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Uplink Performance Evaluation of the Fractional Power Control Algorithm in 5G

تقييم أداء الوصلة الصاعدة لخوارزمية التحكم في القدرة الجزئية في الجيل الخامس

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إستهلال

قال تعالى :

(وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ ۖ وَسَتُرَدُّونَ إِلَىٰ عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُم بِمَا كُنتُمْ تَعْمَلُونَ)

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الإهداء

مرّت قاطرة البحث بكثير من العوائق، ومع ذلك حاولنا أن نتخطّاها بثبات بفضل من الله ومنّه.

إلى أبويَّ أطهر قلبين في حياتي

إالى أخوتي وأصدقائي، فلقد كانوا بمثابة العضد والسند في سبيل استكمال البحث.

إلى أستاذنا وأبونا الروحي من علمنا في جميع نواحي حياتنا أولها حُسن الخُلق د.عماد بشير رحمة الله عليه

"عمر الله البقاء طيب الله الأثر"

وإلي من أرشدونا في حياتنا

وإليك..

ABSTRACT

5G represents a major advance in cellular technology. The role of uplink power control is to suppress interference. Power control refers to set output power levels of transmitters, base stations in the downlink and User Equipment (UE) in the uplink. In this thesis the performance of 5G closed and open loop power control combined with fractional path loss compensation factor is evaluated by simulating the effects of open loop error, Transmit Control Protocol (TCP) command. The power by the UE must be controlled to reduce the power consumption. The uplink power control schemes; the open and the closed loop power control are investigated to reduce the power consumption. The effect of the parameters; the compensation factor, the path loss and the Power Offset were tested in order to have an operating point. The closed loop power control with fractional path loss compensation factor is found to improve the system performance in terms of mean bit rate. The results showed that an increase in any of these parameters increases the transmission power, we observe with $P0=-60$dBm and $\alpha= 0.5$ represents a good solution for the cell spectral efficiency, whereas better performance in the cell border throughput can be obtained with $P0= -120$dBm and $\alpha= 0.6$.

المستخلص

تمثل 5G تقدمًا كبيرًا في التكنولوجيا الخلوية. يتمثل دور التحكم في قدرة الوصلة الصاعدة في قمع التداخل. يشير التحكم في القدرة إلى ضبط مستويات قدرة الخرج لأجهزة الإرسال والمحطات الأساسية في الوصلة الهابطة ومعدات المستخدم في الوصلة الصاعدة. في هذه الأطروحة ، يتم تقييم أداء التحكم في قدرة الحلقة المغلقة والمفتوحة لشبكات الجيل الخامس جنبًا إلى جنب مع عامل تعويض خسارة المسار الجزئي من خلال محاكاة تأثيرات خطأ الحلقة المفتوحة ، أمر بروتوكول التحكم في الإرسال. يجب التحكم في طاقة معدات المستخدم لتقليل استهلاك الطاقة. مخططات التحكم في طاقة الوصلة الصاعدة ؛ يتم فحص التحكم في طاقة الحلقة المفتوحة والمغلقة لتقليل استهلاك الطاقة. تأثير المعلمات ؛ تم اختبار عامل التعويض وخسارة المسار وإزاحة الطاقة من أجل الحصول على نقطة تشغيل. تم العثور على التحكم في قدرة الحلقة المغلقة مع عامل تعويض خسارة المسار الجزئي لتحسين أداء النظام من حيث متوسط معدل البتات. أظهرت النتائج أن الزيادة في أي من هذه المعلمات تزيد من قدرة الإرسال، لاحظنا أن P0=-60dBm و 0.5=α يمثل حلاً جيداً للكفاءة الطيفية للخلية ,بينما يمكن الحصول على أداء أفضل في إنتاجية حدود الخلية مع P0=-120dBm و 0=α. .

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LIST OF ABBREVIATIONS

ABS	Almost Blank Sub frame.
BS	Base stations.
CDMA	Code Division Multiple Access.
CDF	Cumulative distribution function.
CLPC	Close loop power control.
CSI	Channel state information.
CoMP	Coordinated multi-point.
CG	Column generation.
CRE	Cell Range Expansion.
DL	Downlinks.
DRL	Deep reinforcement learning.
DPC	Distributed power control.
EGT	Evolutiary game theory.
FD	Full Duplex.
FPC	Fractional power control.
GSM	Global System for mobile communication.

H. CRANs	Heterogeneous cloud radio access networks.
IOT	Internet of Things.
ILP	Integer linear programming.
IDGS	Increasing demand greedy scheduling.
LIA	Limited interference area.
LTE	Advance long Term Evaluation.
MS	Mobile station.
NBS	Nash Bargaining Solution.
NSA	Non. Standalone.
NoPC	No power control.
OLPC	Open-loop power control.
OFDMA	Orthogonal frequency division multiple access.
PC	Power control.
PDMA	Pattern Division Multiple Access.
QOS	Quality of service.
RA	Resource allocation.
RSRP	Reference symbol receiver power.
SA	Standalone.
SE	Spectral efficiency formula
SDPC	Soft dropping power control.
SINR	Signal to interference plus-noise ratio.
SIC	Successive interference cancellation.
SIR	Signal to interference ratio.
SI	Self. Interference.
TPC	Transmission power control.
TCP	Transmit control protocol.
UL	Uplinks.
URLLC	Ultra Reliable Low Latency Communication.

