CDMA POWER CONTROL USING FIREFLY ALGORITHM

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
SIGNAL PROCESSING AND DIGITAL DESIGN

Submitted by

Anju Gupta

2K12/SPD/24

Under the supervision of

Dr. Rajiv Kapoor
(Professor, ECE Department)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042
2012-2015

CERTIFICATE

This is to certify that the dissertation title "**CDMA Power Control using firefly Algorithm**" submitted by **Anju Gupta**, Roll. No. 2K12/SPD/24, in partial fulfilment for the award of degree of Master of Technology in Signal Processing & Digital Design at **Delhi Technological University, Delhi**, is a bonafide record of student's own work carried out by him under my supervision and guidance in the academic session 2014-15. To the best of my belief and knowledge the matter embodied in dissertation has not been submitted for the award of any other degree or certificate in this or any other university or institute.

Prem R. Chadha	Dr. Rajiv Kapoor
Head of the Department	Professor
ECE Department	ECE Department
Delhi Technological University	Delhi Technological University

CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in the dissertation, entitled "**CDMA Power Control Using Firefly Algorithm**", in partial fulfillment of the requirements for the award of the degree of Master of Technology in Signal Processing & Digital Design and submitted to the Department of Electronics and Communication Engineering of Delhi Technological University, New Delhi is an authentic record of my own work carried out during the period from Januray 2015 to June 2015 under the supervision of Dr. Rajiv Kapoor, Professor, ECE Department.

Anju Gupta
2K12/SPD/24

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dr. Rajiv Kapoor
Professor
ECE Department
Delhi Technological University

ACKNOWLEDGEMENT

I feel great pleasure in expressing my regards and gratitude to my mentor Dr. Rajiv Kapoor, Professor, Electronics and Communication Department, Delhi Technological University, New Delhi for giving me the guidance and opportunity to work on CDMA power control using firefly algorithm.

I am also deeply grateful to my earlier mentor Dr. Nidhi Goel for her support, insightful guidance, understanding and encouragement.

I am grateful to them for their generous guidance at every stage of the project. Their advice, suggestions and encouragement has let me through this dissertation.

ABSTRACT

Power control is an essential radio resource management method in CDMA cellular communication systems because the users transmit their signals simultaneously in the same frequency band. Each user is given a dedicated spreading code, which is used to identify the users in the receivers by correlating the received signal with a replica of the desired user's code. The cross-correlation of different spreading codes is ideally zero, but due to multipath propagation and non-ideal spreading codes this is not the case in practice. The receiver therefore sees the other users' signals as interference and the more users in the system the more interference are generated. CDMA is interference-limited, which means that it is the interference from other users that limits the capacity of the system. To increase capacity, some methods are needed for interference management. Power control aims to control the transmission power levels in such a way that acceptable quality of service for the users is guaranteed with lowest possible transmission powers. All users benefit from the minimized interference and the preserved signal qualities. For CDMA system Power control is the most important system requirement. If power control is not implemented many problems such as the near-far effect will start to dominate and consequently will lower the capacity of the CDMA system. However, when the power control in CDMA systems is applied, it allows multiple users to share resources of the system equally between themselves, leading to increased capacity. With appropriate power control, capacity of CDMA system is high in comparison to frequency division multiple access (FDMA) and time division multiple access (TDMA).For power control in CDMA system optimization algorithms i.e. genetic algorithm, particle swarm algorithm and firefly algorithm can be used which determines a suitable power vector [1], [2]. These power vector or power levels are determined at the base station and told to mobile units to adjust their transmitting power in accordance to these levels. So our aim here was to find out the suitable power vector using firefly algorithm that can be used by different mobile units so that no blocking occurs. In this thesis a new closed loop power control method for CDMA cellular communication systems is proposed.

TABLE OF CONTENTS

TITLE	PAGE NO.
Certificate	i
Candidate’s declaration	ii
Acknowledgement	iii
Abstract	iv
List of figures	vii
List of tables	viii
List of abbreviations	ix
List of symbols	xi
1. CHAPTER 1 Introduction 1	
1.1 Introduction about cellular advancement	1
1.2 Multiple access methods	4
1.2.1 Frequency division multiple access FDMA)	5
1.2.2 Time division multiple access (TDMA)	6
1.2.3 Code division multiple access (CDMA)	6
1.3 Orthogonal Frequency Division multiple access (OFDMA)	9
1.4 Problems and goals of this thesis	9
1.5 Thesis Outline	10
2. CHAPTER 2 Power control in CDMA cellular communication systems	
2.1 Introduction	11
2.2 Need of power control	12
2.3 Uplink versus downlink power control	12
2.4 Open loop versus closed loop power control	13
2.5 Reverse Link Power Control	14
2.5.1 Reverse Link open loop Power Control	15
2.5.2 Reverse Link closed loop Power control	15
2.6 Quality measures for power control	16
3. CHAPTER 3 Literature Review	
3.1 Overview	18
3.2 Genetic Algorithm for Mobiles Equilibrium (GAME)	18
3.3 Particle Swarm Optimization (PSO) Algorithm	20
3.4 PSO-based Algorithm for Power Control Problem	22
4. CHAPTER 4 CDMA Power Control using fire fly algorithm	
4.1 Firefly Algorithm	24
4.1.1 Behavior of Fireflies	24
4.1.2 Concept	24

4.1.3 Light Intensity and Attractiveness 25
4.1.4 Firefly Algorithm 27
4.2 Main objectives of thesis 27
4.3 Problem Description and Fitness Function in thesis 28

5. CHAPTER 5 Implementation, Result and Conclusion
5.1 Software used 30
5.1.1 Key Features of MATLAB 30
5.1.2 Programming and Algorithm Development 31
5.1.3 Application areas of MATLAB software 32
5.2 Flowchart 33
5.3 Results 35
5.4 Conclusion 41

APPENDIX

A References

B MATLAB Code

LIST OF FIGURES

Figure No.	Figure Title	Page No.
1.1	Evolutions of Digital Cellular Standards	2
1.2	Comparison of various technologies	3
1.3	Multiple access methods	5
1.4	OFDM Signal	9
2.1	Near far effect	12
2.2	Open loop and closed loop power control	14
2.3	Reverse Open loop power control	15
2.4	Reverse closed loop power control	16
3.1	Block diagram of PSO-based algorithms for power control	23
5.1	Power vector for 5 users without updating from other iteration	36
5.2	Power vector for 5 users with updating from other iteration	37
5.3	Power vector for 10 users without updating from other iteration	39
5.4	Power vector for 10 users with updating from other iteration	40

LIST OF TABLES

Table No.	Table Title	Page No.
1.1	Comparison of 1G-4G technologies	3
5.1	Table showing power vector for 5 users without updation	36
5.2	Table showing power vector for 5 users with updation using firefly	38
5.3	Final power vector for 5 users	38
5.4	Power vector for 10 users without updating from other iteration	39
5.5	Power vector for 10 users with updating from other iteration	40
5.6	Final power vector for10 users	41

LIST OF ABBREVIATIONS

1G, 2G, 3G	1st, 2nd, 3rd Generations
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
ALP	Active Link Protection
AML	Approximate Maximum Likelihood
AMPS	Advanced Mobile Phone Service
AR	Auto-Regressive Process
ARIX	Auto-Regressive Integrated Process with Exogenous Input
AS	Adaptive Step
AS-A	Asymmetric Adaptive Step
AS-G	Gradual Adaptive Step
AS-VG	Variable Gain Adaptive Step
ASPC	Adaptive Step Power Control
ASPC-A	Asymmetric Adaptive Step Power Control
AWGN	Additive White Gaussian Noise
BEP	Bit Error Probability
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CIR	Carrier-to-Interference ratio
CSOPC	Constrained Second-Order Power Control
DB	Distributed Balancing
DCPC	Distributed Constrained Power Control
DCS	Digital Cellular System
DDPC	Distributed Discrete Power Control
DF	Describing Function
DFB	Decision Feedback
DPC	Distributed Power Control
DPCCH	Dedicated Physical Control Channel
DS	Direct Sequence
EDGE	Enhanced Data Rates for GSM Evolution
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FER	Frame Error Rate
FH	Frequency Hopping
FSPC	Fixed-Step Power Control
GDCPC	Generalized Distributed Constrained Power Control
GMV	Generalized Minimum Variance
GPRS	General Packet Radio Service
GSM	Global System of Mobile Communications
HSCSD	High Speed Circuit Switched Data

HSD	High Speed Data
HSDPA	High Speed Downlink Packet Access
IS-xx	Interim Standard - xx
IMT-2000	International Mobile Communications for the year 2000
JTACS	Japanese Total Access Communications System
LMS	Least Mean Squares
LOS	Line of Sight
MA	Moving Average Process
M-DB	Modified Distributed Balancing
MMSE	Minimum-Mean-Square-Error
MRC	Maximal Ratio Combining
MS	Mobile Station
MTP	Minimum Transmission Power
MV	Minimum Variance
MV-PC	Minimum Variance Power Control
NMT	Nordic Mobile Telephone
NTT	The Nippon Telephone and Telegraph
ODFM	Optimal Decision Feedback Method
PC	Power Control
PCA	Power Control Algorithm
PDC	Personal Digital Cellular
PDF	Probability Density Function
PL	Path loss
PRBS	Pseudo-Random Binary Sequence
QoS	Quality of Service
SIR	Signal-to-Interference Ratio
SMS	Short Message Service
TACS	Total Access Communications System
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TPC	Transmission Power Control
UMTS	Universal Mobile Telecommunication System
UTRA	Universal Terrestrial Radio Access
WCDMA	Wideband Code Division Multiple Access

LIST OF SYMBOLS

Symbol	Meaning of symbol
chip/s	Chips per second
C	Capacity
D	Path loss exponent
E_b	Energy per bit
N_o	Noise power spectral density
E_b/N_o	Bit-energy-to-interference-spectral-density ratio
$(E_b/N_o)_i$	Bit-energy-to-interference-spectral-density ratio of user i
G_p	Processing gain
G_{bi}	Link gain between the base station 'b' and mobile user 'I'
Io	Interference power spectral density
$I(t)$	Interference power in decibels at time instant t
k	Total loop delay
M	Number of users
p_r	Received power
P_i	Transmitted power by ith mobile
R	Distance in meters
R_i	Information bit rate transmitted by ith mobile user
R_b	Data rate in bits/s
p^{-r}	Average received power level
σ_{p^r}	Standard deviation
I_t	Total interference
P_{max}	Maximum power level
W	Transmission bandwidth
w	Weighting parameter
F_i^H	Threshold function defined for ith user
Io	Io Initial light intensity
I_s	Light intensity at the source
β	Attractiveness
γ	Light absorption coefficient
$\emptyset_1$	Random number
A_{ij}	Variation in the received signal due to shadow fading

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

1.1 Introduction about cellular advancement

This chapter provides a quick over read of the cellular technologies from first generation to the milestone fourth generation cellular technologies. Cellular communication has reformed the way of communication dramatically during the past few years. It has removed the distinction between work, home and travel by providing the potent ways of communication in a dynamic and user friendly manner. Cellular technologies are speedily evolving throughout the globe in terms of network coverage and number of users. Immense research work is going round the world in this sector and heap of latest developments regarding technology and services are replacing the present ones. The fundamental operations performed by the various networks are similar to each other up to some extent and they face same challenges in terms of quality and coverage. [3]

Wireless cellular communication system is undergoing a swift growth during the last two decades. The first-generation (1G) systems were analog and provided wireless voice service. Digital transmission technology played a dominant improvement in the transformation to second-generation (2G) systems, which capacitated the use of error correction coding and increased wireless service quality and network capacity. In addition to the standard circuit-switched services like the familiar voice service, 2G systems have developed further to provide also packet-switched wireless data service. Today, data rates provided are of the order of tens or hundreds of kbps (kilobits per second). Still, the focus of 2G systems design was mainly for wireless voice service. As the industry has come forth for high-speed wireless multimedia, the traditional voice service-optimized infrastructures are no longer sufficient. Data rate provided by 2G systems, like GSM-Global System for Mobile Communications, will be upto 384 kb/s even in a mature network. To go further in data rates, new infrastructures and technologies needed to be set up that can fulfil the requirement of high-speed wireless data. These systems, called third-generation (3G) systems, can provide data rates up to 2 Mb/s. These data rates can help in enabling many new services and applications, including video streaming, web browsing and big file transfer. To attract customers, the new services built should be inexpensive and the quality of service should be high. Choosing a multiple access technique suitably proves to be a significant step for attaining these goals. Multiple access method selected for air interface of these 3G systems is Wideband Code Division Multiple Access (Wideband CDMA or WCDMA). The 3G system in Europe is called the Universal Mobile Telecommunication System (UMTS) [4, 5, 6].

The evolution of cellular communication from 1G to 4G is shown as below:-

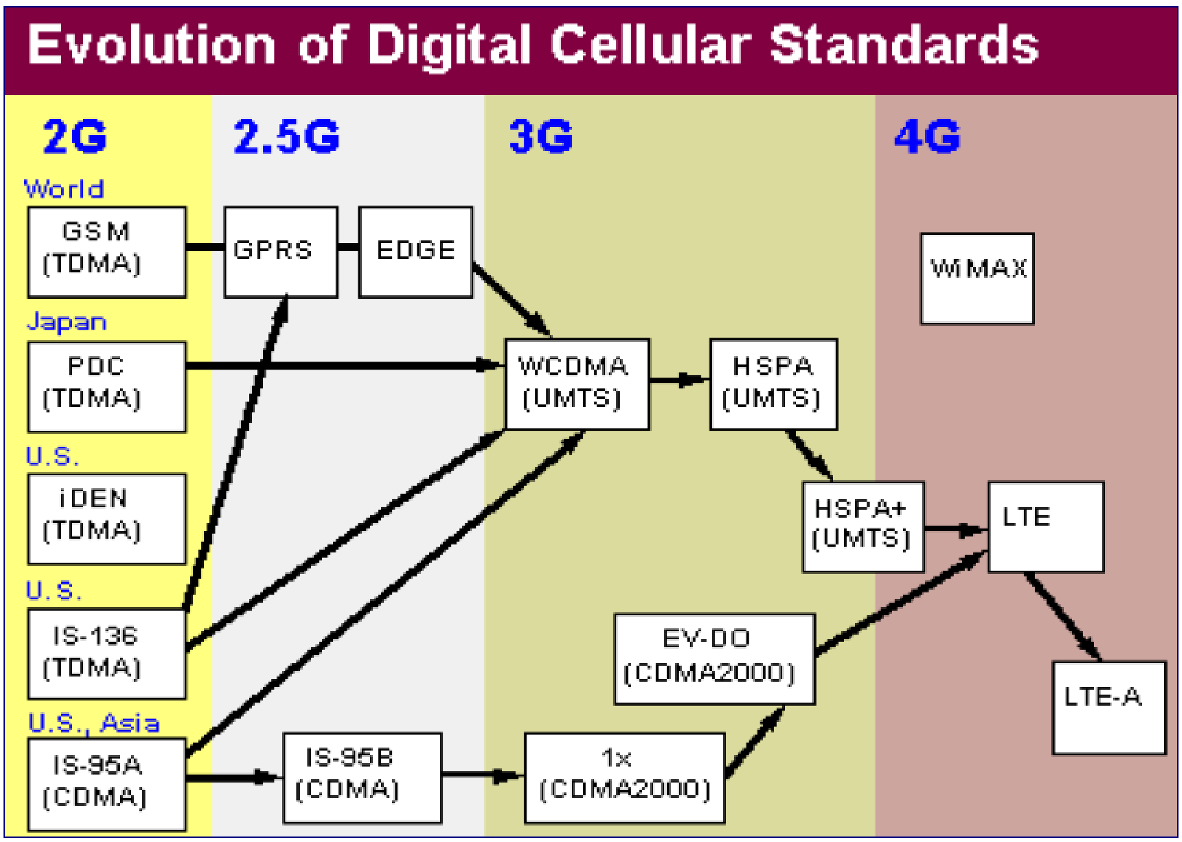


Figure 1.1 Evolutions of Digital Cellular Standards [7]

LTE, Long-Term Evolution, commonly advertised as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. 4G LTE systems provides increase in the network capacity and data speed using a different radio interface all together with new core network structure. Multiple access method selected for air interface of these systems is Orthogonal frequency division multiple access (OFDMA). LTE-A is currently developing and is in under-development stage. 3GPP standards call it as IMT-Advanced. While on 4G technology, fast moving user can achieve a data rate of 100 Mbps for and fixed users can get as high as 1 Gbps data rate [8]. When copared to previous generation 2G/3G, this technology is more bandwidth efficient and will be providing stable and higher data rates.

