, i.e.

$$P_{CCH}=0.15P_{max}$$

$$P_{DCH}=(P_{DCH}+P_{CCH})\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}\left((1-\alpha_i)+\sum_{n=1}^{6}\frac{L_{m,i}}{L_{n,i}}\right)+P_N\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}L_{m,i}$$

$$P_{DCH}=\frac{P_{CCH}\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}\left((1-\alpha_i)+\sum_{n=1}^{6}\frac{L_{m,i}}{L_{n,i}}\right)+P_N\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}L_{m,i}}{1-\sum_{i=1}^{I}\frac{\rho_i R_i v_i}{W}\left((1-\alpha_i)+\sum_{n=1}^{6}\frac{L_{m,i}}{L_{n,i}}\right)}$$

$$P_{DCH} = \frac{P_{CCH}\eta_{DL} + P_N \sum_{i=1}^{I} \frac{\rho_i R_i v_i}{W} L_{m,i}}{1-\eta_{DL}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.10)$$

where η_{DL} *is defined as the downlink load factor.*

$$\eta_{DL} = \sum_{i=1}^{I} \frac{\rho_i R_i v_i}{W} \left((1-\alpha_i) + \sum_{n=1}^{6} \frac{L_{m,i}}{L_{n,i}} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.11)$$

we can define the other to own cell interference ratio k for user i as:

$$k_i = \sum_{n=1}^{6} \frac{L_{m,i}}{L_{n,i}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.12)$$

and can be taken in average over all users

$$k = \frac{1}{I} \sum_{i=1}^{I} \sum_{n=1}^{6} \frac{L_{m,i}}{L_{n,i}}$$

k also represents the degree of the cell isolation, i.e. when k=0, the cell is completely isolated from adjacent cells.

Cell capacity:

When different service types are supported by the system, the number of users can be served simultaneously does not represent the cell capacity; instead the overall cell throughput will be used to evaluate and compare the capacity for different scenarios.

$$Throughput = \sum_{i=1}^{I} R_i (1 - BLER_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.13)$$

where I is the number of users in the cell. R_i and $BLER_i$ is the data rate and block error ratio for user i.

BLER is as the long-term average block error rate calculated for transport blocks (**TB**). Transport block is considered erroneous if it has at least one bit error [6].

In the reference measurement channel defined by [11], UE performance requirement corresponding to BLER of 10^{-1} and 10^{-2} are given. BLER of 10^{-2} will be used in our simulation.

4.6 HSDPA modeling

In the second scenario, when HSDPA is involved, part of the BS power will be allocated to the HS-DSCH; this power allocation is operator dependent and will be denoted P_{HS}, this power will be divided between HSDPA users.

HS-DSCH supports multicode transmission which is allocated to HSDPA users on the basis of TTI of 2 ms. within one TTI, The maximum number of codes that can be allocated is 15 codes with fixed spreading factor of 16. the maximum number of code can be utilized simultaneously by a single user in parallel depend on the terminal capability. HSDPA terminals are categorized according to their capability (maximum transport block size and maximum parallel codes supported) . Table 4.1 indicates HSDPA terminal category.

The HS-DSCH resources (allocated power and 15 codes) will be divided equally between HSDPA users in the cell. Then the data rate for each user will be determined (beside UE category) by the channel conditions of the user via the link adaptation scheme.

In this scheme the UE reports its channel condition via CQI value which is determined by the SNR (level of interference) and quality of service needed (BLER). The relationship between these parameters is given by the following equation [14]

$$SNR = \frac{\sqrt{3} - \log(CQI)}{2} \log(BLER^{-.7} - 1) + 1.03CQI - 17.3 \ldots\ldots\ldots\ldots\ldots (4.14)$$

Table 4.1 HSDPA terminals category [4]

Category	Maximum number of parallel codes HS-DSCH	Minimum inter-TTI interval	Transport channel bits per TTI	Achievable maximum data rate (Mbps)
1	5	3	7298	1.2
2	5	3	7298	1.2
3	5	2	7298	1.8
4	5	2	7298	1.8
5	5	1	7298	3.6
6	5	1	7298	3.6
7	10	1	14 411	7.2
8	10	1	14 411	7.2
9	15	1	20 251	10.2
10	15	1	27 952	14.4
11	5	2	3630	0.9
12	5	1	3630	1.8

NodeB, and according to CQI value received, determines the modulation and coding scheme (MCS) and the number of codes used in parallel, and so the data rate, for the next transmission for the user. This is done using predefined mapping tables specified by 3GPP. Different UE categories have different mapping tables.

In this scenario, the power allocated for HSDPA users P_{HS} will be seen as a noise power and equation 4.10 will be modified as follow:

$$P_{DCH} = \frac{(P_{CCH} + P_{HS})\eta_{DL} + P_N \sum_{i=1}^{I} \frac{\rho_i R_i v_i}{W} L_{m,i}}{1 - \eta_{DL}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.15)$$

where the total power

$$P_t = P_{DCH} + P_{CCH} + P_{HS}$$

$$= P_{DCH} + \beta P_{max} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.16)$$

Where $\beta = \frac{P_{CCH}+P_{HS}}{P_{max}}$ is the percentage of the common channel and HS-DSCH power from the maximum BS transmit power. thus equation 4.15

$$P_{DCH} = \frac{\beta P_{max}\eta_{DL} + P_N \sum_{i=1}^{I} \frac{\rho_i R_i v_i}{W} L_{m,i}}{1-\eta_{DL}} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.17)$$

as the overall cell throughput will be taken as a capacity measure, HS-DSCH can be modeled with a single user that utilizes all HS-DSCH resource (15 cute with all P_{HS}) in this case UE category 9 or 10 must be used, but in this case, HS-SCH throughput is very sensitive to the user position (distance from base station). With UE category 5 or 6, for example, at least three users must be assumed to model the HS-DSCH fully utilized, where each user can support up to 5 parallel codes. The latter choice will be used in the simulation, so the power P_{HS} will be divided between 3 users with different distance from the base station.

4.7 Simulation approach

As we are concerned with the maximum capacity, an algorithm has been developed and implemented using MATLAB to estimate the system capacity under different scenarios.

The approach of this algorithm is to operate the BS at its maximum transmit power then to calculate the number of users in the cell from which the cell throughput can be calculated from Eq. 4.13.

The algorithm flow chart is shown in figure 4.2 and explained in the following steps:

1. *set the system parameters (α, ν, pathloss model,* E_b/N_o*)*
2. *An initial BS transmit power is set to* P_{CCH}

3. *Add one user randomly to the cell with service type chosen randomly with predefined propapility*
4. *Calculate the BS transmit power required for user traffics* P_{DCH}*, Eq.4.17*
5. *Calculate the total transmit power* P_t*, Eq. 4.16*
6. *The resulting* P_t *is compared to the maximum BS transmit power* P_{max}*. if the difference is within a predefined tolerance* Δ*, provided that* $P_{max} > P_t$*, then the cell operates with its maximum capacity. If* $|P_{max} - P_t| > \Delta$ *and* $P_{max} > P_t$ *the steps 3-5 is repeated*
7. If $|P_{max} - P_t| < \Delta$ *and* $P_{max} < P_t$ *then the last user added is dropped and steps 3-5 are repeated*

Table 4.2 indicates the parameter values used in the simulations. These values are assumed unless the parameter sensitivity is under investigation or otherwise stated

Table 4.2 Simulation default parameter

Parameter	**Value**
DL frequency	2140 MHz
Service Activity factor (v)	0.6 for speech (12.2 kbps) 1 for real-time video (64 kbps) 0.2 for web browsing (144 kbps) 1 for file download (384 kbps)
Cell configuration	Hexagonal macrocell with radius=2km, omnidirectional antenna ,P_{max}=20W
Orthogonality factor (α)	0.5

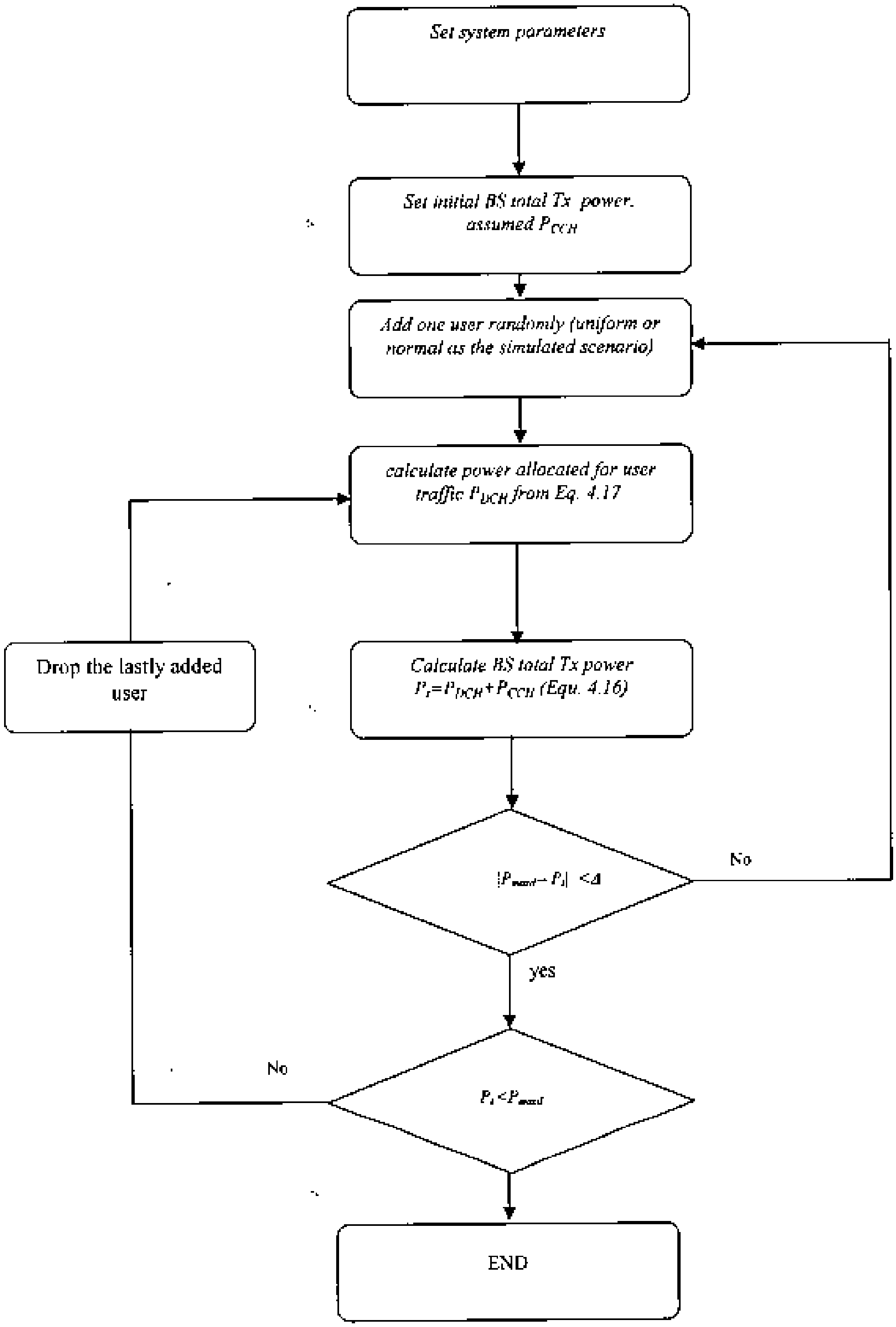


Figure 4.2 The developed algorithm flow chart

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

Based on the algorithm designed in section 4.6, MATLAB program is developed to implement the algorithm and simulate different scenarios. A brief description of the developed program functions can be found in appendix B

