COMPARATIVE INVESTIGATION OF PILOT DECONTAMINATION SCHEME FOR SPECTRAL EFFICIENCY IN UPLINK MASSIVE MULTIPLE INPUT MULTIPLE OUTPUT SYSTEMS

2023
Ph. D. THESIS
ELECTRICAL AND ELECTRONICS ENGINEERING

Salah ALTIRAIKI

Thesis Advisor
Prof. Dr. Necmi Serkan TEZEL

COMPARATIVE INVESTIGATION OF PILOT DECONTAMINATION SCHEME FOR SPECTRAL EFFICIENCY IN UPLINK MASSIVE MULTIPLE INPUT MULTIPLE OUTPUT SYSTEMS

Salah ALTIRAIKI

Thesis Advisor
Prof. Dr. Necmi Serkan TEZEL

T.C.
Karabük University
Institute of Graduate Programs
Department of Electrical and Electronics Engineering
Prepared as
Ph. D. Thesis

KARABUK
June 2023

I certify that in my opinion the thesis submitted by Salah ALTIRAIKI titled "COMPARATIVE INVESTIGATION OF PILOT DECONTAMINATION SCHEME FOR SPECTRAL EFFICIENCY IN UPLINK MASSIVE MULTIPLE INPUT MULTIPLE OUTPUT SYSTEMS" is fully adequate in scope and quality as a thesis for the degree of Ph.D.

Prof. Dr. Necmi Serkan TEZEL ....
Thesis Advisor, Department of Electrical and Electronics Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Electrical and Electronics Engineering as a PhD thesis. 23/06/2023

Examining Committee Members (Institutions)		Signature
Chairman	: Prof. Dr. Ziyodulla YUSUPOV (KBU)	....
Member	: Prof. Dr. Necmi Serkan TEZEL (KBU)	....
Member	: Assoc. Prof. Dr. Zafer ALBAYRAK (SUBU)	....
Member	: Assoc. Prof. Dr. Cevad RAHEBI (ITOU)	....
Member	: Assist. Prof. Dr. Ediz ERDEM (KBU)	....

The degree of PhD thesis Degree by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof. Dr. Müslüm KUZU …………………
Director of the Institute of Graduate Programs.

"I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well."

Salah ALTIRAIKI

ABSTRACT

Ph.D. Thesis

COMPARATIVE INVESTIGATION OF PILOT DECONTAMINATION SCHEME FOR SPECTRAL EFFICIENCY IN UPLINK MASSIVE MULTIPLE INPUT MULTIPLE OUTPUT SYSTEMS

Salah ALTIRAIKI

Karabük University
Institute of Graduate Programs
Department of Electrical and Electronics Engineering

Thesis Advisors:
Prof. Dr. Necmi Serkan TEZEL
Feb, 2023 68 pages

Communication technologies, in particular fifth-generation (5G) mobile phones, are currently developing around the world. Efforts have been made to develop communications infrastructure with the development of the 5G technology, which aims at to deliver very high data transfer rates of up to 20 Gbps. Moreover, this technology has a high capacity to provide services to network users. This important feature, along with reduced communication delays and high speed, is among the advantages of the 5G communications. This technology can also be effectively integrated with new technologies such as the Internet of Things (IoT). Communication delays in 5G networks occur less than in 4G networks and less energy is consumed at the nodes, which leads to energy savings in 5G networks. To study 5G communication technology, its infrastructure should be correctly optimized. Massive multi-input-multi-output (MIMO) systems are usually used in this type of communication network so that a large number of users are able to connect to the network and use its services. Massive MIMO systems are a good solution for 5G communication networks leveraging antennas to improve communication performance. To increase output communication power in 5G networks, the problem was optimized with the butterfly optimization algorithm (BOA). According to the simulation results, the proposed method outperformed other similar communication methods, such as the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms in terms of the signal-to-interference-plus-noise ratio (SINR) and rate of connection of users to the network.

Keywords : Fifth-generation communication network, massive multi-input-multi-output (MIMO) systems, butterfly optimization algorithm (BOA), pilot contamination

Science Code : 90523

ÖZET

Doktora Tezi

UPLINK MASİF ÇOKLU GİRİŞLİ ÇOKLU ÇIKIŞLI SİSTEMLERDE SPEKTRAL VERİMLİLİK İÇİN PİLOT ARINDIRMA ŞEMASININ KARŞILAŞTIRMALI İNCELENMESİ

Salah ALTIRAIKI

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Elektrik-Elektronik Mühendisliği Anabilim Dalı

Tez Danışmanı:
Prof. Dr. Necmi Serkan TEZEL
July, 2023 68 sayfa

İletişim teknolojileri, özellikle beşinci nesil (5G) cep telefonları şu anda tüm dünyada gelişiyor. 20 Gbps'ye kadar çok yüksek veri aktarım hızları sunmayı hedefleyen 5G teknolojisinin gelişmesiyle iletişim altyapısı geliştirilmeye çalışılmıştır. Ayrıca, bu teknolojinin ağ kullanıcılarına hizmet sağlama kapasitesi yüksektir. Bu önemli özellik, azaltılmış iletişim gecikmeleri ve yüksek hız ile birlikte 5G iletişiminin avantajları arasında yer alıyor. Bu teknoloji aynı zamanda Nesnelerin İnterneti (IoT) gibi yeni teknolojilerle de etkili bir şekilde entegre edilebilir. 5G ağlarında iletişim gecikmeleri 4G ağlarına göre daha az olmakta ve düğümlerde daha az enerji tüketilmekte, bu da 5G ağlarında enerji tasarrufu sağlamaktadır. 5G iletişim teknolojisini incelemek için altyapısının doğru bir şekilde optimize edilmesi gerekir. Çok sayıda kullanıcının ağa bağlanabilmesi ve hizmetlerini kullanabilmesi için bu tür iletişim ağlarında genellikle büyük çok girişli çok çıkışlı (MIMO) sistemler kullanılır. Devasa MIMO sistemleri, iletişim performansını iyileştirmek için antenlerden yararlanan 5G iletişim ağları için iyi bir çözümdür. 5G ağlarında çıkış iletişim gücünü artırmak için kelebek optimizasyon algoritması (BOA) ile problem optimize edilmiştir. Simülasyon sonuçlarına göre önerilen yöntem, sinyal-parazit artı gürültü oranı (SINR) ve sinyal hızı açısından Random, SPRS, WGC PD ve SPRS+WGC PD algoritmaları gibi benzer diğer iletişim yöntemlerinden daha iyi performans göstermiştir. kullanıcıların ağa bağlanması.

Anahtar Kelimeler: Beşinci nesil iletişim ağı, büyük çoklu giriş çoklu çıkış (MIMO) sistemleri, kelebek optimizasyon algoritması (BOA), pilot kontaminasyonu.

Bilim Kodu **:** 90523

ACKNOWLEDGMENT

First and foremost, praise be to Allah for granting me success in completing my doctoral thesis as required.

I would like to express deepest gratitude to my supervisor Prof. Dr. Necmi Serkan TEZEL for his grateful motivation, guidance, support, continuous advice and constructive suggestions toward the completion of this thesis.

I would like to acknowledge my committee for their contributions in time and advice to improve this work.

I would like to dedicate my dissertation:

To the pure soul of my father, may Allah have mercy on him.

To my mother, I appreciate her for encouraging me to bring passion and love to whatever endeavor I undertake. She has been there since the beginning, supporting me throughout my degree programs, and even stayed with me to ensure the completion of this thesis.

To my beloved family- my wife and children- who endured the hardship for my sake and encouraged me with endless love during the period of my study.

To my dear Ali Al-Aaieb, who has a great virtues.

To my sisters, brothers, friends, colleagues, and all my loved ones.

Last but not least, with all my gratitude and appreciation, I dedicate this work and ask Almighty Allah to benefit my country and its people. May Allah grant success to everyone

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

SYMBOLS AND ABBREVITIONS INDEX

MIMO	: Multi Input Multi Output
SIMO	: Single Input Multiple Output
MISO	: Multiple Input, Single Output
BTS	: Base Stations
CSI	: Channel Status Information
UL	: Uplink
DL	: Downlink
BOA	: Butterfly Optimization Algorithm
VANETs	: Vehicular Ad Hoc Networks
RFID	: Radio Frequency Identification
ICT	: Integrated Circuit Technology
SoA	: Service-Oriented Architecture
TDMA	: Time-Division Multiple Access
WCDMA	: Wideband Code Division Multiple Access
CE	: Channel Estimation
TDD	: Time Division Duplex
SPRS	: Soft Pilot Reuse Scheme

PART 1

INTRODUCTION

1.1. MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM

Multiple Input Multiple Output (MIMO) denotes a number of areas in wireless transmission in the communications technology, a method and a transmission system for the use of multiple transmitting and receiving antennas for wireless communication.

This is the basis for special coding methods that use not only the temporal, but also the spatial dimension to transmit information (space-time coding). This can significantly improve the quality (bit error frequency) and data rate of a wireless connection. MIMO systems can transmit s per Hz bandwidth occupied substantially more bit / and thus have a higher spectral efficiency than conventional Single Input Single Output (SISO) systems, each with an antenna on the sender and receiver side, or Single Input Multiple Output (SIMO) systems with one antenna on the transmitter side and several antennas on the receiver side.

MIMO technology has been and is constantly being developed. Most recently, in 2014, several router manufacturers presented Multi-User MIMO (MU-MIMO). With this technology, an access point or router can send different data records to several clients at the same time. The radio channel becomes free again more quickly.

In addition to the presently described multi-variable system, there are MIMO SISO in each of which make use of both sender and receiver, an antenna and "mixed" systems (SIMO and Multiple Input, Single Output (MISO). At MISO, for example, a router uses three antennas and a smartphone only one antenna.

1.2. SMART ANTENNAS / SIMO

The use of several antennas or receiving components at one end of the communication link has become widespread in the last few decades. Intelligent is connected to these antennas the downstream signal processing which assembles the received signals. In mobile radio systems such as GSM, in particular, the use of several receiving antennas on the base stations (BTS) side is often found because this offers significant advantages: Several antennas can draw more energy from the electromagnetic field than a single one (group gain). Reflections on the propagation path cause multipath propagation by destructive interference can lead to signal fading in the receiver . If several spatially separated receiving antennas are used in an environment with strong multipath propagation, the fading at the individual antennas is statistically independent and the probability that all antennas are affected by fading at the same time is very low. This effect is called spatial diversity and leads to a diversity gain, but does not grow linearly with the number of antennas, but quickly comes to saturation. Another approach is beam steering, in which the main lobe the antenna is aimed specifically at the remote station. All of these methods can significantly increase the reliability of a connection, but not the average channel capacity .

The channel matrix is shown in figure 1.1.

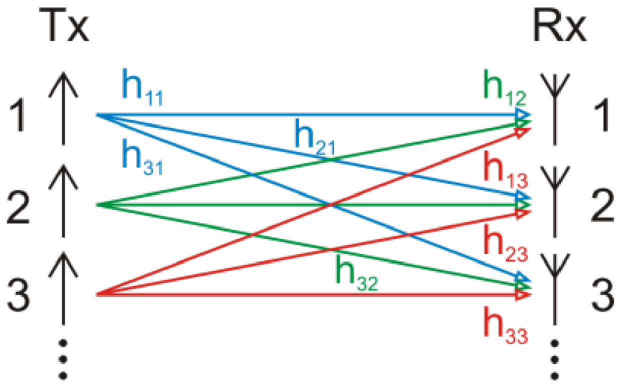

Figure 1.1. Illustration of the channel matrix.

The advantages of MIMO go beyond those of the smart antennas. Looking at a system with n_T Transmitting antennas and n_R Receiving antennas so result $n_R \times n_T$

individual channels. The resulting overall channel can be described as a channel matrix $\underline{H}$ with complex entries h_{ij} represent:

$$\underline{H} = \begin{bmatrix} h_{11} & \cdots & h_{1n_T} \\ h_{21} & \cdots & h_{2n_T} \\ \vdots & \ddots & \vdots \\ h_{n_R1} & \cdots & h_{n_Rn_T} \end{bmatrix} \text{with} \qquad h_{ij} = \alpha + \mathrm{j}\beta \tag{1.1}$$

These different channels can be used at the same time with the same frequency, the transmission power is divided between the antennas. In a system with two participants, the different modes can be used to increase the data rate, but in a system with many users this can also be used as a multiple access method, e.g. B. to separate the signals of the individual users in a cellular network (as an alternative to the FDMA / TDMA in GSM or CDMA in UMTS used today).

Simplifying example: In a system with four transmit and four receive antennas, a bit stream can be divided into four separate bit streams that are transmitted in parallel. On the receiving end, each antenna receives a composite signal from the transmitting antennas. In order to decode and reassemble the bit stream, a system of equations with four equations for four unknowns has to be solved, which is only possible if the four equations are linearly independent, i.e. the channel matrix has full rank has. In physical terms, this means that the individual channels must be very different, which is the case, for example, in environments with strong multipath propagation. If this condition is met, the system can transmit four times the amount of data in the same time without requiring additional bandwidth, which increases the spectral efficiency by a factor of four. A profit is thus achieved through spatial multiplexing.

1.3. CHANNEL CAPACITY

The channel capacity indicates the maximum number of bits / s / Hz that can be transmitted over a disturbed channel with an arbitrarily small error probability. For MIMO systems it is defined as

$$C = \log_2[det(\underline{I}_{n_R} + \frac{\rho}{n_T}\underline{HH^H})], \tag{1.2}$$

in which ρ the mean SNR at the receiver, $(\cdot)^H$ the adjoint and $\underline{I}$ denotes the identity matrix . In a system with a large number of antennas, the average channel capacity is

$$C_a \approx min\{n_T, n_R\}\log_2(1+\rho)$$

Theoretically there is the possibility here to use the channel capacity n_T and n_R to increase at will. The price for this, however, is the growing effort due to the number of antennas and the complexity of the RF receiver and signal processing. In addition, this information-theoretical variable is only an upper limit that is difficult to achieve in practice. In addition, the approximation formula only applies to uncorrelated, i.e. independent signal propagation paths (channels). In practice, however, the propagation paths of the signal are always correlated and the more so the more antennas are used.

1.4. APPLICATIONS

MIMO technology is used in WLAN, WiMax and various cellular standards such as LTE.

1.5. WLAN

The full MIMO support can only be used if both the sender and the recipient are proficient in the MIMO process. For example, if the access point uses MIMO with three antennas (3x3 MIMO), but only two antennas are available to the client (2x2 MIMO), the net throughput for 802.11ac components increases by approx. 20 with 3x2 MIMO compared to a 2x2 stream.

1.6. FIRST GENERATION MIMO HARDWARE

For the first MIMO devices based on the spring of 2005, their providers promised much higher radio coverage compared to the previous 802.11g standard. Examples of product names were or are at Netgear "RangeMax" or "SRX" at Linksys.

1.7. SECOND GENERATION MIMO HARDWARE

In December 2005 a new generation of routers with the new "Airgo" chipset came onto the market. This new chipset with MIMO technology enabled for the first time similar net speeds as in the LAN via copper cable. The network components achieved a gross speed of up to 240 Mbit / s through the simultaneous use of two radio channels.

In spring 2006, WLAN components were presented for the first time at CeBit 2006, which can be operated with the WLAN standard 802.11n. Thanks to new chipsets and adapted technical specifications such as extended MIMO technology, these products had data throughput rates of up to 300 Mbit / s (gross). The technical specifications of these routers and WLAN adapters were initially only based on the preliminary version 802.11n draft. Many hardware components became fully compatible with the 802.11n standard adopted in 2009 with the aid of firmware or software updates.

With the help of MIMO technology, data throughput rates of up to 600 Mbit / s (gross) are possible with the 802.11n WLAN standard as of 2012. The gross rate of 600 Mbit / s can only be achieved in the 5 GHz band with a channel bandwidth of 40 MHz and four antennas (4x4 MIMO) each on the transmitter and receiver side [1]. The 11n standard recommends the MIMO OFDM method.

1.8. WIMAX AND CELLULAR NETWORKS

MIMO technologies are included in the WiMax standard IEEE 802.16 adopted in 2009. The 802.16e standard recommends the MIMO OFDMA method.

Example of an LTE MIMO antenna with 2 connections. The two antenna elements built into the interior of the antenna were offset by 90 ° to each other and thus use multiple input / output technology and antenna diversity.

Various cellular networks such as LTE also use MIMO processes. With MIMO, it is possible for mobile network providers to offer high data speeds with a low error rate [2].

1.9. AIMS AND GOALS

An important challenge in the 5G network is the problem of environmental pollution that a user can use multiple cell services simultaneously and make the system unbalanced. Therefore, in the proposed method to solve this challenge, the problem is assumed to be optimized with using of butterfly optimization algorithm, an attempt has been made to reduce and modify this challenge.

Massive MIMO is a form of multi-user MIMO systems in which the number of antennas is significantly greater than the number of users under service. Using the large number of antennas at the base station, the favorable channel condition is provided, and as a result the use of linear processing schemes is near optimal. The most important factor which limits the performance of these systems is the interference due to the reuse of the similar pilot sequences by users of different cells in the uplink which is known as pilot contamination.

In this thesis, first, spectral efficiency improvement methods based on pilot reuse in the presence of linear receptors will study. Then, effective design ideas will be discussed based on the comparison provided.

1.10. SUBJECT, SCOPE

In Massive MIMO systems, it is important to obtain channel status information (CSI) at the base station. Pilot symbols are needed to obtain CSI information. In practice it is not possible to assign different pilot sequences to each device. The use of the same pilot sequences in different cells reveals the problem of pilot pollution. There are many studies to reduce or eliminate this problem. In this article, we reduce the pilot pollution problem and improve the system performance. It has been observed that it gives better results than the pilot assignment methods proposed previously.

1.11. DESIGN & METHODOLOGY

We designed the optimization algorithm which is name is butterfly to 19 cells, that each of them with a base station and a number of active users. In the proposed method, by implementing the license optimization algorithm, it is possible to optimize user-related vectors for service in a single cell, and the average signal-to-noise index can be maximized throughout the network, and the most optimal license is actually It is a butterfly that has the maximum signal to noise.

1.12. ORIGINALITY

In this paper, in order to increase the output and communication power in the fifth generation networks, the problem has been considered from the perspective of optimizing the problem and the impeller optimization algorithm has been used for it. There is no any similar paper that represented proposed method before.

1.13. FINDINGS

The authors declare there was no funding for this work.

1.14. DECLARATION OF ETHICAL STANDARDS

This article does not contain any studies with human participants or animals performed by any of the authors. The authors declare that there is no conflict of interest regarding the publication of this paper.

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

One of the biggest reasons for the development of wireless communication is the ever-increasing demands of the user. The system currently used is not enough to meet the demands. To meet these needs 5G technology is one of the new generation technology studies; improvements are expected to be made on issues such as delay reduction, increasing data speed, energy savings, cost reduction and spectrum efficiency. The Pilot pollution problem in Massive MIMO systems is shown in figure 2.1.

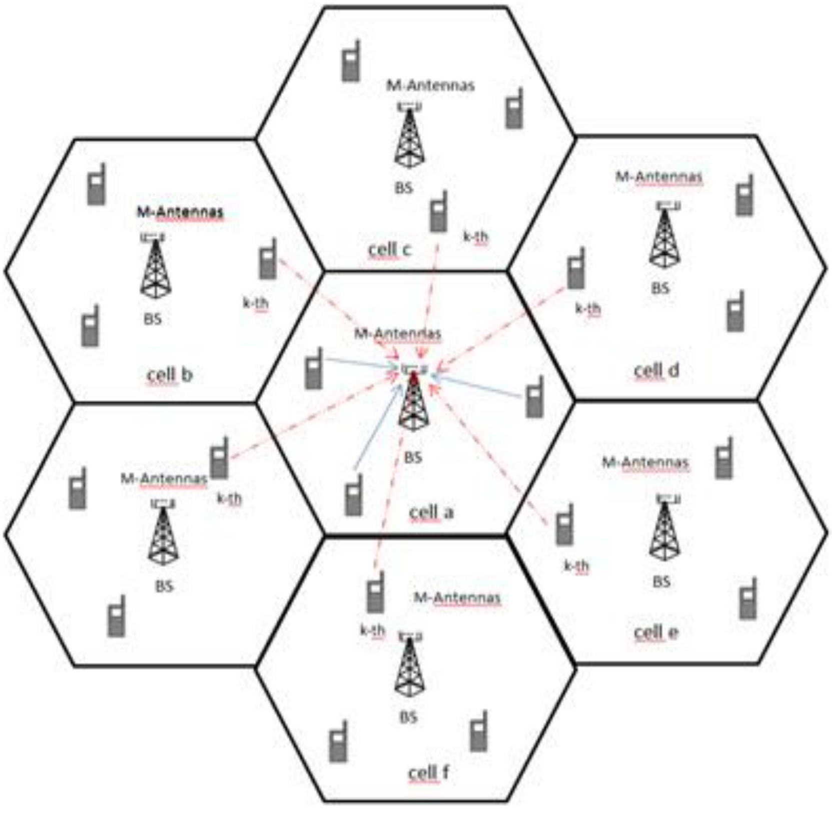

Figure 2.1. Pilot pollution problem in Massive MIMO systems.