Comparison table 1.1 of various technologies					
Technology/ Features	1G	2G	2.5G	3G	4G
Start/ Deployment	1970/1984	1980/1991	1985/1999	1990/2002	2004/2009
Standards	AMPS	TDMA,CDMA, GSM	GPRS, EDGE, 1XRTT	WCDMA, CDMA-2000	LTE, WiMAX
Technology	Analog Cellular Technology	Digital Cellular Technology	Digital Cellular Technology	Broad Bandwidth CDMA	Unified IP and seamless combination of broadband, LAN, WAN, PAN
Service	Mobile telephony (voice)	Digital voice SMS (Short messaging service)	Higher Capacity, Packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable device
Multiplexing	FDMA	FDMA, CDMA	FDMA, CDMA	CDMA	OFDMA
Switching	Circuit	Circuit	Circuit for access network & air interface, Packet for core network & data	Packet except circuit for air interface	All Packet
Core Network	PSTN	PSTN	PSTN & Packet network	Packet network	Packet network

Figure 1.2 Comparison of various technologies [9]

Figure 1.2 shows the comparison of 1G/2G/3G/4G technologies in terms of technological advancements, increasing efficiency of the system and data rates provided by the system. It also provides information about the standard and technologies according to their respective generation.

Mobile users transmit the radio signals concurrently in CDMA systems in the same frequency band. A dedicated spreading code is assigned to each user. This spreading code is used to distinguish the users from each other at the receivers end by correlating the received signal with a transcript of the desired user's code. Ideally, the cross correlation of distinct spreading codes should be zero, but in practice cross correlation does not turn out to be zero as signals undergo multipath propagation and the spreading codes assigned are not ideally distributed. Therefore the other users' signals are interpreted as interference by the receiver. Larger the number of users in the system, more will be the interference generated.

CDMA technology makes an interference-limited system, which implies that the capacity of the system is limited by other users' interference. Interference management is major concern in this system. One such method to manage interference and thereby increasing capacity is power control. Power control (PC) aims to restrain the transmission powers of user equipment in such a way that minimizes co-channel interference, while at the same time it helps in achieving satisfactory quality of service (QoS). Now in CDMA system, it is the users that are interfering with each other, so to minimize co-channel interference transmission powers are needed to be minimized. The problem is then can be framed as to find the minimum transmission powers of the users in a way satisfactory QoS is also achieved per user. Minimizing the transmission powers has the additional beneficial effect of extending the battery lives of the mobile terminals.

Other methods that can be deployed for co-channel interference management are spatial filtering and multiuser detection (MUD). Spatial filtering includes the use of smart antennas (or adaptive antennas), which are multi-antenna arrays with adaptive weights and smart signal processing algorithm in the antennas. Weights of the antennas can be varied in order to adjust antenna gain in desired direction and all other interfering users are attenuated. It takes the advantage of known spreading code structure, and attempts to cancel the interfering users' signals with known spreading codes from the received signal [10].

In this thesis the focus is on power control.

1.2 Multiple access methods

In any communication system, air interface is designed on the basis of how the common transmission medium will be shared between all users, that is known as the multiple access method. Several methods have been exploited to differentiate users from each other. Different outlooks of some multiple access methods are presented, e.g., in [11, 12, 13, 14].

There are basic three types of multiple access methods:-

1. Frequency division multiple access (FDMA)
2. Time division multiple access (TDMA)
3. Code division multiple access (CDMA)

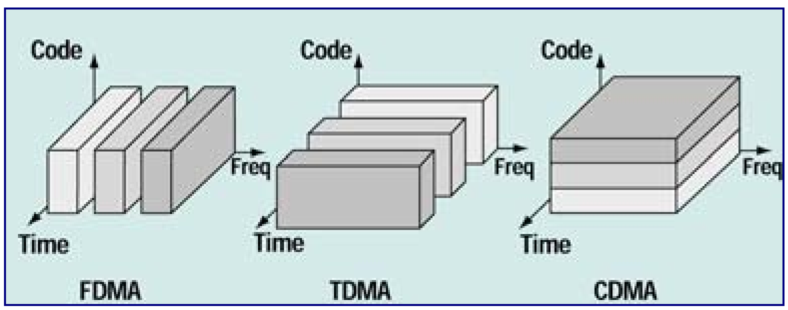


Figure 1.3 Multiple access methods

1.2.1 Frequency division multiple access (FDMA)

In frequency division multiple access (FDMA) method, the total bandwidth of the communication system is arranged into separate narrow frequency channels. This is achieved by use of band pass filters. These separate frequency channels are then allocated to individual users. FDMA was primarily used in the first generation analog cellular communication networks. Nordic Mobile Telephone (NMT) is an example of FDMA based communication system.

FDMA and FDD (frequency division duplexing) are distinct techniques. While FDMA permits many users concurrent access to a communication system, FDD cites how the radio channel at air interface is allotted between the downlink and uplink (for example, the data/voice traffic going to and fro between a mobile station and a base station). FDMA is also distinct from

Frequency-division multiplexing (FDM). FDM technique is applied on physical layer that combines and routes low-bandwidth channels through a high-bandwidth channel. On the other hand, FDMA, is an access technique applied in the data link layer.

FDMA supports both fixed assignments and demand assignments. Demand assignment permits all the users seemingly continuous access of the radio spectrum by providing carrier frequencies on a temporary basis using an assignment process that is statistical. The FDMA demand-assignment system was firstly developed for a satellite by COMSAT for application on the Intelsat series IVA and V satellites.

1.2.2 Time division multiple access (TDMA)

In time division multiple access (TDMA), each frequency band is parted into certain number of time slots that are assigned to the each user. Global System of Mobile Communications (GSM) is an example of a communication system that is based on TDMA method. In this system each band is divided into eight time slots so we can say that eight distinct users are time-multiplexed to the same 200 kHz frequency channel. Also in GSM, FDMA is used to segregate every group of eight users into distinct frequency channels [12]. TDMA method of multiple accesses is a type of Time-division multiplexing; with add on of having multiple transmitters instead of one transmitter being connected to one receiver. In the case of the forward channel i.e. from a mobile phone to a base transceiver station this becomes difficult to achieve because the mobile phone moves around and this changes the timing advance necessary to make its transmission match the gap in transmission from other users.

1.2.3 Code division multiple access (CDMA)

There is another access method in which each user is allocated a pseudo random code that spreads the user information in entire spectrum. The access technique that utilises spread spectrum technology is Code division multiple access (CDMA). Thus narrowband data signal of each user is expanded in frequency which makes the bandwidth of transmitted signals much larger than the bandwidth of original signals. Spreading can be done by two methods: frequency hopping (FH) and direct sequence (DS). In frequency hopping, the frequency of transmitted signal continuously changes as per the spreading code. Since the transmission frequency changes rapidly, it appears that the signals are wideband signals. In direct sequence spread spectrum, bits of data signal are directly multiplied by the code bits (also called chips) In most commercial communication systems, DS-CDMA method is applied, it includes UMTS (3G) as well. The resulting signal in 3G has higher bandwidth as compared to raw data signal as chip rate applied is much larger than the data bit rate. Signals from all the users are transmitted simultaneously in the same radio spectrum (frequency band). To identify the users, received signal is correlated in the receivers with a replica of the chip used by the user when sending the data signal. In the thesis only DS-CDMA is considered, and the term CDMA refers to DS-CDMA unless otherwise noted. The multiple access methods are illustrated in Figure 1.3.

With the incorporation of certain features using, CDMA is made to provide many other benefits that can make it much more bandwidth efficient as compared to plain FDMA or TDMA [16,17]. Noise-like characteristics of the transmitted signal waveform makes it possible to incorporate certain features. The most important of these benefits is universal frequency reuse, i.e, all users attached to a network will share a common radio spectrum. This means that all users will be transmitting and receiving on the same frequency channel. Its direct advantages are increase in radio spectrum utilization and elimination of the requirement for frequency planning for each user so as to provide different frequency bands to neighboring users or cells. Another remarkable benefit that can be taken from the use of CDMA technique is the use of the RAKE receivers. RAKE receivers constructively combine multipath components and helps in the elimination of channel fading effects [18]. Soft handovers are also an added advantage in CDMA. Soft handovers improves cell edge performance and reduce call drops. CDMA can even take benefit from the presence of voice inactivity during a conversation. During silent periods in a call, transmission rate are reduced that helps in preventing interference in the radio channel and thus impacting the capacity of the network.

In literature, wideband CDMA (WCDMA) is not well-defined. No single proper definition exists for WCDMA[19]. But a definition is proposed on the basis of the coherence bandwidth of radio channel. Coherence bandwidth is defined as the least distance between any two frequencies such that the there is no correlation between channel fading at those two frequencies.

When the bandwidth of transmitted signal is greater than the coherence bandwidth of the spectrum then the CDMA system is termed as wideband CDMA (WCDMA). There are some definitions which are based on the bandwidth as a part of centre frequency or chip rate. Anyway, there is no clear threshold that distinguishes WCDMA from narrowband CDMA.

Spread-spectrum characteristics of CDMA: Bandwidth is a finite resource. So, all the modulation schemes strive to minimize the requirement of bandwidth needed for transmitting a signal. However, techniques applied in spread spectrum use a transmission bandwidth that is manifold required signal bandwidth. This technique was earlier developed for military applications viz. guidance and communication systems. Due to superiority of spread spectrum techniques in providing security and resistance to jamming, military systems were designed using the same. In asynchronous CDMA, information signal is spread using a pseudo-random code, thus it has got a certain level of privacy built in . This pseudo-random code makes the transmitted signal appear random or it appears that the signal has noise-like properties due to randomization. Prior knowledge of the pseudo-random code is required by receiver to demodulate the data signal which is encoded by this code. Also, CDMA is resistant to jamming. To jam a data signal, jamming signal can only has a finite amount of power available. Radio jamming can be done by either spreading the energy of radio jammer over the entire bandwidth of the data signal or jamming only certain frequency channel of the data signal. Narrow band interference can also be effectively rejected by CDMA. As we know that narrow band interference will affect only a small portion (specific frequency) of the spread spectrum signal, this kind of interference can easily be excluded by using notch filtering without much loss of information. The lost data can easily be recovered with the assistance of interleaving and convolution encoding. Multipath fading is also minimal in CDMA signals. At any given time only a small portion (specific frequency) of spread spectrum signal will go through fading due to multipath. So a larger bandwidth part will be saved form fading. Using the same reasoning as for narrow band interference, loss of data will be small and can be easily overcome. Also the delayed versions of signals transmitted with a specific pseudo-random code will have very less correlation with the original pseudo-random code. This will make CDMA more resistant to multipath interference because of non-correlation between the delayed versions of the transmitted signal, and these will appear as separate user and these delayed versions will be ignored at the receiver end. As long as a delay of one chip is generated by the multipath channel, the multipath versions of transmitted signals reaching at the receiver will appear as they are shifted in time. The pseudo-random codes have properties such that even the slightest delay in the multipath signal will make it appear as uncorrelated with the original signal, and thus the multipath signal will be ignored. CDMA devices also use a rake receiver, which can extract benefits from the delayed versions of the transmitted signal and this can help in improving performance of the communication system. In a rake receiver, many correlators are used. These correlators are tuned to different path delays. Rake receiver merges the information signal from all the correlators to produce a stronger version of the original signal by inducing proper delays in multipath signal. This rake receiver signal is much stronger than the signal obtained from a simple receiver which has a single correlator tuned to the path delay of the strongest information signal.

Within a cellular system, use of same radio channel frequency at other sites is termed as frequency reuse. Frequency planning is an important aspect of the FDMA and TDMA systems. Frequency planning must be done carefully such that same frequencies are not allotted to nearby sites. Effective frequency planning will ensure transmitted signals from different sites are not interfering with each other. Now in a CDMA system, channels are separated using pseudo-random codes and thus same frequency can be used at every site. This will eliminate the need for frequency planning in a communication system based on CDMA; however, pseudo-random sequences' planning is required to make sure that the signal receiver from one cell is not having any correlation with the information signal from a nearby cell.

Since same frequencies are used by adjacent cells, CDMA communication systems have the ability to implement soft hand offs. Soft hand offs permit the mobile equipment to transmit/receive signals concurrently to and from two or more cells. The signal having the best quality is chosen until the hand off procedure is complete. This handoff procedure is different from hard hand offs which is implemented in other cellular communication systems. Radio signal strength varies abruptly in the situation of hard hand, when the mobile telephone equipment reaches a hand off. In comparison, soft hand off gives a higher quality signal with more reliability and hence a CDMA system has better performance.

1.3 Orthogonal Frequency division multiple access (OFDMA)

OFDM is a type of multicarrier modulation. A number of nearly well placed and closely spaced modulated carriers make an OFDM signal. When a carrier is modulated by any type of signal viz. - voice, data, etc., then sidebands are produced which spreads on either side of the modulated signal. A successful demodulation involves receiving whole signal by the receiver including the sidebands so that complete data can be reproduced. The signals that are close to one another must be spaced in such a way that they can be distinguished by the receiver using a filter. To ensure faithful separation of received signals, a guard band must be introduced between them. But OFDM works without guard bands. Although there will be overlapping from each carrier, these can still be transmitted-received without the interfering each other. This is attained by having the spacing between each carrier equal to the reciprocal of the signal symbol period.