The results of the simulation scenarios are presented in this chapter. Two main scenarios can be distinguished with different cases in each one, the first scenario is for R99 including four different service types, speech service (12.2 kbps), video telephony service (64kbps) , WWW service (web browsing of 144 kbps) and FTP service (file download, 384kbps). As a result of the simulation, the capacity is estimated for different coverage requirement (cell radius r) and maximum BS transmitted power P_{max}, as variables. The cell throughput is used as a capacity measure because it's more indicative in the case of mixed traffic (speech and data), also the number of users is given for each simulation case.

In the second scenario, HSDPA, feature of Release 5 of 3GPP, is simulated, the cell is assumed to support both R99 and HSDPA users. The capacity is estimated and compared to the first scenario.

In each of the two scenarios, the effect of the cell isolation on the capacity will be studied. A uniform user distribution is assumed unless other wise stated

5.2 R99 users only

As mentioned above, four service types will be simulated. The ratio between the number of users of each service is given as

[Speech:Video:WWW:FTP] . First the capacity of speech user only will be estimated then speech and data users will be assumed with a user ratio [0.6 : 0.4] and the results are compared.

5.2.1 Speech service capacity

In this case the capacity of speech service is estimated, with activity factor v=0.6 and uniform user distribution. From figures 5.1-a and 5.1-b we note that for a certain coverage (r), there is a maximum capacity limit that cannot be exceeded whatever P_{max} is increased, also noted that this maximum capacity is decreased for larger cell radius r (larger coverage area).

The voice users capacity at P_{max}=20W and cell radius r=2km will be taken as a reference case for the reason of comparison. For this reference case, the number of users is about 82 voice users, as in figure 5.1-a, and the cell throughput is 593 kbps/cell, as in figure 5.2-b.

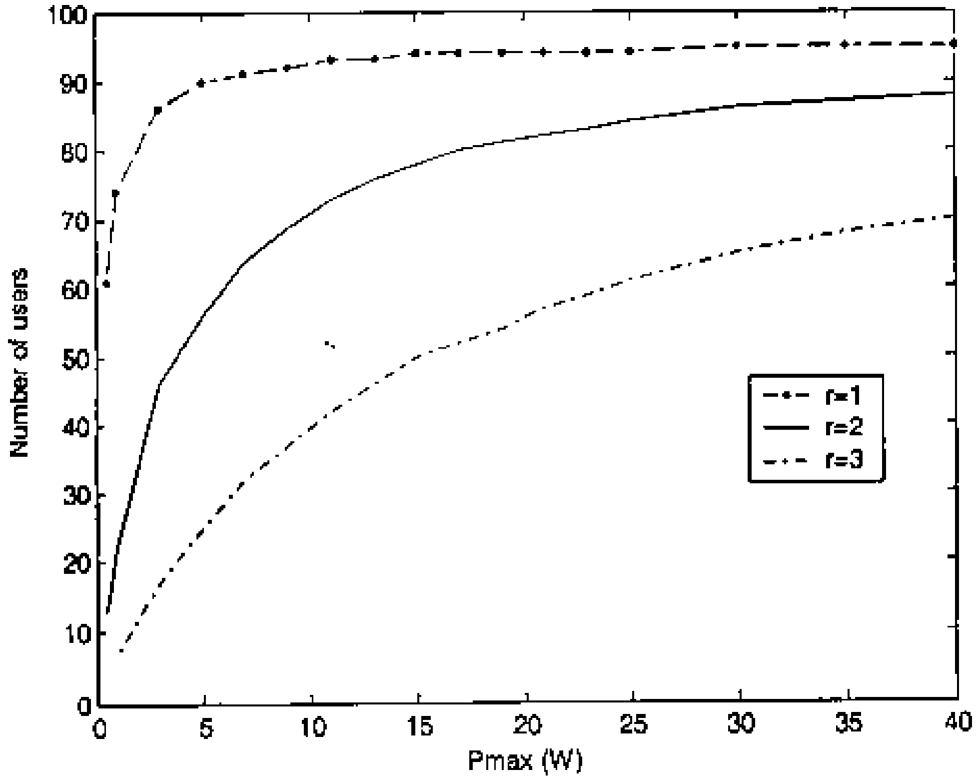


Figure 5.1-a The No. of user for speech service [1:0:0:0]

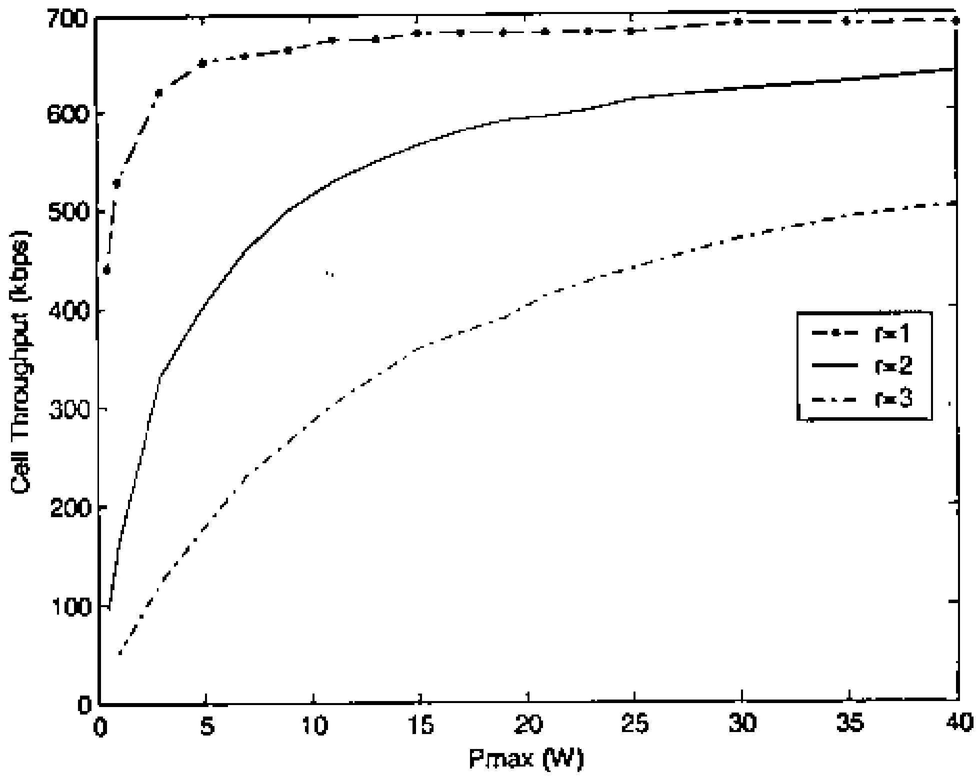


Figure 5.1-b Cell throughput for speech service [1:0:0:0]

5.2.2 Speech and data service capacity

In this case the capacity of a cell with different service type and uniform user distribution is estimated, three sub-cases illustrated in figures 5.2, 5.3 and 5.4. Figure 5.2 shows the case where the service ratios [speech : video : www : FTP] = [0.6 : 0.4 : 0 : 0], i.e. speech and video services is assumed. In figure 5.3 speech and www services is assumed with a service ratio [0.6 : 0 : 0.4 : 0] and www activity factor v=0.2. In figure 5.4 speech and FTP services is assumed with a service ratio [0.6 : 0 : 0 : 0.4] and FTP activity factor v=1. For comparison, figure 5.5 is a chart indicating the capacity for each case at r=2, P_{max}=20W.

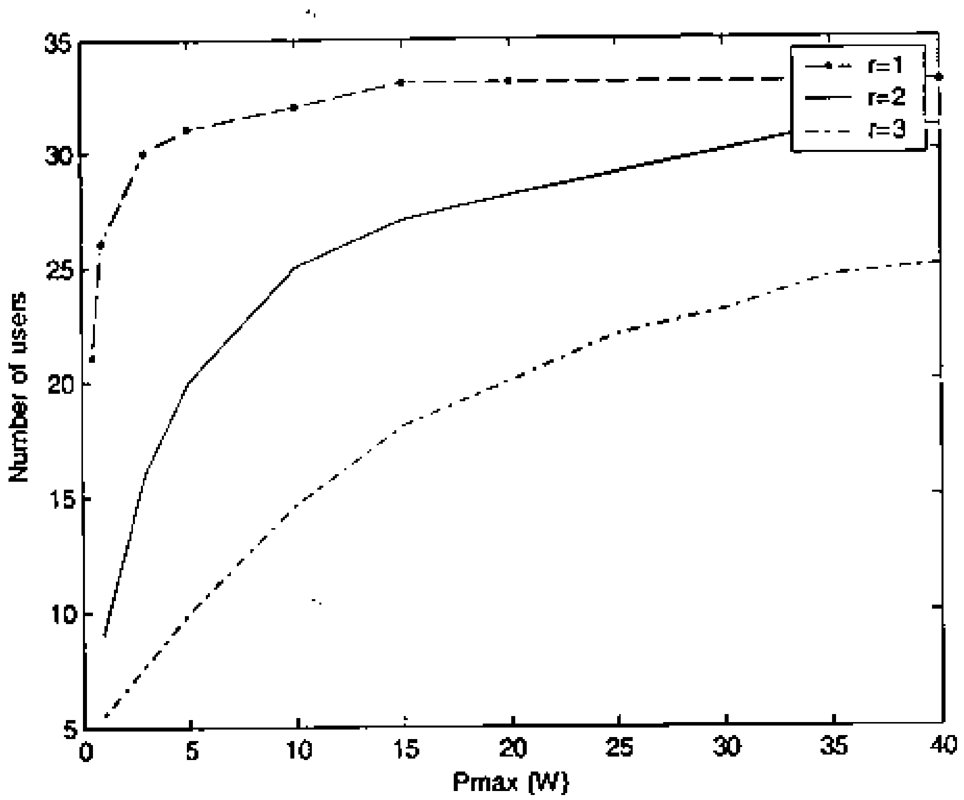


Figure 5.2-a No. of users for mixed traffic [0.6 : 0.4 : 0 : 0]