The Uplink (UL) and downlink (DL) transfer in large MIMO system when pilot contamination occurs is shown in figure 2.2.

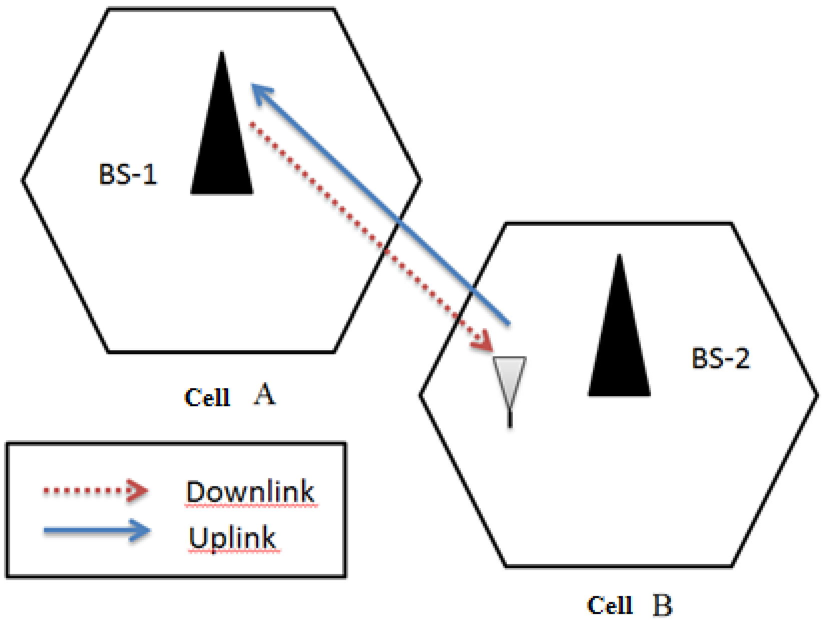

Figure 2.2. Uplink (UL) and downlink (DL) transfer in large MIMO system when pilot contamination occurs.

It is aimed to improve the system performance by optimizing the pilot pollution problem by using graph based coloring and SPRS pilot assignment method by Munkres method.

We will use the most commonly used symbols to make it easier to understand. We are considering a Massive MIMO system consisting of L cell count and $M \geq K$ antenna number. Here K is the number of users with a single antenna. As shown in Figure 2.2, k. from the user to the cell network base station m. antenna propagation factor:

$$ga,b,k,m = \sqrt{\beta a,b,k}\ ha,b,k,m. \quad (2.1)$$

Here, ha, b, k, m are small scale damping factors and are random variables with independent and uniform distribution (i.i.d) and symmetrical Complex Gaussian CN (0,1). β "a, b, k" is the Large Scale Damping Factor. The channel matrix representation of all K users in the cell is expressed as follows:

$$\mathbf{G}a,b=\sqrt{\mathbf{D}a,b}\,\mathbf{H}a,b = \begin{pmatrix} ga,b,1,1 & \cdots & ga,b,k,1 \\ \vdots & \ddots & \vdots \\ ga,b,1,m & \cdots & ga,b,k,m \end{pmatrix} \quad (2.2)$$

Here;

$$\mathbf{H}a,b = \begin{pmatrix} ha,b,k,m & \cdots & ha,b,k,m \\ \vdots & \ddots & \vdots \\ ha,b,k,m & \cdots & ha,b,k,m \end{pmatrix} \quad (2.3)$$

$$\mathbf{D}a,b = \begin{pmatrix} \beta a,b,1 & & \\ & \ddots & \\ & & \beta a,b,k \end{pmatrix} \quad (2.4)$$

2.2. UPLINK (UL) TRAINING PHASE

Channel status information is obtained by means of pilot sequences of length τ, which are sent via uplink to base station (BS) received from users (UTs). $\varphi b^H \varphi b=\tau I$ is such that. Here matrix b pilot is sequence and orthogonal matrix

$\varphi b=[\varphi_{b,1}\ \varphi_{b,2} \ldots\ldots\ \varphi_{b,K}]$ **(τ x K)**

b is signal received from the base station.

$$Y_b = \sqrt{p_u} \sum_{j=1}^{L} D_{b,j}^{1/2} H_{b,j} \phi_{b,j}^{T} + N_b \quad (2.5)$$

Nb Here is the Collected White Gaussian Noise matrix and the elements of this matrix indicate the CN(0,1) random variable values. (Mx**τ**) p_u is the average sending power of each user in the uplink.

2.3. PILOT CONTAMINATION

In general, the problem of pilot contamination arises from the use of the same pilot sequence between the two terminals and the absence of orthogonal sequences. These pilot sequences, which are proportional to the number of system terminals, require limited use due to limited bandwidth and time consistency range. For this reason, an unlimited number of pilot assignments are not made. Reduction of system performance rates due to pilot pollution and decreases in performance are observed. Damaged equipment is another cause of pilot pollution in non-reciprocating receivers and transmitters. However, this study focuses on the solution of the problem arising from the use of the same pilot sequences in two adjacent cells. In this thesis, it is assumed that large-scale extinction coefficients ($\beta_{a,b,k}$) change slowly and block fading.

UL SINR in the cell k. for the user;

$$SINR_{a,k} = \frac{\left|h_{a,a,k}^{H} h_{a,a,k}\right|^2}{\sum_{b=1,a\neq b}^{N}\left|h^{H}_{a,b,U(b,k^{(i)})} h_{a,b,U(b,k^{(i)})}\right|^2 + \frac{\left|v_{d,a,k}\right|^2}{P_d}} \qquad (2.7)$$

Asymptotic UL SINR in accordance with the random matrix theory;

$$SINR_{a.k}^{\alpha} \triangleq \lim_{M\to\infty} SINR_{a,k} = \frac{\beta_{a,a,k}^2}{\sum_{b=1,a\neq b}^{N} \beta^2_{a,b,U(b,k^{(i)})}} \qquad (2.8)$$

This mathematical expression shows that the asymptotic UL SINR value depends on the large scale fading coefficients and pilot assignments when the sending power and the pilot power depend.

2.4. PILOT ASSIGNMENT SCHEME

Minimizes the pilot pollution problem in uplink phase. Here it is assumed that large scale fading coefficients change slowly. Large-scale damping is block fading [3]. The Separation of active users in a cell by the recommended method is shown in figure 2.3.

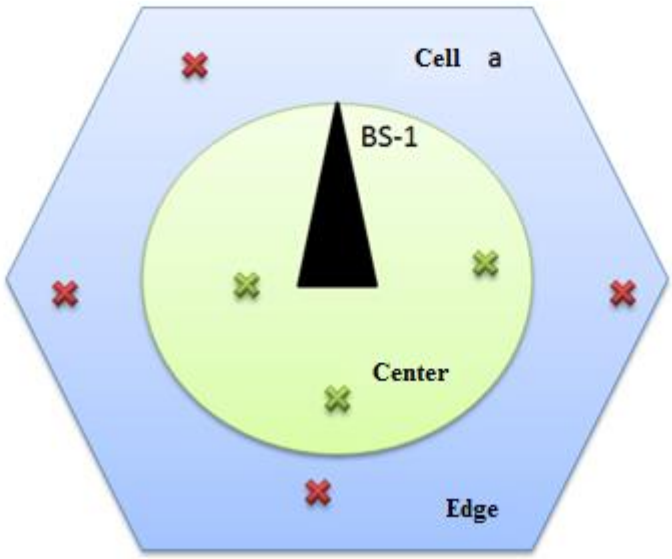

Figure 2.3. Separation of active users in a cell by the recommended method.

The schema, which we propose here, was formed by combining SPRS, WCPDA and munkres pilot designation methods. Assignment methods have been made for the users who are on the edge. We have developed an appointment by considering the academic work and user justice.

The pilot assignment problem for a two-cell scenario is as follows:

$$\min_{s_{k,l}k,l\in K} \sum_{k\in K} \sum_{l\in K} c_{k,l} s_{k,l} \tag{2.9}$$

$$\sum_{l\in K} s_{k,l} = 1, \forall k \in K;$$

$$\sum_{k\in K} s_{k,l} = 1, \forall l \in K;$$

$$s_{k,l} \in \{0,1\}, \forall k \in K, \forall l \in K;$$

The $c_{k,l}$ values are:

$$c_{k,l} = \frac{\beta_{1,2,l}^2}{\beta_{1,1,k}^2} + \frac{\beta_{2,1,k}^2}{\beta_{2,2,l}^2} \tag{2.10}$$

This problem is a minimum-weighted two-part comparison problem [3]. In this thesis, the Hungarian algorithm will used to solve this problem [4].

2.5. INTERNET OF THINGS (IoT)

Internet of Things (IoT) is a technology in which everything can be considered a node or network member. Smart sensors and devices may be simple objects or wireless sensors or actor networks (WSAN). There are different technologies in IoT to achieve communications at such levels. IoT makes use of the communication technologies employed in WSAN and radio-frequency identification (RFID) [5]. There are many applications for IoT, including smart homes, smart cities and industrial and agricultural applications [6]. Smart devices are an integrated component of IoT and include various types of communication equipment and peripheral information collectors for data transfer and exchange among smart devices. Various communication technologies such as WiFi and Bluetooth are used for communication in the network nodes [7]. IoT includes a large number of nodes and devices in the network and it is capable of generating a high traffic volume called big data, the processing of which is carried out using cloud computing systems [8]. IoT can be used at a vast operational scale in which each node sends important information to the base station. To accelerate data processing, this network can be combined with big data processing models to analyze the data collected by the sensors. IoT networks are currently integrated with various communication infrastructures such as fifth-generation (5G) communication technology [9]. Wireless telecommunications are of great importance in today’s world with a great impact on various communication layers. The advent of wireless telecommunication networks has led to a high value adding for such networks. These technologies have been introduced as one of the most profitable industries in the world leading to a rapid growth and intense competition in this area. According to the literature, a new generation of mobile network is usually introduced to the communications market each decade. On the other hand, due to competition among large communications companies, a beta version of the technology is provided to the market prior to finalization [10]. In fact, this rapid development is mainly due to factors such as rapid growth in demand, customer acceptance, profitable trade and intense competition among large companies. Although 4G technology has been recently presented, the new 5G communications have already been emerging and are ready for use. Due to numerous factors, in particular considerable profit, communications research centers around the world have focused on mobile communications [11].

Due to the rapid growth of telecommunication networks and their various generations, the old generation of networks are slowly being replaced, further slowing down the integration of new generations with day-to-day applications. Another side effect is the diversity of the existing communication and telecommunication networks. On the other hand, similarly to IoT, 5G communication networks assume an intrinsic heterogeneous and unpredictable nature as it includes a large number of communication nodes and not all the connected devices are necessarily identical [12][13].

In this paper, a novel method based on pilot contamination in massive MIMO systems used in 5G communication networks is presented using metaheuristic algorithms to evaluate the problem from an optimization perspective. Given the fact that the butterfly optimization algorithm (BOA) is an exact metaheuristic algorithm with a higher accuracy than conventional metaheuristic algorithms, this algorithm is nevertheless used to eliminate pilot contamination in 5G networks. The prerequisites for 5G communication technology, such as IoT, are first discussed and then metaheuristic methods are reviewed. The butterfly optimization algorithm is then discussed and the proposed method is formulated. The algorithm is then implemented and the results are analyzed and discussed.

A degree of intelligence can be considered for any object (device) around us. Many objects and devices in our life today are highly intelligent and have multiple sensors to collect peripheral information. The connection of these smart objects and devices has led to the creation of IoT. In addition to devices, IoT is also able to connect computer networks such as wireless sensor networks (WSN) [14] and vehicular ad hoc networks (VANETs). These networks are, in fact, considered to be part of a larger network. IoT makes use of technologies employed in WSN and radio frequency identification (RFID) labels for the identification of devices in a network [15]. IoT is extensively used in agriculture, transportation, industry, smart homes and smart cities. The number of IoT users is increasing daily and its role in industry and in many other applications is becoming more evident. IoT consists of a large number of devices which may number in the billions in some cases. These smart devices are able to generate a large volume of data the analysis of which requires cloud computing systems. The information and data sent to the cloud computing system will be only applicable when the location of the collected data and information is correctly provided.

IoT is a vast network of "things" (devices) wherein each node is a smart device with multiple sensors that interact with the surroundings. These devices can interact with each other and send their information to users or to a base station for final processing. A radio frequency identification (RFID) system and its tags are used in IoT for the identification of "things" (devices). Tags contain important information on identification and authentication. Figure 2.4 shows an IoT communication infrastructure and its main components. The sensor node is able to send information to a collector or sink node, the process of which requires them be authenticated. In this case, the RFID tags are activated by radio waves from reader sensor nodes, and the information is sent through the Internet to a base station or cloud computing platform for final analysis and evaluation. According to Figure 2.4, today's communications are, in fact, based on the integration of different networks such as WSN and RFID, as observed in IoT.

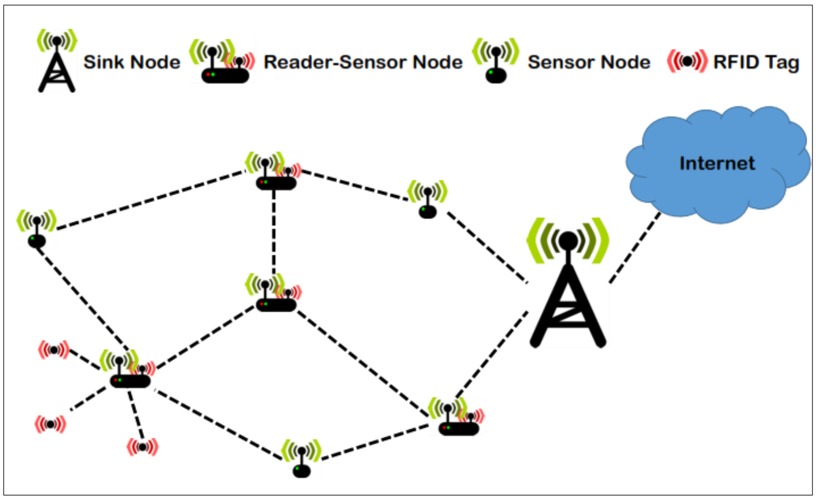

Figure 2.4. A model for processing and integrating WSN with IoT reader sensor nodes [16].

2.5.1. IoT Growth

The emergence and growth of smart devices around us is considered an important requirement for the realization of IoT. Today, smart devices around us have grown so much that they can be considered members of a global network capable of exchanging data. The ascending trend of the number of smart devices from 1950 to 2050 is shown in Figure 2.5 As can be clearly seen, the number of smart devices in the world will reach over 100 billion by 2050 and thus IoT can be considered a massive network in this regard.

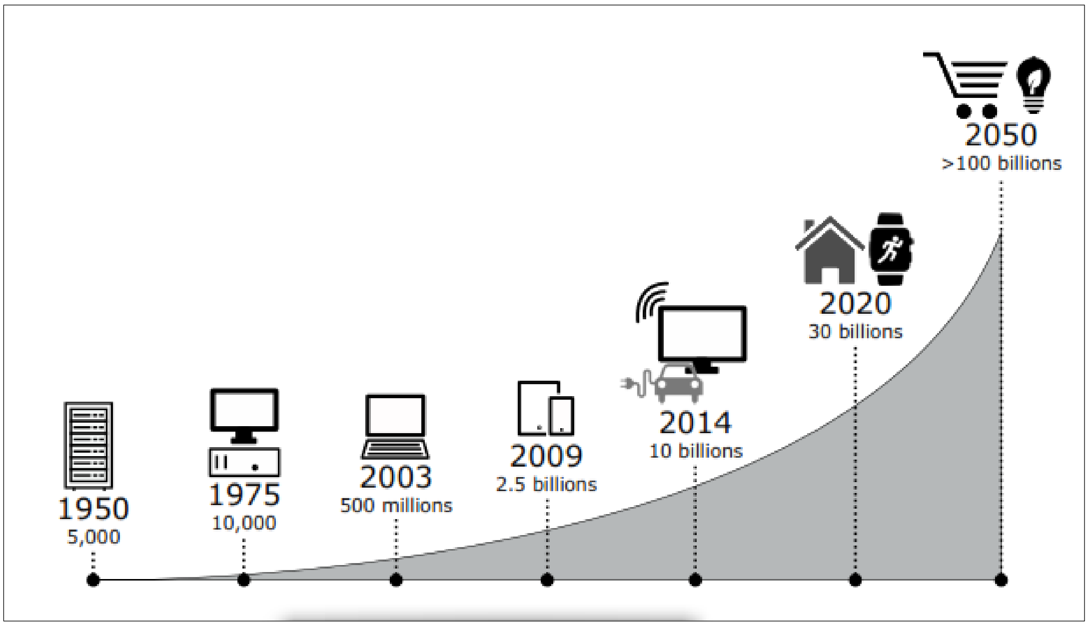

Figure 2.5. Growth and projected growth of the IoT network and related smart devices up to 2050 [17].

The future rise in the number of smart devices leads to the development of an IoT network with a large number of nodes and smart devices. The resulting network will face more challenges than other networks because in addition to devices, IoT as a massive network also includes the network infrastructure for WSN or VANETs. Increasing the number of nodes poses critical challenges such as routing, locating and generating big data. A large volume of data is nowadays produced on the Internet and these data should be processed in distributed systems. The growth of IoT can be related to the ever-increasing advances in integrated circuit technology (ICT) as well as the reduced cost and dimensions of connecting to IoT.

2.5.2. Communication Technologies in IoT

IoT can be considered a network infrastructure in which different technologies are employed in such a manner that the network would be able to collect peripheral information and send them through the network infrastructure to be processed in a cloud computing system. IoT includes various technologies such as sensors, communications, networking, cloud processing and identification. Radio frequency identification (RFID) and wireless sensor networks are commonly used in IoT. Various technologies employed in WSN can be used at different levels such as application software, communication infrastructures, and sensing and sensor layers. The Communication technologies and infrastructure of IoT is shown in figure 2.6.