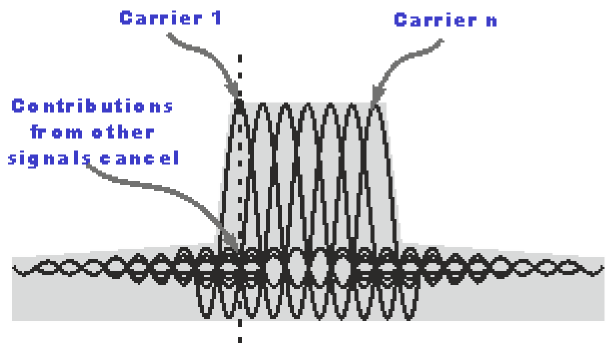


Figure 1.4 OFDM Signal

1.4 Problems and goals of this thesis

In a conventional CDMA communication system, three different power control (PC) modes are exploited: open loop power control, outer loop power control and closed loop power control (or inner loop Power control). Open loop PC works while establishing a radio link during initiation of network access or making a call to set the transmission power of the user in accordance with the measurements of the return channel link gain. The target signal-to-interference ratio (SIR) is set by outer loop PC at a level that provides a sufficient quality of service, and this SIR target is maintained using feedback signals from the receiver by closed loop PC. The purpose in this thesis is to study the power control problem and algorithms in CDMA cellular communication systems and finally CDMA power control using firefly algorithm has been implemented.

Main goals of this thesis are given as below:

1. Mobile battery is a limited resource and it has to be charged after a certain period of time. To minimize the battery discharging, transmitting power from the mobile units should be kept as low as possible in order to raise the battery lifetime. This is the first goal.

2. While reducing the transmitted power from mobile equipment, a certain quality of service parameter (QOS) of the connection must be ensured. This is achieved by making the value of E_b/N_o of each received signal to exceed a certain threshold $(E_b/N_o)_{th}$. The mobile unit is taken out of service or the connection is dropped when the received E_b/N_o value from a certain unit is less than this threshold. This is the second goal.

E_b is the energy per bit and N_o is the noise power spectral density.

3. Near-far effect is to be minimized. This is obtained by making the received signal levels from different mobile units very close to each other. This is third goal in this thesis.

1.5 Thesis Outline

The thesis is organized as follows. In Chapter 1, an overview on cellular radio systems is given. This chapter is mainly for those unfamiliar with such systems, and introduces briefly the key aspects, problems and design challenges in these systems. Power control in CDMA cellular communication systems is discussed in detail in Chapter 2, which gives the necessary background to understand power controlling concept. A literature survey of previous work in this area is also provided in Chapter 3. In chapter 4 the main idea about firefly algorithm is given. In the later part of this thesis results and conclusion are given.

Chapter

2

Power control in CDMA cellular communication systems

CHAPTER 2

POWER CONTROL IN CDMA CELLULAR COMMUNICATION SYSTEMS

The objective of this Chapter is to give a somewhat detailed overview of power control in CDMA cellular communication systems and to present the relevant problems within the scope of the thesis. A literature survey of power control algorithms is given. As this thesis focuses mainly on power control using firefly algorithm, a survey of power controls using various algorithm e.g. PSO, GA is also discussed.

2.1 Introduction

As communication systems are high interference systems due to various factors including frequency reuse, so for performance and capacity transmission power control (TPC) is vital. The main aim is to regulate the powers of the transmitters in such a way that minimizes the interference power to other co-channel users (users that share the same radio resource simultaneously) while maintaining sufficient quality of service (QoS) among all co-channel users. Management of interference in the transmitters belonging to same channel is of utmost importance in any communication system using frequency reuse. However, in communication systems employing spread spectrum technique CDMA, interfering users are present both inside and outside a cell, which makes CDMA interference limited. Therefore, effective TPC is indispensable in CDMA, especially in the uplink (from mobile to base station communication).

Consider the situation depicted in Figure 2.1. Same frequency band is being shared by Mobile stations MS1 and MS2 and their unique spreading codes distinguish the signals at the base station BS. At a particular instant of time, the path loss and hence the link attenuation of MS2 to BS might be much greater than that from MS1 to BS. If power control is not employed, the received signal from MS1 to BS will overpower the signal from MS2 to BS. This is the so-called near-far effect [14]. Power control aims to regulate and set the transmission powers of MS1 and MS2 in such a way so that both the transmitted signals are received at equal mean power level at the base station, thereby alleviating near-far effect.

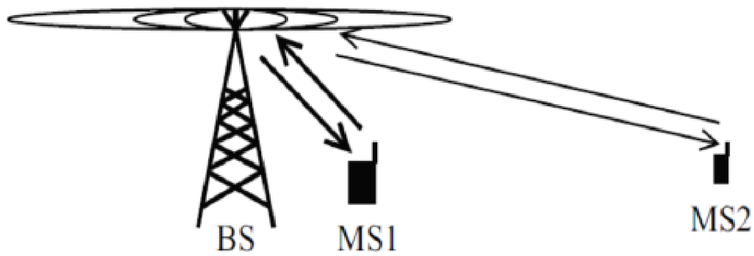


Figure 2.1 Near far effect [3]

2.2 Need of power control

Power control is essential in CDMA communication systems due to below reasons

- CDMA communication systems are Interference-limited systems (not frequency-limited)
- CDMA system uses Same frequency channel for entire system so internal interference handling is crucial to gain system capacity and voice quality
- Interference to be limited by controlling transmission power of each mobile station
- Variation in RF environment that included slow and fast fading, external interference and shadowing
- Mitigation of Near-Far effect: Transmit power of Mobile stations closer to the base station to be made less as compared to far away mobiles
- As mobile stations have limited battery life, battery usage to be minimized

2.3 Uplink versus downlink power control

A near far situation is created In CDMA if power control is not employed. This happens as the signals transmitted from different mobile stations travel through different radio conditions before reaching their serving base station. In order to compensate for the changing radio channel attenuations, power control employed to vary the transmission powers of mobile stations, so that the received power of each mobile station has same mean power level at the base station. Power control in uplink is critical for the capacity of CDMA communication systems as well [14]. An order of 80 db dynamic range of uplink power control can be required.

The situation is different in downlink, as all the signals transmitted by a base station travel through the same radio channel before reaching a mobile station. Thus, all the signals undergo same level of attenuation and hence, power control is not required for near-far problem. Instead, power control is used in downlink to provide more power to mobile stations located near the cell edges, which are suffering from high interference from adjacent cells and, on the other hand, to use only adequate transmission powers in a way to minimize the interference produced to adjacent cells [20]. In principle, by the use of proper spreading codes downlink signals to different users can be made orthogonal. But, the orthogonality of the transmitted signals in downlink direction is lost in practice due to varying radio channel caused by multipath propagation. Thus, assigning different powers to different mobile stations in downlink could cause a near-far condition at the mobile station end. This makes the dynamic range of downlink power control much smaller as compared to uplink, typically of the order of 20-30 dB.

2.4 Open loop versus closed loop power control

Channel attenuation in the uplink can be compensated by measuring the strength of a pilot signal transmitted in downlink, and adjusting the transmission power of the element in an inverse proportion of this measurement. As transmitted power of the pilot signal is constant, the change in its strength gives the amount of the attenuation present in downlink direction. This type of adjustment in transmitted power is called open loop power control. Unfortunately uplink and downlink transmissions occur at centre frequencies that are usually widely separated, and hence, the correlation between uplink and downlink attenuations is generally weak. Therefore, the transmission power of a mobile station must be updated based on feedback value of the received SIR at the base station, which will form a closed loop between mobile and base station.

The closed loop power control, also known as inner loop power control, attempts to maintain the received uplink signal power level at a certain target. Moreover, this specified target must also be varied with changing BER, because the SIR requirement is not constant for a given BER, but depends on the radio channel conditions. This task is accomplished by outer loop power control. Initial power settings are done by Open loop power control, when the two-way dedicated communication link is not yet present and a closed loop is not made. Objective of Closed loop power control is to keep the received SIR at a fixed target value. Now, to track the variations in channel at a fast rate only one bit is used to flag the received SIR information. If the received SIR is below the target, transmitter is ordered to increase its power by a fixed step, and if the received SIR is above the target, transmitter is ordered to decrease its power by a fixed step. This type of algorithm is used in the IS-95 (CDMA) system [21].

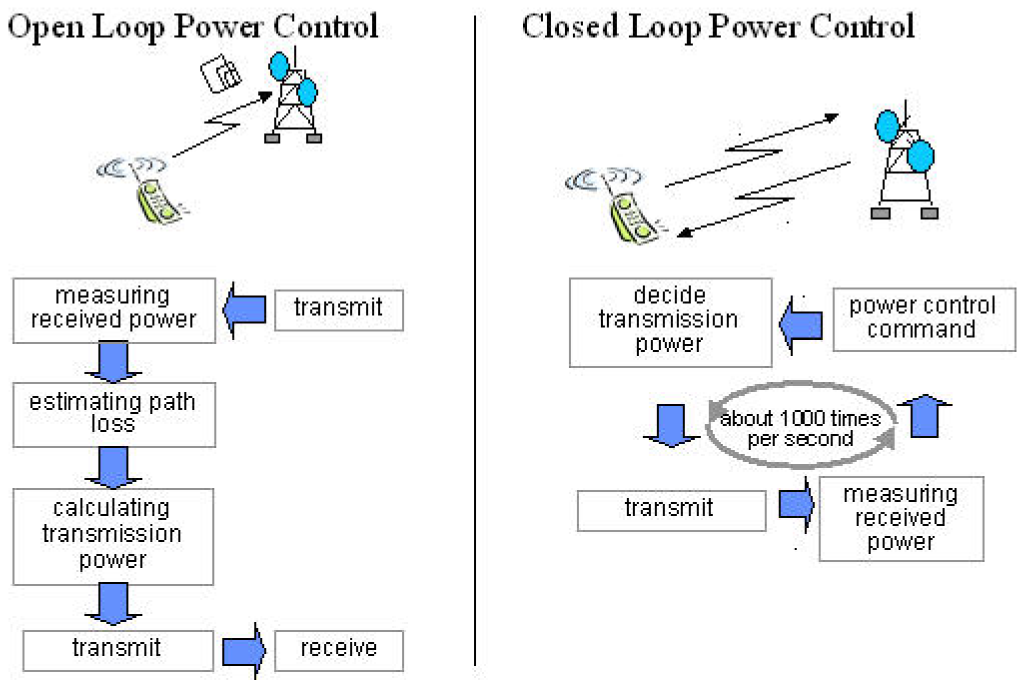


Figure 2.2 Open loop and closed loop power control [7]

There are some more degrees of freedom in WCDMA [22, 5], for instance, it also includes a "no change" command. This helps in reducing the "Ping-Pong" effect around the target by not ordering any changes in power when the received SIR is reasonably close to the target. The same idea was employed in the dynamic step size power control algorithm proposed in [23, 24]. To guarantee a desired FER, outer loop power control adjusts the SIR target. This can be achieved in practice by raising the target by a larger step δ_{up} when a received frame is discarded, and by decreasing the target with a smaller step δ_{down} when a received frame is error free. This type of algorithm was proposed in, where step sizes used are $\delta_{up} = K\delta$ and $\delta_{down} = \delta$, where K is a positive integer. Resulting average FER can be calculated by using the relation between the step sizes; average FER = $1/K+1$.

2.5 Reverse Link Power Control

Detection at base station is non-coherent, due to which Reverse link power control has more importance than forward link power control. Reverse link power control algorithm is used to perform power control on reverse traffic channels and access channels. This algorithm is used for establishing a radio link while originating a call. The reverse link power control is composed of open-loop power control (also called as autonomous power control) and the closed loop power control. Also, inner-loop and outer loop power control are embodied in closed loop power control.

2.5.1 Reverse Link open loop Power Control

Base transceiver stations (BTS) are not involved in this method. Principle on which this algorithm is based suggests that mobile stations (MS) which are closer to the base station are required to transmit less power as compared to mobile stations which are far away from the base station or are in deep fading conditions. Based on the power received in the 1.23 MHz band, mobile stations adjust their power i.e. power received in pilot, sync, paging and traffic channels. The fundamental rule is that a mobile station transmits in inverse proportion of the power it receives. If the power received by mobile station is low then the power transmitted by that mobile station will be high and vice versa.

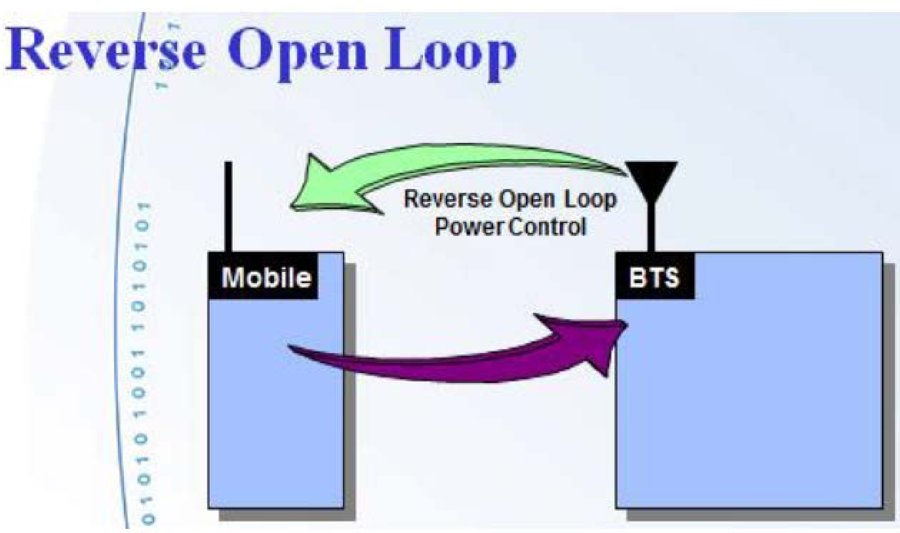


Figure 2.3 Reverse Open loop power control [25]

2.5.2 Reverse Link closed loop Power Control

Base transceiver stations (BTS) are involved in this method. For power adjustment, base station sends the power control bits to the mobile station. On a forward traffic channel, a power control sub channel is being continuously transmitted. This power control sub channel runs 800 power control bits per second. Thus every 1.25 ms a power control bit 0 or 1 is transmitted by BTS. A '0' indicates that the mobile station should increase its mean output power level while '1' indicates that the mobile station should decrease its mean output power level. This method has a response time of 1.25 ms which is very low as compared to response time of open loop power control (30ms). This is done to counter deep fading condition.

The reverse link closed loop power control comprises of two parts-outer loop power control and inner-loop power control. The outer loop power control mechanism adjusts the base station E_b/I_t for a given mobile station whereas inner loop power control mechanism keeps the mobile station as close to its target E_b/I_t as possible. E_b is the energy per bit and I_t is the total interference in the channel.