LIST OF SYMBOLS

P_k	The power used by UE k to transmit power
$P^{(UE)}$	23 dBm is the maximum transmit power of the UE
P_0	A parameter used to control per-RB SNR target
α	Fractional compensation factor of the large scale fading attenuation
L_k	The large scale fading attenuation between UE k and its anchor BS
PL	Path loss
Fc	Frequency in GHZ
D	Distance in meter
Pr	Power RX
Pt	Power transmit
γ_u	The SINR of user u
S_u	The received power of u at gNB
I_{ext}	External interference
N	The thermal noise power in the System bandwidth

$g_{u,b}$	Designates the UE scheduled by gNB
TH	Throughput
B	Bandwidth
RC	Code Rate
M	Logarithm of actual data rate

CHAPTER ONE

INTRODUCTION

1.1 Preface

5G network construction differs significantly from 4G in terms of networking modes, product forms, and performance parameters. The power consumption of 5G hardware is between two and four times greater than 4G, posing unprecedented challenges for site infrastructure construction. It calls for systematic research and innovative 5G energy solutions to meet the energy challenges brought by 5G. The 5G era will be a fully mobile, fully connected smart era. It will see the growth of connections and communication between people, between people and things, and between things and things. With the number of global connections set to exceed 100 billion, 5G will engender a greater diversity of scenarios and service requirements. in Figure 1 show connection between people and things in 5G network.

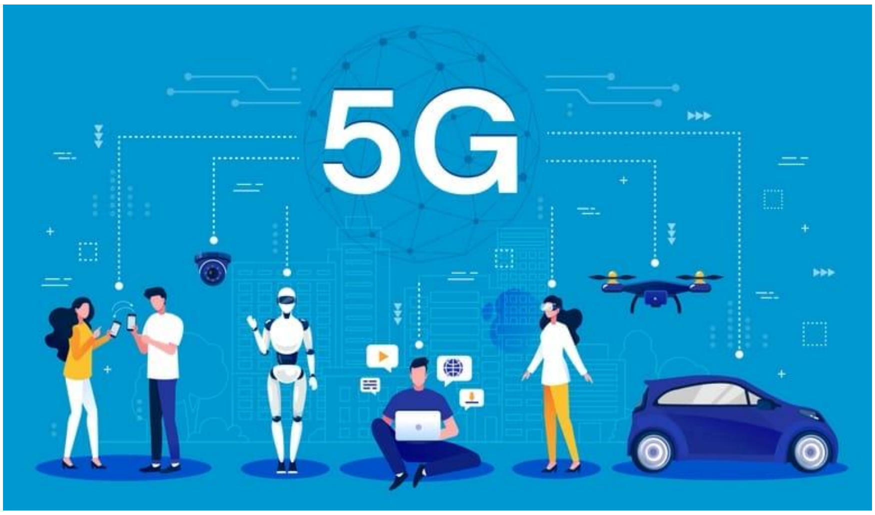

Figure 1.1: connection between people and things in 5G network

Transmission powers represent a key degree of freedom in the design of wireless networks. In both cellular and ad hoc networks, power control helps with several functionalities:

Interference management: Due to the broadcast nature of wireless communication, signals interfere with each other. This problem is particularly acute in interference-limited systems, such as CDMA systems where perfect orthogonality among users are difficult to maintain. Power control helps ensure efficient spectral reuse and desirable user experience.

Energy management: Due to limited battery power in mobile stations, handheld devices, or any “nodes” operating on small energy budget, energy conservation is important for the lifetime of the nodes and even the network. Power control helps minimize a key component of the overall energy expenditure.

Connectivity management: Due to uncertainty and time variation of wireless channels, even when there is neither .

1.2 Problem Statement

wireless networks are facing one of their greatest limiting factors: interference, this is due to the unprecedented increase in the number of connected devices. Therefore, in order to meet the ever increasing demand for data rate and quality of services, today are required to deal with signal interference nor energy limitation, the receiver needs to be able to maintain a minimum level of received signal so that it can stay connected with the transmitter and estimate the channel state, And the near-far mobiles problem.

1.3 Proposed Solution

Performance power control in 5G and we use matlab program to describe results of the algorithm.

1.4 Thesis Objective

The objectives of this thesis are

- To identify 5G network.
- To provide and investigate fractional power control technique in 5G network.
- To simulate and evaluate the fractional power control technique in 5G network.

1.4 Methodology

We will provide and investigate fractional power control technique in 5G network and use matlab software to implement Fractional power control and presents the results for 5G network.

1.5 Thesis Outline:

The rest of this thesis include the following

- Chapter (2) presents the background، to wireless communication and power control in 5G.
- Chapter (3) shows the methodology to implement the fractional power control.
- Chapter (4) presents the simulation results and the discussion.
- Chapter (5) describes the conclusion of the work and recommendation for future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