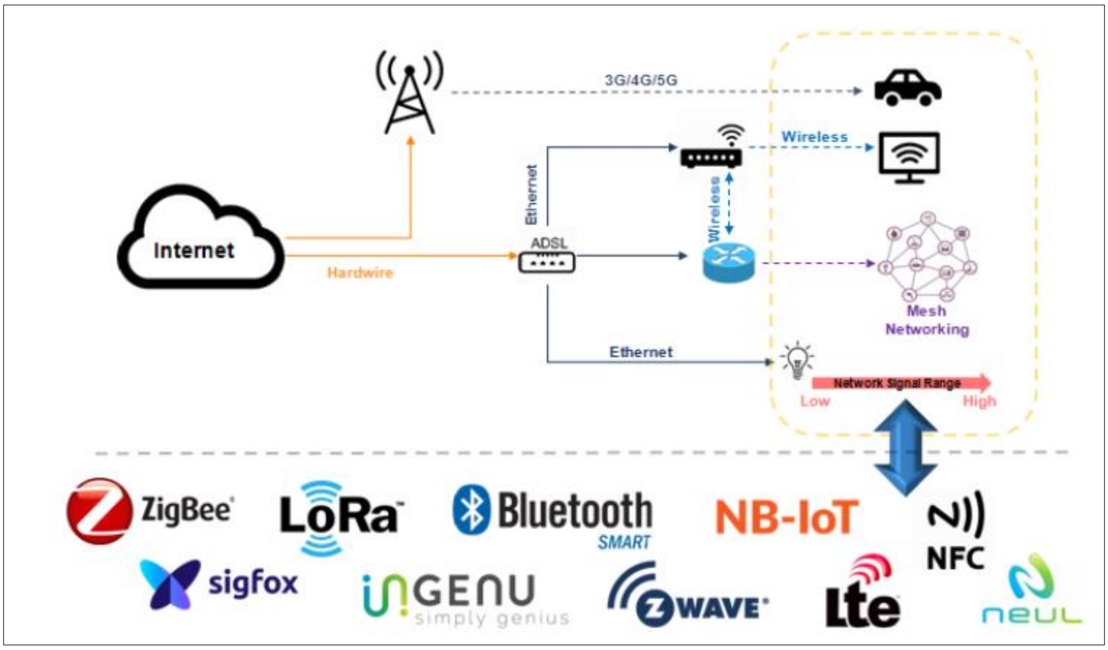

Figure 2.6. Communication technologies and infrastructure of IoT [18].

Communication platforms such as WiFi, ZigBee and WinMax play a key role in the development of IoT. In addition to the above technologies, WSN and RFID have a considerable impact on IoT development such that the communication model and monitoring of WSN and label-assisted identification may be considered two integrat-ed parts of IoT. The range and energy consumption by communication protocols such as WiFi, Bluetooth and ZigBee significantly differ from other communication protocols. Obviously, an increase in the radio range of sensor nodes improves their operating power. However, energy consumption of the nodes also increases, leading to a decrease in the network lifetime since sensor nodes are eliminated over time and their function becomes disrupted. Technologies such as GPRS with a long range and moderate energy consumption are suitable for satellite communications. A technology such as BLE (or Bluetooth) has a limited range and also minimum energy consumption. WiFi communications are extensively used in WSNs with a maximum range of 100 and an approximate energy consumption of 835 mW [19].

2.5.3. IoT Layers and Architecture

Various models are available to describe IoT, the most notable of which is based on service-oriented architecture (SoA) in which each layer consists of a set of services provided to the upper layers. In some cases, there is a five-layer model for this architecture consisting of a business layer, an application layer, a processing layer, a transport layer and a sensing layer. In some cases, a three-layer model, consisting of a medium or application layer, network layer and perception or sensing layer, is presented to describe IoT [20]. Figure 2.7 shows the three-layer architecture for IoT.

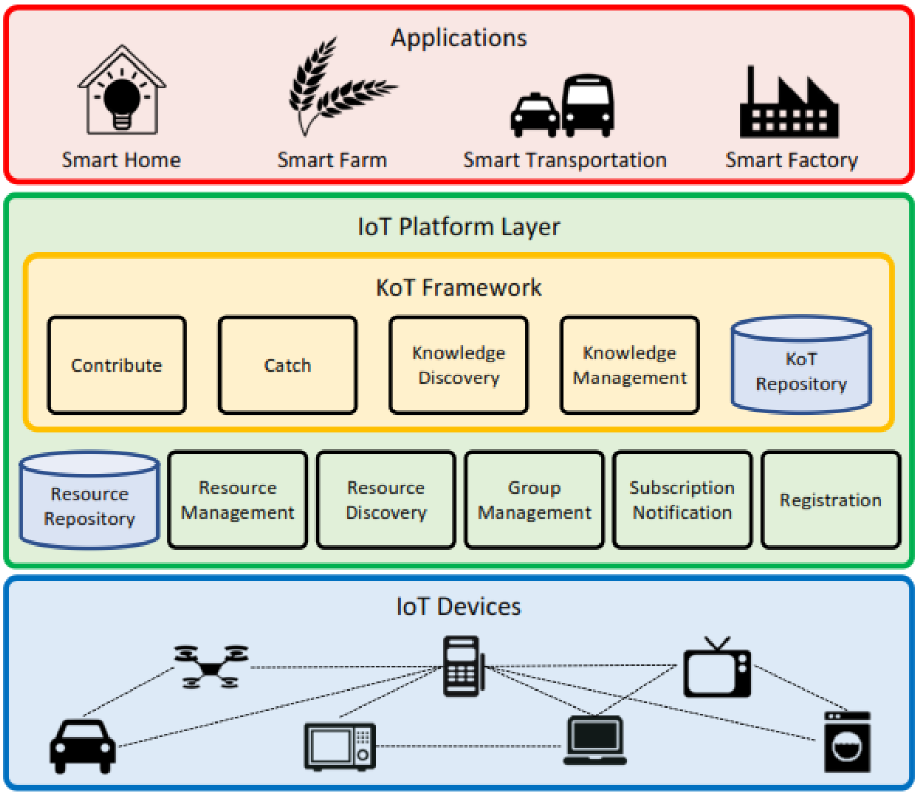

Figure 2.7. Three-layer architecture of IoT [21].

According to the above architecture, the IoT model consists of sensors, networks and application layers where IoT software exists in the application layer, network communication protocols such as WSNs and Bluetooth exist in the network layer, and a set of smart devices capable of collecting peripheral information such as RFID and RFID are found in the sensor layer.

2.6. FIFTH-GENERATION (5G) COMMUNICATION TECHNOLOGY

Fifth-generation (5G) telecommunication technologies refer to a set of technologies delivering higher communication speeds than older generations such as 4G communications. The need for 5G networks is on the rise due to the increase in the number of users connected to networks such as IoT, IoT applications and machine-to-machine communications. In addition, a variety of services with different functions are required at different speeds due to the increased demand of users for rapid and high-quality communications. Given the increased demand and data volume in the future, it is predicted that 4G communications will fail to offer high performance, at which point 5G networks step in with a bright future [22]. The history of the growth and development of communication networks is an interesting topic. Bell Labs launched the first generation of cellular communications called the Advanced Mobile Phone System (AMPS) in the US in 1983, which was later referred to as 0G. The second generation of cellular communications (IS-54) was launched in North America in 1990 using digital communications and multiplexing (time-division multiple access (TDMA)). Later, GSM took over IS-54 in the market. In 1995, using CDMA and a 2.5-MHz bandwidth, GSM equipped GPRS and EDGE data transfer systems with voice contact leading to 2.5G communication networks. The third-generation (3G) developed by ITU made use of Wideband Code Division Multiple Access (WCDMA) technology. WiFi and WiMax technologies are used in the fourth generation (4G), which was presented for the first time in 2010. The LTE system was then developed and it achieved a greater share of the market. This generation gained popularity by providing a fast data transfer rate on mobile phones. It is predicted that the fifth generation (5G) will be launched and become public in 2021 [23][24]. While having a very high capacity and data transfer rate, this communication system is more cost-effective than previous generations in terms of energy consumption as well as launching and maintenance costs. Figure 2.8 shows the evolution of different communication technologies from 2017 to 2021. As seen in the figure, this communication technology evolved from 3G to 5G to increase data transfer rates and data connectivity to IoT or wireless networks.

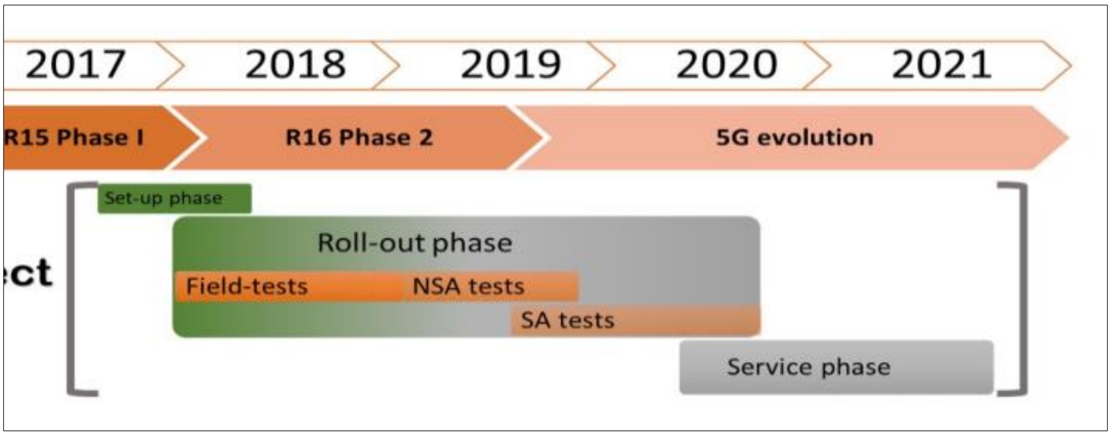

Figure 2.8. Evolution of communication technologies from 3G to 5G.

Figure 2.9 shows the structure of a 5G network and communications within this network. As shown, the 5G network uses a wireless communication technology suitable for use in every section. As its most important advantages, this technology offers a higher data transfer rate and high connectivity for each node in the network. Heterogeneous communications in this type of network include mesh, D2D, and centralized and distributed communications.

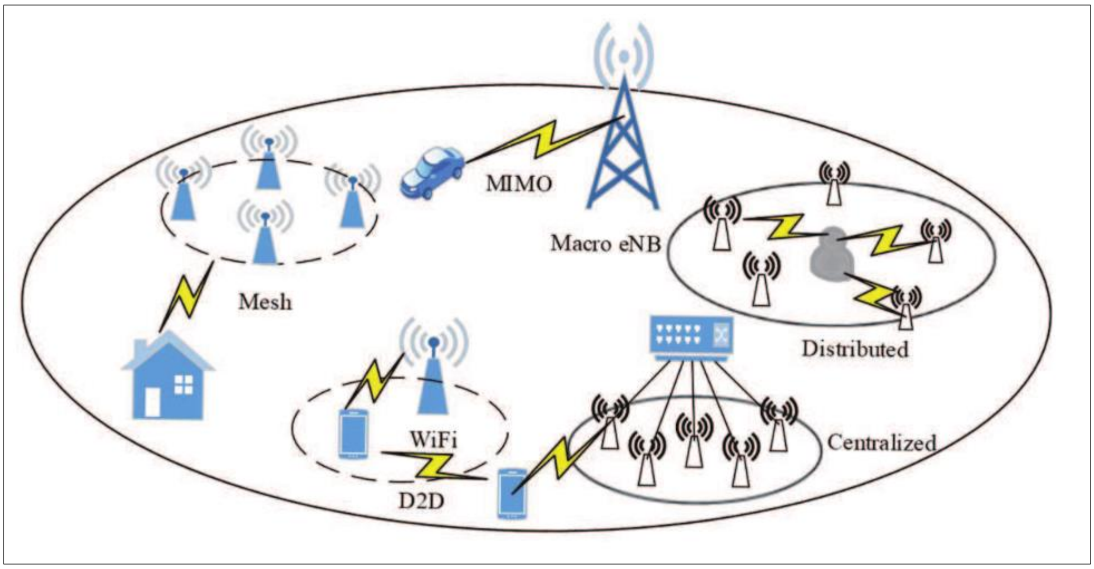

Figure 2.9. Structure of a 5G network.

2.6.1. 5G Communication Technology and Software-Defined Networking

5G communication technology has led to the development of software-defined networking for data transfer in parallel with this type of communication. Software-defined networking is a novel network architecture suggested by the Stanford University to separate logically the control and data. It is also one of the most popular networking technologies and an important route for future development of networks. Software-defined networking allows integrated management and provides a flexible programmable architecture along with an easy approach to network management. It is a combination of controllability, separate control, and programmability in the network. This has been extensively studied and is currently used in cloud computers and virtualization technologies [25][26].

2.6.2. 5G Communication Technology and Data Processing

Sending all the data for computation in a cloud may not impose a huge computational burden for small and medium data. However, the cloud computing space may undergo a high computational load when facing big data or fog data. One important challenge in cloud computing is the lack of use of IoT infrastructure for preliminary data processing. In other words, the data collected by IoT sensors are directly sent to the cloud computing space to perform any necessary computations. This in turn imposes a high computational load on the cloud and may even prolong processing times. Fog computing is a new concept indicating the relationship of IoT and cloud computing aiming at employing the processing resources of devices in addition to cloud computing for more optimal processing of the data in the cloud [27][28]. The use of 5G communication technologies allows fog computing, which provides the necessary infrastructure for distributed processing in IoT. Figure 2.10 shows the model used in fog computing along with other technologies such as cloud computing and IoT. Fog computing along with cloud computing and IoT improves the performance of IoT. In fact, the fog computing layer in 5G communication technology is at a higher level than devices and it is responsible for preliminary processing using the resources available in the network nodes. The real time is not so long but computations to be performed are distributed among the network nodes. The request for more complex computations is then sent to the upper layer or the cloud space. As observed, the IoT nodes on the 5G communication platform process data in the computation layer, after which the final processing is performed in the computing layer. Hence, it can be stated that 5G has been successful in the processing of big data by providing optimal solutions.

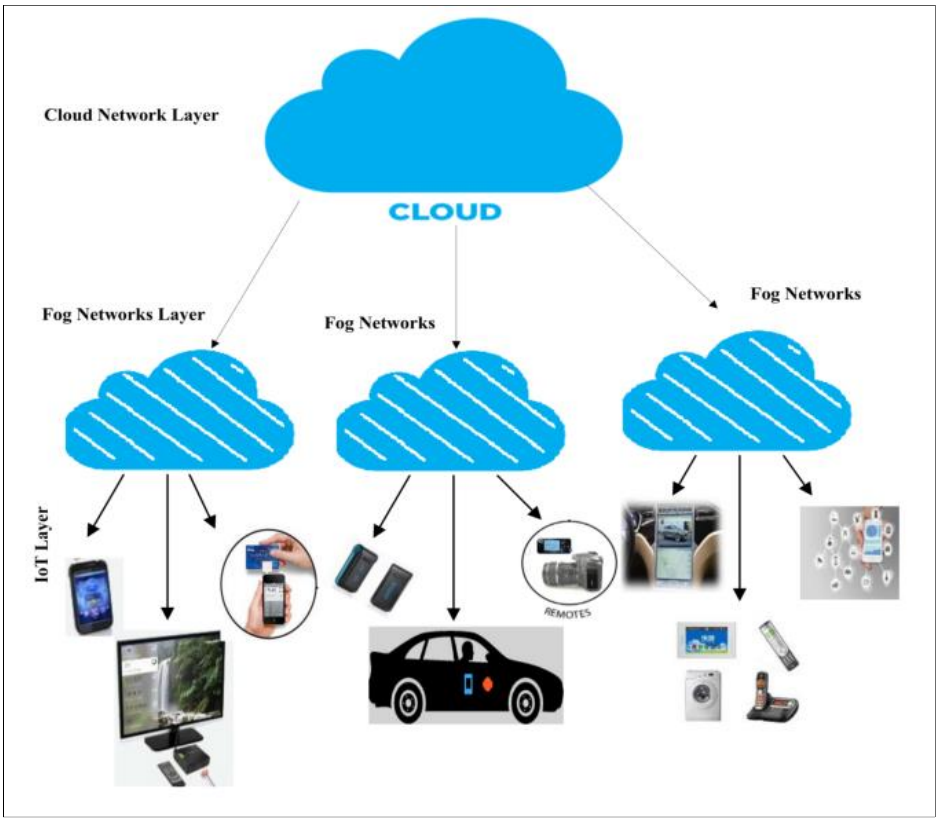

Figure 2.10. 5G communication technology in combination with fog computing and the IoT network [29].

The use of the Massive MIMO wireless system is essential for these improvements in 5G systems. Massive MIMO systems are user-friendly and have many antennas on the receiver and transmitter. The main advantages of the Massive MIMO system are: increased energy and spectral efficiency, reduced cost, delay in air interface, simplified multiple access layer, wireless communication robustness, simplicity of simple RF linear pre-decoder and detectors, since the number of BS antennas is simpler than UTs [30][31]. Besides these advantages, there are some difficulties. These are: Transceiver calibration need, timely provision of channel state information, Pilot contamination and rapid processing algorithms for RF chains, Radio propagation and orthogonality of responses [4][32].

In Massive MIMO (multi-input and multi-output) systems, it is important to obtain channel status information (CSI) at the base station.

In order to obtain the channel between the cell base station and the user terminals, a large portion of them is composed of pilot sequences and correspondence in the Uplink phase (UL). The transmitter transmits symbols in the form of packets, while the specific symbols are transmitted to these sequences containing predefined values. These symbols are called pilot symbols. The receiver uses the pilot sequences in each position to estimate channel status information (CSI).

One of the many challenges arising from the nature of wireless communication is the pilot pollution problem. This problem is a communication problem arising from the use of the same pilot sequence as the reference signal between the two terminals. In addition, the reuse of pilot sequences from two neighboring cells also causes pilot pollution problems. In this case, since the channel status information can be estimated, it will affect the system performance and the pilot allocation algorithms are of great importance.

There are many academic studies in this area to reduce the problem of pilot pollution. Some of these are: A time-shifted method (TSP) is carried out at different times to avoid the problem of pilot pollution, but is a disadvantage due to the interaction between data and pilot broadcasts [33], data-aided channel estimation scheme using AoA-based methods it is suggested, but partially, that the data is decoded. With this method, the complexity of the process is seen to be increased [34][35] in the proposed method of pilot pollution problem is eliminated, but a complex satellite and uplink (UL) training procedure is seen, however, for different users cannot be achieved justice, [36]. In addition, the cell edge and the center are divided into two, and using the soft re-pilot assignment (SPR) to the edge of the cell is more pollution-causing interference. However, this study requires relatively more pilot sequences [37]. SPA and pilot sequences were randomly assigned to users in the other cell and are designed to improve poor UL in the target cell, aiming at minimizing the problem of pilot contamination by proposing different methods and algorithms in the channel estimation phase in academic studies. It is also examined in the pilot and channel estimation stage of security issues in communication issues by taking the unwanted user into the channel and not being involved in communication [37].

In cellular communication systems known as 5G (Fifth generation) where the letter "G" means "generation", higher radio frequencies are used compared to other generations. User demands are increasing each year compared to the previous year and this increase necessitates improvement in communication systems. In addition to the advantages that can be provided with fifth generation cellular communication systems, studies are still ongoing to solve the disadvantages it may bring along. Compared to fourth generation communication systems, this band has been increased to 6 GHz in fifth generation communication systems. The primary reason for using high frequencies is that they can move data faster. There are many promised advantages with 5G, the most important of which is high speed data transmission. The disadvantage of using high frequency signals is that they can reach shorter distances than low frequency signals. For this reason, it is expected that multi-input multi-output (MIMO) antennas will be used in places where 5G service is provided. Although certain standards cannot be established about the architecture of 5G technology, studies are still ongoing. In order to set certain standards, projects such as METIS [38], 5GNOW [39], EARTH [40], MOTO [41] have been started. With the use of 5G technology, some areas that research will focus on are given in [42]. The advantages provided with 5G technology as well as the disadvantages that may occur are explained below. Fifth generation cellular networks architecture can be seen in Figure 2.11. Technologies that can be included in this architecture are shown.