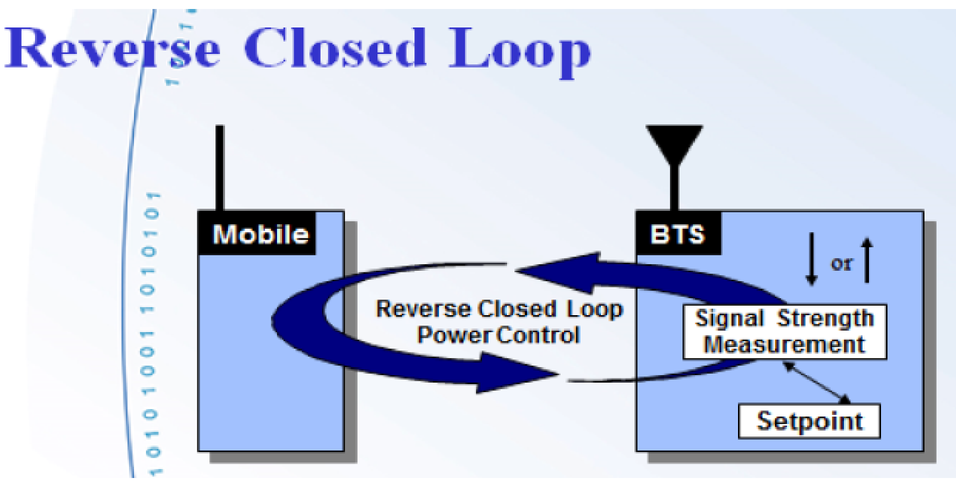


Figure 2.4 Reverse closed loop power control [25]

2.6 Quality measures for power control

A notable amount of the work on power control algorithms in CDMA cellular communication systems has focused on how to regulate the transmission powers of the network elements so that all mobile users in the system have affable bit-energy-to-interference spectral-density ratio (E_b/I_o). This approach is based on the fairly rational assumption that the bit error probability

(BEP) at the receiver end is strictly monotonically decreasing function of E_b/I_o. As we know that, BEP P_b of binary phase shift keying (BPSK) modulation in an additive white Gaussian noise (AWGN) channel is given by [26]

$$P_b = Q(\sqrt{2\frac{E_b}{I_0}})$$

where Q(x) is defined by

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^{\infty} e^{-x^2/2}\, dt \qquad x \geq 0$$

A more appropriate case for CDMA cellular systems is the bit error probability (BEP) performance of RAKE receiver in fading radio channels.

Another measure, namely the signal-to-interference ratio (SIR), is closely related to E_b/I_o. SIR is denoted by γ , such that

$$E_b/I_0 = \gamma\frac{W}{R_b}$$

where W is the transmission bandwidth in Hz and R_b is the data rate in bits/s. The quantity $W=R_b$ is called the processing gain [16]. When the data rate is fixed, the SIR differs from E_b/I_o by merely a scaling factor.

In digital cellular communication systems, the information to be transmitted from network terminals is arranged in strings of bits called frames [27], and error correction coding is implemented on each frame to reduce the bit error rate (BER) after decoding. After decoding, if there are still bit errors in the frame then the frame is useless, and it must be discarded. Hence, a sufficiently low frame error rate (FER) should be guaranteed depending on the service to be accessed. However, to obtain reliable estimates of BER or FER long time delays are needed. But in practice these delays might be unacceptably long due to rapidly varying channel conditions Hence most of the focus in the power control algorithms has been on SIR-based algorithms.

Chapter

3

Literature Review

CHAPTER 3

LITERATURE REVIEW

3.1 Overview

Optimization algorithms are used to implement power control in CDMA systems. In order to reach zero probability of Outage, most of the power control algorithms practically present today require high number of iterations. The power control mechanism based on genetic algorithm was proposed by M. Moustafa et.al (Oct. 2000) [4] and based on particle swarm algorithm was proposed by Hassan M. Elkamchouchi Hassan et.al in 24th National radio science conference (NRSC 2007) [2].

3.2 Genetic Algorithm for Mobiles Equilibrium (GAME)

In a CDMA based communication network, providing suitable QoS and achieving channel efficiency for each user makes resource allocation critical. Several QoS measures, including bit error rate, depend on the E_b/N_o given by [4]:

$$\left(\frac{E_b}{N_o}\right)_i = \frac{G_{bi} p_i / R_i}{\left(\sum_{j \neq i}^{M} G_{bj} p_j + \eta\right) \Big/ W}$$

where W is the total spread spectrum bandwidth of the CDMA system

G_{bi} denotes the radio link gain between the path between base b and mobile i

η denotes noise arise due to the presence of thermal noise contained in W and

M is the total number of mobile stations

p_i is the power transmitted by mobile i which is limited by a maximum power level as

$0 \leq pi \leq P_{max}$ for $1 \leq i \leq M$

R_i is the information bit rate transmitted by mobile i which is fixed through our study at 15.5 kbps

As transmission power of a user increases, its E_b/N_o also increases, but this also increases the interference to other users in the shared spectrum, causing reduction in their E_b/N_o. Regulating powers of the mobile users therefore amounts to directly managing the QoS that is usually specified as a pre-specified calculated target Eb/No value called $(E_b/N_o)_{th}$. It can also be defined in terms of the probability that E_b/N_o lies below $(E_b/N_o)_{th}$ (Outage probability). Therefore, the aim here is to calculate a nonnegative power vector P = [p_1, p_2, ... , p_M] which maximizes the function F stated as

$$F = \left(\frac{1}{M} \sum_{i=1}^{M} \omega_P F_i^E F_i^P \right) + \omega_H F^H$$

where F_i^E is a threshold function defined for user i as

$$F_i^E = \begin{cases} 1 & (E_b/N_o)_i \geq (E_b/N_o)_{th} \\ 0 & \text{otherwise} \end{cases}$$

In addition to limit the search space for solutions such that average QoS is maximized, through F_i^E, it is also necessary to minimize mobiles stations' power. As low mobiles stations' power will help in reducing interference and increasing battery life, F_i^P will favour the solutions that will use minimum power and punishes the users using high power levels.

$$F_i^P = 1 - p_i / P_{\max} \,.$$

To minimize the near-far effect, we have to make sure that the received powers from all mobile stations at the base station are lying in a narrow range. The received power at the base station, represented by p_i^r , is the product of link gain Gb_i and p_i. F^H, defined in the following equation, punishes the solution where received power components are diverging far away from its mean power value.

$$F^H = \begin{cases} 1 - 5\left(\sigma_{p^r} / \overline{p}^r \right) & \sigma_{p^r} \leq 0.2\overline{p}^r \\ 0 & \text{otherwise} \end{cases}$$

where $\overline{p}^r$ is the average received power level at the base station, and σ_{pr} is the standard deviation.

For each objective, ω_P and ω_H are nonnegative priority weights respectively. The weights help to prioritize an objective over the other. For instance, if our highest priority is to minimize the mobile transmitted power, then highest value would be given to weight ω_P.

GAME is a steady state genetic algorithm which terminates evolution after a defined time period [4]. The inputs to this algorithm are current power levels from different mobile users. Additional data like $(E_b/N_o)_{th}$, radio link gains G and maximum power level P_{max} are also needed.

In GAME algorithm, the power levels from mobiles are encoded to form initial population of chromosomes. The chromosome is represented as a string of N bits which encodes power level of M mobile stations. If q bits are used to encode each mobile user then N=q×M. These chromosomes are then evaluated by the fitness function. The cycle of reproduction and evolution repeats till a stopping criterion is reached. New power vectors are transmitted to the users by the base station. At the next control period, this new solution obtained is being used to initiate the next cycle by using them in the input vectors. The assumption for GAME algorithm was that the base station is situated at the centre of a cell. This method was only for single cell with radius of unit distance. The users' distribution is uniform over the complete cell area. The distance loss model is used as path loss model. The radio link gain is $G_{ij} = A_{ij} \times D_{ij}$.

A_{ij} is the variation in the received signal due to obstructions (shadow fading), and is assumed to be independent and log normally distributed with a mean of 0 dB and a standard deviation of 8 dB.

The variable D_{ij} is the large scale propagation (path) loss. Let d_{ij} is the distance between receiver i and transmitter j then it is assumed that (in decibels)

$$10\log D_{ij} = \begin{cases} -127.0 - 25\log d_{ij} & d_{ij<1} \\ -127.0 - 35\log d_{ij} & 1 \le d_{ij} \le 3 \\ -135.5 - 80\log d_{ij} & 3 \le d_{ij} \end{cases}$$

This path loss model uses three different slopes ant for the 1 unit distance interception assumes -127.0 dB. The required QOS target or $(E_b/N_o)_{th}$ is 5 dB and P_{max} is 1 watt. The transmission rate is fixed as 15.5 kbps and the thermal noise density is -174dbm/Hz.

3.3 Particle Swarm Optimization (PSO) Algorithm

Particle Swarm Optimization (PSO) is a technique for global optimization [28] and it is distinct from other well-known Evolutionary Algorithms. In Evolutionary Algorithms, a population of probable solutions is used to seek the search space, but new solutions are generated without use of any operators on the population. In PSO, every individual particle of the population is called swarm. A swarm calibrates its path towards its own previous best position, and toward the last best position procured by any other member of its topological neighborhood. The whole swarm is taken as the neighbourhood, in the global variant of PSO. Thus, information is shared globally and the particles gain from the discoveries and former experience of all other fellows during the scrutiny for promising regions of the landscape. For instance, in the single-objective minimization case, a lower function values is possessed by such regions as compared to others, visited earlier. Now, in the local variant of PSO, the neighbourhood is restricted and is considered as certain number of other particles in the vicinity but the guidelines of movement for each particle remain same in the two variants. There are two versions of basic algorithm of PSO. In the first version of the algorithm, particles are represented by binary strings while in the other version, particles are depicted by real numbers in an 'n' dimensional space where n is the dimension of the optimization problem under discussion. Firstly, the author in [4] has summarized the basic algorithm of PSO in real number problems. The Pseudo-code for this algorithm is:

```
For i = 1 to number of individuals
    If G(x̄_i) > G(p̄_i) then do                 // G() evaluates fitness
        For d = 1 to dimensions
            p_id = x_id                          // p_id is best so far
        Next d
    End do
    g = i                                        // arbitrary
    For j = indices of neighbors
        If G(p̄_j) > G(p̄_g) then g = j           // g is index of best performer in the neighborhood
    Next j
    For d = 1 to dimensions
        v_id(t) = v_id(t-1) + φ1(p_id - x_id(t-1)) + φ2(p_gd - x_id(t-1))
        v_id ∈ (-V_max, +V_max)
        x_id(t) = x_id(t-1) + v_id(t)
    Next d
Next i
```

Here xi is the position of particle i, vi is the velocity of particle i, ø1 is a random number that gives the size of the step towards personal best, ø2 is a random number that gives the size of the step towards global best (the best particle in the neighborhood) and G is the fitness function which we are trying to minimize.

For the binary PSO, the component value of xi vi and pg are restricted to the set {0, 1}. The velocity vi is interpreted as a probability to change a bit from 0 to 1, or from 1 to 0 when updating the position of particles. Therefore, the velocity vector remains continuous-valued but the value of the velocity needs to be mapped from any real value to a probability in the range

[0, 1]. A sigmoid function is used onto squash velocities to change their range to [0, 1]. Finally, the equation for updating positions is replaced by the probabilistic update equation:

$$x_{id} = \begin{cases} 0 & if\ \rho_{id}\,(t-1) \geq sig(v_{id}(t)) \\ 1 & \rho_{id}\,(t-1) \leq sig(v_{id}(t)) \end{cases}$$

$\overline{\rho(t)}$ is a vector representing random numbers, drawn from a uniform distribution between 0 and 1.

3.4 PSO-based Algorithm for Power Control Problem

In PSO based [4] method the author uses basic binary PSO technique. In this algorithm, all the objectives of the power control problem are taken into consideration to maximize a fitness function.

In PSO-based algorithm, a power vector containing power values is represented by every particle in the swarm. These values are to be transmitted by all mobile units in order to be assessed and enhanced by the algorithm. The representation of particles in swarm is like the representation of chromosomes in the power vector in GAME technique with q = 15 bits. This gives a favourable resolution of tuning the power of the mobile stations. If P_{max} = 1 watt then power tuning can be done at a resolution of the unit $1/2^{15}$ = $3.051758 X 10^{-15}$ watts (approx. 30.5 W). Maximum power constraint is also inherently satisfied by this method of representation of the power vector as P_{max} is always assigned with the value of the string of 15 ones.

In this algorithm, the author first tried to use the same fitness function as of GAME method. Good results were obtained from that fitness function in terms of minimization of the transmitted power from the mobile stations and making the value of E_b/N_o of the received signals from all mobile units exceed the threshold but this fitness function failed to fulfill the aim of minimization of the near-far effect. The reason for the failure is the way the algorithm used to handle this objective. The parameter F^H favours the solutions in which received power levels are close to each other but the issue here is that this parameter is set to zero for all the solutions in which received power components diverge far away from mean power value. Assuming two solutions, the first has $\sigma_{p^r} = 0.3p^{-r}$ and the second has $\sigma_{p^r} = 3p^{-r}$. The first solution is considered better than the second one, however, the parameter F^H is set to zero for both cases. Thus in order to minimize the near-far effect, the second solution will not be encouraged to update itself towards the first solution. To solve this issue, a new fitness function is considered in PSO. This fitness function will be maximised considering all the factors required in power control and is described as below

$$F = \left(\frac{1}{M} \sum_{i=1}^{M} \omega_P F_i^E F_i^P \right) + \frac{\omega_S}{\sigma_{p^r}}$$

The first term of this fitness function is taken from the fitness function of GAME method but a new term is also added which gives credit to the solution with small value of standard deviation of received power distribution. This term will not become zero for all particles and will give remarkable results in minimization of near far effect. w_s is priority weight which tells the relative importance of near-far problem objective over other objectives. Effectiveness of the PSO algorithm was firstly checked by initializing the particles of the swarm using random bits. But this is not the real case. In a real communication system, the mobiles stations' power values are updated from the power values of the last frame. After initializing with random bits, PSO algorithm with the new fitness function is applied to these randomly initialized particles [2]. The complete procedure of proposed algorithm is shown in Fig.3.1.