Power Control in 2G Networks Early digital cellular systems are typically referred to as 2G systems to set them apart from 1G analog cellular systems. The 2G systems were primarily designed for voice which is generated at a fixed bit rate, and the power control mechanisms were geared towards targeting a fixed SIR, determined by the quality of voice that needs to be supported. Qualcomm proposed an OLPC scheme for a CDMA based cellular system where the transmit power is set inversely proportional to the received power. The OLPC scheme was augmented by a CLPC scheme where the receive powers were equalized through a 1-bit feedback. This power control solution to the near-far problem was instrumental in enabling the success of CDMA networks. More recent CLPC algorithms implement a discretized version of the DPC algorithm where the feedback from the BS is limited to a finite number of bits, and the transmit power at the MS is altered by a fixed step-size update based on the feedback. The feedback is typically 1-bit or 2-bits, and represents either a increment or decrement of the power level rather than the absolute power level. A two-bit feedback (more precisely, a 3-level or a 1.5-bit feedback) either increases or decreases the transmit power level by δdB or maintains the transmit power at the same level based on the feedback. The feedback frequency presents a trade-off between power-control overhead and the Doppler-tolerance CLPC is an important component of the CDMA based IS-95 system where neighboring sectors use the same frequency. It helps in minimizing inter-sector interference and enabling frequency reuse of one. In addition, MSs in the same sector of an IS-95 system are not orthogonal on the uplink since it is prohibitively expensive to maintain CDMA chip-level synchronization among MSs. CLPC ensures that the MSs closer to the BS does not swamp out the MSs further away from the BS. The CLPC scheme on the uplink in IS-95 uses 1-bit feedback at the rate of 800 every second. The power control update is in steps of 1dB with choices of smaller steps allowed in later revisions of the standard. On the downlink, CLPC is less important since the downlink signals emanating from the same BS are orthogonal, and as such the feedback rate is once every 20ms reporting a frame error in 1-bit The GSM based 2G standard is an orthogonal scheme where the MSs within a sector are allocated a separate time and frequency slot for both uplink and downlink. Maintaining orthogonality between MSs of the same sector implies that the time-frequency resource for each MS is limited and the SIR requirement for voice communication is higher in comparison to IS-95. This rules out frequency reuse of one in GSM systems. The non-existence of inter-sector interference from the immediate neighbors of a sector and the non-existence of intra-cell interference due to the orthogonality of MSs within a sector imply that the need for CLPC in GSM standard is less in comparison to IS-95. As such, GSM implements a CLPC scheme both on the uplink as well. In addition to voice, the 3G and 4G cellular systems support data of varying rates. Rather than formulating power control as a fixed SIR feasibility problem, SIR assignment and power control need to be jointly designed. The time and frequency allocation for each MS, unlike the case in a 2G system, is not static but depends on the traffic arrivals, channel conditions, and QoS classes. Scheduling refers to allocation of time and frequency slots to the MSs. Power control determines the transmit power allocated to the links.

Power control and scheduling are therefore done in conjunction in 3G systems to maximize the efficiency of the system. The time and frequency resources are split into chunks that form the time-frequency slabs. For each time-frequency slab, the scheduling algorithm decides the set of MSs that are allowed to participate in data transmission in that slab, and the power control part determines the data rate of transmission by allocating appropriate power levels to the participating MSs through a power-control algorithm. The ultimate objective, whether stabilizing queues resulting from a set of arrivals or maximizing network-wide criteria, is realized through both scheduling and rate selection through power control. To support different data rates according to the traffic requirements but would be efficient only in supporting uniform data rates. An important factor that determines the total uplink capacity in commercial networks is the interference limit qm, often stated in terms of IOT and ROT factors. The IOT limits bound the interference to the cell ensuring stability of rate al- location on the uplink, and in addition limits the power required for new mobiles to access the network. Typical IOT values in commercial networks range from 3 to 10 dB.

2.2 Related Work

It is analyzed that nearly 57% of the world's population will be facilitated by IOT system with high resources. But one of the challenging issues of the IOT devices and networks is the high-power drain and limited battery lifetime with regular recharging from the external sources. The wireless link or channel status varies with different conditions such as, interference from same network devices, internal noise and environmental factors and so forth, also natural hindrances for example, roofs and walls are degrading the signal strength at the larger level. In addition, it increases the contention in the network. For prolonging the network lifetime and increasing transmission reliability (i.e., reducing PLR), transmission power control (TPC) mechanism is most appropriate one because it increases/decreases power according to the need of the end user and predefined threshold levels by adopting the channel conditions. Key purpose of TPC strategy is to achieve optimal transmission power.[1]

A reinforcement-learning technique for energy optimization with fifth-generation communication in VSNs. To achieve energy optimization, we use centralized Q-learning in the system and distributed Q-learning in the vehicles. The proposed algorithm learns to maximize the energy efficiency of the system by adjusting the minimum signal-to-interference plus noise ratio to guarantee the outage probability. D2D communication is highly susceptible to interference because of the reuse of cellular resources. Specifically, for D2D communication in H-CRANs, various interference problems are caused by the dense deployment of RRHs. Mode selection is a technique that can solve the interference problem. Another solution to solve the interference problem is to use the power-control method Power control is a method that manages interference by controlling the power of the D2D links. Using the power-control method increases the energy efficiency of a device by decreasing the transmission power in low-interference situations and increasing the transmission power in high-interference situations to guarantee the QoS [2].

A mode-selection algorithm that considered the link quality of D2D links was proposed to maximize the system throughput. It estimated the expected system throughput considering the SINR and available resources, so it could maximize the system throughput. As

D2D communication reuses cellular resources, interference management between cellular and D2D links is important. The power-control method that controls the transmission power of D2D links is one method used to manage interference [3]. a power-control algorithm with variable target SINRs was proposed for application in multicellular scenarios. It aimed to maximize the system spectral efficiency using a soft-dropping algorithm to control the transmission power to meet the variable target SINR. A power-control algorithm using stochastic geometry was proposed [4].

The algorithm can be divided into two types: centralized and decentralized. The centralized type aims to guarantee the coverage probability by solving the optimization power problem. The decentralized type was an interference mitigation method to maximize the sum rates of the devices. To take advantage of both mode selection and power control, jointly designed algorithms were proposed [5].