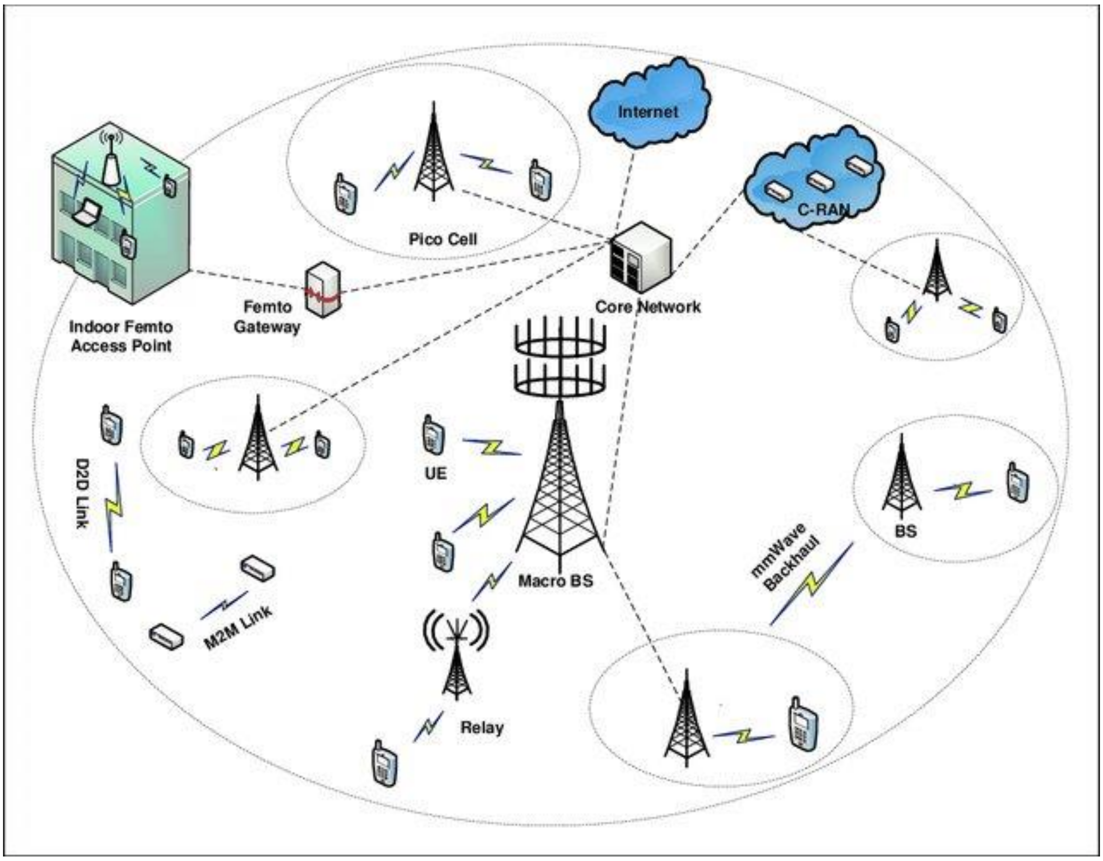

Figure 2.11. 5G cellular networks architecture [43].

The most important expectation promised with 5G technology is that data can be transmitted at high speed. Here, it is mentioned that 5G technology transmits data 30 times faster than 4G technology when the user is not moving [44]. But this will change when the device is in motion. It is thought that high data rates of gigabyte can be achieved for 5G technology. In fact, 5G technology is a promising technology given the increasing number of devices, air is thought to be the environment in a wireless communication, and the increasing demands and complexity of the system.

Governments all over the world are doing important work for the efficient use of energy. Efficient use of energy will also result in cost reductions. Considering the energy consumed by base stations and system users in a wireless communication system, the importance of this issue emerges. In this case, a two-sided examination should be made here in terms of the energy consumed by the base stations and the energy consumed by the user devices. Due to path loss, multipath propagation, the signal weakens in the receiver and the signal transmission power must be increased to eliminate this weakening. System users' devices should be designed to consume less power in terms of hardware. In the study in [45]; It was emphasized that if the energy consumption of hardware components is taken into account, it is an issue that will contribute to the improvement and development of energy efficiency.

In a wireless communication, a signal can reach the receiver in many ways on the channel while being transmitted from the transmitter. This situation is called multipath propagation in the literature. One of the difficulties caused by the air in the wireless communication is that the sent signal reaches the receiver, hitting human structures or natural structures and undergoes a certain delay. These delays accumulate in the receiving antenna, causing the signal to weaken, distort and even damp. Since this situation was not a striking factor in the first generations and it was a disadvantage, it should be addressed in 5G technology with the developing technology. Considering studies such as IOT (Internet of Things), D2D (Vehicle to vehicle), serious problems that may be caused by delay are predicted. For these reasons, while the delay in 4G (fourth generation) technology is 15ms, this delay is desired to be approximately 1ms for 5G [46].

Considering the amount of energy consumed, it is obvious that there will be two ways of cost reduction. One of them is to reduce the amount of energy consumed by base stations, while the other is to reduce the amount of energy consumed by user devices. In the new generation communication systems, high transmission speeds have been mentioned for the state of the devices in a fixed position, but when the user is in motion and the distance between them is too long or considering the situations where the base station may need to increase the signal power, the increase in the user devices and the increasing demands are It is predicted to increase. Hardware changes to be made in order to reduce the battery consumption of user devices will affect the cost. It is mentioned about a system in which human power will decrease in the coming years and will be in constant communication with each other. At this point, one of the important issues to be addressed is that the cost and energy consumption are at optimum levels. The frequency bands is shown in figure 2.12.

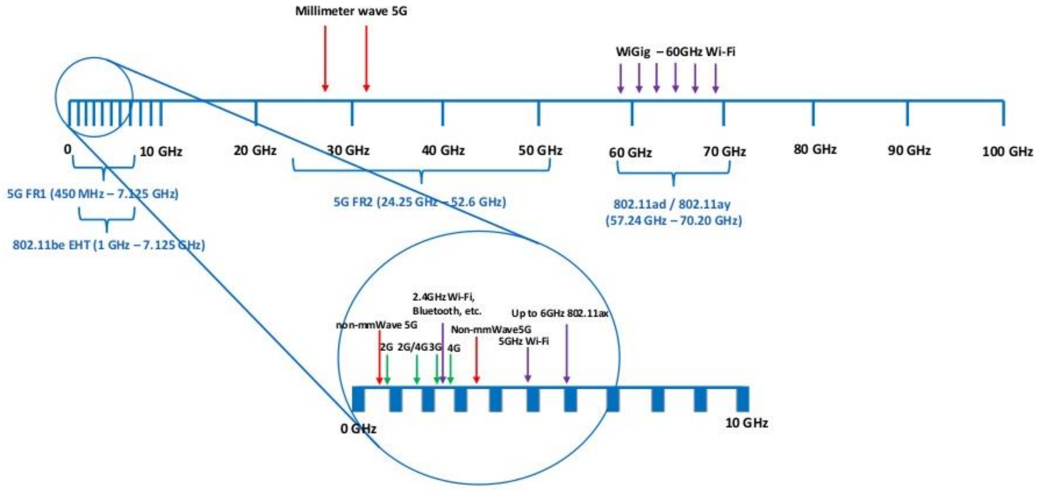

Figure 2.12. Frequency bands (https://www.slideshare.net/3G4GLtd/beginners-5g-spectrum-short-version)

It was explained that as the demand for wireless communication data volume increases, the electromagnetic spectra that can be used will never increase and the band ranges that can be processed are determined, and it may be more appropriate to make improvements in the spectrum used instead of producing new spectra [47]. As stated in the study in [42]; It is mentioned that the use of spectrum includes careful consideration of studies in new spectrum regimes, as well as providing a complete system concept considering the scenario used and the broad spectrum working band for the new spectrum regime. Frequency band allocation can be seen as indicated in Figure 2.12. Since frequency bands will not be sufficient for 5G technology [48], some solution suggestions have been made in studies on this subject. Spectrum sharing is mentioned in [49]. In the study conducted in [49], spectrum efficiency has been tried to be increased with hybrid techniques.

2.6.3. Disadvantages of Fifth Generation Cellular Communication Systems

It should not be forgotten that there are some disadvantages as well as some advantages to be achieved with 5G technology. It is thought that the most important point here will be the radiation emission. Smart houses, driverless cars, smart cities that will come into our lives with 5G technology, such as IoT [50], D2D [51], will be connected to each other and all of these will be controlled by the users. In other words, since the devices will be open to continuous signal interaction, it is mentioned that the radiation risk will increase with the increase of electromagnetic fields. A second risk is that it threatens cyber security. In the World Economic Forum 2018 Global Risk Report, cyber security has been declared as one of the biggest risks. If there are not enough precautions regarding security, it will bring negative and unwanted consequences such as remote exposure of medical devices and ease of access to personal information. Considering that the environment used for wireless communication is air and that 5G technology has multiple sub-architectures, it is thought that the rate of signal interference will also increase. At this point, solutions should be produced for these problems and studies in this area should be increased.

Every evolution or development in mobile communication technology is always driven by the need and demand for communication systems with higher data rate, better coverage and Quality of Service (QoS). Since the beginning of mobile communications in the late 1970s, it has moved from being a technology that provides only analog voice call services to digital technology that supports high-quality broadband systems that provide complex services and applications to subscribers at a data rate of several megabits per subscriber [52]. Significant improvements have been made in the architectures and methods used in each generation, and progress has been made in many ways in communication systems. With the introduction of smart communication devices with very high capabilities and many functionalities, great developments have also been made in mobile communication systems, as can be seen in Figure 2.1. Therefore, telecommunications companies need next generation communication systems to meet these demands. Thus, studies on the development of Fifth Generation (5 Generation, 5G) wireless communication networks have begun.

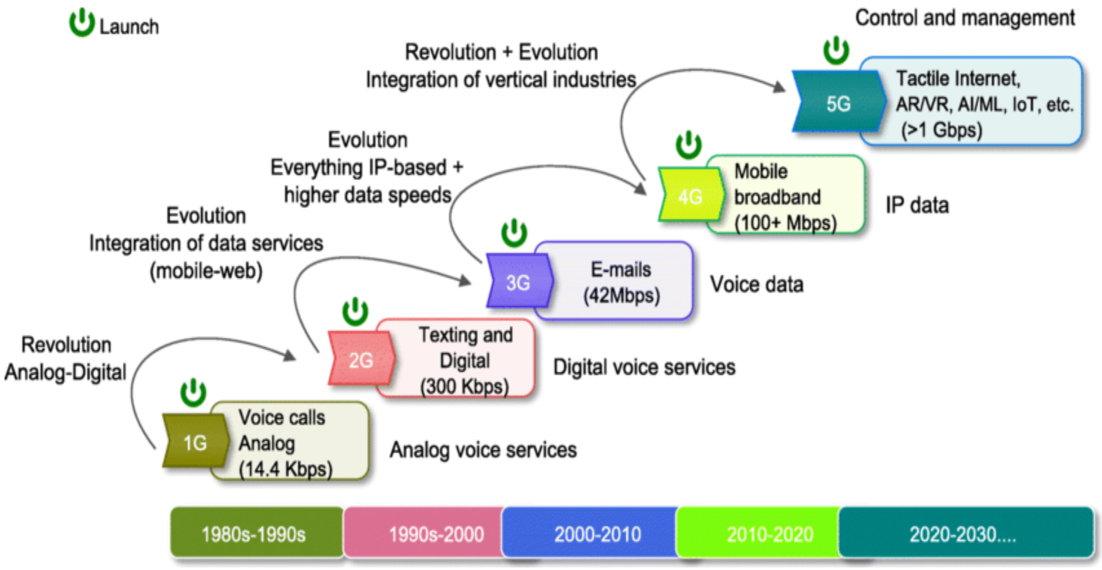

Figure 2.13. Development of mobile communication technology [53].

2.7. FIFTH GENERATION MOBILE COMMUNICATION SYSTEMS

It is widely accepted that the capacity of 5G wireless communication systems should be 1000 times larger than the Fourth Generation (4G) Long Term Evolution (LTE) / LTE-Advanced (Long Term Evolution Advanced, LTE-A) wireless communication system. has seen [54]. In addition, 1 ~ 10 Gbps user data rate in 5G mobile communication system, 10 to 100 times more number of connected devices, 1 ms round-trip delay, almost 100% coverage for anytime and anywhere connection, almost 100% in energy usage A reduction of 90 percent and high battery life are targeted [55]. With the increase in the number of users in 5G mobile communication systems, the usage areas are also enriched. As seen in Figure 2.2, 5G will be used in different areas of life.

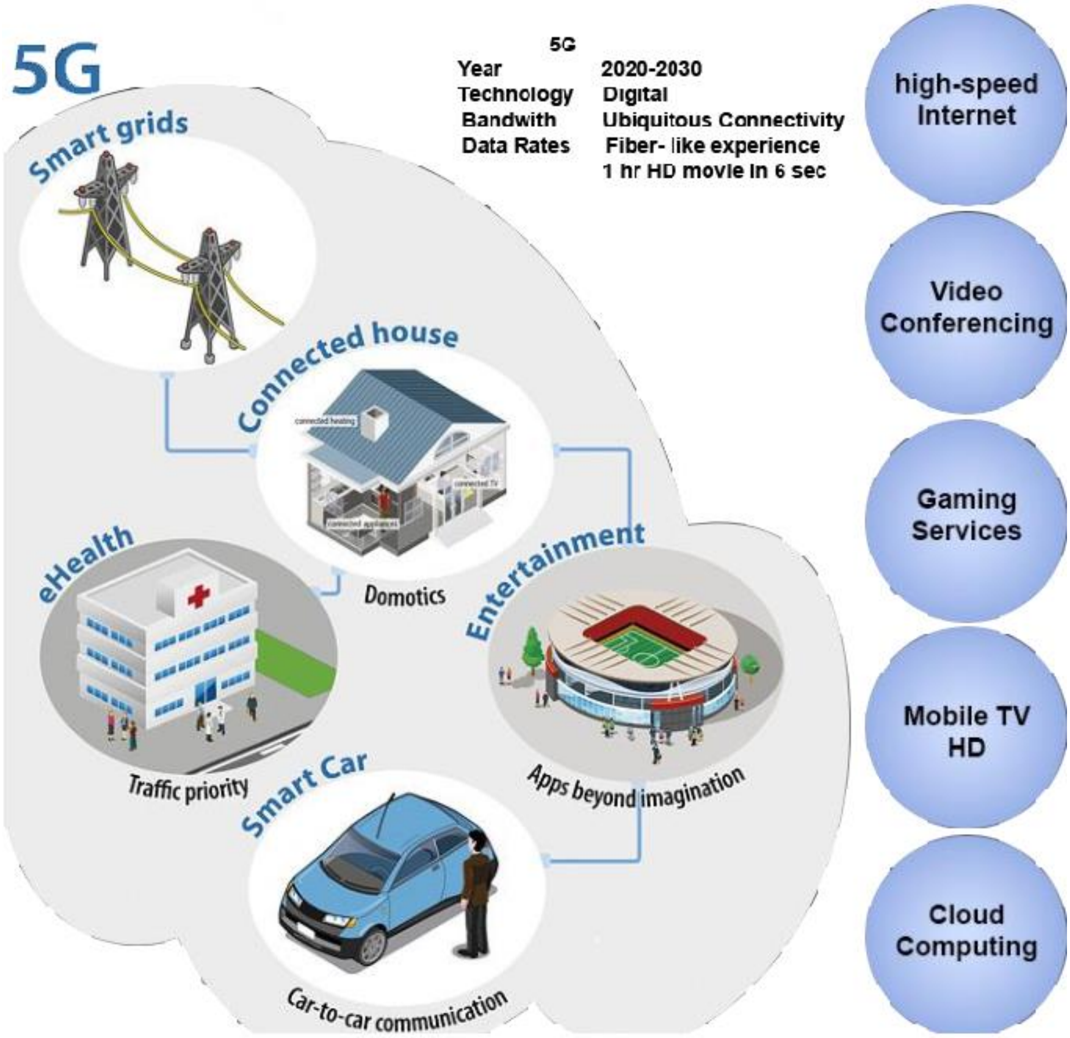

Figure 2.14. 5G usage areas [56].

2.7.1. Advantages of Fifth Generation Communication Systems

Due to the increase of a large number of wireless devices will result in higher amount of data receiving and sending (for example, videos, audio, social media data, gaming, real-time signals, photos, fast data and multimedia). Therefore, one of the priority issues of 5G technology is data speed. For this reason, it is aimed to reach 30 times more data rate than 4G technology [57]. Energy efficiency is an important design consideration when developing 5G. Today, Information and Communication Technologies (ICT) consumes 5% of the electricity produced worldwide [6]. Therefore, if energy consumption is reduced, the cost arising from consumption will be reduced. Energy efficiency is viewed from two perspectives: the network infrastructure and the energy efficiency of the terminal [58]. Higher energy efficiency of the network and terminal means lower operating costs and longer battery life respectively. It can improve link efficiency by reducing energy consumption in the radio link. Thus, both the network and the terminal save energy consumption at the same time [59]. Wireless communication systems cause a certain delay due to the environment in which they are located. Current 4G roundtrip delays are around 15ms. Although this delay is sufficient for most existing services, the expected Internet of Things (IoT), vehicle-to-device (Device to Device, D2D), remote surgeries and machine-to-machine (Machine to Machine, M2M) as shown in Figure 2.3.) poses a problem for applications such as As a result, 5G needs to be able to support a round trip delay of around 1 ms, which is faster than 4G [60]. Spectrum efficiency is vital to bring ultra-fast data speeds to more smartphones and tablets than ever before in 5G. However, due to limited bandwidths, improvements on spectrum efficiency are required.

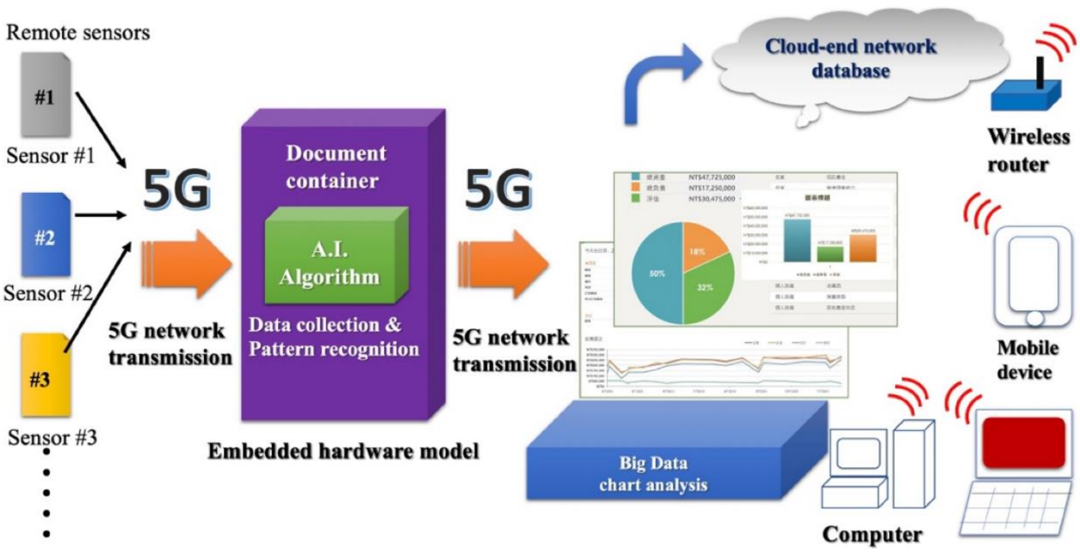

Figure 2.15. M2M application in 5G technology [61].

2.7.2. Disadvantages of Fifth Generation Cellular Communication Systems

It should not be forgotten that 5G systems have advantages as well as disadvantages. The most important problem is thought to be radiation. In the face of this problem, some countries have announced that they have stopped working on 5G technology [62]. With 5G technology, some security problems arise. Smart homes, driverless cars and smart cities that will come into our lives allow use by others. Researchers are working to solve these problems.

2.7.3. 5G International Research Activities

5G technology has recently attracted great attention by researchers. Most of the research activities in Europe are carried out mainly within the scope of the European Union 7th Framework Program (FP7) Future Networks and Cluster Radio Access and Spectrum projects. The largest and foremost FP7 5G project is the METIS (Mobile and wireless communications Enablers for the Twenty-twenty Information Society) project, which consists of 29 partners, including top telecommunications companies and academic institutions [63]. METIS has identified some scenarios to illustrate and address the potential challenges 5G will face. The first of these scenarios is to try to provide high data rates with very little latency. The second is to provide excellent service in crowded areas such as stadiums, concert venues and airports where there is a high density of people. The third is to provide high service opportunities to users on the move with their vehicles. The fourth scenario includes the necessary studies for reliability and latency. The last scenario is to make studies for a large number of devices to communicate with each other [9]. As one of the 5G research studies, the 5GNOW (5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling) project proposes a scalable and efficient air interface, abandoning the strict orthogonality and synchronization principles followed in older generation networks [9]. With the 5GNOW project, it will be able to increase the number of devices connected to the networks 100 times. It will also realize that the response time of networks is reduced by 50 times. With this project, the communication delays between machines are reduced to less than 1 ms. Thus, traffic congestion caused by IoT, smart cities, M2M, smart homes and wireless sensors will not be experienced [64]. The Clear5G (Reliable 5G MTC- Wireless Access) project is an international 5G project that Türk Telekom and Argela work together. The project aims to reduce data transmission delays in factories to less than 1 ms. For the factories of the future, studies are also carried out to enable all machines to communicate with each other, data-based smart systems, to manage the network infrastructure and to increase the battery life of the materials used in the factories.