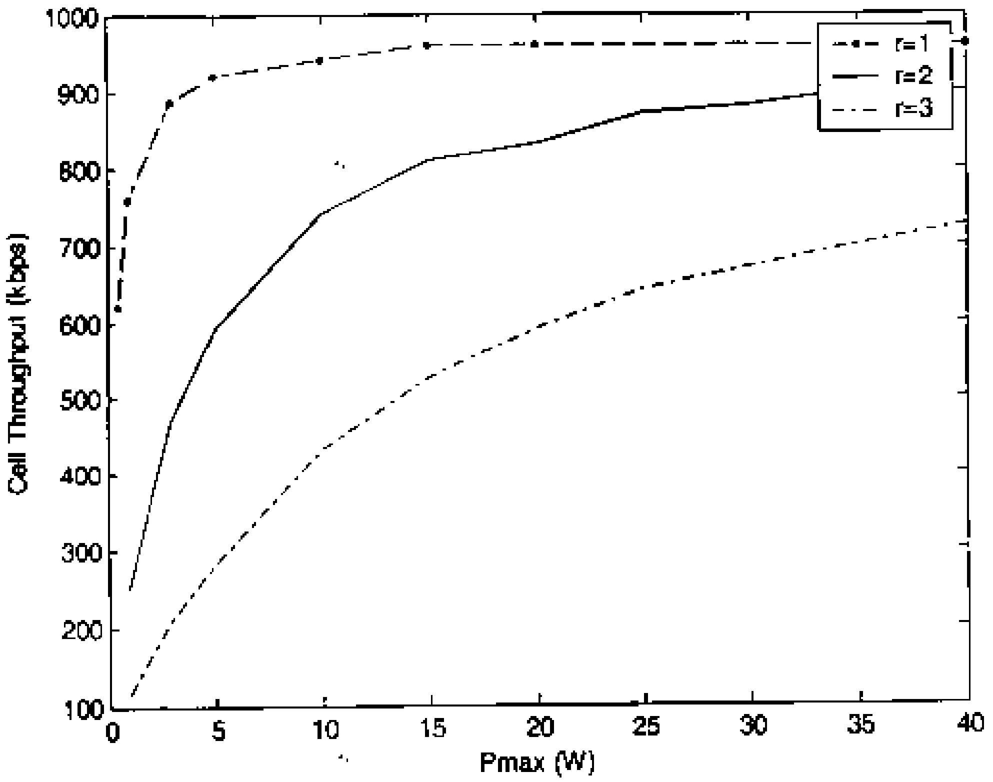


Figure 5.2-b Cell throughput for mixed traffic [0.6 : 0.4 : 0 : 0]

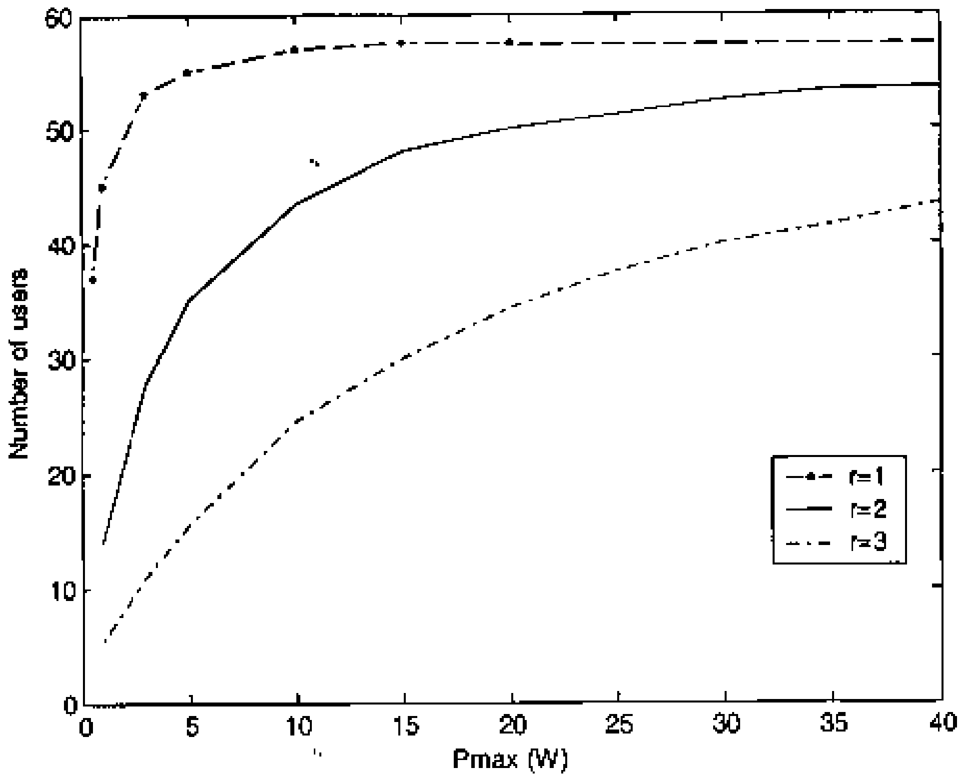


Figure 5.3-a No. of users for mixed traffic [0.6 : 0 : 0.4: 0]

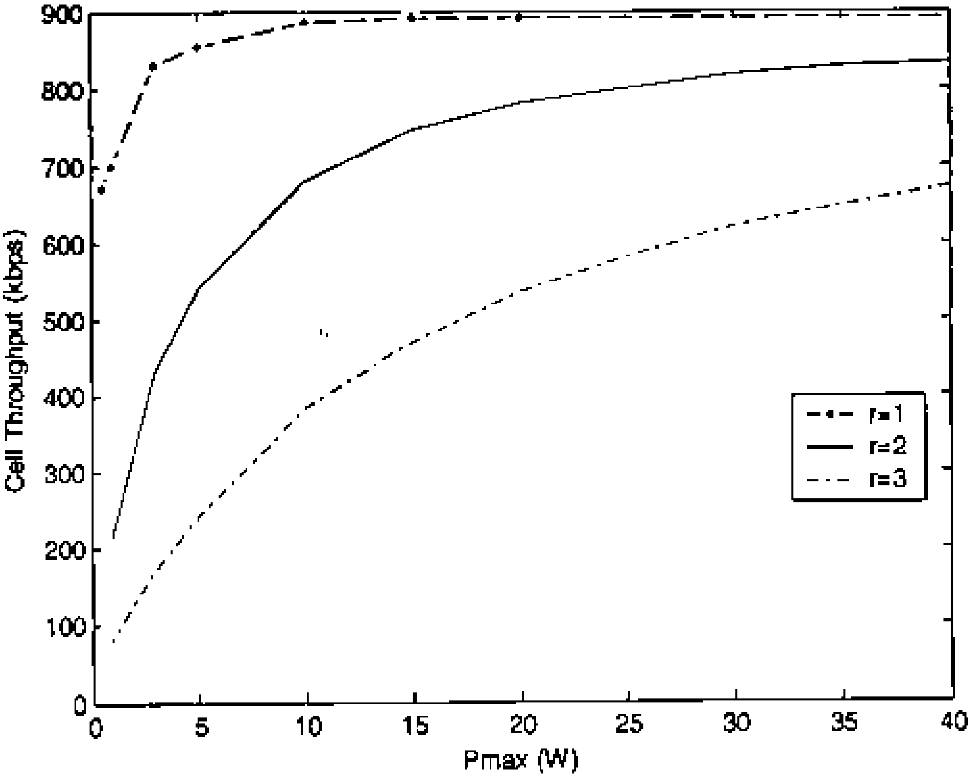


Figure 5.3-b Cell throughput for mixed traffic [0.6 : 0 : 0.4 : 0]

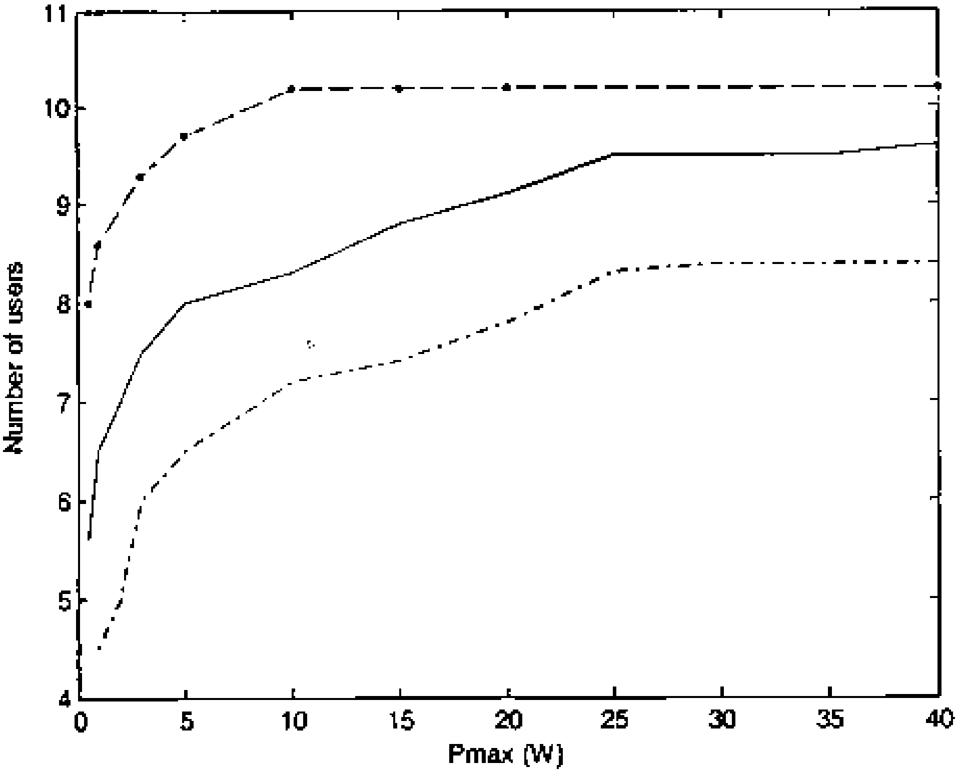


Figure 5.4-a No. of users for mixed traffic [0.6 : 0 : 0 : 0.4]