A mode-selection and power-control algorithm was proposed to maximize the sum of the achievable data rate. It selected the mode to satisfy the distance and interference constraints from an operator perspective. After mode selection, it first proved that the power-control problem was quasiconvex for the D2D mode and then solved it. the Soft Dropping Power Control (SDPC) scheme adjusts the transmit power to meet a variable target SINR in an UL single-carrier system, the SDPC scheme was used to protect cellular and D2D communications from mutual interference in a Downlink (DL) Orthogonal Frequency Division Multiple Access (OFDMA) system. A DRL based communication link scheduling algorithm is developed for a cache-enabled opportunistic interference alignment wireless network. Markov process is used to model the network dynamics including the dynamics of cache states at the transmitter side and channel state information (CSI). A mode-selection algorithm based on Q-learning was proposed to maximize QoS and minimize interference. It considered the delay, energy efficiency, and interference to determine the transmission mode [6] .

A mode-selection method based on deep reinforcement learning was proposed to minimize the system power consumption in a fog radio access network. To make optimal decisions, it formulated the energy minimization problem with a Markov decision process by considering the on-off state of processors, communication mode of the device, and precoding vectors of RRH. Resource Allocation and Power Control RA and power control (PC) gained considerable attention in the design of the in-band D2D networks, where the D2D users share the same resources with the CUs A variety of interference mitigation techniques exist in literature to address this problem, which can be divided into interference avoidance, interference coordination and interference cancellation. A limited interference area (LIA) surrounding the D2D users was introduced to prevent any CU from transmitting within the LIA as a way of interference avoidance. For interference coordination, optimal RA and PC were investigated between D2D users and CUs. The genetic algorithm, game theory and the optimization theory were utilized as efficient mathematical tools for coordinating the interference and controlling the power among CUs and D2D users. A new research direction is to use the social activities of the users in interference mitigation among D2D users and CUs. For interference cancellation, techniques based on successive interference cancellation (SIC), coordinated multi point (CoMP) and full-duplex (FD)-based self-interference cancellation were investigated in the literature to cancel the interference occurs between D2D users and CUs. Fortunately, for the out-of-band D2D networks, including mmWave D2D, the problem of interference between CUs and D2D users does not exist. Figure 1 shows some case studies of current critical D2D scenarios in real life, such as disaster management, unmanned aerial vehicles (UAVs) communications, vehicle to everything (V2X) applications [7] .

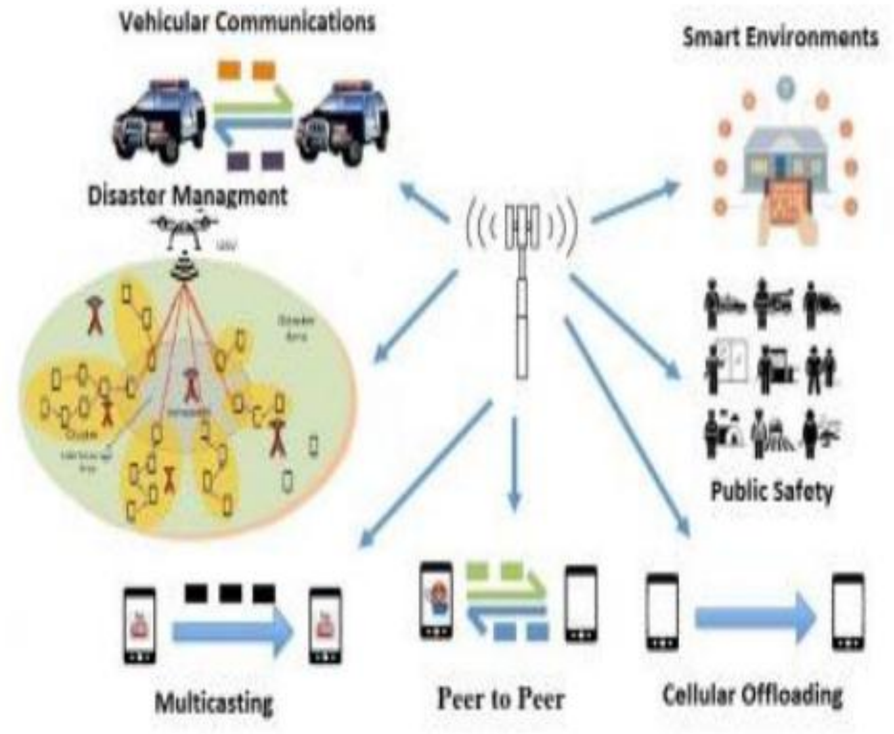

Figure 2.1: Samples of device-to-device (D2D) applications.

Interference management in 5G networks requires efficient distributed CAPC schemes such that each user can possibly connect simultaneously to multiple BSs (can be different for uplink and downlink), while achieving load balancing in different cells and guaranteeing interference protection for the HPUEs. A. Prioritized Power Control to guarantee interference protection for HPUEs, a possible strategy is to modify the existing power control schemes such that the LPUEs limit their transmit power to keep the interference caused to the HPUEs below a predefined threshold, while tracking their own objectives. In other words, as long as the HPUEs are protected against existence of LPUEs, the LPUEs could employ an existing distributed power control algorithm to satisfy a predefined goal B. Resource-Aware Cell Association Schemes Cell association schemes need to be devised that can balance the traffic load as well as minimize interference or maximize SIR levels at the same time and can achieve a good balance between these objectives without the need of static biasing-based CRE or ABS schemes. The high-power BS may consider minimizing its transmit power subject to a maximum interference level experienced by the off-loaded users (i.e., prioritized power control in the downlink)[8].