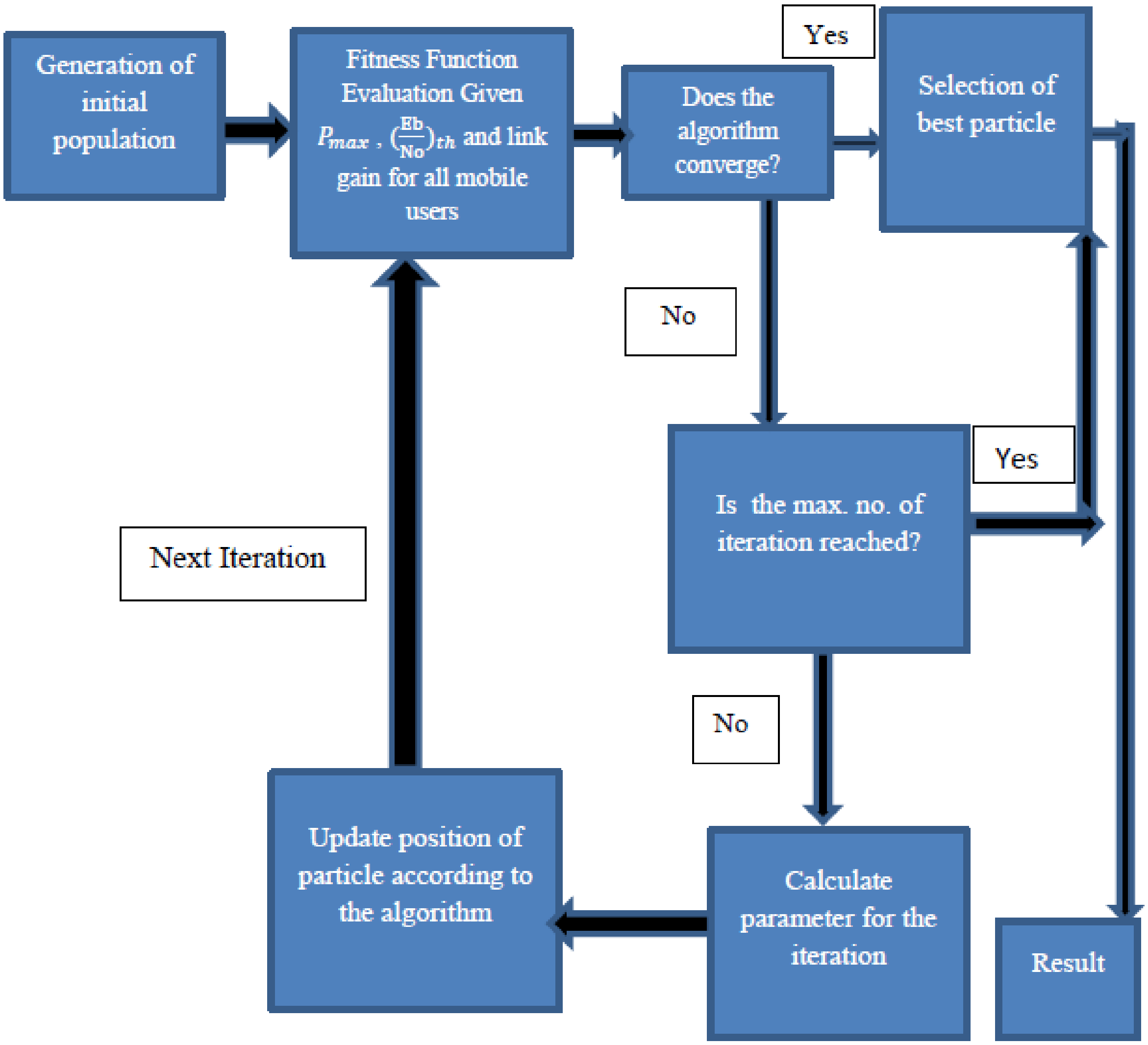


Figure 3.1 Block diagram of PSO-based algorithms for power control [2]

Chapter

4

CDMA Power Control using fire fly algorithm

CHAPTER 4

CDMA POWER CONTROL USING FIREFLY ALGORITHM

4.1 Firefly Algorithm

Firefly Algorithm [1] is a population based metaheuristic algorithm, developed by Xin-She Yang in 2007[28, 29]. The firefly algorithm (FA) is inspired by the flashing behaviour of fireflies. The primary purpose of a firefly's flash is to act as a signal system to attract other fireflies.

4.1.1 Behavior of Fireflies

The sky filled with the flickering light of fireflies makes a marvellous view in the summer in the moderate temperature regions. There exist nearly two thousand firefly species, and almost all of them produce rhythmic and short flashes of light. For a specific species, the pattern produced by these firefly flashes is unique for most of the times. The pattern formed by the rhythm of the flashes, considers both rate of flashing and the time for which the flashes occur together. This type of patterns attracts both the females and males to each other. Females of a specific species respond to individual and unique pattern of the male of that particular species.

It is known the intensity of light at a distance r from the source of light follows the inverse square law. In other words, the intensity of the light I will go on decreasing as the distance r increases, in terms, $I \alpha (1/r^2)$. In addition to this, the surrounding air assimilates the light making it weaker with the increase in the distance. As these two factors got combined in the atmosphere, it makes most of the fireflies visible only at a limited distance, usually to a few hundred meters at night, however, this distance is quite enough for fireflies to communicate easily with each other.

4.1.2 Concept

To develop firefly-inspired algorithms, let’s idealize a few flashing characteristics of fireflies. Firefly Algorithm (FA or FFA) [28, 29] was developed by Xin-She Yang at Cambridge University in 2007 and the three idealized rules were followed which can be written as:

• All the fireflies are considered unisex. This means one firefly will get attracted to other fireflies irrespective of their sex.

• Brightness and attractiveness are proportional to each other, therefore for any two flashing fireflies, the firefly with less brightness will move towards the one which is having greater brightness. Both Attractiveness and brightness decrease with distance. However, they will move randomly when their brightness cannot be compared or if there is no one brighter than other.

• The view of objective function determines the brightness of a firefly.

The brightness can be taken as proportional to the value of the objective function, for a maximization problem. Other types of the brightness can be defined in a similar way to the fitness function as in genetic algorithms.

4.1.3 Light Intensity and Attractiveness

Two important points are to be noted while implementing firefly algorithm: formulation of the attractiveness and the variation in the light intensity. For simplicity, it can be assumed that the brightness of the firefly flash determines its attractiveness which in turn is related to the encoded objective function.

Considering the simplest case for maximum optimization problems, for a particular location x, the brightness I of a firefly could be chosen as $I(x) \alpha f(x)$. Now, the attractiveness β of a firefly is relative and hence, it should be judged by the considering other fireflies. Therefore, it will differ with the distance r_{ij} between firefly i and firefly j. Also, light intensity will decrease with the distance from its source, and light is also absorbed by the propagating media, so attractiveness is to be allowed to vary with the varying degree of absorption of media. In the elementary form, the light intensity I(r) follows the inverse square law.

$$I(r) = {}^{I_s}\!/_{r^2}$$

where I_s denotes the intensity at the source. For a given medium having a fixed light absorption coefficient γ, the light intensity (brightness) I vary with the distance r. That is

$$I = I_0 e^{-\gamma r}$$

where I_o gives the initial light intensity. Now, we need to take combined effect of both the absorption and inverse square law. It will also mitigate the singularity at r = 0 in the expression. The expression of brightness can then be approximated in the following Gaussian form.

$$I = I_0 e^{-\gamma r^2}$$

As a firefly's attractiveness is proportional to the intensity of light seen by adjacent fireflies, attractiveness β of a firefly can now be defined as

$$\beta = \beta_0 e^{-\gamma r^2}$$

where βo is the attractiveness at r = 0. Keeping in mind the mathematical calculation needed for an exponential function, it is often easier and faster to calculate $1/(1+r^2)$ as compared to exponential function. We can this approximate the above function as shown below:

$$\beta = \beta_0/(1+\gamma r^2)$$

Let us say the two fireflies i and j are positioned at xi and xj, respectively, then the distance between them can be calculated using the Cartesian distance formula. It can be given as:

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{i,j})^2}$$

Firefly i will move towards brighter firefly j. This movement of the firefly i can be determined by

$$x_i = x_i + \beta_0 e^{-\gamma r_{i,j}^2} + \alpha \epsilon_i$$

where the second term is due to the attraction of fireflies and third term is randomization with α as the randomization parameter, and is a vector of random numbers that are drawn from a Gaussian (uniform) distribution. For e.g., in the simplest form ϵ_i could be replaced by (rand − ½) where rand represents a random number generator which is uniformly distributed in [0, 1]. For most of our implementation, we have taken βo =1 and α Є [0, 1]. In this thesis α = 0.25, γ = 1 and I_o = 1.

If βo = 0, it will become a simple random walk. In addition, the randomization term can easily be extended to other distributions such as L´evy flights [30]. The contrast of the attractiveness is now characterized by parameter γ, and its value is extremely important in concluding the speed of the convergence and in knowing the behaviour of FA algorithm. Theoretically, γ Є [0,

∞], but in practically, γ= O(1) and is determined by the characteristic length Γ of the system under optimization. Thus, for most of the applications, this value typically varies from 0.1 to 10.

4.1.4 Firefly Algorithm

```
Objective function f(x), where x=(x1,........,xd)T
Generate the initial population of fireflies xi (i=1, 2,..., n)
Light intensity of Ii at xi is detrmined by f(xi)
Define light absorption coefficient γ
While (t < MaxGeneration)
for i = 1 to n (all n fireflies);
        for j=1 to n (all n fireflies)
                If (Ij> Ii),
                move firefly i towards j;
                end if
        vary Attractiveness with distance r via exp [-γr2];
        evaluate new solutions and update light intensity;
        end for j;
end for i;
rank the fireflies and find the current best go;
end while;
Post process results and visualization;
```

4.2 Main objectives of this thesis

1. Minimizing the transmitting power of the mobile stations which in turn will lead to increase in the battery lifetime of mobile units.

2. Ensuring a certain level of quality of service parameter (QOS) is satisfied. For this purpose, the E_b/N_o value of the received signals from all mobile units will be made to exceed the threshold $(E_b/N_o)_{th}$ .If a mobile unit is found to have the received E_b/N_o lower than this threshold, then this particular unit will be made out of service.

E_b is the energy per bit and N_o is the noise power spectral density.

3. Minimizing the near-far effect in communication system. This will be done by making the received power levels from all the mobile stations very close to each other.

Firefly algorithm has been used to attain all these objectives.

4.3 Problem Description and Fitness Function in thesis

Main objective of this thesis is to provide suitable QOS for each user and achieve channel efficiency. Many QOS measures, including bit error rate, depends on E_b/N_o the given by [4]:

$$\left(\frac{E_b}{N_o}\right)_i = \frac{G_{bi} P_i / R_i}{\left(\sum_{j \neq i}^{M} G_{bi} P_j + \eta\right)/W}$$

where W is the total spread spectrum bandwidth of the CDMA system

G_{bi} denotes the radio link gain between the path between base b and mobile i

η denotes noise arise due to the presence of thermal noise contained in W and

M is the total number of mobile stations

p_i is the power transmitted by mobile i which is limited by a maximum power level as

$0 \leq pi \leq P_{max}$ for $1 \leq i \leq M$

R_i is the information bit rate transmitted by mobile i which is fixed through our study at 15.5 kbps

As transmission power of a user increases, its E_b/N_o also increases, but this also increases the interference to other users in the shared spectrum, causing reduction in their E_b/N_o. Regulating powers of the mobile users, i.e., implementing power control therefore amounts to directly managing the QoS that is usually specified as a pre-specified calculated target Eb/No value called $(E_b/N_o)_{th}$. It can also be defined in terms of the probability that E_b/N_o lies below $(E_b/N_o)_{th}$ (Outage probability). Therefore, the aim here is to calculate a nonnegative power vector P = [$p_1, p_2, \ldots\ldots, p_M$] which maximizes the function F stated as

$$F = \left(\frac{1}{M}\sum_{i=1}^{M} w_p\, F_i^E\, F_i^P\right) + \frac{w_s}{\sigma_{p^r}}$$

where F_i^E is a threshold function defined for user i as

$$F_i^E = \begin{cases} 1 & (E_b/N_o)_i \geq (E_b/N_o)_{th} \\ 0 & \text{otherwise} \end{cases}$$

In addition to limit the search space for solutions such that average QoS is maximized, through F_i^E, it is also necessary to minimize mobiles stations' power. As low mobiles stations' power will help in reducing interference and increasing battery life, F_i^P will favour the solutions that will use minimum power and punishes the users using high power levels.

$$F_i^p = 1 - \frac{P_i}{P_{max}}$$

To minimize the near-far effect, we have to make sure that the received powers from all mobile stations at the base station are lying in a narrow range. The received power at the base station, represented by p_i^r , is the product of link gain Gb_i and p_i. F^H punishes the solution where received power components are diverging far away from its mean power value.

Here p^{-r} is the average received power level and σ_{p^r} is the standard deviation.

For each objective, ω_P and ω_H are nonnegative priority weights respectively. The weights help to prioritize an objective over the other. For instance, if our highest priority is to minimize the mobile transmitted power, then highest value would be given to weight ω_P.

In this thesis the objective function is used as

$$F = \left(\frac{1}{M} \sum_{i=1}^{M} w_p \, F_i^E \, F_i^P \right) + \frac{4 \times 10^{-15}}{3.6303 \times 10^{-14}}$$

Chapter 5

Implementation, Result and Conclusion

CHAPTER 5

IMPLEMENTATION, RESULT AND CONCLUSION

As discussed in previous chapter we have to find out a power vector which will maximize the objective function F. The power vector should be determined at the base station. One firefly will represent one power vector .Out of many fireflies one will give the best result in terms of reduction in interference. The programme is written in Mat lab software.

5.1 Software Used

In this thesis MATLAB software has been used. MATLAB is a high-level language and it provides an interactive interface for mathematical computation, programming and visualization. Using MATLAB, data analysis is performed, algorithms are developed, and models and applications can also be created. The tools and built-in mathematical functions enable you to prospect various approaches and find an optimum solution faster than with excel, spreadsheets or traditional programming languages, like C++, C, dot net or Java. Applications in which MATLAB can be used are spread widely and in various spheres such as signal processing, image processing, video processing, communication systems, control systems, computational finance, computational biology and test and measurement. MATLAB is the language of technical computation which is being used by millions of engineers and scientists in academia and industry.

5.1.1 Key Features of MATLAB

- High-level language and an interactive interface for mathematical computation, programming and visualization
- Interactive medium for iterative problem solving , design and exploration
- Mathematical tool box which can be used in statistics, linear algebra, numerical integration, Fourier analysis, filtering, solving differential equations and optimization
- Built in tools for creating customized plots and graphics for depicting data
- Development tools which helps in improving quality and maintainability of code and maximizing the performance

- Tools for creating applications with customized graphical interfaces
- Functions for collaborating MATLAB based algorithms along with external applications and programming languages like C++, C, Dot NET, Java, and MS Excel

5.1.2 Programming and Algorithm Development

MATLAB is a high-level language and set of tools that allow us to quickly build and assess algorithms and applications. MATLAB helps in performing matrix and vector based operations that are elementary and essential in solving engineering and scientific problems.

With the MATLAB language, programs and algorithms can be developed quickly as compared to traditional languages since there are limitations with the usage of traditional languages. MATLAB overcomes the limitations of performing low-level administrative tasks such as variables declaration, data type specification, and memory allocation. In many scenarios, one line of MATLAB code plays the same role as done by plenty of lines of C/C++ code. Also, with the quick usage of matrix and vector based operations in MATLAB helps in eliminating the need of lengthy for-loops in C/C++.

MATLAB has an inherent quality in providing most of the features of a traditional programming language that may vary from flow control to error handling, and even be extended to object-oriented programming (OOP). It also gives a provision to make use of fundamental or custom data types and advanced data structures.

There are multiple tools, which are being provided by MATLAB for efficient development of algorithm, such as:

- **Command Window** – This helps in interactive data entry, program and command execution and display of results.
- **MATLAB Editor** – This can be used for features like debugging and editing, such as marking breakpoints and traversing through individual code lines.