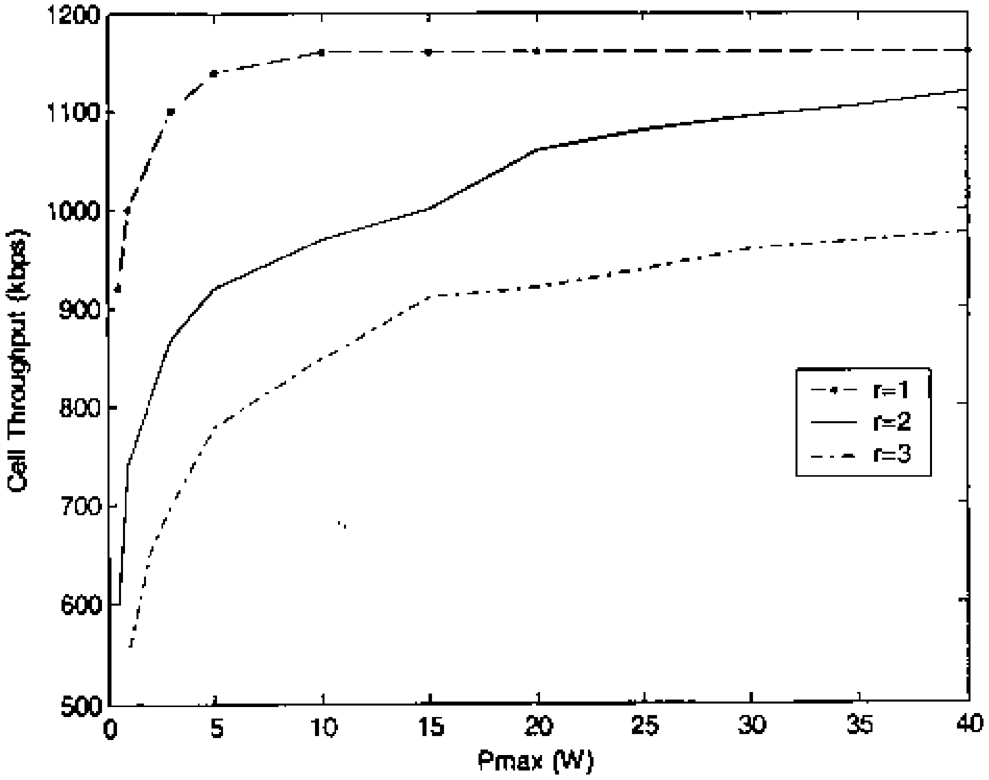


Figure 5.4-b Cell throughput for mixed traffic [0.6 : 0 : 0 : 0.4]

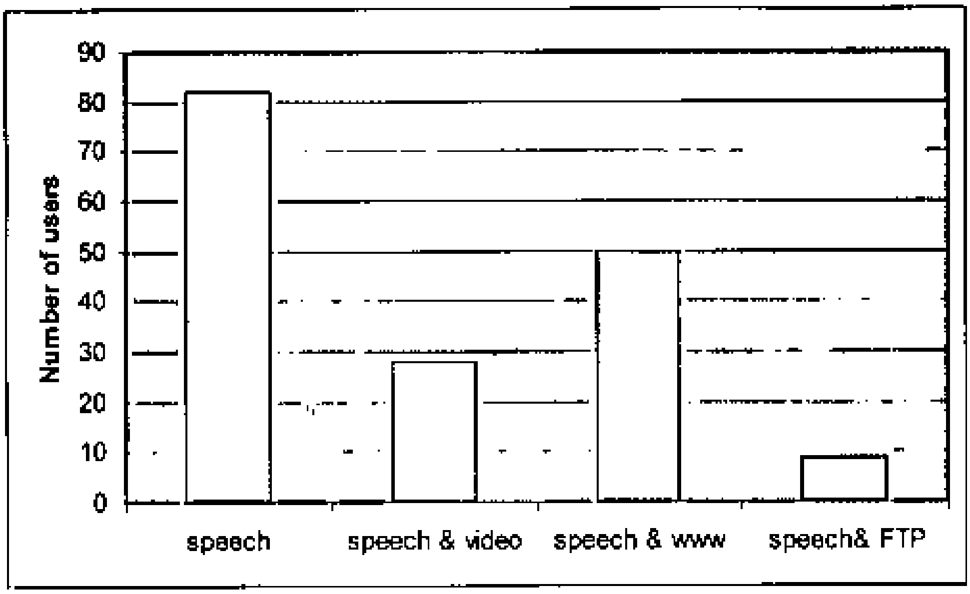


Figure 5.5-a Number of users for different services

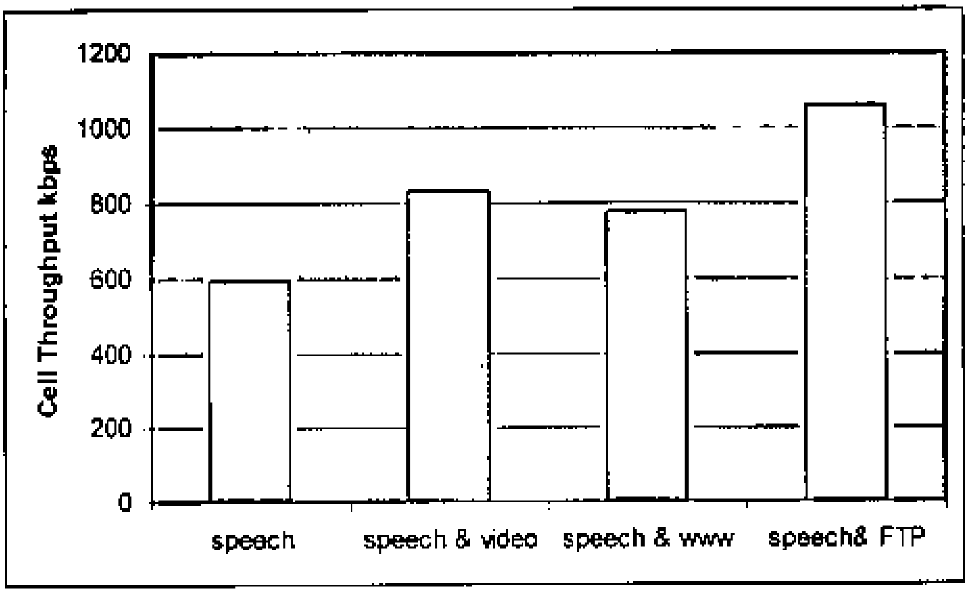


Figure 5.5-b Cell throughput for different services

From figure 5.5-a we note that the number of users in the cell is severely decreased when FTP service is enabled where the total number of users is 9 users, and the number of users is less than 30 for video telephony service, which is still low compared to the case of speech service only where the number is 82. This decrease in number of users when data services are enabled caused by the high data rate and activity factor (v=1) for these services, which implicates a high power requirements for video and FTP services. The low activity factor of www service (v=0.2) implicates a relatively large number of user can be served.

On the contrary to the number of users, the cell throughput is higher for FTP and video services; this is again because the high data rate and activity factor for these services as indicated above.

5.2.3 Uniform vs. Normal distribution

In this case the user distribution (user locations in the cell) is assumed normal where a larger number of users are located closer to the base station. Figure 5.6-a shows that with normal distribution 52 extra users can be added to the cell as compared to uniform distribution, for the reference case (P_{max}=20W, r=2), this gives capacity gain of 65%. This capacity gain acquired from the feature of WCDMA that closer users to the base station require less power resulting in less interference to other users and consequently less transmitted power. The capacity gain in term of cell throughput illustrated in figure 5.6-b