By using sophisticated power allocation at the transmitters, as well as successive interference cancellation (SIC) to mitigate multi-user interference at receivers, the number of users and the spectrum efficiency can be significantly improved, especially when the channel conditions of the users are quite different. Propose to decompose the original problem into two sub-problems which are relatively easy to solve. One sub problem is a power control and beam gain allocation problem, which can be solved directly with an analytical approach, and the other is a beamforming problem under the CM constraint, which can be converted into a standard convex optimization problem [1].

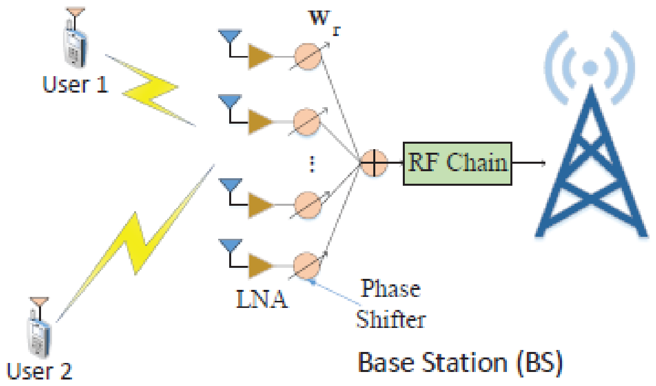

Figure 2.2: Illustration of an mmWave mobile cell, where one BS with N antennas serves multiple users with one single antenna.

A lower bound on the achievable uplink signal to interference plus noise ratio (SINR) is derived, and, based on that, uplink pilot and data powers are optimized to maximize the energy efficiency. This optimization is further decentralized by using game theory A joint optimization of pilot coordination among cells and uplink PC is performed, where, differently the pilot signals are modeled as continuous optimization variables. A similar joint optimization[9].

In D2D, users with short distance and high signal-to-interference-plus-noise ratio (SINR) ratio may directly communicate with each other without sending the information through base station (BS), BS only sends the control signals to these users. These users can either use license excused bands or licensed frequency bands [2]. authors have investigated different resource allocation approaches for D2D, where D2D connection can use dedicated resource or using resources of one or more than one users. One of the main technology component of D2D is mode selection (MS), which selects the cellular or direct communication mode for a D2D pair based on issues such as the current resource condition, traffic load, and level of the interference signals [2].

A. Device-to-device communication (D2D) Has been announced as a key technology to LTE-Advance networks. In D2D, users with short distance and high signal-to-interference plus- noise ratio (SINR) ratio may directly communicate with each other without sending the information through base station (BS), BS only sends the control signals to these users. Device-to-device communications in cellular spectrum supported by a cellular infrastructure has the potential of increasing spectrum and energy efficiency as well as allowing new peer-to-peer services by taking advantage of the so called proximity and reuse gains. B. Smart Mobility Management for D2D Communications requires the network’s control on D2D radio resources in order to provide optimized resource utilization, minimized interference among D2D links and from D2D links to cellular link, as well as more robust mobility. Formulate the joint design of beamforming, power control, and interference coordination as a non-convex optimization problem to maximize the signal to interference plus noise ratio (SINR) and solve this problem using deep reinforcement learning. By using the greedy nature of deep Q-learning to estimate future rewards of actions and using the reported coordinates of the users served by the network, the algorithm improves the performance measured by SINR and sum-rate capacity. Power control in voice bearers makes them more robust against wireless impairments, such as fading. It also enhances the usability of the network and increases the cellular capacity power control, and interference coordination, can improve the robustness of these data bearers, improve the data rates received by the end-users, and avoid retransmissions. Algorithm for this joint solution by utilizing the ability of reinforcement learning to explore the solution space by learning from interaction. This algorithm applies to both voice and data bearers alike. and study the overhead introduced as a result of passing information to a central location, which computes the solution through online learning [10].

D2D communication can potentially improve throughput, energy efficiency and fairness. However, reusing cellular spectrum resources will bring severe interference between D2D communication and cellular system due to the random positions of D2D users and cellular users communicating with their respective serving BS. Consider the uplink transmission in hybrid underlying cellular and D2D system, there exists three kinds of interference: interference of D2D links to cellular link and vice visa, interference among D2D links. Therefore, interference management becomes the most important issue in under-laying D2D communications, and interference management techniques such as power control are needed to protect the cellular links. Q-learning is a basic RL algorithm and also an effective way for power control. They are studied both independent and coordinate Q-learning for power control in femto-cell networks An asynchronous dynamic power allocation among femto-cells based on Q-learning to mitigate the interference in the cellular network. Although most literatures focus on femto network ,studied resource allocation and power control problem in D2D communication, and used Q-learning better-reply dynamics to achieve equilibrium in power control problem [11].