Thus, with the Clear5G project, Industry 4.0 aims to create the infrastructure that will support the use in factories [65]. Many joint or independent studies are being carried out for the 5G technology, which is planned to be implemented in 2020. Vodafone, which wants to be at the forefront of 5G technology, has established a 5G laboratory together with the Technical University of Dresden in Germany. Within the scope of the project, which was also found by Turkish engineers, studies such as data rate increase, latency reduction and IP services are carried out in 5G technology [66].

2.8. MASSIVE MIMO SYSTEM

A Large-Scale MLC (Multi-Input Multi-Output) system is a type of Multi-User MLC systems in which the Base station (BS) antennas and the number of users are large. Large Scale LCW has emerged as a promising technology that uses multiple antennas to meet the increasing data and capacity demands in next generation wireless communication networks. Recently, Large Scale LCW technology has attracted the attention of many researchers because of its potential to greatly improve the spectral efficiency, energy efficiency, and robustness of the system. In a Large-Scale LCW system, both the transmitter and receiver are equipped with multiple antenna elements.

2.8.1. Transmission Schemes in the Large-Scale LCW System Model

Two types of transmission schemes are mentioned to find the channel state information in the Large-Scale LCW system model.

Time Division Doubling

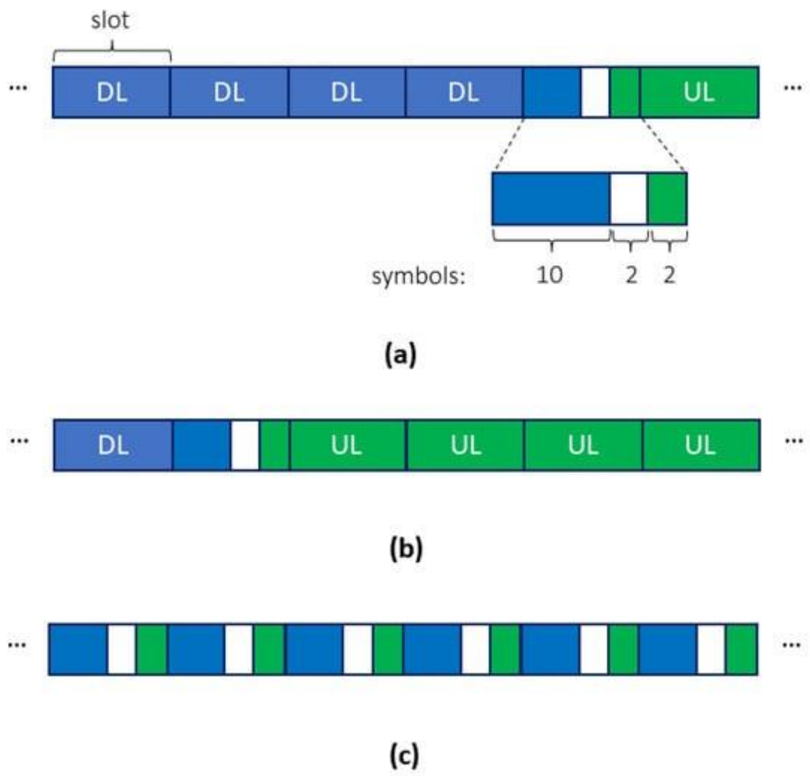

Figure 2.16. TDD transmission scheme , (**a**) for heavy DL traffic, (**b**) for heavy UL traffic, (**c**) for mixed traffic [67].

As seen in Figure 2.4, in the Time Division Duplex (TDD) system, data is transferred between the base station and the user (User Terminal, UT) in the same frequency band and at different times. In the TDD system, data transfer is carried out in two phases. These are the uplink (Uplink, UL) and downlink (Downlink, DL) phases. Two-phase data transfers are carried out at different times and in the same frequency band. Thus, the TDD system sends the data in half the period of the FDD (Frequency division coupling) system. In addition, there is no need for a multiplexer in this site. It should be noted that the use of TDD communication scheme has its advantages as well as its limitations. One of these limitations is pilot pollution [68]. Orthogonal pilot arrays are assigned to each user in the Large-Scale LCW system to allow channel estimation. However, the number of orthogonal pilot arrays is limited due to channel coherence spacing and bandwidth. Therefore, pilot arrays need to be reused between cells. Users assigned the same pilot sequences interfere with each other. This interference is called pilot pollution. It is one of the most important problems of TDD communication scheme. TDD transmission scheme mainly depends on channel reciprocity. In an ideal situation, users send their pilot sequences to the base stations and the uplink channel matrix estimation is made with the received pilot sequences from the base stations. The transpose of the uplink matrix estimated by the base stations is received and sent back to the users. Consequently, this scenario has to be performed within the channel coherence time [69]. Otherwise, problems occur in TDD transmission.

Frequency Division Doubling Diagram

As seen in Figure 2.5, in Frequency Division Duplex (FDD) system, uplink and downlink data signals are transmitted between BS and UT in the same time slot but in different frequency bands. Both connections do not interfere with each other when sending data signals. This system requires a multiplexer. The use of the FDD transmission scheme has some disadvantages. One of them is the pilot load during channel estimation. In the FDD system, both uplink and downlink channel matrices are made separately [70]. This increases the pilot load. Another problem with FDD is channel feedback. The channel estimation of the Large-Scale LCWC system using the FDD communication scheme is transmitted to the BS by the users. However, due to the large number of channel coefficients, the amount of information passing through the channel feedback can easily occupy a large part of the available bandwidth. This problem also affects precoder design in BS.

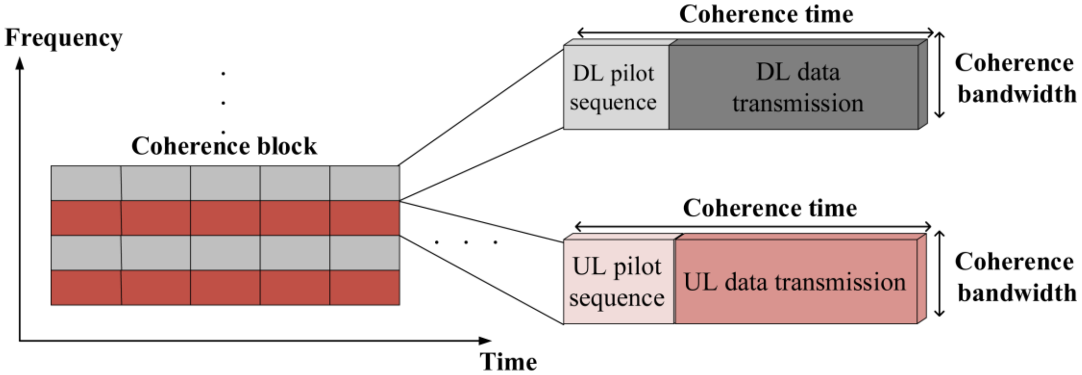

Figure 2.17. FDD transmission scheme [71].

Comparison of TDD Chart and FDD Chart

When these two schemes are evaluated in Large-Scale LCW systems, the TDD scheme is a more useful scheme in terms of estimating the best channel state information compared to the FDD scheme. It will be possible to talk about the advantages and disadvantages of both schemes. The difference between the channel state information obtained for the uplink and the channel state information obtained for the downlink will increase the processing load for Large Scale LCW systems. Feedback is needed for the downlink. However, this feedback load has difficulties in practice due to resource limitations. Preferring the TDD scheme is more advantageous as it will reduce the feedback load.

PART 3

MATERIAL AND METHODS

3.1. METAHEURISTIC METHODS

As previously mentioned, metaheuristic algorithms are a set of pseudo-random methods based on the behavior of living organisms or natural physical phenomena. Metaheuristic algorithms are able to mimic the behavior of organisms or non-living physical phenomena for mathematical modeling. Each solution or factor in a metaheuristic algorithm is encoded by a natural factor and is moved toward an optimal solution via mathematical modeling. Metaheuristic algorithms have been classified based on their utilized approach to different categories in the literature. Mirjalali and Lewis (2016) classified metaheuristic algorithms into four categories of evolutionary, swarm-based, physical-based and human-based algorithms. The mathematical modeling of these algorithms is briefly discussed below [72]:

- Evolutionary algorithms: The principle of competence and survival is used in this type of metaheuristic algorithm. It is assumed that a more competent solution has a higher probability of survival and is able to produce similar solutions. The genetic algorithm is a good example of an evolutionary algorithm.
- Physical-based algorithms: In this type of algorithm, a physical factor is modeled based on physical laws to find optimal solutions for difficult and complex problems. Water wave optimization (WWO) is an example of a physical-based algorithm [73].
- Swarm-based algorithms: This type of metaheuristic algorithm mimics the behavior of organisms through a collective approach. A type of social behavior is observed among these organisms. The sailfish optimizer algorithm (SOA) is an example of a swarm-based algorithm introduced in 2019 [74].

- Human-based algorithms: The political, cultural or social behavior of humans is used in this type of algorithm to solve optimization problems. Teaching-learning-based optimization algorithms is fall into this category [75].

In addition to the above approach, other classification approaches have also been proposed for metaheuristic algorithms. For instance, Diman and Kumar (2017) classified metaheuristic algorithms into five categories, as shown in Figure 3.1. They classified metaheuristic algorithms into evolutionary, swarm-based, physics-based, bio-inspired and nature-inspired algorithms. The bio-inspired algorithms were placed in a new category. This type of algorithm includes those with non-intelligence swarm behavior making use of cells or microscopic organisms lacking high intelligence.

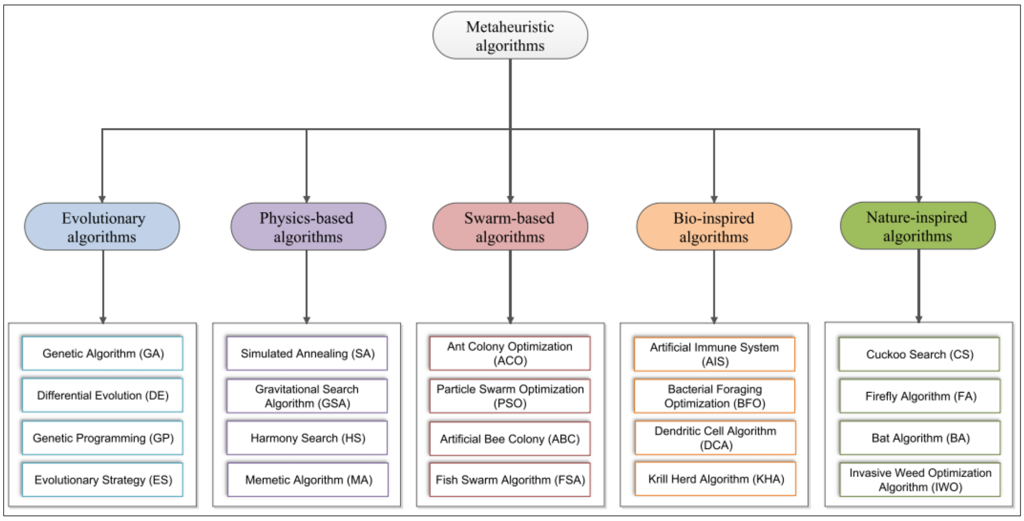

Figure 3.1. Classification of metaheuristic algorithms into five categories [76].

Nature-inspired metaheuristic algorithms model smart organisms that rarely use their intelligence in their swarm behavior and have a few or weak social interactions between each other. However, swarm-based algorithms rely on many social interactions between organisms and use this swarm intelligence to find solutions.

3.2. BUTTERFLY OPTIMIZATION ALGORITHM

Butterflies are insects capable of communicating through chemicals called pheromones. As shown in Figure 3.2, butterflies release pheromones into the air for various purposes such as finding food or to attract other butterflies. Butterflies usually move toward a pheromone source with the highest concentration. The Butterfly Optimization Algorithm (BOA) is a swarm-based metaheuristic algorithm taking inspiration from the behavior of butterflies in releasing pheromones and its absorption by other butterflies. In this algorithm, each butterfly is a solution capable of releasing pheromones into the air according to its competence [77].

Figure 3.2. Pheromones are released by butterflies to attract other butterflies [77].

A butterfly in the butterfly optimization algorithm is able to make two types of movements. First, it moves toward the source with the maximum pheromone concentration in the problem domain released by the most competent butterfly with a random probability. In fact, this leads to a local search around the optimal solution. A butterfly in the population then randomly selects two other butterflies, becoming attracted to their released pheromones. A global search, in fact, occurs in this case. Evaluations of the butterfly optimization algorithm indicate its higher accuracy and lower error rate in finding the optimal solution compared to genetic, swarm optimization, differential evolutionary, firefly, cuckoo search and artificial bee colony algorithms.

3.3. PROPOSED METHOD

Massive multi-input-multi-output (MIMO) systems are among the most important applied technologies to meet the demands of users in a 5G network. In a MIMO system, a communication device equipped with an antenna, which is used for the provision of services, contains one or multiple systems with multiple inputs and outputs. This base station is equipped with an array antenna the number which amounts to over 100 in some cases. In contrast, a mobile station contains a small number of antennas for communications. The main advantages of massive MIMO systems over other communication methods such as non-massive MIMO systems are as follows:

- Improved communication efficiency
- Improved communication productivity and reduced energy consumption
- High reliability in continuous communications
- Less interference in communications between users

In a particular type of MIMO system known as multi-user MIMO in the communications and telecommunications literature, a large number of mobile stations can be connected to a base station. In this system, the pilot channel considered for information and signal transfer between transmitter and receiver should be correctly modeled to improve their performance. The impulse and frequency responses in the transmission channel are among the most important specifications of these systems. The multi-path effects experienced by any given node while communicating with the base station can be modeled using random values in wireless telecommunication systems. In general, for signal detection at the receiver of massive MIMO systems in 5G networks, the specification of the channel between the users and all receivers in the base station should be completely specified. Communications in 5G networks should offer two important features:

- Increased network connectivity for users
- An increased data transfer rate

Multi-input-multi-output (MIMO) systems have been taken into consideration in this technology. To this end, each base station contains several antennas that are provided to the users, allowing them to connect to the optimal connection line. This in turn leads to a lower energy consumption in the base stations, reduced intercellular interference and noise, and improved strength. Despite the many advantages of 5G communication networks, they suffer from pilot contamination, which reduces their performance. Figure 3.3 shows pilot contamination in a 5G cellular communication network.

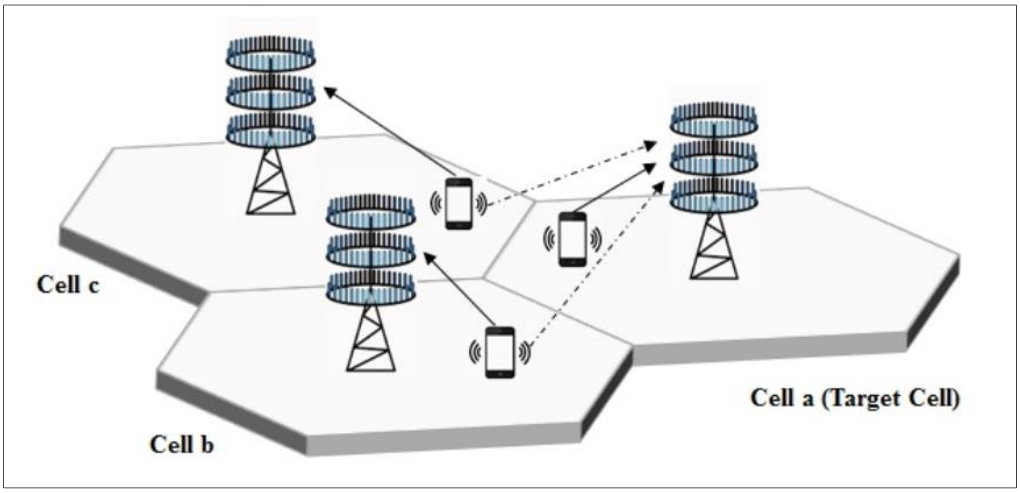

Figure 3.3. Pilot contamination in a 5G network [78].

This problem occurs due to the reuse of the same set of test sequences (i.e., training sequences) by users of different cells. Wireless communications between users and their BSs occur in certain frames known as coherence intervals. In smooth fading mode, the specification of the channel between any user and the base station can be expressed by a random vector resulting from small-scale fading multiplied by a random coefficient induced by large-scale fading. The dimensions of this channel vector equal the number of antennas in the base station in this communication network. Channel estimation (CE) aims to find the channel vector. Channel estimation in massive MIMO systems differs from those in non-massive MIMO systems because of the larger number of base station antennas in the former, which leads to pilot contamination of the training data. Channel estimation is performed in both the uplink and downlink directions; however, the process is easier in the uplink direction given the large number of antennas in this direction. In contrast, there is a connection challenge in the downlink direction which includes a lower number of antennas. The time division duplex (TDD) technique can be used to solve this problem. To this end, in addition to channel estimation in the uplink direction, the channel should also be estimated in the downlink direction for signal detection in the user receiver. The training data is used in some methods for CE in the downlink direction of massive MIMO systems. Considerable effort has been made to solve this challenging problem. Therefore, channel estimation and pilot contamination in massive MIMO system have been evaluated. A simple practical channel estimator and data-assisted MMSE evaluation have been proposed, with both showing desirable performance without any previous knowledge. However, pilot reuse has not been considered in any of them because CE requires training resources while such resources are limited and should be used in multi-cellular scenarios. Various methods have been proposed to eliminate pilot contamination, one of which is the coloring graph and weighted coloring graph (WGC-PD) method. This method not only reduces pilot contamination, but also reaches a high upstream. Moreover, a scheme called the soft pilot reuse scheme (SPRS) has been presented for the reuse of training data, where users are divided into *center users* and *edge users*.

Center users (probably exposed to partial pilot contamination) are able to use the same pilot contamination source while edge users (probably exposed to serious pilot contamination) apply other cellular pilot subsets in neighboring cells, which increases pilot contamination due to flexibility. A novel method is presented in this paper for pilot contamination elimination based on SPRS and WGC-PD with the help of the butterfly optimization algorithm. In the proposed scheme, SPRS is first applied to divide the users and then the cells, after which pilot contamination is emphasized. To solve this challenge among center users, WGC-PD is applied to achieve better performance in the upper band of the massive MIMO. A multi-cellular uplink MIMO system was considered in this study. It is assumed that the system contains J cells in which each cell has N antennas providing services to K users so that K is much smaller than N. The impulse response of the connection vector for the user k in cell j to the BS in cell i can be written as follows [3]:

$$h_{i,k,j} = b_{i,k,j}\sqrt{\gamma_{i,k,j}} \tag{3.1}$$

where $b_{i,j,k}$ and $\gamma_{i,j,k}$ respectively represents small-scale and large-scale fading coefficients and $h_{i,j,k}$ shows the channel response of the connection vector for user k in cell j. The objective function can be defined as follows to maximize the SINR in the 5G network cells [3]:

$$SINR = \frac{\left\|h^H_{<j,k>,j}\right\|^4}{\sum_{<j',k'>\in\Gamma<j,k>}\left\|h^H_{<j,k>,j}\right\|^4 + \frac{\sigma^2_{<j,k>}}{\delta^2}} \approx \frac{\gamma^2_{<j,k>,j}}{\sum_{<j',k'>\in\Gamma<j,k>}\gamma^2_{<j',k'>,j}} \tag{3.2}$$

This relation has been defined for a single cell and can be extended to other cells to obtain the following objective function [3]:

$$\max_{a_{k,j}}\left\{\sum_{<j,k>} \log_2(1 + SINR)\right\} \tag{3.3}$$

Combining the above equation with the previous one gives the following objective function which should be maximized [27]:

$$\max_{a_{k,j}}\left\{\sum_{<j,k>} \log_2\left(1 + \frac{\gamma^2_{<j,k>,j}}{\sum_{<j',k'>\in\Gamma<j,k>} \gamma^2_{<j',k'>,j}}\right)\right\} \tag{3.4}$$

This objective function can be maximized using metaheuristic methods. The butterfly optimization algorithm is used in this study for this purpose. To obtain the maximum point of the objective function in the proposed method, the users connected to the cellular network are divided into *center users* and *edge users*.