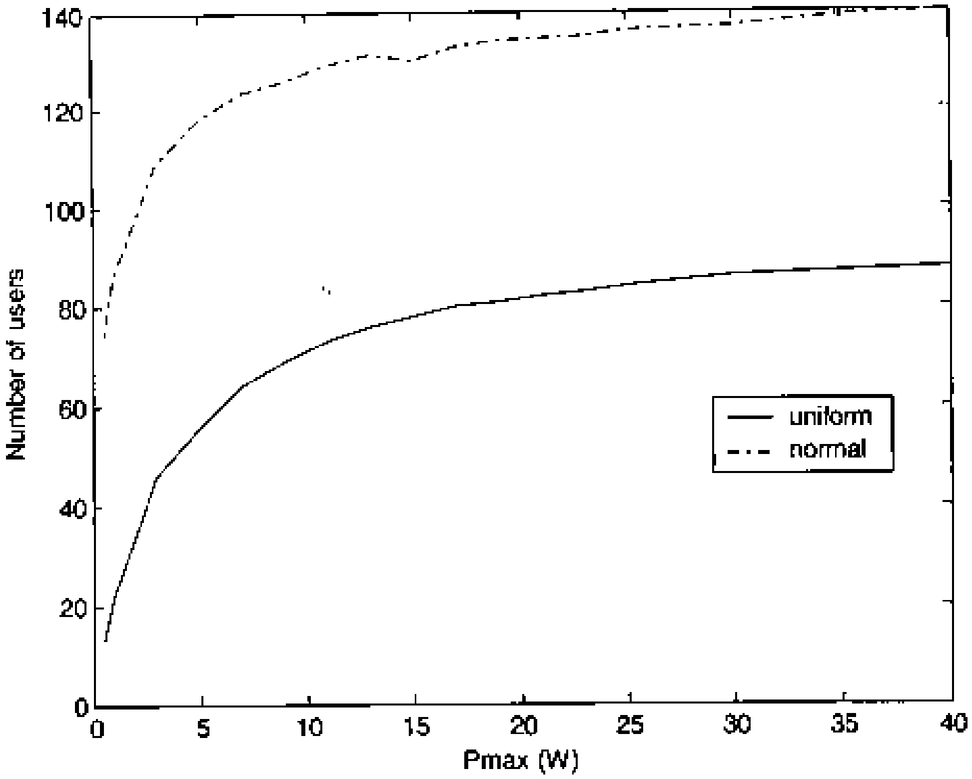


Figure 5.6-a No. of users with uniform and normal user distributions

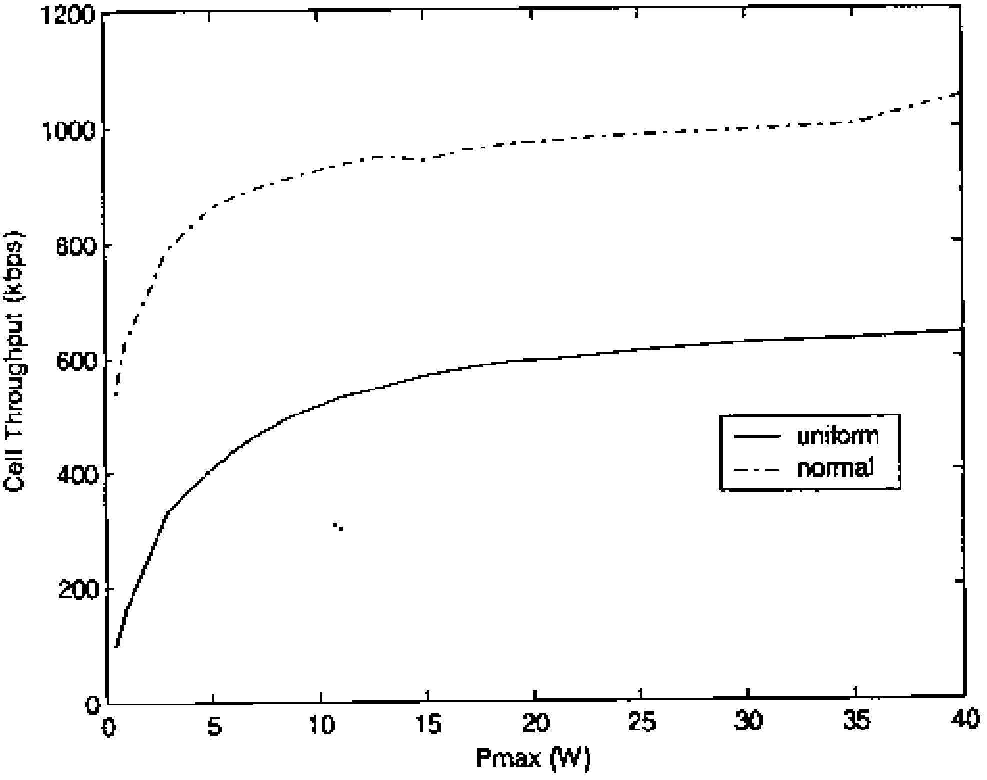


Figure 5.6-b Cell throughput uniform and normal user distributions

5.2.4 Isolated Cell Capacity

In this case it's assumed that the cell is isolated; i.e. the inter-cell interference is neglected. In figure 5.7-a, the number of users is plotted for different cases. Compared to reference case (P_{max}=20W, r=2, uniform distribution), the isolated cell with uniform distribution has capacity gain of 70% (extra 57 users). In the case of isolated cell with normal distribution this gain rises to 100% with a total number of 165 users, the throughput at this point is 1200kbps/cell as in figure 5.7-b.

In figure 5.8 the isolated cell throughput with normal distribution is simulated for different coverage requirement. For cell radius r=4 km, the number of users falls to 149 user at P_{max} =20W, which is still high capacity.

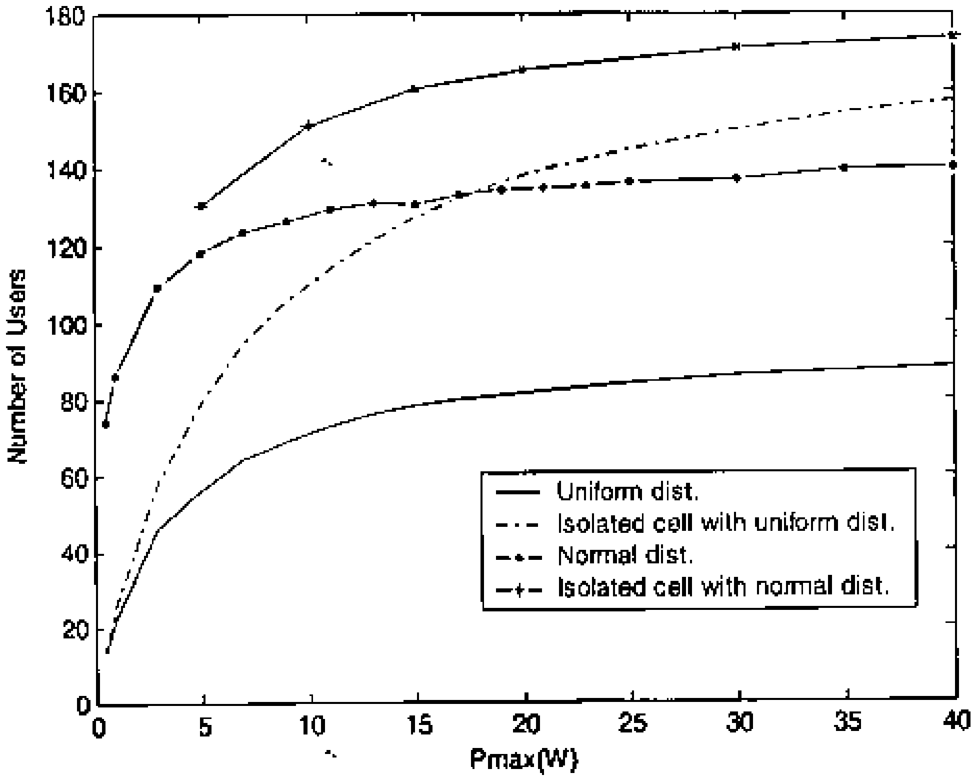


Figure 5.7-a Isolated cell capacity

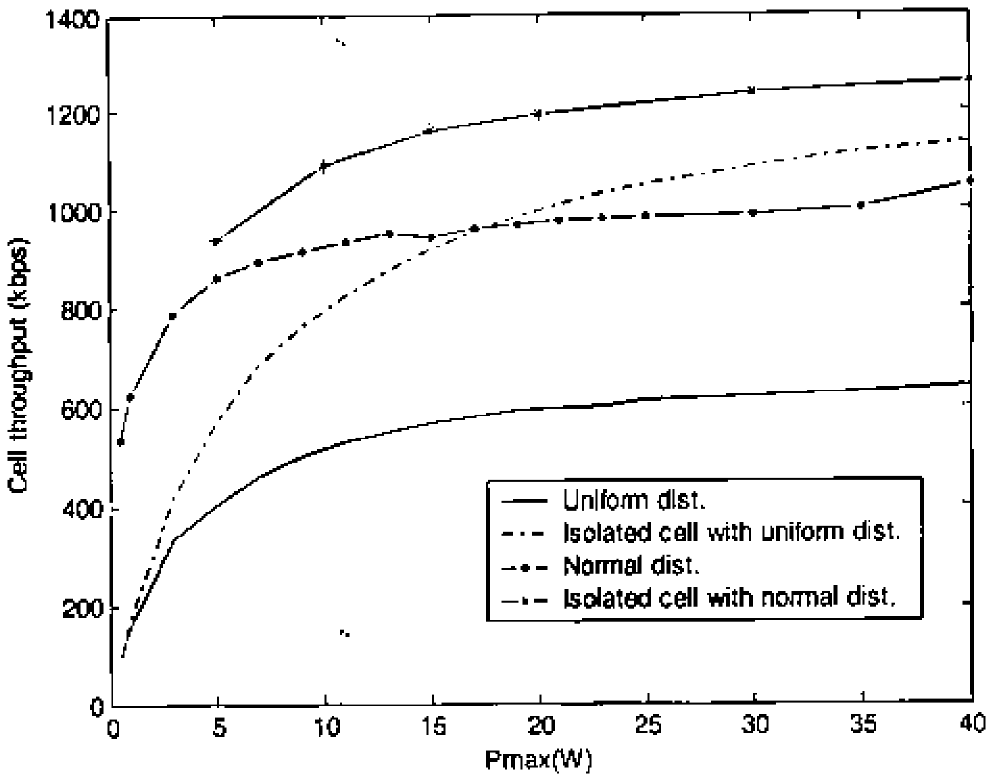


Figure 5.7-b Isolated cell throughput

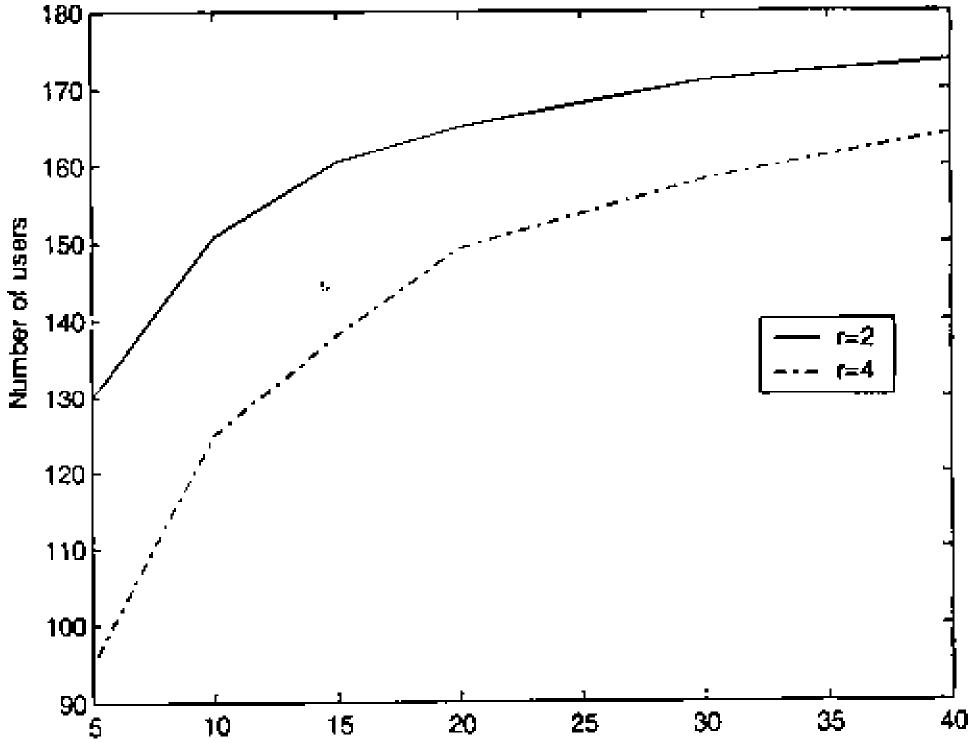


Figure 5.8 Isolated cell capacity with different coverage requirement

5.2.5 Orthogonality factor sensitivity

For R99 with voice service, orthogonality change from 0.5 to 0.9 will increase the capacity from 593 to 915 kbps (82 to 126 users) with a gain of 54%, as indicated in figure 5.9