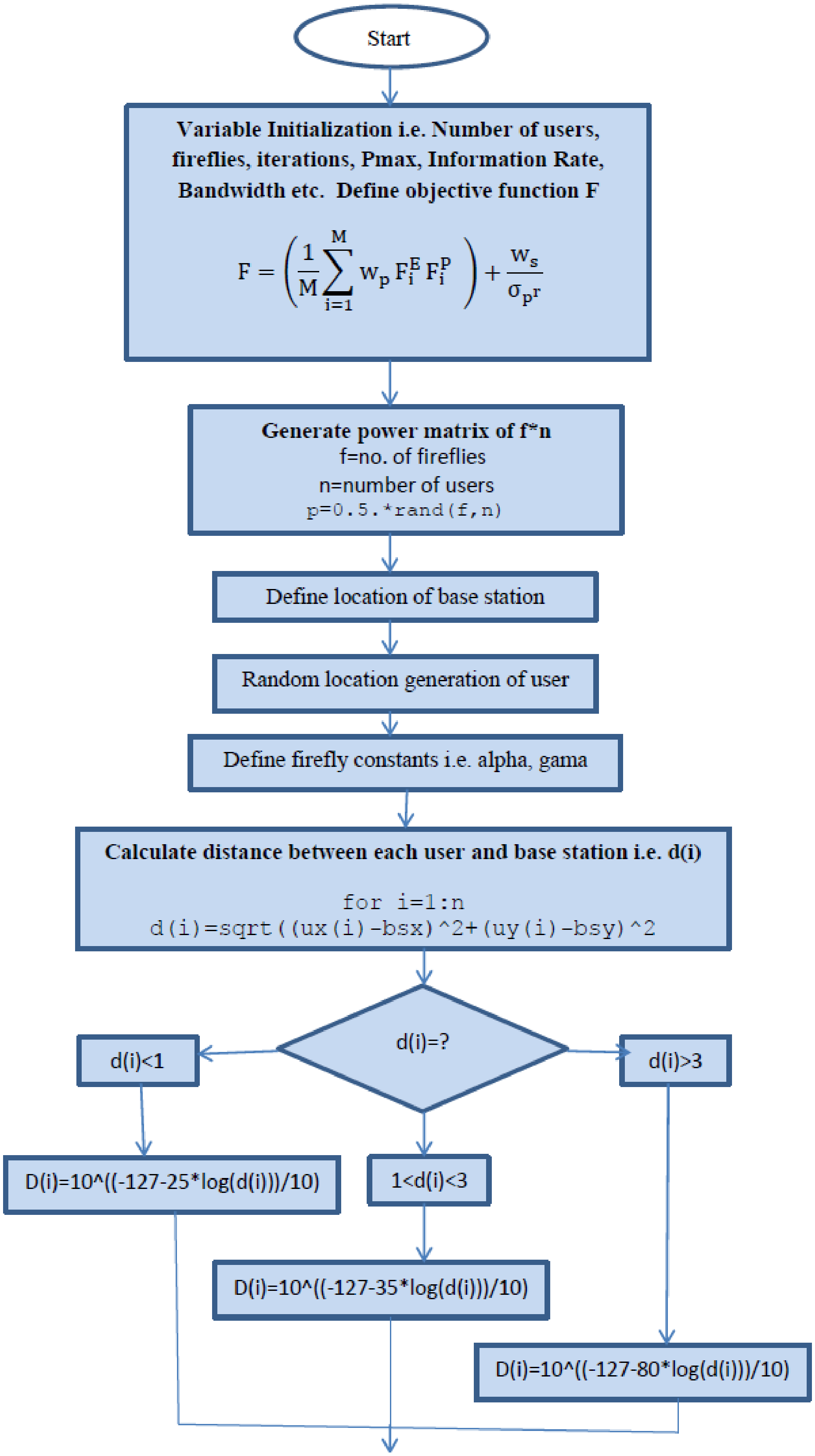
- **Code Analyzer** – This helps in auto-checking problematic codes and recommending the needed rectifications to enhance the performance.
- **MATLAB Profiler** – This helps in measuring performance of MATLAB program codes and in identifying areas of code improvement for attaining optimum performance.

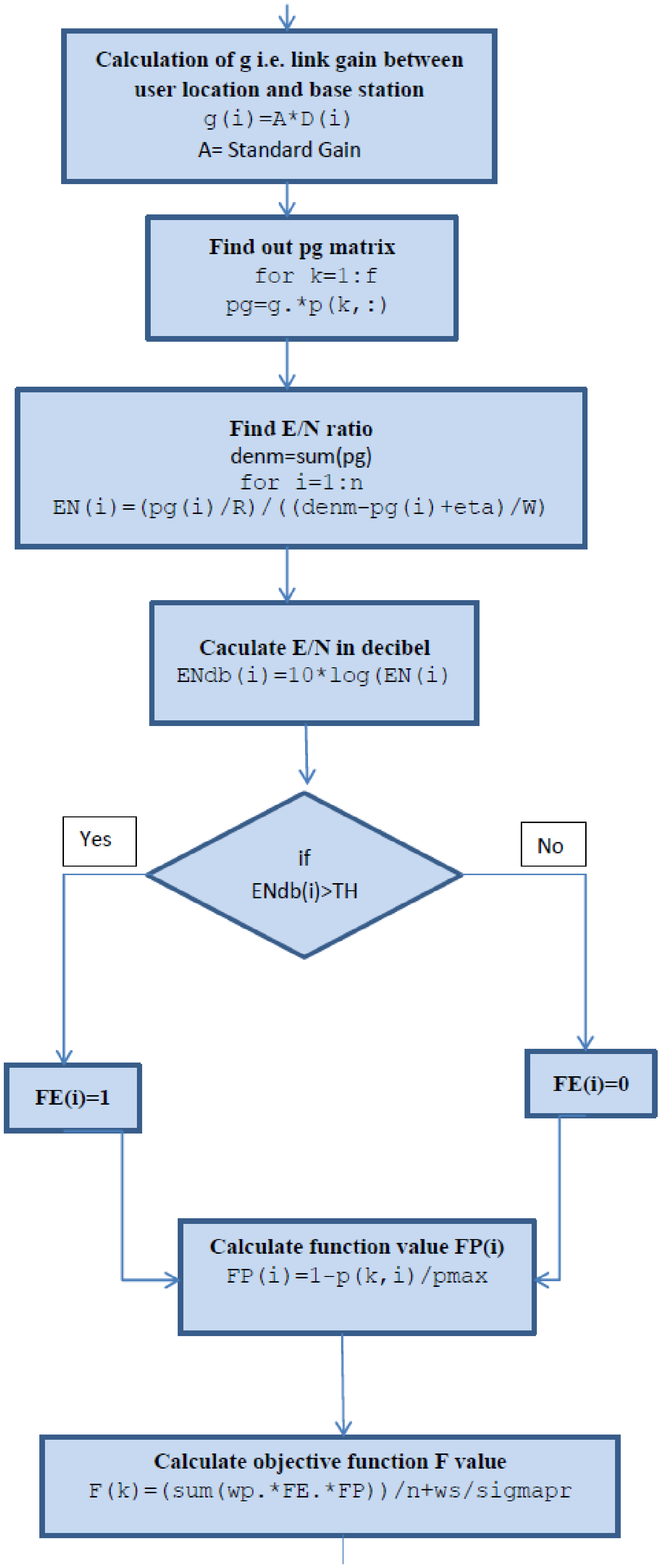
5.1.3 Application areas of MATLAB software

MATLAB is used widely in following areas of technology

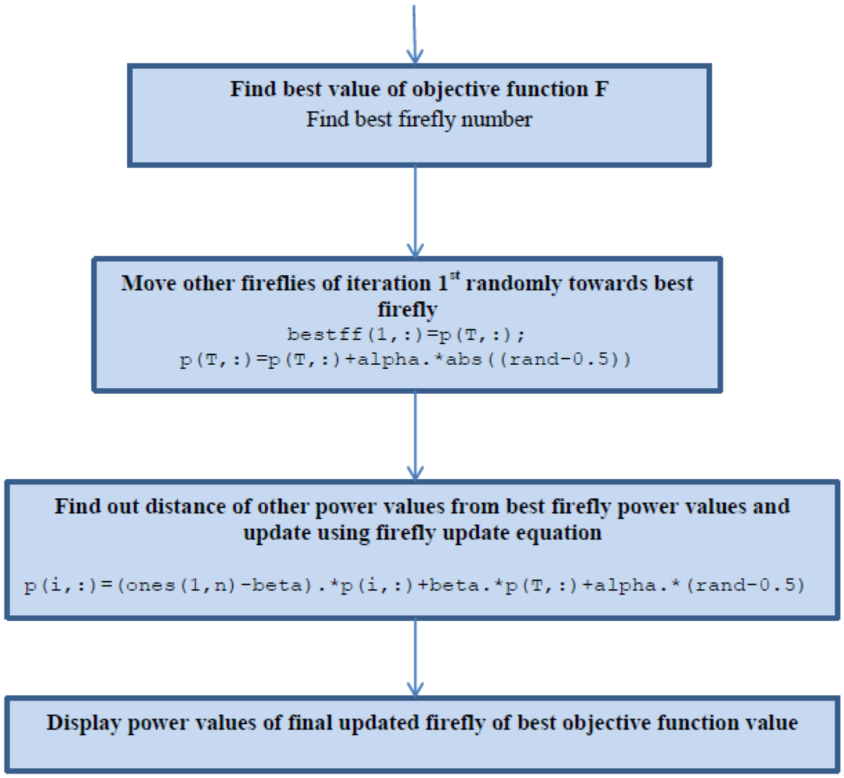
- Communications Systems
- Computational Biology
- Computational Finance
- Control Systems
- Digital Signal Processing
- Embedded Systems
- FPGA Design and Co design
- Image and Video Processing
- Mechatronics
- Technical Computing

5.2 Flowchart





Calculation of g i.e. link gain between user location and base station
g(i)=A*D(i)
A= Standard Gain
Find out pg matrix
for k=1:f
pg=g.*p(k,:)
Find E/N ratio
denm=sum(pg)
for i=1:n
EN(i)=(pg(i)/R)/((denm-pg(i)+eta)/W)
Caculate E/N in decibel
ENdb(i)=10*log(EN(i)
Yes
if
ENdb(i)>TH
No
FE(i)=1
FE(i)=0
Calculate function value FP(i)
FP(i)=1-p(k,i)/pmax
Calculate objective function F value
F(k)=(sum(wp.*FE.*FP))/n+ws/sigmapr



With the help of flow diagram we can easily understand that how we can find out suitable power vector at base station while satisfying criteria of minimum power transmission, QoS criteria and near far problem reducing factor.

5.3 Results

Result for 5 users:

First run the programme for 5 users with 10 fireflies and 10 iterations. The result obtained i.e. power vector from 1st iteration is shown in figure 5.1. After using firefly updation in next iterations we have final power vector as shown in figure 5.2. We can see changes in the function value, firefly number and power vector.

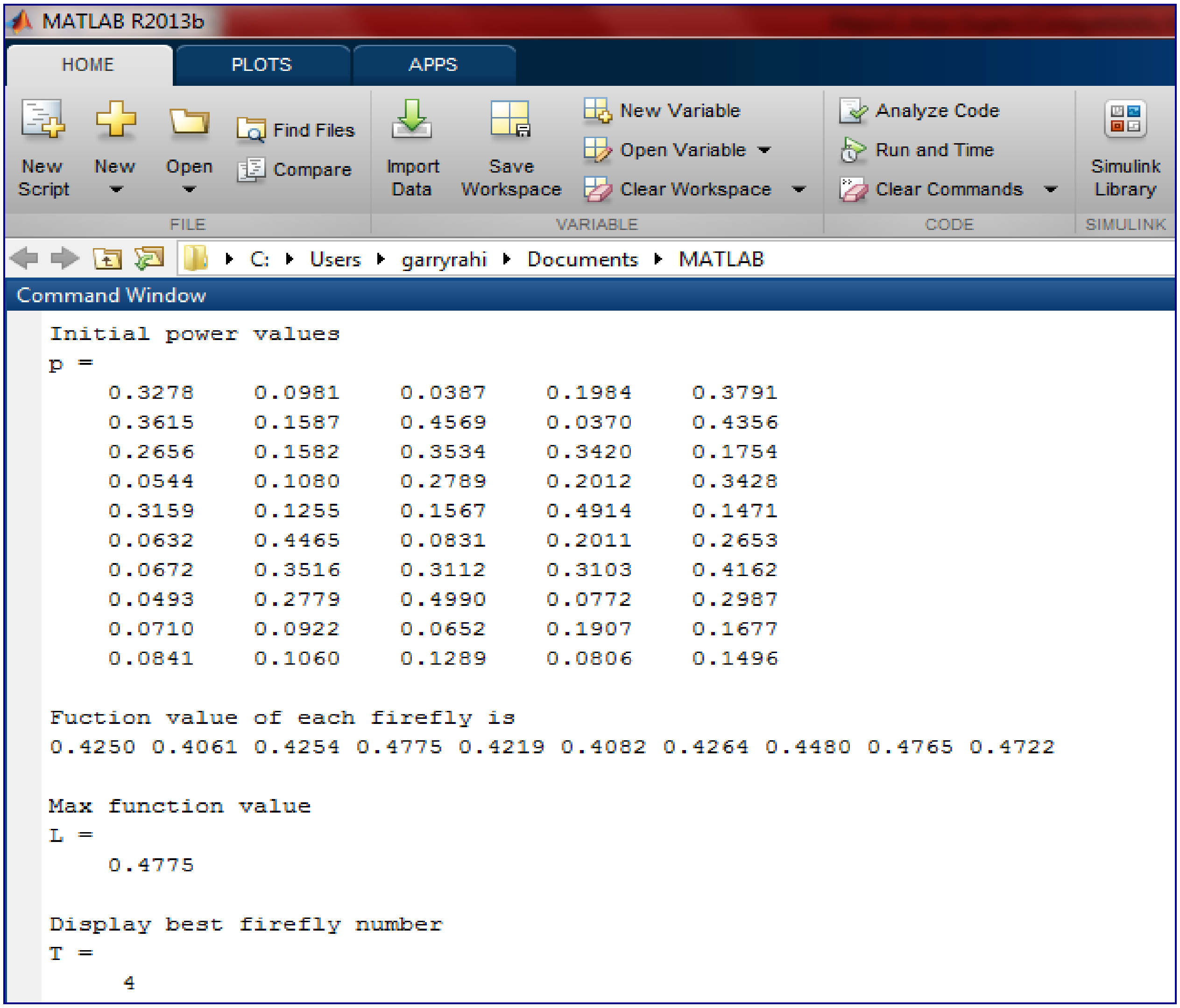


Figure 5.1 Power vector for 5 users without updating from other iteration

User number Power/ Firefly number (T)	1st user Power (watt)	2nd user Power (watt)	3rd user Power (watt)	4th user Power (watt)	5th user Power (watt)	Function value=F
1	0.3278	0.0981	0.0387	0.1984	0.3791	0.4250
2	0.3615	0.1587	0.4569	0.0370	0.4356	0.4061
3	0.2656	0.1582	0.3534	0.3420	0.1754	0.4254
4	0.0544	0.1088	0.2789	0.2012	0.3428	0.4775
5	0.3159	0.1255	0.1567	0.4914	0.1471	0.4219
6	0.0632	0.4465	0.0831	0.2011	0.2653	0.4082
7	0.0672	0.3516	0.3112	0.3103	0.4162	0.4264
8	0.0493	0.2779	0.4940	0.0772	0.2987	0.4448
9	0.0710	0.0922	0.0852	0.1907	0.1677	0.4775
10	0.0841	0.1060	0.1289	0.0806	0.1496	0.4722

Table 5.1 Table showing power vector for 5 users without updation

Best firefly number = 4

Max. Function value = 0.4775

As shown in the table each firefly represents a power vector i.e. power values to be transmitted by each user. For each power vector function value is calculated. It can be seen that the 4th firefly gives maximum value of objective function so in first iteration 4th firefly represents a power vector which have maximum function value.