A threshold is used to determine the type of user. According to the following relation, if the squared large-scale fading coefficient ($\gamma_{i,j,k}$) is larger than the considered threshold (ρ_i), then the user is considered a center user, otherwise ($\gamma_{i,j,k} \geq \rho_i$), the user is considered an edge user [3]:

$$\gamma^2_{i,k,i} > \rho_i \rightarrow \begin{cases} Yes \rightarrow Center\ Users \\ No \rightarrow Edge\ Users \end{cases} \tag{3.5}$$

The following equation can be used to define the threshold for dividing the users into two categories [3]:

$$\rho_i = \frac{\theta}{K} \sum_{k=1}^{K} \gamma^2{}_{i,k,j} \tag{3.6}$$

where θ is the convergence coefficient for the users and K is the total number of users. To maximize the objective function in this problem, each solution can be considered a vector of users, each of which making use of a cell in the 5G communication network in the equation below. In fact, each butterfly or solution in the *D*-dimensional space in the proposed method can be formulated as follows:

$$B_i = \{B_i^1, B_i^2, \dots, B_i^D\} \quad (3.7)$$

where each solution or butterfly, B_i, can be randomly generated in the range of (L, U):

$$B_i = L + (U - L).rand(0,1) \quad (3.8)$$

Then a population of solutions can be considered to be a population of butterflies in the problem space searching for an optimal solution:

$$Pop = \{B_1, B_2, \dots, B_N\} \quad (3.9)$$

where *N* is in the number of the initial population and *Pop* is the initial population of solutions or butterflies dispersed in the population. The best butterfly in this maximization problem can be calculated with the proposed algorithm:

$$Pop^* = max\{SINR(B_1), SINR(B_2), \dots, SINR(B_N)\} \quad (3.10)$$

where *f* is the objective function to evaluate butterflies or initial solutions, *N* the butterfly population size, B_i a butterfly or solution, and $Pop*$ the most attractive (popular) butterfly or solution in the population. Each butterfly is capable of local searching at a probability of 50%:

$$B_i(t+1) = B_i(t) + (r^2 \times Pop^* - B_i(t)) \times f_i \quad (3.11)$$

Moreover, each butterfly is capable of global searching in the problem space with a probability of the remaining 50%:

$$B_i(t+1) = B_i(t) + (r^2 \times B_j(t) - B_k(t)) \times f_i \quad (3.12)$$

where $B_i(t+1)$ is the new position of the butterfly $B_i(t)$ and f_i the attractiveness of a butterfly when attracting other butterflies in proportion to the objective function. $B_k(t)$ and $B_j(t)$ are the current positions of two arbitrary butterflies, and r is a random number between 0 and 1. By executing the butterfly optimization algorithm in the proposed method, the user vectors can be optimized to receive services from a given cell. Moreover, the mean SINR can be maximized in the entire network and, in fact, the most optimal butterfly would be the one with the maximum SINR. Figure 3.4 shows the proposed method to maximize SINR using the butterfly optimization algorithm:

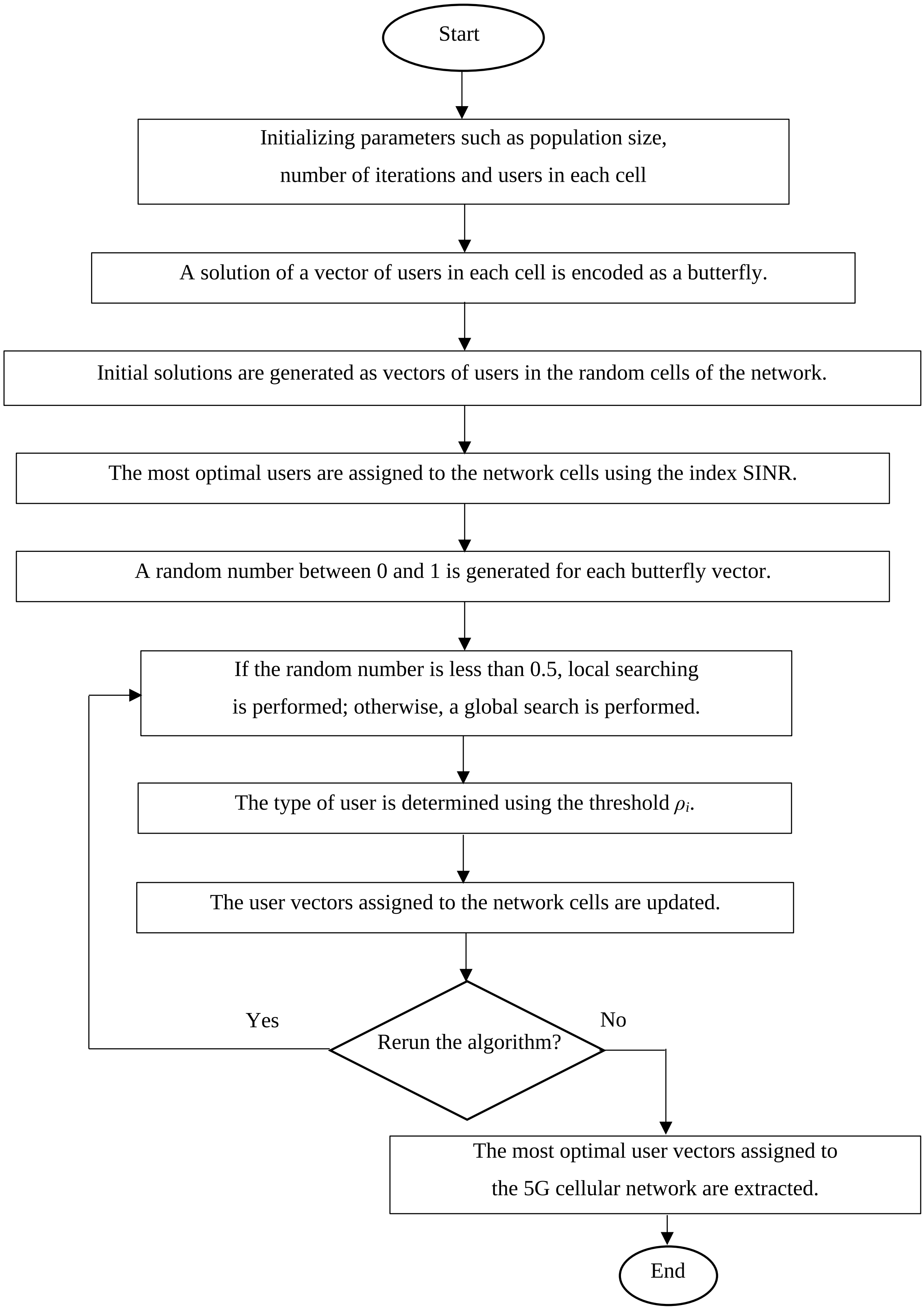

Figure 3.4. Flowchart of the proposed algorithm.

The above flowchart can be represented with more details by adding the optimal user vector to the cellular network. The Proposed flowchart to reduce pilot contamination is shown in figure 3.5.

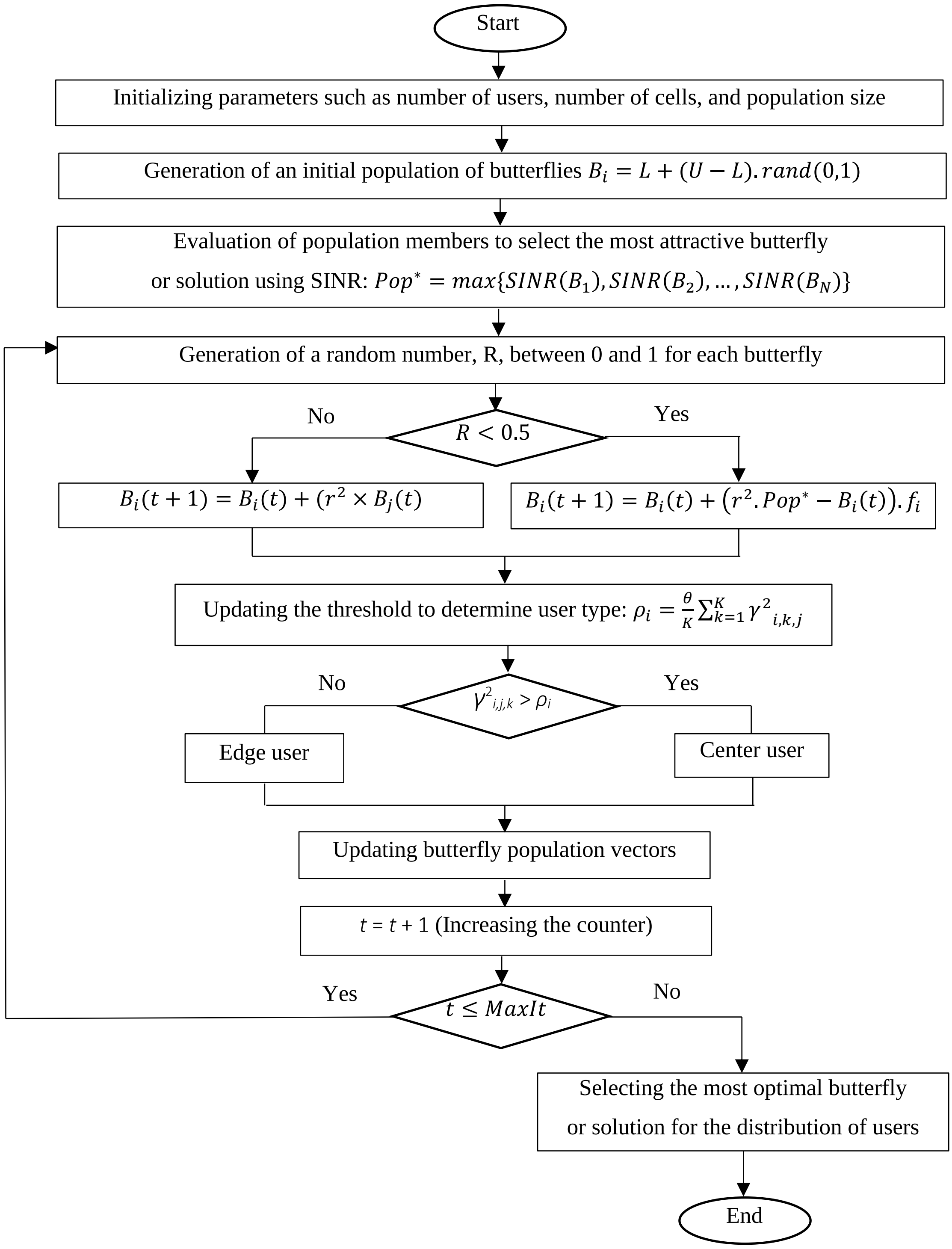

Figure 3.5. Proposed flowchart to reduce pilot contamination.

SINR: the signal-to-interference-plus-noise ratio

PART 4

EXPERIMENTAL RESULT

The proposed algorithm is implemented and analyzed with the help of MATLAB 2019 using the scenario shown in Figure 4.1 with 19 cells, each with a base station and a number of active users:

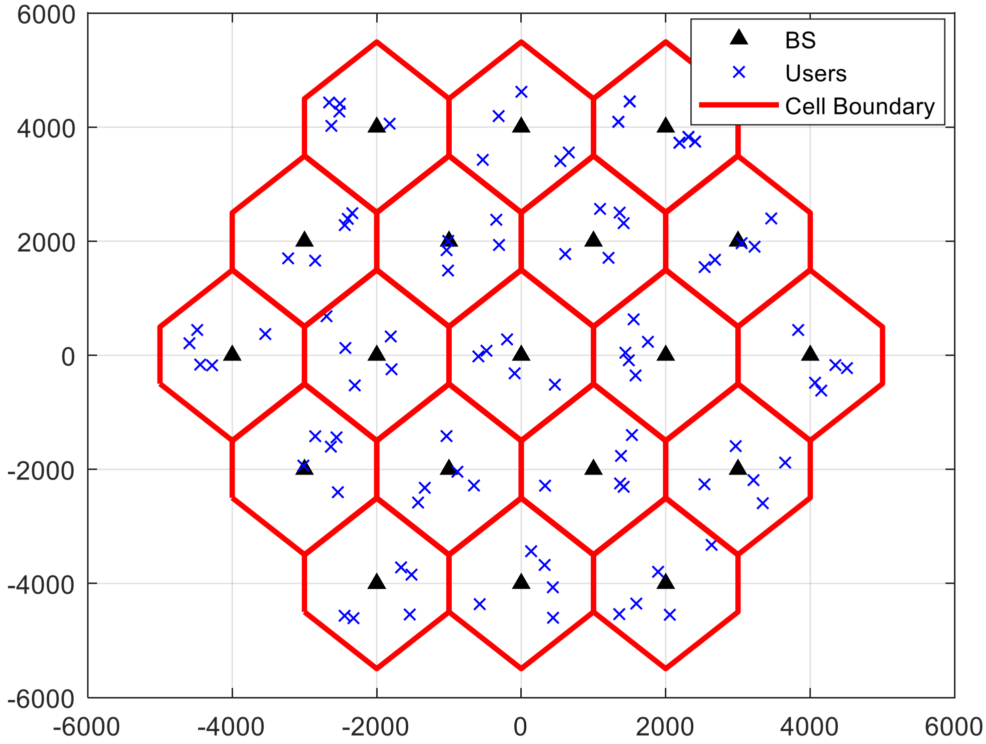

Figure 4.1. Implementation and simulation scenario.

As can be observed, each cell has been able to provide services to a number of users. The parameters used in the algorithm implementation and simulation are initialized according to Table 4.1:

Table 4.1. Parameters used in the proposed method.

Parameter	Description
nPop	Population size = 10
Maxiter	Maximum iteration number = 50
K	Number of users in each cell = 10
J	Number of cells = 19
μ	Spectral frequency coefficient = 0.5
θ	Initial threshold = 0.1
N	Number of antennas in each cell = 512

A cumulative distribution function (CDF) can be plotted as a function of the objective function (SNIR). In this case, the vertical and horizontal axes respectively show the CDF and SINR in terms of dB. Figure 4.2 compares the proposed method with the Random, SPRS, WGC-PD and SPRS+WGC-PD methods.

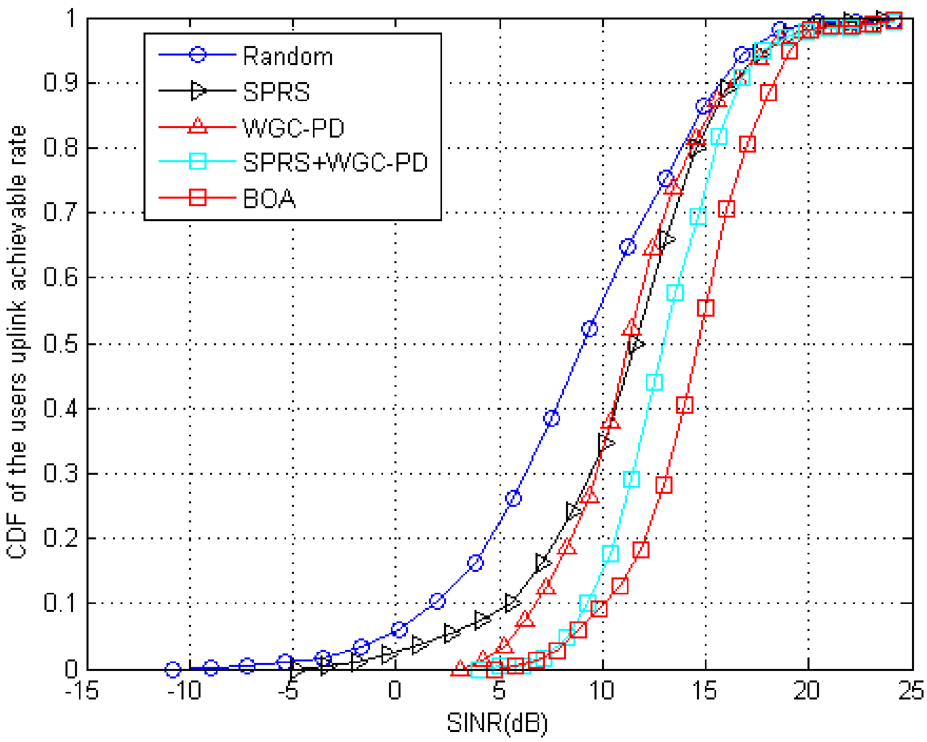

Figure 4.2. Cumulative distribution function (CDF) versus SINR in various scenarios.

As can be observed, the proposed BOA shows a higher SINR than the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms. In fact, BOA has a greater ability to connect users and maximize the objective function SINR. BOA ranks first in terms of efficiency, followed by the SPRS+WGC-PD algorithm. The SPRS and WGC-PD algorithms show a relatively similar performance, while the Random algorithm performed the least well. The proposed algorithm and the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms show almost identical performance when the CDF equals 0 or 1. When the cumulative distribution function (CDF) is greater than 0.1, the proposed method outperforms the others. Figure 4.3 compares CDF and bit transfer rate (per sec) in the proposed algorithm and the SPRS, WGC-PD and SPRS+WGC-PD algorithms. As can be clearly seen, the proposed BOA shows a higher bit transfer rate than the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms.

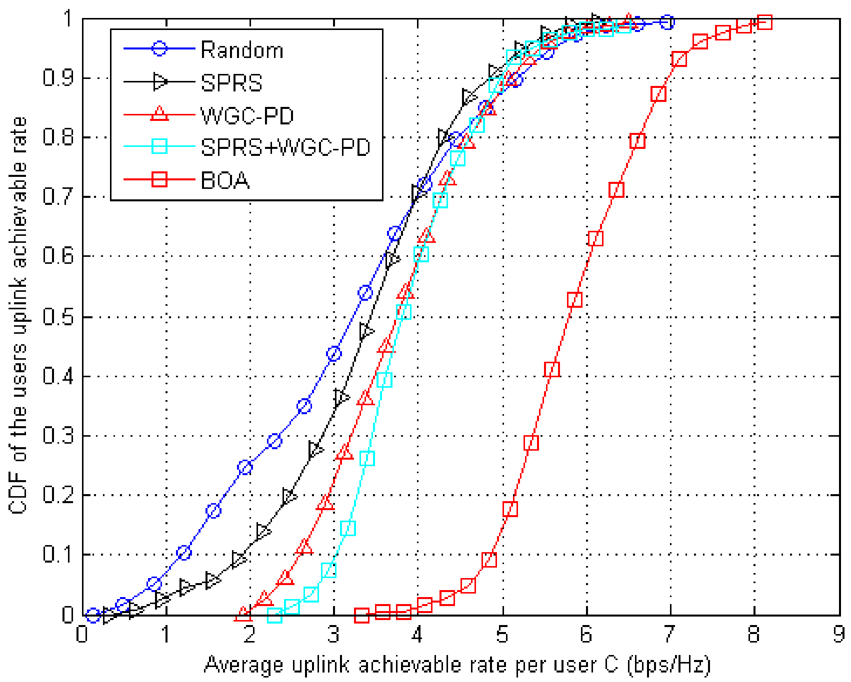

Figure 4.3. CDF versus average uplink achievable rate per user in various scenarios.