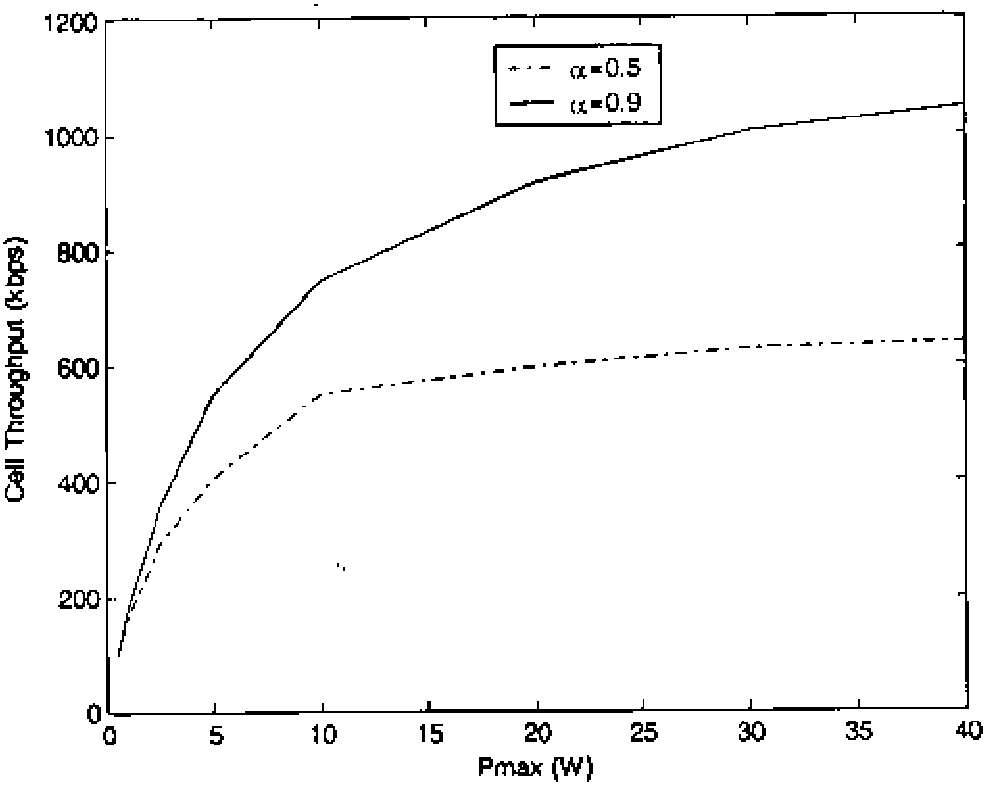


Figure 5.9 Cell capacity with different orthogonality

5.3 Capacity of Mixed R99 and HSDPA users

In this scenario both R99 users and HSDPA service are assumed to exist in the same cell. The power allocated for HSDPA users P_{HS} is part of the maximum power P_{max} with a percentage Γ, where $\Gamma=(P_{HS}/P_{max})*100$. For R99 users only speech service is assumed with a throughput of 7.25 kbps/user (data rate* activity factor*(1- BLER)= 12.2*0.6*(1-0.01)=7.25kbps

5.3.1 Uniform user distribution with Γ as a parameter

In figure 5.10 it is observed that the number of voice users is decreased for larger power allocation for HSDPA service. At the reference point of P_{max}=20W and r=2km, the number of R99 voice users is 57 user for Γ=20%, 32 users for Γ=40% and 7 users for Γ=60%.

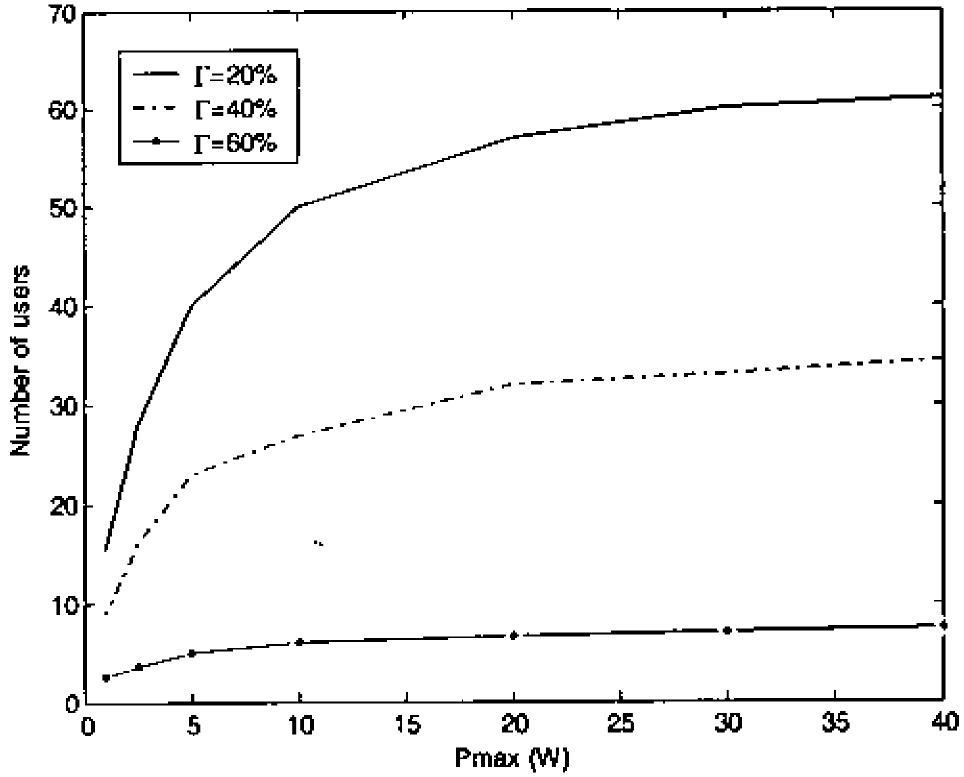


Figure 5.10 Number of speech users with HSDPA enabled, r=2

The overall cell throughput, increases with higher power allocation for HSDPA service as shown in figure 5.11. For Γ=60% the overall cell throughput is 1600 kbps/cell including the throughput of 7 R99 users as mentioned above, where 7 voice users require 50kbps/cell and the remaining capacity (1550 kbps/cell) is the throughput for the data users served by HSDPA service, HSDPA throughput can be allocated to one user or a number of users with data rates depends on the handset capability (UE category) and the reported CQI that express the channel condition.

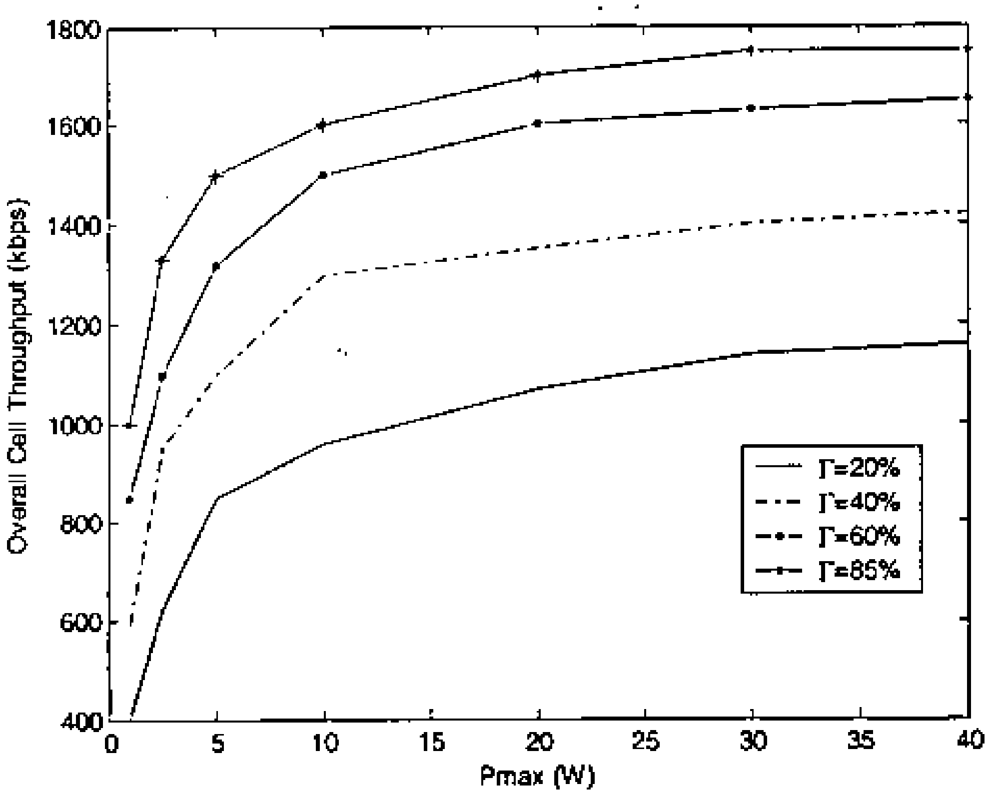


Figure 5.11 Overall cell throughput with HSDPA enabled, r=2

When **Γ** is decreased to 40% the overall cell throughput is also deceased to about 1350 kbps/cell but the number of voice users can be served increased to 32. This means that more power allocation to HSDPA results in higher overall cell throughput, but at the expense of the number of R99 users.

When the cell radius is increased to r=3km, with Γ=40%, the number of voice users falls from 32 (at r=2) to 22 users, as shown in figure 5.12, and the overall cell throughput falls to 1100 kbps/cell, as shown in figure 5.13.