Now all fireflies will move towards 4th firefly and then other iteration firefly will also move towards best firefly. This result is shown in figure 5.2.

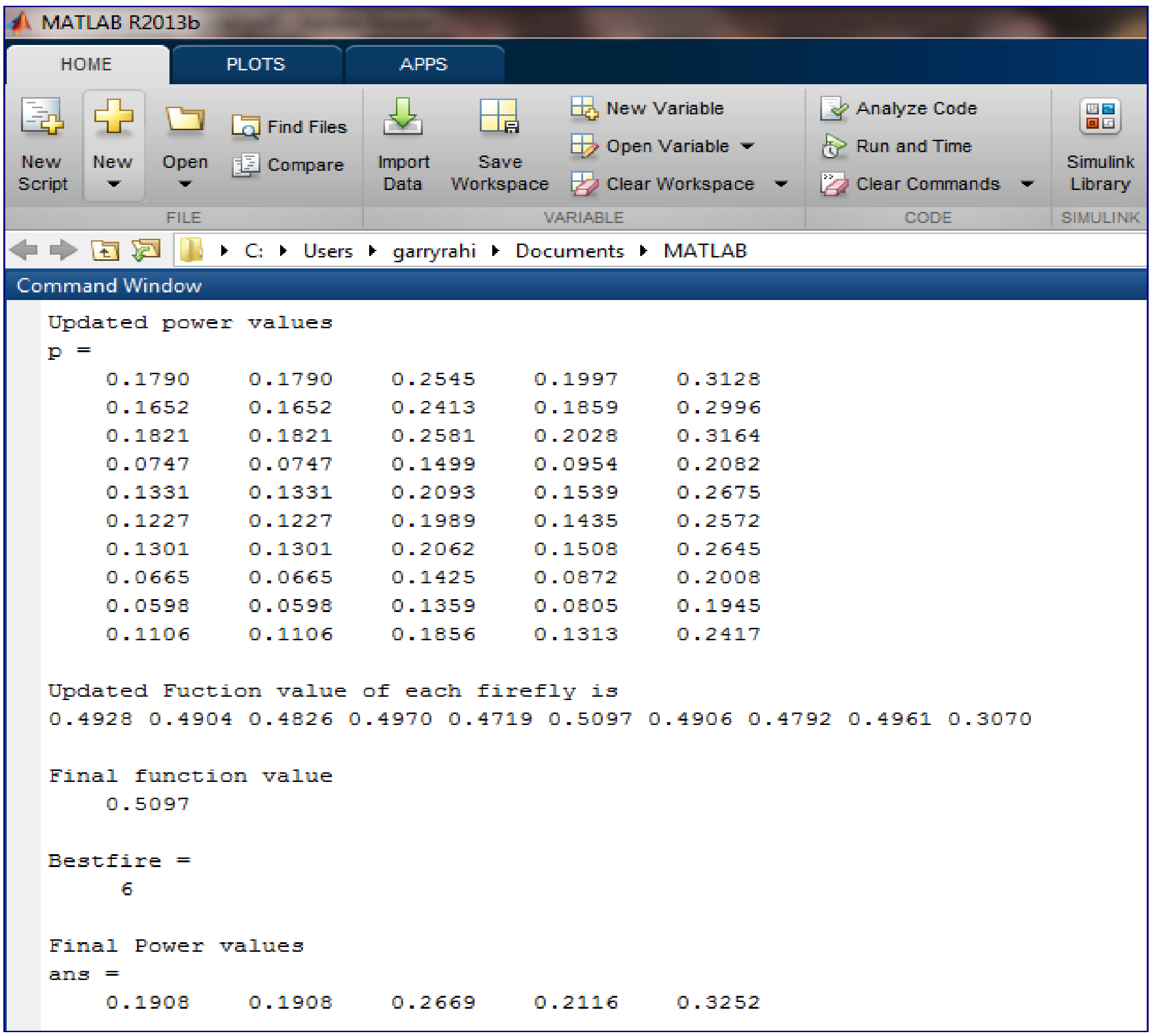


Figure 5.2 Power vector for 5 users with updating from other iteration

User number Power/ Firefly number (T)	1st user Power (watt)	2nd user Power (watt)	3rd user Power (watt)	4th user Power (watt)	5th user Power (watt)	Function value=L
1	0.1790	0.1790	0.2545	0.1997	0.3128	0.4928
2	0.1652	0.1652	0.2413	0.1859	0.2996	0.4804
3	0.1821	0.1821	0.2581	0.2028	0.3164	0.4826
4	0.0747	0.0747	0.1499	0.0954	0.2082	0.4970
5	0.1331	0.1331	0.2093	0.1539	0.2675	0.4719
6	0.1227	0.1227	0.1989	0.1435	0.2572	0.5097
7	0.1301	0.1301	0.2062	0.1508	0.2645	0.4906
8	0.0665	0.0665	0.1425	0.0872	0.2008	0.4792
9	0.0598	0.0598	0.1359	0.0805	0.1945	0.4961
10	0.1106	0.1106	0.1856	0.1313	0.2417	0.3070

Table 5.2 Table showing power vector for 5 users with updation using firefly

Previous Best firefly number = 4

Previous Max. Function value = 0.4775

Present Best firefly number = 6

Present Max. Function value = 0.5097

As shown in the table 5.2 each firefly represents a power vector i.e. power values to be transmitted by each user. For each power vector function value is calculated. It can be seen that the now 6th firefly gives maximum value of objective function. After updating this power vector we finally have power vector as shown below:

Final power value (watt)				
1st User	2nd User	3rd User	4th User	5th User
0.1908	0.1908	0.2669	0.2116	0.3252

Table 5.3 Final power vector for 5 users

Result for 10 users:

Now run the programme for 10 users with 10 fireflies and 10 iterations. The result obtained i.e. power vector from 1st iteration is shown in figure 5.3. After using firefly updation in next iterations we have final power vector as shown in figure 5.4. Again we can see changes in the function value, firefly number and power vector.

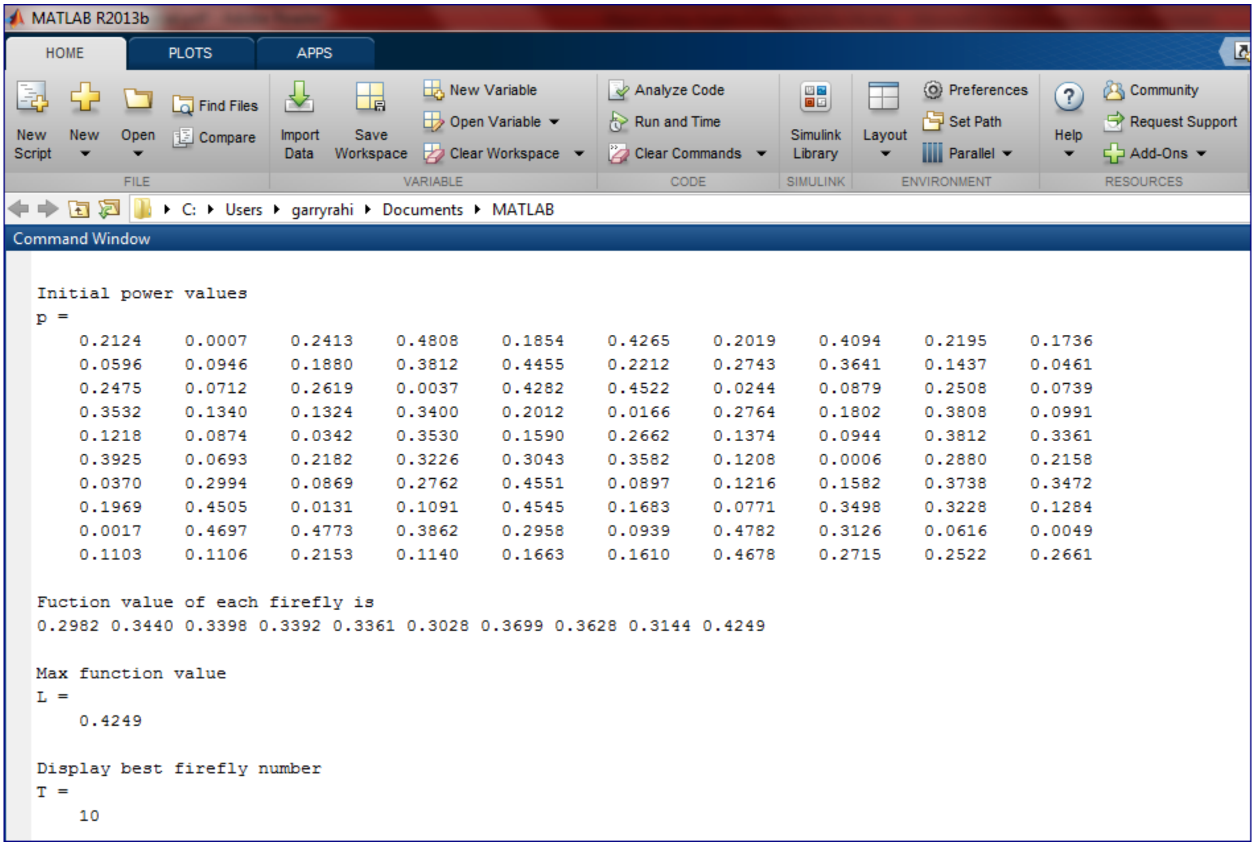


Figure 5.3 Power vector for 10 users without updating from other iteration

User number Power/ Firefly number (T)	1st user Power (watt)	2nd user Power (watt)	3rd user Power (watt)	4th user Power (watt)	5th user Power (watt)	6th user Power (watt)	7th user Power (watt)	8th user Power (watt)	9th user Power (watt)	10th user Power (watt)	Function value= F
1	0.2124	0.0007	0.2413	0.4808	0.1854	0.4265	0.2019	0.4094	0.2195	0.1736	0.2982
2	0.0596	0.0946	0.1880	0.3812	0.4455	0.2212	0.2743	0.3641	0.1437	0.0461	0.3440
3	0.2475	0.0712	0.2619	0.0037	0.4282	0.4522	0.0244	0.0879	0.2508	0.0739	0.3398
4	0.3532	0.1340	0.1324	0.3400	0.2012	0.0166	0.2764	0.1802	0.3808	0.0991	0.3392
5	0.1218	0.0874	0.0342	0.3530	0.1590	0.2662	0.1374	0.0944	0.3812	0.3361	0.3361
6	0.3925	0.0693	0.2182	0.3226	0.3043	0.3582	0.1208	0.0006	0.2880	0.2158	0.3028
7	0.0370	0.2994	0.0869	0.2762	0.4551	0.0897	0.1216	0.1582	0.3738	0.3472	0.3699
8	0.1969	0.4505	0.0131	0.1091	0.4545	0.1683	0.0771	0.3498	0.3228	0.1284	0.3628
9	0.0017	0.4697	0.4773	0.3862	0.2958	0.0939	0.4782	0.3126	0.0616	0.0049	0.3144
10	0.1103	0.1106	0.2153	0.1140	0.1663	0.1610	0.4678	0.2715	0.2522	0.2661	0.4249

Table 5.4 Power vector for 10 users without updating from other iteration

Best firefly number = 10

Max. Function value = 0.4249

As shown in the table 5.4 each firefly represents a power vector i.e. power values to be transmitted by each user. For each power vector function value is calculated. It can be seen that the 10th firefly gives maximum value of objective function so in first iteration 10th firefly represents a power vector which have maximum function value.

Now all fireflies will move towards 10th firefly and then other iteration firefly will also move towards best firefly. This result is shown in figure 5.4.

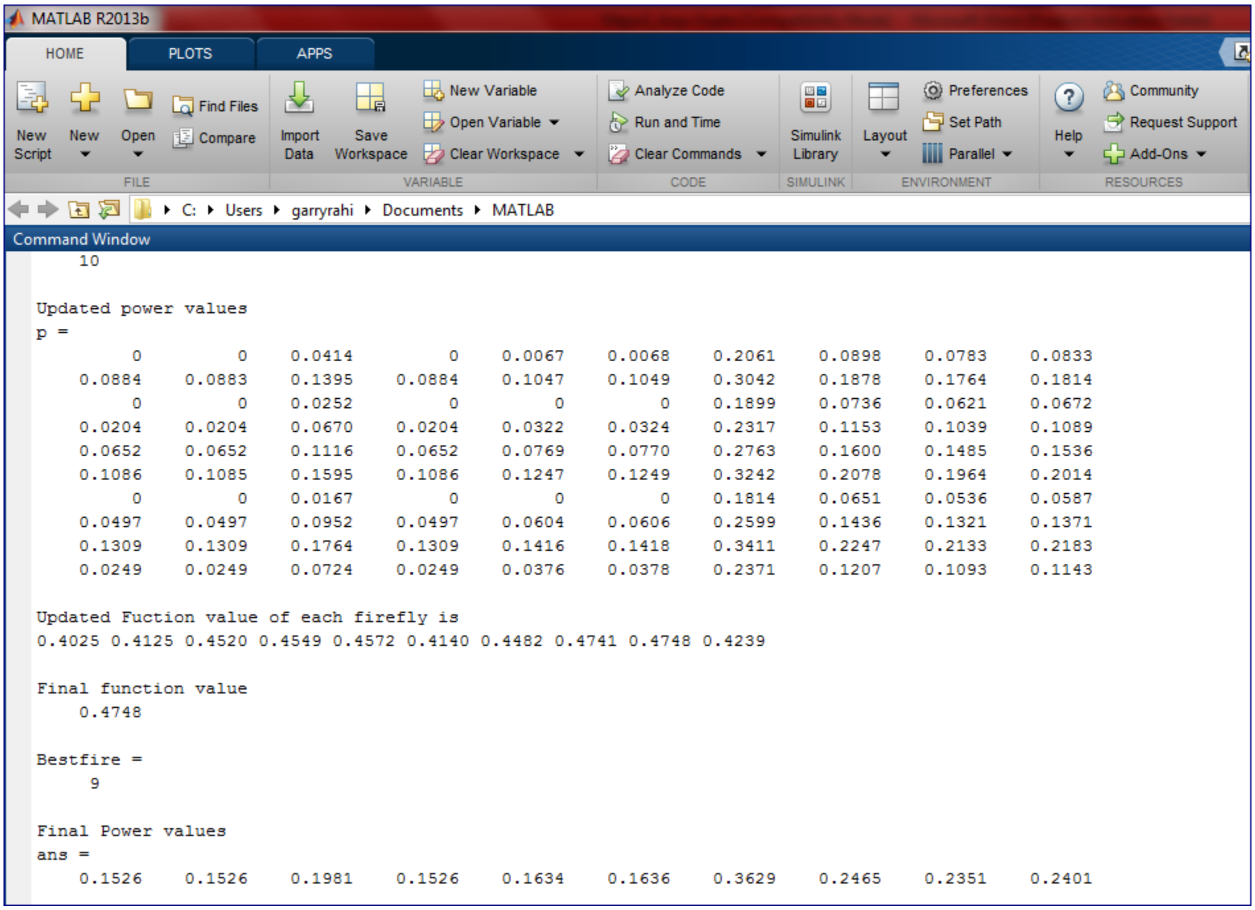


Figure 5.4 Power vector for 10 users with updating from other iteration

User number Power/ Firefly number (T)	1st user Power (watt)	2nd user Power (watt)	3rd user Power (watt)	4th user Power (watt)	5th user Power (watt)	6th user Power (watt)	7th user Power (watt)	8th user Power (watt)	9th user Power (watt)	10th user Power (watt)	Function value= F
1	0.0000	0.0000	0.0414	0.0000	0.0067	0.0068	0.2061	0.0898	0.0783	0.0833	0.4025
2	0.0884	0.0883	0.1395	0.0884	0.1047	0.1049	0.3042	0.1878	0.1764	0.1814	0.4125
3	0.0000	0.0000	0.0252	0.0000	0.0000	0.0000	0.1899	0.0736	0.0621	0.0672	0.4520
4	0.0204	0.0204	0.0670	0.0204	0.0322	0.0324	0.2317	0.1153	0.1039	0.1089	0.4549
5	0.0652	0.0652	0.1116	0.0652	0.0769	0.0770	0.2763	0.1600	0.1485	0.1536	0.4572