New distributed power control algorithm that iteratively determines the signal-to-noise-and-interference-ratio (SINR) targets in a mixed cellular and D2D environment and al- locates transmit powers such that the overall power consumption is minimized subject to a sum-rate constraint. The performance of the distributed power control algorithm is benchmarked with respect to the optimal SINR target setting that we obtain using the Augmented Lag rangian Penalty Function (ALPF) method. Device-to-device (D2D) communications supported by a cellular infrastructure holds the promise of three types of gains. The reuse gain implies that radio resources may be simultaneously used by cellular as well as D2D links thereby tightening the reuse factor even of a reuse-1 system. Secondly, the proximity of user equipment’s (UE) may allow for extreme high bit rates, low delays and low power consumption, the hop gain refers to using a single link in the D2D mode rather than using an uplink and a downlink resource when communicating via the access point in the cellular mode. Additionally, D2D communications may also facilitate new types of wireless peer-to-peer services. However, D2D communications utilizing cellular spectrum poses new challenges, because relative to cellular communication scenarios, the system needs to cope with new interference situations [12].

In general, D2D connections can be divided into two categories, that is, D2D overlay connections and D2D connections based on them [8]. In excessive D2D connections, cellular resources are allocated to D2D users. In contrast, basic D2D communication allows cellular and D2D communication to share the same resources, which can improve spectrum efficiency but cause interference between D2D communication and cellular communication. This interference can be mitigated through energy control and resource allocation. An issue for D2D communications that underpins a cellular uplink to maximize the overall network while meeting Quality of Service (QoS) requirements for both D2D users and cellular users. Based on stochastic geometry, Or it is based on D2D communication and the development of centralized and distributed power control algorithms. Allocate shared resources and power control to maximize the energy efficiency of the D2D communications that underpin cellular networks.

Devices can receive or send. The use of the full-duplex method, which allows devices to transmit and receive at the same time and on the same frequency, due to strong self-interference (SI), has long been considered impractical. Recently, encouraged by advances in SI cancellation techniques[13].

Pattern division multiple access (PDMA) can be applied to several domains, such as the power domain, code domain, space domain or their combinations. PDMA uses non-orthogonal patterns at the transmitter side for less interference among multiple users. Implementation of multiplexing in code domain is similar to low-density signature (LDS)-CDMA presented by Al-Imarietal. Motivation for developing uplink power control Mobile users adapt to a time varying channel by regulating their transmitted power. The power control decision of a user eliminates interference for other users and provides an acceptable network connection. Also, the channel capacity is increased by iterative power adjustments. Thus, reduced interference and improved spectral efficiency allow us to accommodate massive connectivity by means of NOMA, satisfying the core objectives of future 5G networks [14].

Power control has been extensively studied in recent years, especially for CDMA systems. It has mainly been used to reduce co-channel interference and to guarantee the signal-to-interference ratio (SIR) of ongoing connections, resulting in a higher utilization and/or better quality of service (QoS). From the viewpoint of practical applications, distributed power-control schemes are of special interest and importance. In practice, although achieving satisfactory QoS is important for users, they may not be willing to achieve it at arbitrarily high power levels, because power is itself a valuable commodity. Cutting power consumption not only prolongs the life of the battery and alleviates health concerns about electromagnetic emission, but also decreases the interference to other users. In addition, different users may have different views of power consumption. For example, a handset user is more concerned about the power than a user with a vehicle-mounted device. We can capture a user’s view of power consumption by also considering the cost of power [15].

The problem of finding the minimum-length TDMA frame of a power-controlled wireless network subject to traffic demands and SINR (signal- to-interference-plus-noise ratio) constraints. Formulate the general joint link scheduling and power control problem as an integer linear programming (ILP) problem. present a computationally efficient heuristic algorithm, called the Increasing Demand Greedy Scheduling (IDGS) algorithm, to solve the general ILP problem. In addition, using a column generation (CG) method as an augmentation to IDGS to further improve its performance. to avoid detrimental interference, the transmissions on wireless links in the proximity of each other need to be properly scheduled. In an effort to boost network capacity [16].

5G radio must support Ultra Reliable Low Latency Communication (URLLC) use cases, which include applications such as traffic safety, remote touch control, distribution automation in smart grid. Ultra Reliable Low Latency Communications (URLLC) delivers the most challenging use cases for 5G mobile networks. Traditionally, the focus on mobile broadband has been to improve system throughput for high-speed data traffic. However, URLLC's optimization criteria should focus on achieving small packet transmissions under strict goals such as 99.999% reliability within 1 millisecond. Investigate the power control of non-grant URLLC transmissions through comprehensive system-level simulations in an urban outdoor scenario. Initially compare different OLPC settings with full partial path loss compensation. Then evaluate whether the ability that enhances retransmission can reduce the probability of packet delays under the 1 MS limitation. Non-orthogonal multiple access (NOMA) is applied to improve the capacity of a system by servicing a huge number of devices [17] .

PC method makes use of the evolutionary game theory (EGT) model to adaptively adjust the transmitted power level of the users which helps in mitigating user interference. A successive interference cancellation (SIC) receiver is applied at a base station (BS) in order to separate the users' signals [18].

CHAPTER THREE

METHODOLOGY

3.1 System Model:

3.1.1 Mathematical Model:

- **FRACTIONAL UPLINK POWER CONTROL:**

By allowing the UEs at the cell center to transmit at lower power than the UEs at the cell edge, uplink PC has been recognized since the start of cellular networks as an efficient way to manage intra-cell interference and balance the different SINR conditions of the UEs . Following the current 5G standardization direction, we focus in this work on the FPC mechanism already developed for LTE. And numerically optimize its parameters as a function of different massive MIMO configurations. Our aim is to verify its effects on the downlink system performance, with particular attention at the cell edge UEs.