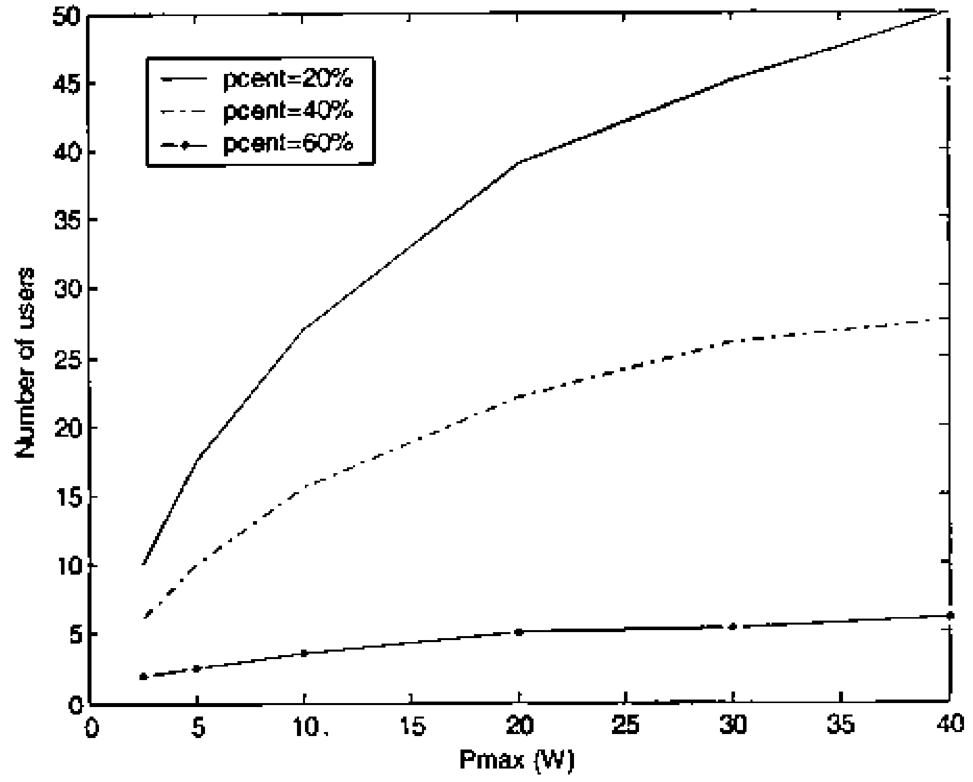


Figure 5.12 Number of speech users with HSDPA enabled, r=3

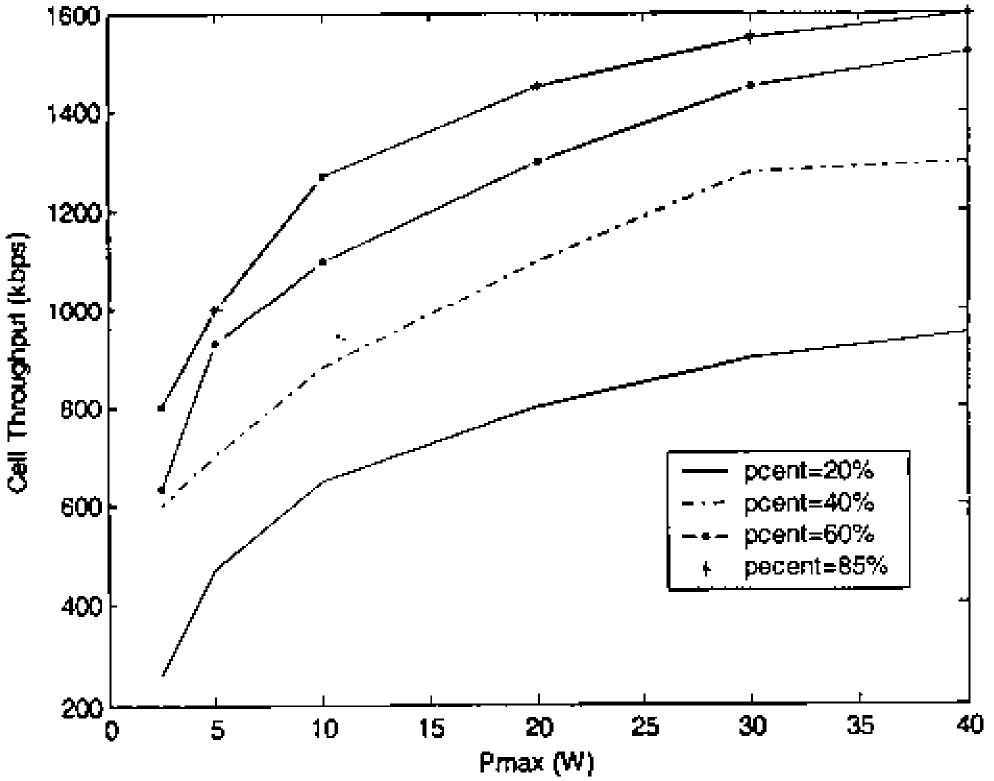


Figure 5.13 Overall cell throughput with HSDPA enabled, r=3

5.3.2 Capacity of isolated cell with normal user distribution

In this case we study the performance at r=2km and the same power allocation, Γ=40%. Normal user distribution, isolated cell and isolated cell with normal distribution are simulated and the results are plotted in figures 5.14 and figure 5.15.

From the previous case with uniform distribution and P_{max}=20W, the number of voice users was 32 and the overall cell throughput was 1350kbps/cell. Now With normal distribution the number of voice users increased to 52 users and overall cell throughput 1960 kbps/cell. With isolated cell and normal distribution the number of users rises to 64 users and overall cell throughput 2150kbps/cell.

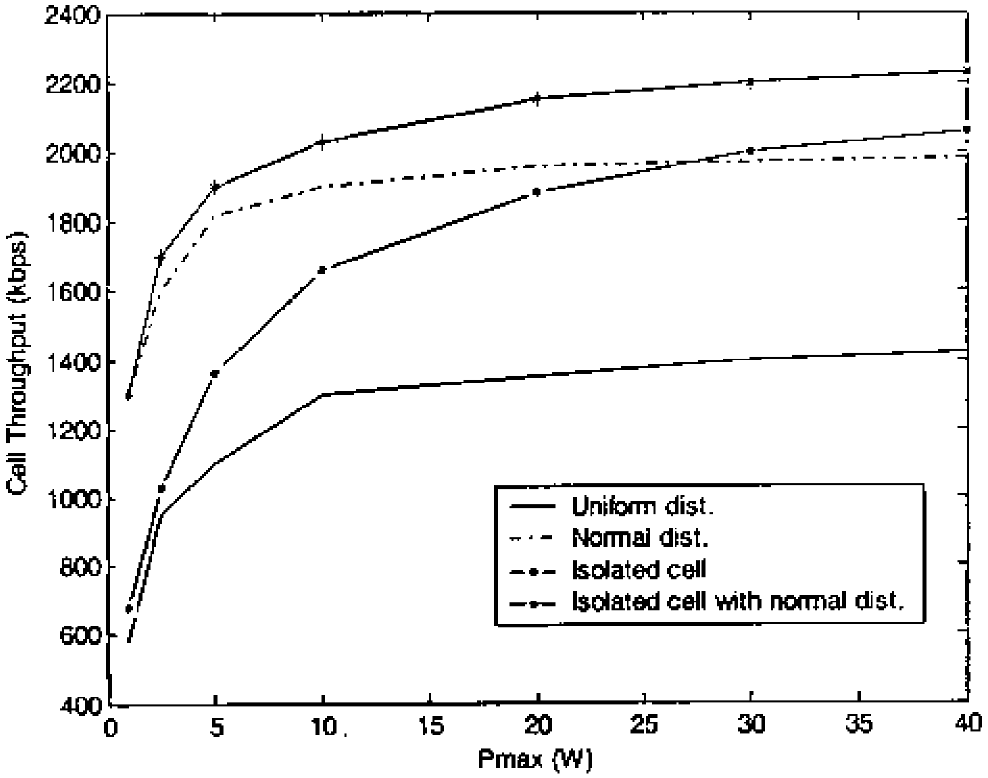


Figure 5.14 cell throughput of isolated cell with normal dist. r=2

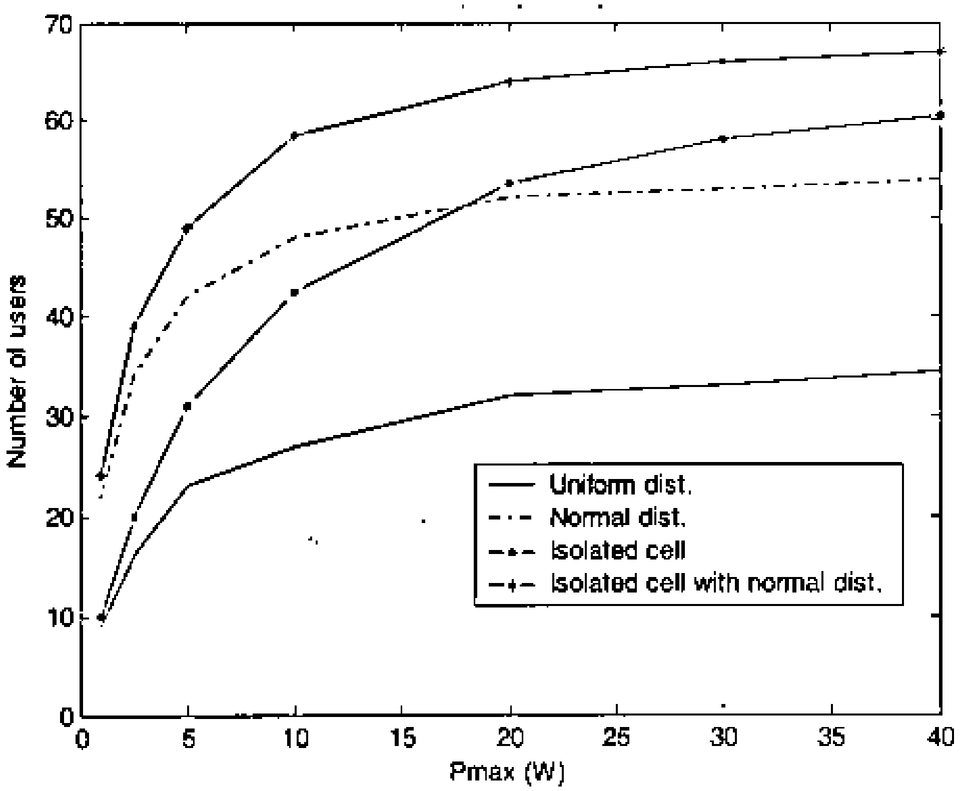


Figure 5.15 Number of users isolated cell with normal dist. r=2

5.3.3 Effect of orthogonality on the capacity of isolated cell with normal user distribution

In this case the effect of orthogonality is studied. In small cells the multipath delay is small, resulting in high orthogonality, typically α=0.9 in microcell. Figure 5.16 illustrates the capacity of isolated cell with normal distribution, r=2km, Γ=40%. The overall capacity is increased by 146% when orthogonality increased from 0.5 to 0.9 and the number of voice users rises from 64 to 230 user.