User number Power/ Firefly number (T)	1st user Power (watt)	2nd user Power (watt)	3rd user Power (watt)	4th user Power (watt)	5th user Power (watt)	6th user Power (watt)	7th user Power (watt)	8th user Power (watt)	9th user Power (watt)	10th user Power (watt)	Function value= F
6	0.1086	0.1085	0.1595	0.1086	0.1247	0.1249	0.3242	0.2078	0.1964	0.2014	0.4140
7	0.0000	0.0000	0.0167	0.0000	0.0000	0.0000	0.1814	0.0651	0.0536	0.0587	0.4482
8	0.0497	0.0497	0.0952	0.0497	0.0604	0.0606	0.2599	0.1436	0.1321	0.1371	0.4741
9	0.1309	0.1309	0.1764	0.1309	0.1416	0.1418	0.3411	0.2247	0.2133	0.2183	0.4748
10	0.0249	0.0249	0.0724	0.0249	0.0376	0.0378	0.2371	0.1207	0.1093	0.1143	0.4239

Table 5.5 Power vector for 10 users with updating from other iteration

Previous Best firefly number = 10

Previous Max. Function value = 0.4249

Present Best firefly number = 9

Present Max. Function value = 0.4748

As shown in the table 5.5 each firefly represents a power vector i.e. power values to be transmitted by each user. For each power vector function value is calculated. It can be seen that the now 9th firefly gives maximum value of objective function. After updating this power vector we finally have power vector as shown below:

Final power value (watt)									
1st User	2nd User	3rd User	4th User	5th User	6th User	7th User	8th User	9th User	10th User
0.1526	0.1526	0.1981	0.1526	0.1634	0.1636	0.3629	0.2465	0.2351	0.2401

Table 5.6 Final power vector for10 users

5.4 Conclusion

CDMA is an interference limited system. Power control is the most important requirement of the CDMA system as it helps in interference management. In this thesis, demonstration of CDMA power control is represented using 'Firefly Algorithm'. Power to be transmitted by mobile is calculated at base station using the firefly algorithm.

The algorithm is implemented in such a way that it ensures a certain quality of service by taking into account Eb/No of the received signals from the user. It also minimize near far effect by taking into consideration the standard deviation of received power components from its mean value. Also transmitted power of mobile station is minimized by penalizing high power transmitting mobiles.

A fitness function is proposed that takes into account the above mentioned factors for limiting interference and then power vectors for mobile users are calculated by using above said algorithm. Implementation is carried out by MATLAB. It can be seen from results that we can find out power vector for any number of users with minimum transmission value of power. Also, all power values in a power vector come to be same if the number of iteration of the algorithm increases beyond 50.

In future, this algorithm can also be implemented on WCDMA (3G) Technology as it also relies on power control.

APPENDIX A

REFERENCES

[1] Iztok Fister Jr., Matjaz Perc, Salahuddin M. Kamal, Iztok Fister, "A review of chaos-based firefly algorithms: Perspectives and research challenges", Elsevier Inc., 2014.

[2] Hassan M. Elkamchouchi , Hassan M. Elragal ,Mina A. Makar "Power control in CDMA system using particle swarm optimization", *24th national radio science conference (NRSC)*,2007.

[3] Matti Rintamaki, "Adaptive power control in CDMA cellular Communication systems" , *Dissertation for the degree of Doctor of Science in Technology* ,Department of Electrical and Communications Engineering, Helsinki University of Technology, November 18, 2005.

[4] M. Moustafa, I. Habib and M. Naghshineh, "Genetic algorithm for mobiles equilibrium", *in Proceedings of MILCOM 2000: 21st Century Military Communications Conference*, vol. 1, pp. 70–74, Oct. 2000.

[5] H. Holma and A. Toskala, Eds.," WCDMA for UMTS", *West Sussex: John Wiley & Sons*, 2000.

[6] The 3rd generation partnership project (3GPP) home page. ,3GPP (2004), Online available: http://www.3gpp.org

[7] Online available: *http://common.ziffdavisinternet.com/encyclopedia_images/3GA.GIF*

[8] K. S. Gilhousen, I. M. Jacobs, R. Padovani, A. J. Viterbi, L. A. Weaver, Jr., and C. E.Wheatley III, "On the capacity of a cellular CDMA system," *IEEE Trans. Veh. Techno*logy, vol. 40, no. 2, pp. 303–312, May 1991.

[9] Online available: *http://www.taiwan4g.com/2012/img/comparison_1g-4g.png*

[10] S. Moshavi, "Multi-user detection in DS-CDMA communications," *IEEE Commun. Mag*.,vol. 34, no. 10, pp. 124–136, Oct. 1996.

[11] G. Calhoun, Ed., *Handbook for Digital Cellular Radio*, Norwood, MA: Artech House, 1988.

[12] R. Steele and L. Hanzo, Eds., *Handbook for Mobile Radio Communications*, 2nd ed. England: John Wiley & Sons, 1999.

[13] P. Jung, P. W. Baier, and A. Steil, "Advantages of CDMA and spread spectrum techniques ofer FDMA and TDMA in cellular mobile radio applications," *IEEE Trans. Veh. Technol*., vol. 42, no. 3, pp. 357–364, Aug. 1993.

[14] K. S. Gilhousen, I. M. Jacobs, R. Padovani, A. J. Viterbi, L. A. Weaver, Jr., and C. E.Wheatley III, "On the capacity of a cellular CDMA system*," IEEE Trans. Veh. Technol., vol*. 40, no. 2, pp. 303–312, May 1991.

[15] Online available: *http://www.ce-mag.com/archive/2000/sepoct/0009c30a.jpg*

[16] A. J. Viterbi, *Handbook on CDMA: Principles of Spread Spectrum Communication. Reading,* MA:Addison-Wesley Publishing Company, 1995.

[17] A. M. Viterbi and A. J. Viterbi, "Erlang capacity of a power controlled CDMA system," *IEEE J. Select. Areas Commun*., vol. 11, no. 6, pp. 892–899, Aug. 1993.

[18] J. G. Proakis, *Handbook on Digital Communications*, 3rd ed. Singapore: McGraw-Hill, 1995.

[19] L. Milstein, "Wideband code division multiple access," *IEEE J. Select. Areas Commun.*, vol. 18, no. 8, pp. 1344–1354, Aug. 2000.

[20] W. C. Y. Lee, "Power control in CDMA (cellular radio)," *in Proc. IEEE Veh. Tech. Conf. (VTC*), St. Louis, Missouri, USA, May 1991, pp. 77–80.

[21] TIA/EIA, "Mobile station-base station compatibility standard for dual-mode wideband spread spectrum cellular system," Telecommunications Industry Association," Interim Standard-95, 1993.

[22 Technical Specification 25.214 V5.3.0. Physical Layer Procedures (FDD), The 3rd Generation Partnership Project (3GPP).

[23] S. Naghian, M. Rintamäki, and R. Baghaie, "Dynamic step-size power control in UMTS," *in Proc. IEEE Int. Symp. on Personal, Indoor and Mobile Radio Commu*n. (PIMRC), vol. 4, Sept. 2002, pp. 1606–1610.

[24] S. Naghian, "Location-sensitive interlligent radio resource management and its application in WCDMA mobile systems," Ph.D. dissertation, Helsinki University of Technology, Espoo, Finland, 2001.

[25]Online available: intra.itiltd-ndia.com/.../CDMA%5CCDMA%20Key%20Technology.ppt

[26] J. G. Proakis*, Handbook on Digital Communications, 3rd ed*., Singapore: McGraw-Hill, 1995.

[27] A. Baier, U.-C. Fiebig, W. Granzow, W. Koch, P. Teder, and J. Thielecke, "Design study for a CDMA-based third generation mobile radio system," *IEEE J. Select. Areas Commun.,* vol. 12, no. 4, pp. 733–743, May 1994.

[28]Xin-She Yang, "Chaos-Enhanced Firefly Algorithm with Automatic Parameter Tuning", *International Journal of Swarm Intelligence Research*, December 2011.

[29] Sh. M. Farahani, A. A. Abshouri, B. Nasiri, and M. R. Meybodi, “A Gaussian Firefly Algorithm”, *International Journal of Machine Learning and Computing*, Vol. 1, No. December 2011

[30] X. S. Yang, “Nature-Inspired Metaheuristic Algorithms”, *Luniver Press*, 2008.

[31] W. C. Y. Lee, “Overview of cellular CDMA,” *IEEE Trans. Veh. Technol*., vol. 40, no. 2,pp. 291–302, May 1991.

[32] R. D. Yates and C.-Y. Huang, “Integrated power control and base station assignment,” *IEEE Trans. Veh. Technol*., vol. 44, no. 3, pp. 638–644, Aug. 1995.

[33] L. Gao and T. F. Wong, “Power control and spreading sequence allocation in a CDMA forward link,” *IEEE Trans. Inform. Theory*, vol. 50, no. 1, pp. 105–124, Jan. 2004.

[34] D. N. Knisely, S. Kumar, S. Laha, and S. Nanda, “Evolution of wireless data services: IS-95 to CDMA-2000,” *IEEE Commun. Mag.,* vol. 36, no. 10, pp. 140–149, Oct. 1998.

[35] A. Furuskär, S. Mazur, F. Müller, and H. Olofsson, “EDGE: Enhanced data rates for GSM and TDMA/136 evolution,” *IEEE Pers. Commun*., vol. 6, no. 3, pp. 56–66, June 1999.

[36] Online available: http://www.ericsson.com

[37] 3GPP2, “The 3rd Generation Partnership Project 2 (3GPP2) home page,” 2004.Online Available: http://www.3gpp2.org

[38] UMTS World.com, “UMTSWorld home page,” 2005.Online available: http://www.umtsworld.com

[39] B. Sklar, *Handbook on Digital Communications, Fundamentals and Applications, 2nd ed*., Upper Saddle River, NJ: Prentice-Hall, 2001.

[40] Y. Okumura, E. Ohmori, T. Kawano, and K. Fukuda, “Field strength and its variability in VHF and UHF land-mobile radio service,” *Rev. of the Electrical Commun. Lab*., vol. 16, no. 9-10, pp. 825–873, Sept.-Oct. 1968.

APPENDIX B

MATLAB CODE

```
clear all;
clc;

% n    = no of user
% f    = no of firefly
% ite  = no of iterations
% matr = [n f ite]

matr =[5 10 3];
n = matr(1);
f = matr(2);
ite = matr(3);
p =(0.2).*rand(f,n);
pmax=0.250; % max standard power
A=6.3;     % standard A
R=15500;   % transmission bit rate
W=125000;  % max bandwidth
eta=0.0001;
sigmapr=3.6303*10^(-14);
ws=4*10^(-15);
wp=1;
ux=zeros(1,n);
uy=zeros(1,n);
d=zeros(1,n);
TH=5;                 % EN threshold value in db
bsx=0;                % x co ordinate of base station
bsy=0;                % y co ordinate of base station
ux=(-5)+10.*rand(1,n);  % x co ordinate of users
uy=(-5)+10.*rand(1,n);  % y co ordinate of users

% distance between base station and user

for i=1:n
   d(i)=sqrt((ux(i)-bsx)^2+(uy(i)-bsy)^2);
end
disp(d)

% calculation of D

for i=1:n
   if d(i)<1
```

```
        D(i)=10^((-127-25*log(d(i)))/10);
    elseif 1<=d(i)<3
        D(i)=10^((-127-35*log(d(i)))/10);
    else
        D(i)=10^((-127-80*log(d(i)))/10);
    end
    g(i)=A*D(i);
end
for m=1:ite
    for k=1:f
        pg=g.*p(k,:);
        denm=sum(pg);
        for i=1:n
            EN(i)=(pg(i)/R)/((denm-pg(i)+eta)/W);
            ENdb(i)=10*log(EN(i));
            if ENdb(i)>TH
                FE(i)=1;
            else
                FE(i)=0;
            end
            FP(i)=1-p(k,i)/pmax;
        end
        F(k)=sum(wp.*FE.*FP)/n+ws/sigmapr;
    end
end

[L,T]=max(F);

disp('Initial power values ');
disp('p =');
disp(p);

disp('Fuction value of each firefly is ');
disp(F);

disp('Max function value ');
disp('L =');
disp(L);

disp('Display best firefly number ');
disp('T =');
disp(T);

alpha= 0.25;
bestff(1,:)=p(T,:);
p(T,:)=p(T,:)+alpha.*abs((rand-0.5)) ;
```

```
beta = 1;
for i=1:f
p(i,:)=(ones(1,n)-beta).*p(i,:)+beta.*p(T,:)+alpha.*(rand-0.5) ;
end

disp('Updated power values ');
disp('p =');
disp(p);

for m=1:ite
   for k=1:f
      pg=g.*p(k,:);
      denm=sum(pg);
      for i=1:n
         EN(i)=(pg(i)/R)/((denm-pg(i)+eta)/W);
         ENdb(i)=10*log(EN(i));
         if ENdb(i)>TH
            FE(i)=1;
         else
            FE(i)=0;
         end
         FP(i)=1-p(k,i)/pmax;
      end
      F(k)=sum(wp.*FE.*FP)/n+ws/sigmapr;
   end
end

disp('Updated Fuction value of each firefly is ');
disp(F);

[Final_Function,Bestfire]=max(F);

disp('Final function value ');
disp(Final_Function);

disp('Bestfire =');  %Display Updated best firefly number
disp(Bestfire);

bestff_updated(1,:)=p(T,:);
ans = p(T,:)+alpha.*abs((rand-0.5)) ;

disp('Final Power values ');
disp('ans =');
disp(ans);
```