According to the above diagram, the proposed method outperforms the other methods in terms of average uplink achievable rate per user. The SPRS+WGC-PD ranks second in this regard and WGC-PD and SPRS are placed in the third and fourth places. The Random algorithm shows the worst performance in terms of average uplink achievable rate per user. The average achievable uplink rate per user (R (bps/Hz)) in terms of the number of antennas in the BS is another important index. Figure 4.4 compares the average achievable uplink rate per user (R (bps/Hz)) in terms of the number of antennas in the BS in the proposed algorithm and the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms. An increase in the number of antennas improves the average achievable uplink rate per user, causing an increase in the diagrams for the proposed algorithm as well as the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms. Despite this ascending behavior, the average achievable uplink rate per user is further increased by increasing the number of antennas in the proposed method as compared to the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms. According to the above diagram:

- As the number of antennas increases, the quality of services is improved with different methods, but what is achieved in the proposed method is higher than the other methods;
- The average achievable uplink rate per user increases more sharply in the proposed method than in the other methods when increasing the number of antennas.

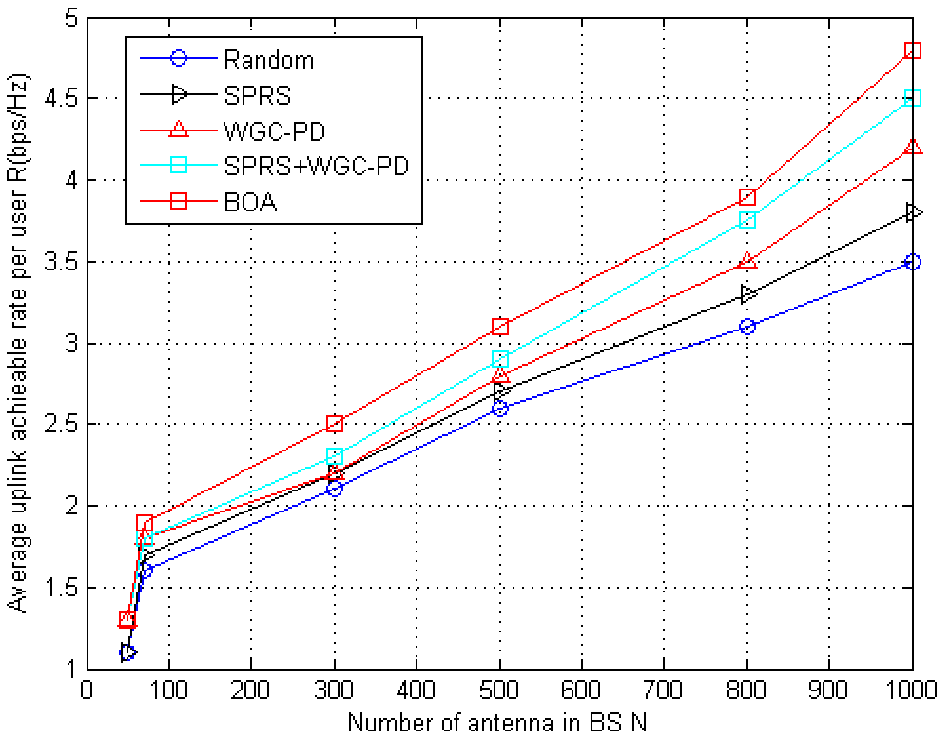

Figure 4.4. Average uplink achievable rate per user versus number of antennas in the proposed method and other methods.

In this section, the performance of WGC-PD is investigated through Monte Carlo simulations. A hexagonal cell network with L cells is considered, where each K cell has a single antenna user and one BS with M antenna. The spectral efficiency reduction with S = K is equal to μ0 = 0.05 and μS corresponds to:

- The system parameters are summarized in Table 4.1. The number of BS antennas is randomly distributed in the range of 8 to 256 user positions. As shown, the large-scale reduction coefficient, β⟨j, k⟩, i, is modeled as follows:

$$\beta\langle j,k\rangle,i = z\langle j,k\rangle,i/(r\langle j,k\rangle,i/R)\alpha,$$

Figure 4.5 shows the CDF accumulation distribution function related to users' uplift access speed so that the system parameters L = 3, S = K = 4, = 10 dBρ and M = 32 are considered. The proposed scheme is compared with existing solutions. The classic pilot allocation scheme randomly assigns pilots to users, regardless of inter-cell collaboration. The pilot scheme eliminates the temporal displacement of the pilot's immunization by using uncoordinated transitions between adjacent cells at the cost of cross-interactions. The smart pilot feature design optimizes the pilot allocation for each cell. P1 and P2 optimization answers Obtained through other research.

The comparison between random pilot allocation + matched filter and weighted graph dyed pilot allocation + matched filter is shown in figure 4.5.

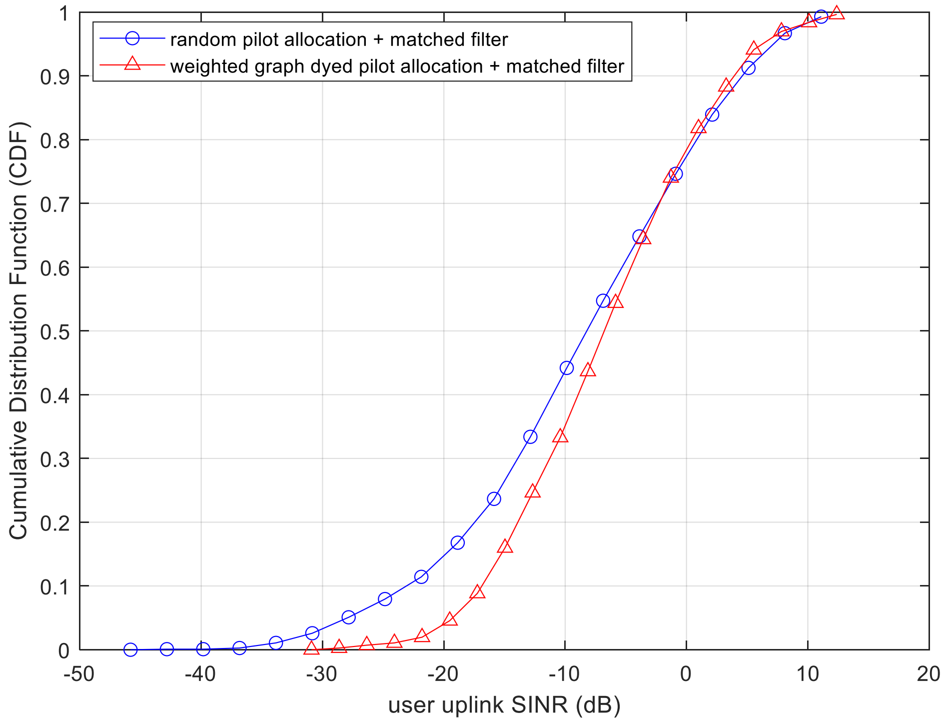

Figure 4.5. Cumulative Distribution Function (CDF) vs. user uplink SINR (dB).

The comparison between random pilot allocation + zero forcing and weighted graph coloring pilot allocation + zero forcing is shown in figure 4.6.

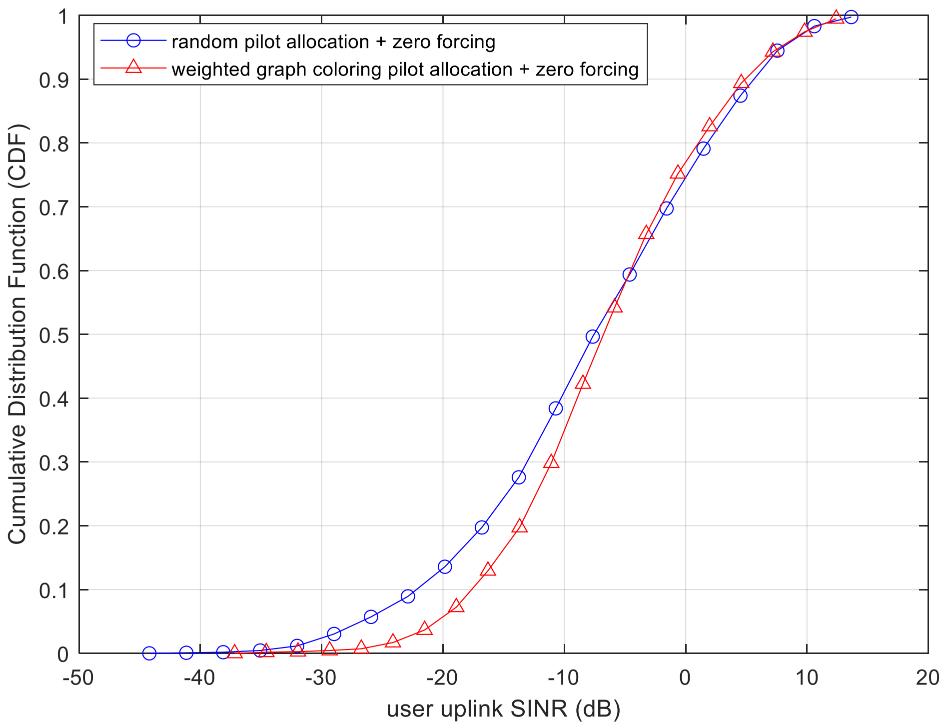

Figure 4.6. Cumulative Distribution Function (CDF) vs. user uplink SINR (dB).

The comparison between random pilot allocation + matched filter and weighted graph dyed pilot allocation + matched filter is shown in figure 4.7.

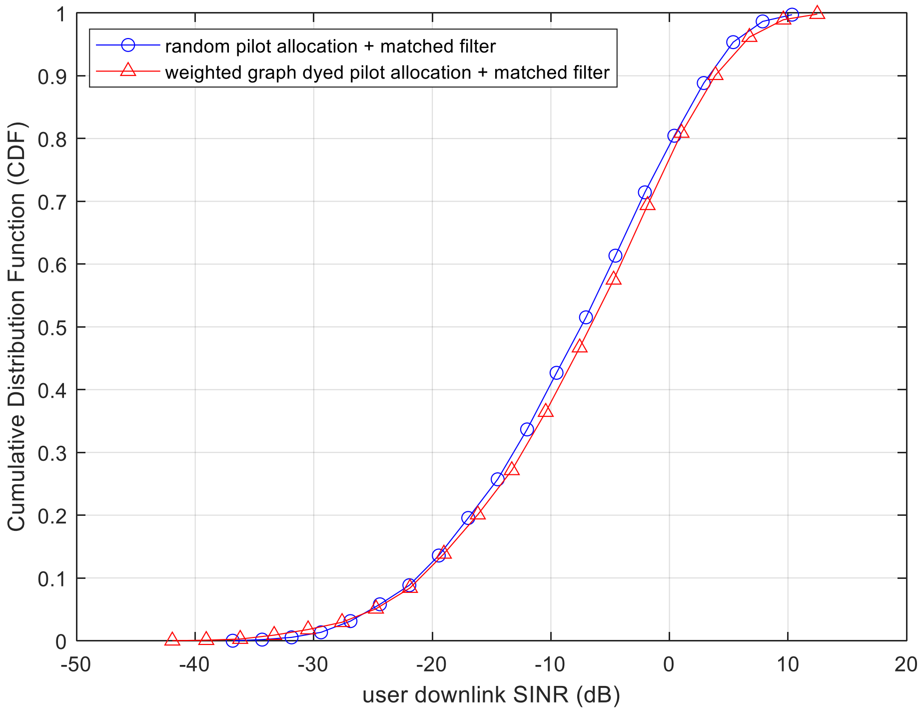

Figure 4.7. Cumulative Distribution Function (CDF) vs. user downlink SINR (dB).

The comparison between random pilot allocation + zero forcing and weighted graph coloring pilot allocation + zero forcing is shown in figure 4.8.

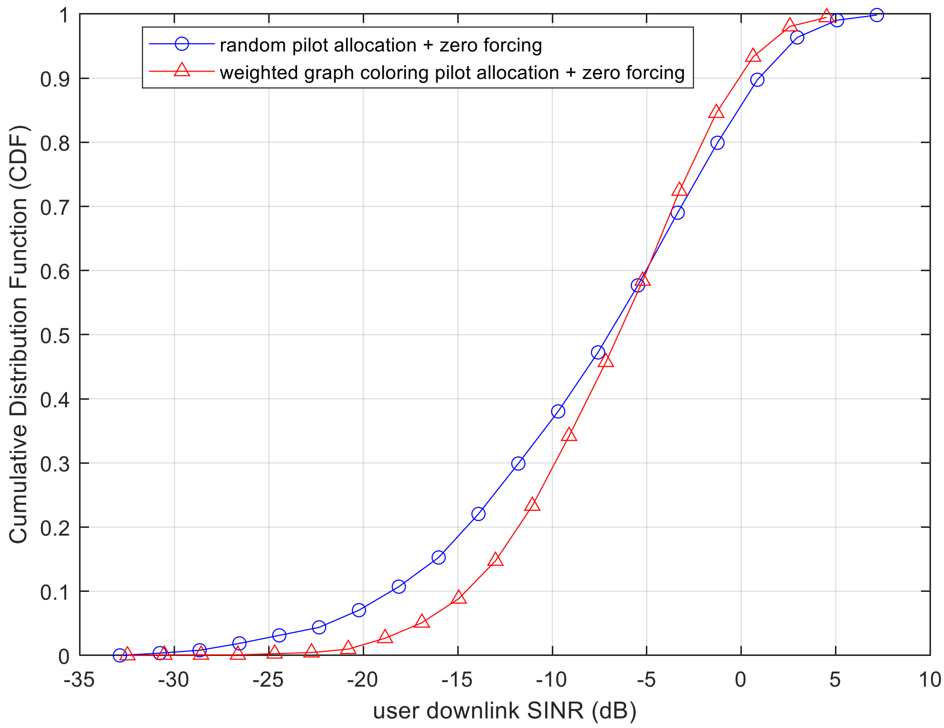

Figure 4.8. Cumulative Distribution Function (CDF) vs. user uplink SINR (dB).

Figure 4.9 shows the average speed of each user's application, which is in contrast to the number of pilot S sources. While the system parameters are L = 7, K = 16 and = 10 dBρ M = 128. For a temporal displacement pilot design, more pilots, or S> K, do not perform any better because neighboring cells normally transmit Uplink pilots incomprehensibly. We use the constant S = K = 16, which is used in another displacement scheme.

Considering the source S / K≤4 pilot source, it is again available that the proposed design is normally visible if it is better to move from the design.

The comparison between random pilot allocation + matched filter and weighted graph dyed pilot allocation + matched filter and random pilot allocation + zero forcing and weighted graph coloring pilot allocation + zero forcing is shown in figure 4.9.

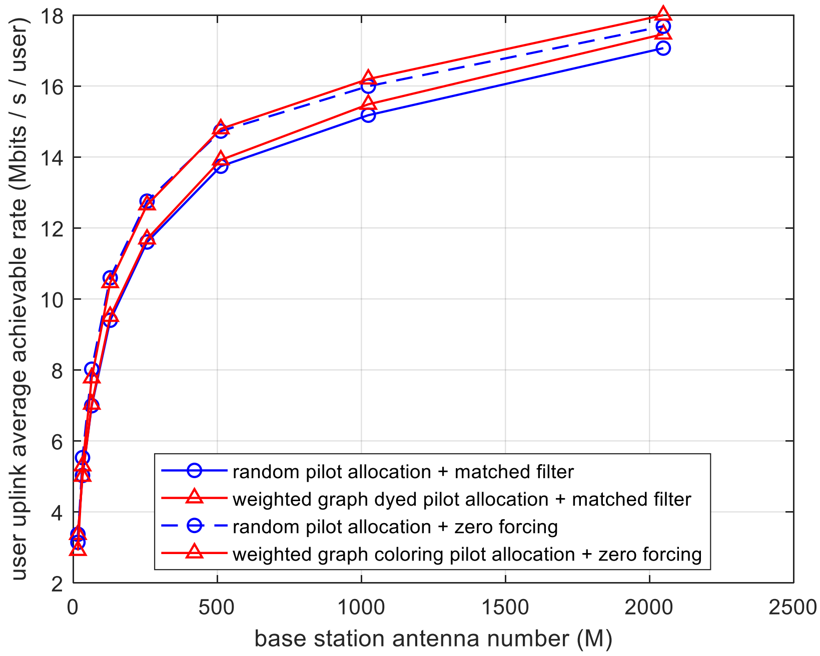

Figure 4.9. User uplink average achievable rate (Mbits / s / user).

The comparison between random pilot allocation + matched filter and weighted graph dyed pilot allocation + matched filter and random pilot allocation + zero forcing and weighted graph coloring pilot allocation + zero forcing is shown in figure 4.10.

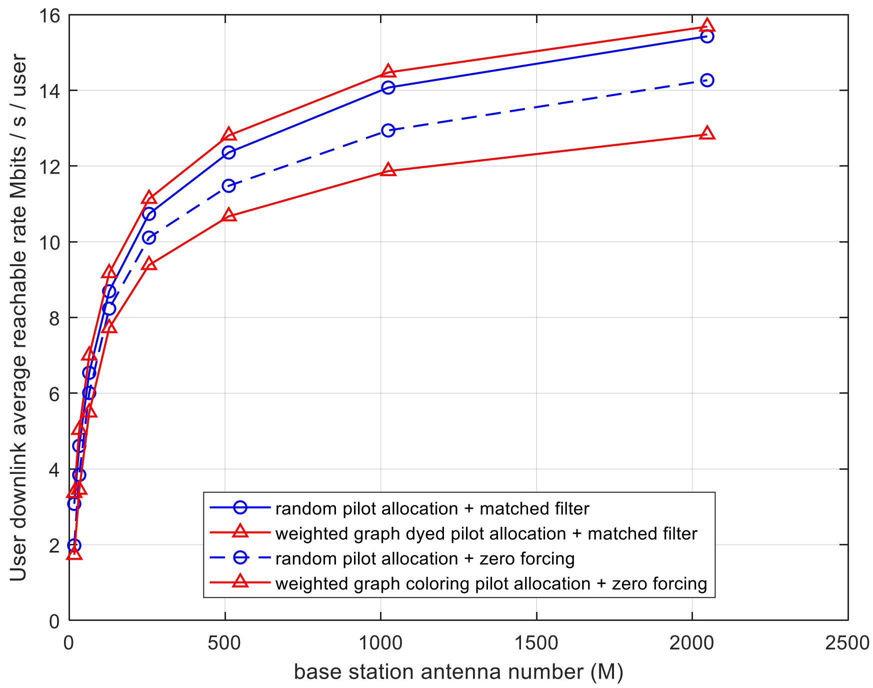

Figure 4.10. User downlink average reachable rate Mbits / s / user.

PART 5

CONCLUSION

MIMO has been explored to increase the visibility of mobile traffic on 5G wireless systems in the future, while a BS equipped with a large number of antennas will serve multiple users simultaneously. The number of BS antennas is infinite while the number of users is kept constant, thus significantly reducing intracellular interference and uncoordinated sounds. In addition, bulky MIMO systems are very useful in identifying and estimating problems related to sensor networks.

Although PCs are created due to the reuse of pilots in adjacent systems as a result of limited pilot resources, they do not go away as the number of BS antennas increases, so the PC as a limiting factor for bulky MIMO systems. A known cell. Many efforts have been made to solve the challenging PC problem. The pilot scheme of temporal displacement is an effective solution, which works through asynchronous transfer between adjacent cells, but this process leads to interference between the data and the pilot.

Fifth-generation (5G) mobile telecommunication is a new communication technology forming the next generation of communication services. Various technologies such as the Internet of Things (IoT) and novel computing models such as fog computing have been considered for 5G telecommunications. The main advantages of this generation of communication over its fourth generation counterpart include increased speed and higher rates of connection of users to the communication network. A number of mechanisms has been considered for this communication technology to increase the number of users connected to the network as well as to implement concepts such as IoT and offer diverse services to network users.

MIMO systems, which use a large number of base station antennas to serve multiple users simultaneously, undergo experimental immunizations due to the reuse of pilots in adjacent cells. This thesis presents a optimization scheme based on experimental immunization to reduce PC for bulky, multicellular MIMO systems. Specifically, based on the limited cooperation between cells, a heavy-edge intervention graph is first constructed to show the potential PC connection between users, so that when two users in different cells are connected by such a graph. This indicates the potential power of the PC if using the same pilot.