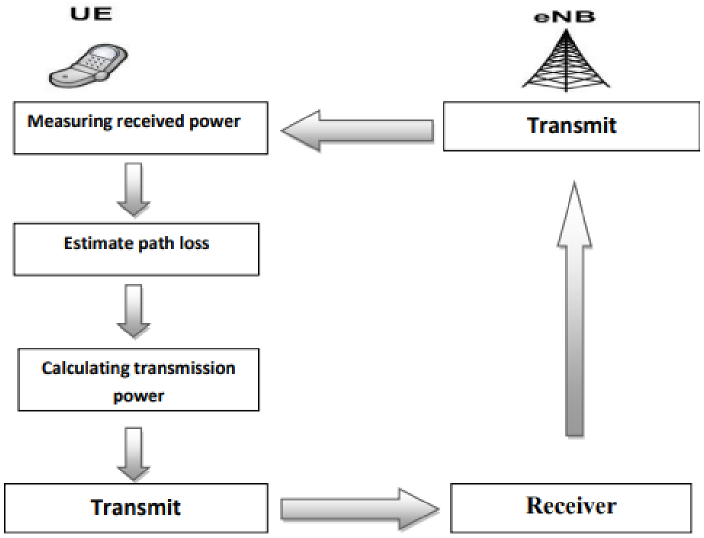

Figure 3-1: Block diagram of steps involved in setting uplink Fractional power

The Figure 3-1 shows a block diagram of the steps involved in setting the uplink transmit power using the open loop power control. Estimate of the path loss is obtained after measuring reference symbol received power (RSRP) and then the calculation for transmission power. With open-loop FPC, the power P_k used by UE k to transmit power can be written, in logarithmic scale, as

$$P_k = \min\{P^{(UE)}, P_0 + 10\log_{10}(N) + \alpha L_k\} \dots\dots\dots\dots\dots\dots (3.1)$$

where $P^{(UE)}$ = 23 dBm is the maximum transmit power at the UE, L_k is the large scale fading attenuation between UE k and its anchor BS (which includes path-loss, shadowing and antenna element gain), P_0 is a parameter used to control the per-RB SNR target, and $\alpha \in [0, 1]$ defines the fractional compensation factor of the large scale fading attenuation. By properly setting the two parameters P_0 and α in P_k, different working modes can be obtained.

• α = 0: In this case, we impose that all the UEs transmit at the same power, and the UE transmit power is mainly regulated by the value of P_0. In the following, as a baseline case, we will force all the UEs to transmit at full power in p_k i.e $p_k = p^{(UE)}$,$\forall k$, and refer to this case as no power control (noPC).

•α= 1: In this case, FPC tries to fully compensate the large scale fading attenuation. Because of the constraint on the maximum transmit power $P^{(UE)}$, this policy is such that some UEs will scale down their transmit power to achieve a certain SNR target, which depends on P_0, whereas the remaining UEs will all transmit at maximum power. One of the limits of this configuration is that, if the value of P_0 is too high, a large number of UEs will transmit at maximum power generating a high level of interference and pilot contamination.

• 0 < α <1: This corresponds to the real application of FPC. A higher value of in α traduces less difference in the uplink SNR, i.e., it guarantees more fairness among the UEs, but needs to be coupled with a lower value of $P_0\ in$ order to avoid a strong level of interference in the network.

Compare between two reuse factors in the pilot sequence allocation to the UEs, the UEs transmit uplink pilot sequences to allow channel estimation at the BSs. With reuse 1 (R1), we have the same set of pilot sequences is reused by all the sectors in the network. It introduces strong pilot contamination in the system. With reuse 3 (R3), we have, orthogonal pilot sequences are allocated among the three sectors of the same site. In an attempt to limit the impact of pilot contamination.

- **Path loss Equation**

PL=32.25+20log (fc)+20log(d)…………………….(3.2)

Where:

Fc ≡ frequency in GHz

d ≡ distance in meter

- **Power Rx**

Pr = $Pt/PL^{\alpha-1}$……………………………………...(3.3)

Where:

Pt ≡ power transmit .

PL ≡ Path loss.

Alfa ≡ fractional compensation factor.

3.2 Performance Metrics:

- **Signal to Interference plus Noise Ratio (SINR):**

$$\gamma_u = \frac{\text{Su}}{(I_{ext}+N)} \text{ ………………………….(3.4)}$$

Where N is the thermal noise power in the system bandwidth. The received power of u at gNB can be written (in mW):

$$S_u = p_0 g_{u,0}^{1-\alpha} \text{ ………………………..(3.5)}$$

Where p_0= 10 log(p_0) ($p_0$is the target received power in dBm and $p_0$in mW) and $g_{u,b}$ is the path-gain between UE u and gNB b.

On one RB, user u suffers from the interference of a single UE in each of the network cells.

In absence of inter-cell coordination, interfering UE can be located anywhere in the interfering cells. External interference can thus be written:

$$\mathrm{I}_{\mathrm{ext}} = \sum_{b=1}^{B-1} p_0 g_{u,(b),b^{g}}^{-\alpha}\ g_{v(b),0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

Where v(b) designates the UE scheduled by gNB b.