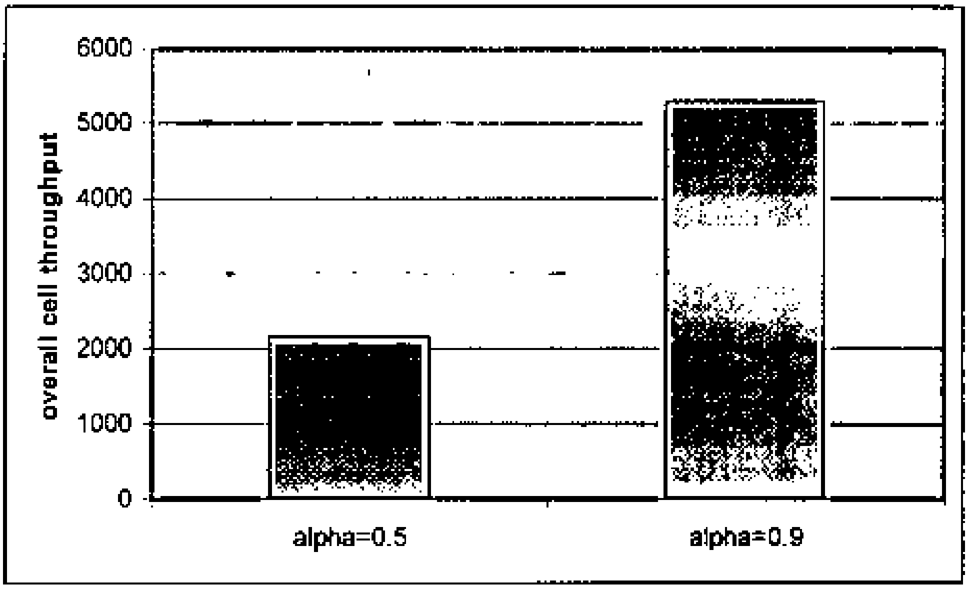


Figure 5.16 orthogonality effect on capacity

5.4 comparison between R99 only & mixed traffic (R99+HSDPA) scenario

Finally, Figure 5.17 compares the two scenarios at two different cases, one with uniform distribution and the other for isolated cell with normal distribution.

The first scenario simulates a cell with R99 service including speech and FTP users, the second scenario simulates a cell with HSDPA enabled and allocated 40% of the maximum BS transmitted power. The data are taken at P_{max}=20W, cell radius r=2km

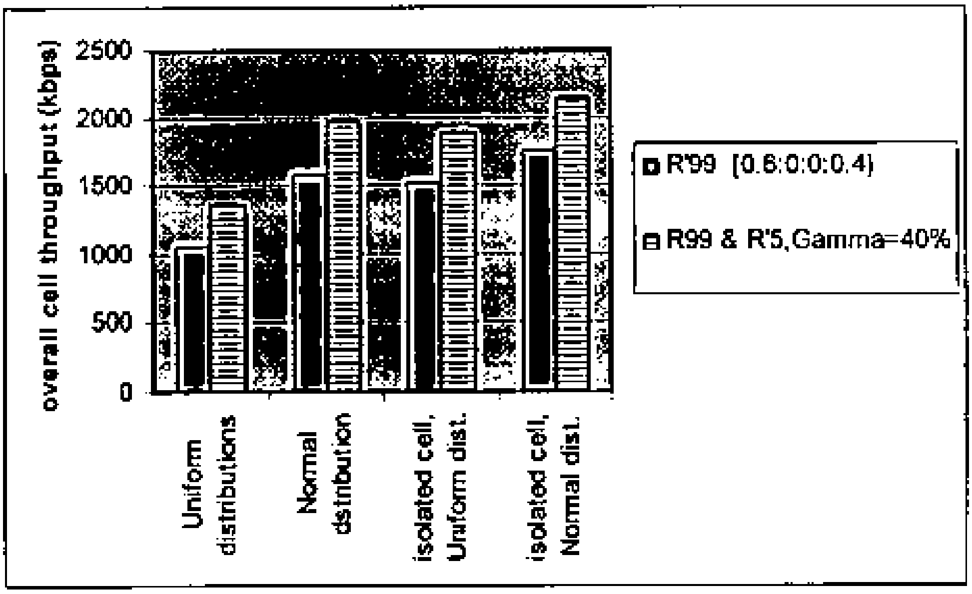


Figure 5.17 Comparison of R99 and mixed traffic scenarios

Figure 5.17 is summarized in tables 5.1 (a,b,c). In Table 5.1-a the cell capacity results are indicated in terms of No. of users and overall cell throughput for the two simulation scenarios with different cell configurations.

Table 5.1-b gives the cell capacity gain when HSDPA is enabled compared to R99 service only.

Table 5.1-a Comparison of implementation Scenarios

Scenario / Cell Configuration	R99 Speech:FTP = 6:4		R99 + HSDPA	
	No. of users	Cell T-put (kbps)	No. of users	Cell T-put (kbps)
Uniform	9	1000	32	1350
Normal	13	1570	52	1960
Isolated uniform	12	1520	54	1880
Isolated normal	20	1750	64	2150

Table 5.1-b Gain achievement by HSDPA

Value of relative gain / Cell Configuration	In No. of users	In Cell T-put
Uniform	251%	35%
Normal	309%	24.8%
Isolated uniform	342%	23.7%
Isolated normal	220%	22.9%

Table 5.1-c indicates the gain of the isolated cell with normal distribution compared to uniform distribution for each scenario. In overall cell throughput this gain is 65% for R99 scenario and 59% when HSDPA is enabled.

Table 5.1-c Gain of isolated cell with normal distribution over uniform distribution cell

Value of relative gain / Sim. Scenario	In No. of users	In Cell T-put
R99 **Speech:FTP = 6:4**	119.8%	65.1%
R99 + HSDPA	100%	59.2%

CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

In cells with R99 services only, we noted that the number of users increases with increasing $P_{max,}$ till we reach specific power level beyond which no new users can be added to the cell because the interference rises to a level doesn't allow more user without degrading the service quality of the other users. This indicates that downlink capacity is interference limited in multiple service WCDMA network. It's also noted that when data service is enabled, which is the case in 3G networks, the total number of users decrease because of the high data rate required for such service; e.g. one FTP user affect the capacity drastically in terms of the number of users.

In cells with HSDPA service, cell throughput can be increased to 35% higher than R99 cells, which means more data users can be offered with still reasonable number of voice users. Moreover, the HSDPA power allocation is an operator issue, that is, power allocations can be configured as required, for example in cells in public places, we expect more voice users to be served, so the operator can allocate more power for R99 service.

With HCS Capacity can be improved significantly by cells located in selected hotspots, i.e. isolated cells, with carrier frequency different from the one used in other layer, hence the condition of isolation and normal distribution with the high orthogonality factor is assumed to be satisfied and the cell capacity reaches 5.3Mbps/cell with capacity gain of more than 300% as compared to continuous layer cell with uniform distribution

6.2 Recommendations

One goal of the thesis is to indicate relative increase in capacity as being carried out using different techniques. This was done by adding features or changing the values of some parameters by introducing some simplifications to the system model and some features were not simulated at all. Therefore for future work we recommend the following issues to be part of next work that can be tackled.

For future work we do recommend

(a) Including the HARQ in simulating HSDPA service.

(b) Embedding a handover algorithm which is not simulated in our model.

(c) Embedding power control algorithm to simulate practical power control where we assumed perfect power control.

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Appendices

Appendex A

Table A.1: Propagation Conditions for Multi path Fading Environments (Cases 1 to 6)[11].

Case 1, speed 3km/h		Case 2, speed 3 km/h		Case 3, speed 120 km/h		Case 4, speed 3 km/h		Case 5, speed 50 km/h		Case 6, speed 250 km/h	
Relative Delay [ns]	Relative mean Power [dB]	Relative Delay [ns]	Relative mean Power [dB]	Relative Delay [ns]	Relative mean Power [dB]	Relative Delay [ns]	Relative mean Power [dB]	Relative Delay [ns]	Relative mean Power [dB]	Relative Delay [ns]	Relative mean Power [dB]
0	0	0	0	0	0	0	0	0	0	0	0
976	-10	976	0	260	-3	976	0	976	-10	260	-3
		20000	0	521	-6					521	-6
				781	-9					781	-9

Appendix B

MATLAB Functions Descriptin

The simulation algorithm is implemented using MATLAB Release 13 (v.6.5.1), so it's expected to be run properly on version 6.5 or later versions.

The following functions are developed:

1. [d,user_profile,]=adduser(r,prob)

This function adds one user uniformly on a hexagonal cell with radius **r** (km)
Four user types can be added [Voice: Video : WWW :FTP]
prob is a four elements row vector containing the percentage of each user
type
d is the distance of the added user from the base station
user_profile is the profile of the added user (data rate, activity factor, E_b/N_0 Requirement

2. [d,user_profile,]=addusern(r,prob)

The same as **adduser** function with normal user distribution instead of uniform user distribution

3. function CQI=snr2cqi(SNRm)

This function converts the measured SNR to Channel Quality Indicator (CQI)

4. usersmix(r,P,prob,stddev)

Calculates the max. number of users can be served
r is the cell radius.
P is a two element row vector [Pmax pcent] where Pmax is the Maximum BS Tx Power, pcent is the percentage of P_{HS} set by operator

prob is a 4 element row vector corresponding to for service type in Rel'99
stddev is optional input, if used then the users added with normal distribution with standard deviation stddev. If not used uniform user distribution is assumed
p is the Tx power from BS to each rel'99 user
Pt is the total BS Tx power.

Required M-files:

adduser.m, addusern.m, snr2cqi.m

5. usersmixiso(r,P,prob,stddev)

Calculates the max. number of users can be served, in case of ***isolated cell***
The arguments defined as in **usermix** function

Required M-files:

adduser.m, addusern.m, snr2cqi.m