When a user makes use of services in multiple cells simultaneously, the resulting pilot contamination may cause system imbalance, which is considered a great challenge in such networks. Accordingly, to deal with this challenge, the optimization problem was solved using the butterfly optimization algorithm (BOA). According to simulation results in MATLAB, the BOA caused a further increase in the SINR compared to the Random, SPRS, WGC-PD and SPRS+WGC-PD algorithms. The proposed algorithm also outperformed the other methods in terms of average uplink achievable rate per user. BOA also further increased the average uplink achievable rate per user by increasing the number of antennas. In future studies, a novel metaheuristic algorithm will be provided based on the intelligent behavior of living organisms to improve the connection of users to the 5G communication network.

In the multicellular Massive MIMO system, the pilot pollution problem can limit system performance. In this study, we proposed a method for generating large scale fading coefficients between users and base stations and a pilot sequence scheme to maximize accessible pollution rates in order to reduce the pilot pollution problem and increase performance in a target cell. Simulation results were significantly improved by using the proposed scheme.

In this thesis, an optimization method titled Butterfly optimization method, for pilot decontamination scheme, studied and evaluated to reduce pilot contamination in multicellular multimodal systems. The numerical results of the proposed method significantly improved. However, design considered to have weaknesses due to the need for a large number of pilot sequences that are proportional to the pilot reuse factor that leads to more overhead.

The results of simulation in MATLAB environment shows that the proposed method based on butterfly algorithm has been able to increase the SINR level more than other methods such as Random, SPRS, WGC-PD and SPRS + WGC-PD. The bit rate for each user is better than the other methods that discussed inside of the paper, and the proposed method is more efficient than other methods such as Random, SPRS, WGC-PD and SPRS + WGC-PD.

REFERENCES

[1] L. Liu, R. Chen, S. Geirhofer, K. Sayana, Z. Shi, and Y. Zhou, "Downlink mimo in lte-advanced: Su-mimo vs. mu-mimo," *IEEE Commun. Mag.*, vol. 50, no. 2, pp. 140–147, 2012.

[2] E. Telatar, "Capacity of multi-antenna Gaussian channels," *Eur. Trans. Telecommun.*, vol. 10, no. 6, pp. 585–595, 1999.

[3] W. Yuan, X. Yang, and R. Xu, "A Novel Pilot Decontamination Scheme for Uplink Massive MIMO Systems," *Procedia Comput. Sci.*, vol. 131, pp. 72–79, 2018.

[4] S. Ma, E. L. Xu, A. Salimi, and S. Cui, "A novel pilot assignment scheme in massive MIMO networks," *IEEE Wirel. Commun. Lett.*, vol. 7, no. 2, pp. 262–265, 2017.

[5] X. Lu, V. Petrov, D. Moltchanov, S. Andreev, T. Mahmoodi, and M. Dohler, "5G-U: Conceptualizing Integrated Utilization of Licensed and Unlicensed Spectrum for Future IoT," *IEEE Commun. Mag.*, 2019.

[6] I. B. F. de Almeida, L. L. Mendes, J. J. P. C. Rodrigues, and M. A. A. da Cruz, "5G Waveforms for IoT Applications," *IEEE Commun. Surv. Tutorials*, 2019.

[7] S. Kaneriya, J. Vora, S. Tanwar, and S. Tyagi, "Standardising the use of Duplex Channels in 5G-WiFi Networking for Ambient Assisted Living," in *2019 IEEE International Conference on Communications Workshops (ICC Workshops)*, 2019, pp. 1–6.

[8] A. Kumari, S. Tanwar, S. Tyagi, N. Kumar, M. S. Obaidat, and J. J. P. C. Rodrigues, "Fog Computing for Smart Grid Systems in the 5G Environment: Challenges and Solutions," *IEEE Wirel. Commun.*, vol. 26, no. 3, pp. 47–53, 2019.

[9] S. Banik, I. S. Cardenas, and J. H. Kim, "IoT Platforms for 5G Network and Practical Considerations: A Survey," *arXiv Prepr. arXiv1907.03592*, 2019.

[10] R. Su *et al.*, "Resource allocation for network slicing in 5G telecommunication networks: A survey of principles and models," *IEEE Netw.*, vol. 33, no. 6, pp. 172–179, 2019.

[11] R. Khan, P. Kumar, D. N. K. Jayakody, and M. Liyanage, "A survey on security and privacy of 5G technologies: Potential solutions, recent advancements and future directions," *IEEE Commun. Surv. Tutorials*, 2019.

[12] I. Ahmad, Z. Kaleem, R. Narmeen, L. D. Nguyen, and D.-B. Ha, "Quality-of-service aware game theory-based uplink power control for 5G heterogeneous networks," *Mob. Networks Appl.*, vol. 24, no. 2, pp. 556–563, 2019.

[13] N.-N. Dao, M. Park, J. Kim, J. Paek, and S. Cho, "Resource-aware relay selection for inter-cell interference avoidance in 5G heterogeneous network for Internet of Things systems," *Futur. Gener. Comput. Syst.*, vol. 93, pp. 877–887, 2019.

[14] W. Chen, X. Yang, W. Fang, W. Zhang, and X. Jiang, "Cluster Routing Protocol for Coal Mine Wireless Sensor Network Based on 5G," in *International Conference on 5G for Future Wireless Networks*, 2019, pp. 60–67.

[15] M. H. Alsharif, S. Kim, and N. Kuruoğlu, "Energy harvesting techniques for wireless sensor networks/radio-frequency identification: A review," *Symmetry (Basel).*, vol. 11, no. 7, p. 865, 2019.

[16] J. V. V Sobral *et al.*, "A framework for enhancing the performance of Internet of Things applications based on RFID and WSNs," *J. Netw. Comput. Appl.*, vol. 107, pp. 56–68, 2018.

[17] M. Capra, R. Peloso, G. Masera, M. Ruo Roch, and M. Martina, "Edge computing: A survey on the hardware requirements in the internet of things world," *Futur. Internet*, vol. 11, no. 4, p. 100, 2019.

[18] J. de C. Silva, J. J. P. C. Rodrigues, J. Al-Muhtadi, R. A. L. Rabêlo, and V. Furtado, "Management platforms and protocols for internet of things: A survey," *Sensors*, vol. 19, no. 3, p. 676, 2019.

[19] H. M. Jawad, R. Nordin, S. K. Gharghan, A. M. Jawad, and M. Ismail, "Energy-efficient wireless sensor networks for precision agriculture: A review," *Sensors*, vol. 17, no. 8, p. 1781, 2017.

[20] L. Tello-Oquendo, S.-C. Lin, I. F. Akyildiz, and V. Pla, "Software-Defined architecture for QoS-Aware IoT deployments in 5G systems," *Ad Hoc Networks*, vol. 93, p. 101911, 2019.

[21] I. Jang, D. Lee, J. Choi, and Y. Son, "An approach to share self-taught knowledge between home IoT devices at the edge," *Sensors*, vol. 19, no. 4, p. 833, 2019.

[22] S. Li, L. Da Xu, and S. Zhao, "5G Internet of Things: A survey," *J. Ind. Inf. Integr.*, vol. 10, pp. 1–9, 2018.

[23] G. A. Jeffrey *et al.*, "What will 5G be?," *IEEE J. Sel. areas Commun.*, vol. 32, no. 6, pp. 1065–1082, 2014.

[24] H. Magsi, A. H. Sodhro, F. A. Chachar, S. A. K. Abro, G. H. Sodhro, and S. Pirbhulal, "Evolution of 5G in Internet of medical things," in *2018 international conference on computing, mathematics and engineering*

technologies (iCoMET), 2018, pp. 1–7.

[25] J. Yao, Z. Han, M. Sohail, and L. Wang, “A robust security architecture for SDN-based 5G networks,” *Futur. Internet*, vol. 11, no. 4, p. 85, 2019.

[26] M. Chen, Y. Qian, Y. Hao, Y. Li, and J. Song, “Data-driven computing and caching in 5G networks: Architecture and delay analysis,” *IEEE Wirel. Commun.*, vol. 25, no. 1, pp. 70–75, 2018.

[27] A. H. Sodhro, S. Pirbhulal, A. K. Sangaiah, S. Lohano, G. H. Sodhro, and Z. Luo, “5G-based transmission power control mechanism in fog computing for Internet of Things devices,” *Sustainability*, vol. 10, no. 4, p. 1258, 2018.

[28] A. N. Toosi, R. Mahmud, Q. Chi, and R. Buyya, “Management and Orchestration of Network Slices in 5G, Fog, Edge and Clouds,” *Fog Edge Comput.*, vol. 10, 2019.

[29] M. Aazam, K. A. Harras, and S. Zeadally, “Fog computing for 5G tactile industrial Internet of Things: QoE-aware resource allocation model,” *IEEE Trans. Ind. Informatics*, vol. 15, no. 5, pp. 3085–3092, 2019.

[30] O. Elijah, C. Y. Leow, A. R. Tharek, S. Nunoo, and S. Z. Iliya, “Mitigating pilot contamination in massive MIMO system—5G: An overview,” in *2015 10th Asian Control Conference (ASCC)*, 2015, pp. 1–6.

[31] O. Elijah, C. Y. Leow, T. A. Rahman, S. Nunoo, and S. Z. Iliya, “A comprehensive survey of pilot contamination in massive MIMO—5G system,” *IEEE Commun. Surv. Tutorials*, vol. 18, no. 2, pp. 905–923, 2015.

[32] A. Soysal, “MIMO systems with non-exact CSI,” in *2010 IEEE 18th Signal Processing and Communications Applications Conference*, 2010, pp. 531–534.

[33] F. Fernandes, A. Ashikhmin, and T. L. Marzetta, “Inter-cell interference in noncooperative TDD large scale antenna systems,” *IEEE J. Sel. Areas Commun.*, vol. 31, no. 2, pp. 192–201, 2013.

[34] H. Yin, D. Gesbert, M. Filippou, and Y. Liu, “A coordinated approach to channel estimation in large-scale multiple-antenna systems,” *IEEE J. Sel. areas Commun.*, vol. 31, no. 2, pp. 264–273, 2013.

[35] J. Zhang, B. Zhang, S. Chen, X. Mu, M. El-Hajjar, and L. Hanzo, “Pilot contamination elimination for large-scale multiple-antenna aided OFDM systems,” *IEEE J. Sel. Top. Signal Process.*, vol. 8, no. 5, pp. 759–772, 2014.

[36] X. Zhu *et al.*, “Soft pilot reuse and multicell block diagonalization precoding for massive MIMO systems,” *IEEE Trans. Veh. Technol.*, vol. 65, no. 5, pp. 3285–3298, 2015.

[37] X. Zhu, Z. Wang, L. Dai, and C. Qian, “Smart pilot assignment for massive MIMO,” *IEEE Commun. Lett.*, vol. 19, no. 9, pp. 1644–1647, 2015.

[38] H. Tullberg *et al.*, “METIS system concept: the shape of 5G to come,” *IEEE Commun. Mag.*, 2015.

[39] G. Wunder *et al.*, “5GNOW: non-orthogonal, asynchronous waveforms for future mobile applications,” *IEEE Commun. Mag.*, vol. 52, no. 2, pp. 97–105, 2014.

[40] G. Auer *et al.*, “D2. 3: Energy efficiency analysis of the reference systems, areas of improvements and target breakdown,” *Earth*, vol. 20, no. 10, 2010.

[41] H. Woesner and S. Azodolmolky, “Openflow extensions towards multi-layer and multi-domain networks: OFELIA,” in *2011 37th European Conference and Exhibition on Optical Communication*, 2011, p. 1.

[42] R. Q. Hu and Y. Qian, “An energy efficient and spectrum efficient wireless heterogeneous network framework for 5G systems,” *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 94–101, 2014.

[43] U. N. Kar and D. K. Sanyal, “A sneak peek into 5G communications,” *Resonance*, vol. 23, no. 5, pp. 555–572, 2018.

[44] A. Mahmood, M. L. B. M. Kiah, S. R. Bin Azzuhri, and A. N. Qureshi, “Wireless Backhaul Network Optimization Using Automated KPIs Monitoring System Based on Time Series Forecasting,” in *2018 IEEE World Symposium on Communication Engineering (WSCE)*, 2019, pp. 1–6.

[45] D. Zhang, K. Yu, Z. Zhou, and T. Sato, “Energy efficiency scheme with cellular partition zooming for massive mimo systems,” in *2015 IEEE Twelfth International Symposium on Autonomous Decentralized Systems*, 2015, pp. 266–271.

[46] J. G. Andrews *et al.*, “What will 5G be?,” *IEEE J. Sel. areas Commun.*, vol. 32, no. 6, pp. 1065–1082, 2014.

[47] O. Dikmen and S. Kulaç, “5. Nesil ve Ötesi Teknolojiler için Çok Girişli Çok Çıkışlı Sistemler ile Spektrum Verimliliğin Gerçekleştirilmesi,” *Düzce Üniversitesi Bilim ve Teknol. Derg.*, vol. 6, no. 2, pp. 349–356, 2018.

[48] D. Choudhury, “5G wireless and millimeter wave technology evolution: An overview,” in *2015 IEEE MTT-S International Microwave Symposium*, 2015, pp. 1–4.

[49] V. Jungnickel *et al.*, “The role of small cells, coordinated multipoint, and massive MIMO in 5G,” *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 44–51, 2014.

[50] J. M. Khurpade, D. Rao, and P. D. Sanghavi, “A Survey on IOT and 5G Network,” in *2018 International Conference on Smart City and Emerging Technology (ICSCET)*, 2018, pp. 1–3.

[51] R. I. Ansari *et al.*, “5G D2D networks: Techniques, challenges, and future prospects,” *IEEE Syst. J.*, vol. 12, no. 4, pp. 3970–3984, 2017.

[52] A. A. El-Saleh, A. Alhammadi, I. Shayea, W. H. Hassan, M. S. Honnurvali, and Y. I. Daradkeh, "Measurement analysis and performance evaluation of mobile broadband cellular networks in a populated city," *Alexandria Eng. J.*, vol. 66, pp. 927–946, 2023.

[53] S. Aggarwal and N. Kumar, "Fog computing for 5G-enabled tactile Internet: Research issues, challenges, and future research directions," *Mob. Networks Appl.*, pp. 1–28, 2019.

[54] R. Senapati, "LTE-advanced cell capacity estimation model and algorithm for voice service," *J. Ambient Intell. Humaniz. Comput.*, vol. 14, no. 2, pp. 1203–1216, 2023.

[55] H. Attar *et al.*, "5G System Overview for Ongoing Smart Applications: Structure, Requirements, and Specifications," *Comput. Intell. Neurosci.*, vol. 2022, 2022.

[56] M. Fizza and M. A. Shah, "5G Technology: An overview of applications, prospects, challenges and beyond," *Proc. Appear. IOARP Digit. Libr.*, 2016.

[57] J. Hasneen and K. M. Sadique, "A survey on 5G architecture and security scopes in SDN and NFV," in *Applied Information Processing Systems: Proceedings of ICCET 2021*, 2022, pp. 447–460.

[58] W. Chen and B. Yang, "Energy efficiency analysis of e-commerce customer management system based on mobile edge computing," *Sci. Program.*, vol. 2022, pp. 1–9, 2022.

[59] A. K. Sangaiah, A. Javadpour, P. Pinto, F. Ja'fari, and W. Zhang, "Improving quality of service in 5G resilient communication with the cellular structure of smartphones," *ACM Trans. Sens. Networks*, vol. 18, no. 3, pp. 1–23, 2022.

[60] T. Zhivkov and E. I. Sklar, "5G on the Farm: Evaluating Wireless Network Capabilities for Agricultural Robotics," *arXiv Prepr. arXiv2301.01600*, 2022.

[61] S.-J. Hsiao, "Employing a Wireless Sensing Network for AIoT Based on a 5G Approach," *Electronics*, vol. 11, no. 5, p. 827, 2022.

[62] N. Quliyev, "5G technologies are creating a new world order," *Nor. J. Dev. Int. Sci.*, no. 82, pp. 62–68, 2022.

[63] L. Banda, M. Mzyece, and F. Mekuria, "5g business models for mobile network operators–a survey," *IEEE Access*, 2022.

[64] M. Esposito, A. Belli, L. Palma, and P. Pierleoni, "Design and Implementation of a Framework for Smart Home Automation Based on Cellular IoT, MQTT, and Serverless Functions," *Sensors*, vol. 23, no. 9, p. 4459, 2023.

[65] W. Hong and C.-Y. D. Sim, *Microwave and Millimeter-wave Antenna Design for 5G Smartphone Applications*. John Wiley & Sons, 2023.

[66] E. Bozkaya, “Digital Twin-assisted and mobility-aware service migration in Mobile Edge Computing,” *Comput. Networks*, p. 109798, 2023.

[67] K. Glinskiy, A. Kureev, A. Krasilov, and E. Khorov, “PABAFT: Channel Prediction Approach Based on Autoregression and Flexible TDD for 5G Systems,” *Electronics*, vol. 11, no. 12, p. 1853, 2022.

[68] G. Yassine, A. H. Aicha, M. Fatiha, and D. Younes, “Review of Machine Learning for Antenna Selection and CSI Feedback in Multi-antenna Systems,” in *Proceedings of the International Conference on Paradigms of Computing, Communication and Data Sciences: PCCDS 2022*, 2023, pp. 165–181.

[69] F. G. Mengistu and G. A. Worku, “Performance analysis of downlink massive MIMO system with precoding techniques and pilot reuse factor,” *Cogent Eng.*, vol. 10, no. 1, p. 2210387, 2023.

[70] J. Guo, T. Chen, S. Jin, G. Y. Li, X. Wang, and X. Hou, “Deep learning for joint channel estimation and feedback in massive MIMO systems,” *Digit. Commun. Networks*, 2023.

[71] A. M. Abdul-Hadi, M. A. Naser, M. Alsabah, S. H. Abdulhussain, and B. M. Mahmmod, “Performance evaluation of frequency division duplex (FDD) massive multiple input multiple output (MIMO) under different correlation models,” *PeerJ Comput. Sci.*, vol. 8, p. e1017, 2022.

[72] S. Mirjalili, “SCA: a sine cosine algorithm for solving optimization problems,” *Knowledge-based Syst.*, vol. 96, pp. 120–133, 2016.

[73] L. Jin, S. Li, J. Yu, and J. He, “Robot manipulator control using neural networks: A survey,” *Neurocomputing*, vol. 285, pp. 23–34, 2018.

[74] H.-Y. Lee, H. Shin, and J. Chae, “Path planning for mobile agents using a genetic algorithm with a direction guided factor,” *Electronics*, vol. 7, no. 10, p. 212, 2018.

[75] J. Xu, F. Yan, K. Yun, L. Su, F. Li, and J. Guan, “Noninferior solution grey wolf optimizer with an independent local search mechanism for solving economic load dispatch problems,” *Energies*, vol. 12, no. 12, p. 2274, 2019.

[76] X. Qi, Y. Zhu, and H. Zhang, “A new meta-heuristic butterfly-inspired algorithm,” *J. Comput. Sci.*, vol. 23, pp. 226–239, 2017.

[77] S. Arora and S. Singh, “Butterfly optimization algorithm: a novel approach for global optimization,” *Soft Comput.*, vol. 23, no. 3, pp. 715–734, 2019.

[78] A. S. Al-hubaishi, N. K. Noordin, A. Sali, S. Subramaniam, and A. Mohammed Mansoor, “An Efficient Pilot Assignment Scheme for Addressing Pilot Contamination in Multicell Massive MIMO Systems,” *Electronics*, vol. 8, no. 4, p. 372, 2019.

RESUME

Salah Meftah ALTIRAIKI completed high school education in Indus trial Institute - Misurata, after that, he started undergraduate program in Higher Poly Technique Institute - Misurata. Trainer in the college of industrial technology from 2001-2014. From 2014 until 2017 he graduated master science education at Karabuk University Department of Electric Electronics Engineering. From 2018 until 2023 he graduated phD at Karabuk University Department of Electric Electronics Engineering.