- **Throughput:**

$$\mathrm{TH}= \sum_{t=0}^{T} \mathrm{B} * \mathrm{Rc} * \mathrm{M} \ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

Where:

TH ≡ is Throughput

B ≡ is Bandwidth

RC ≡ is Code Rate

M ≡ is Logarithm of actual data rate

T ≡ is the total time of transmit

- **Spectral efficiency formula(SE):-**

$$SE = \frac{Data\ rate\ or\ Throughput(bps)}{Channel\ Bandwidth(HZ)} \ldots\ldots\ldots\ldots\ldots (3.8)$$

CHAPTER FOUR

SIMULATION RESULTS AND DISCUSSION

4.1 Simulation Description:

A path loss propagation model was employed to evaluate the performance of fractional power control. A hexagonal pattern is used with 10 uniformly distributed users per cell, where each cell has the same number of users. The target gNB experiences strong inter cell interferers from neighboring cells. MATLAB simulation used to simulate the algorithms and equation founded in the previous chapter. We assume a hexagonal deployment with three sites, an inter-site distance of 500 m, three sectors per site and BS antenna array 4 x 4. Each BS transmits with a maximum power of 46 dBm over a system bandwidth of 10 MHz operating at a carrier frequency of 2 GHz: we assume the band to be divided into M = 128 resource blocks (RBs) with a bandwidth of 180 kHz each. The simulation parameters are given in Table1.

TABLE3-1: Simulation Parameters

Parameter	**Description**
Mobiles	10

BS inter-site distance	500 m
Carrier frequency	2 GHz
BS max Transmit Power	46 dBm
Maximum UE Transmit Power	23 dBm
Noise	-174 dBm
Theta	20
Bandwidth	10 MHZ
M	128
BW per RB	180 KHz
SF	8
I	50

Compared to a baseline scheme where each UE just transmits at maximum power its assigned pilot sequence.

4.2 Results and Discussion:

We present numerical results to verify the theoretic analyses and simulation results of The Power Control (PC) which is measured by Signal interference to Noise ratio (SINR) and Spectral Efficiency (SE) and Throughput (TH).

To better understand the previous results, we show in Fig.1 and Fig. 2 the cumulative distribution function (CDF) of the UE transmit power P_k and of the resulting channel estimation SINR at the BS, respectively, for the same setup. Observe in the noPC there UEs is transmitted at the same power p_k . In α=0.8 result in lower power distribution this is highly beneficial from a UEs power consumption point of view , with a higher transmit power reduction as expected in FPC0.8 because of the lower value of P0 the difference is in the $p_k$for the 50% probability up to 5dBm and In α=0.5 up to 12dBm , of difference are obtained whereas at high values they tend to be quite similar and the amount of power limited UEs is the same for both case . It is Visualized as an arrived to a probability op 0.89 in 23dBm.

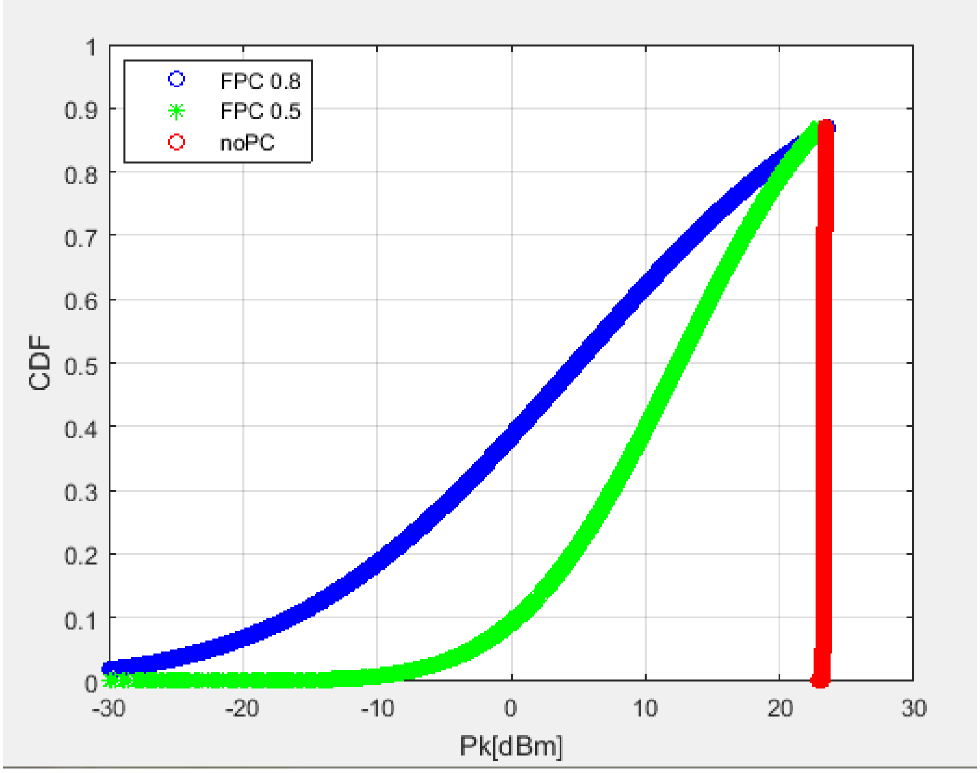

Figure 4.1: CDF of the UE transmit power p_k with M=128 And R3

In fig.2, FPC allows to strongly reduce pilot contamination, thus improving the channel estimation SINR at the BS and the fairness among the UEs. When compared to noPC, we observe a gain in the one percentile of the channel estimation SINR of about 19-20dB achieved by $\mathrm{FPC}_{0.5}$ and $\mathrm{FPC}_{0.8}$ respectively.We observe for the 55% probability SINR up to 10dB when α=0.5, when α=0.8 and noPC SINR equal 5dB.for the 99% probability SINR up to 15dB when α=0.8, 29dB when α=0.5, for the 92% probability SINR the noPC=30dB.

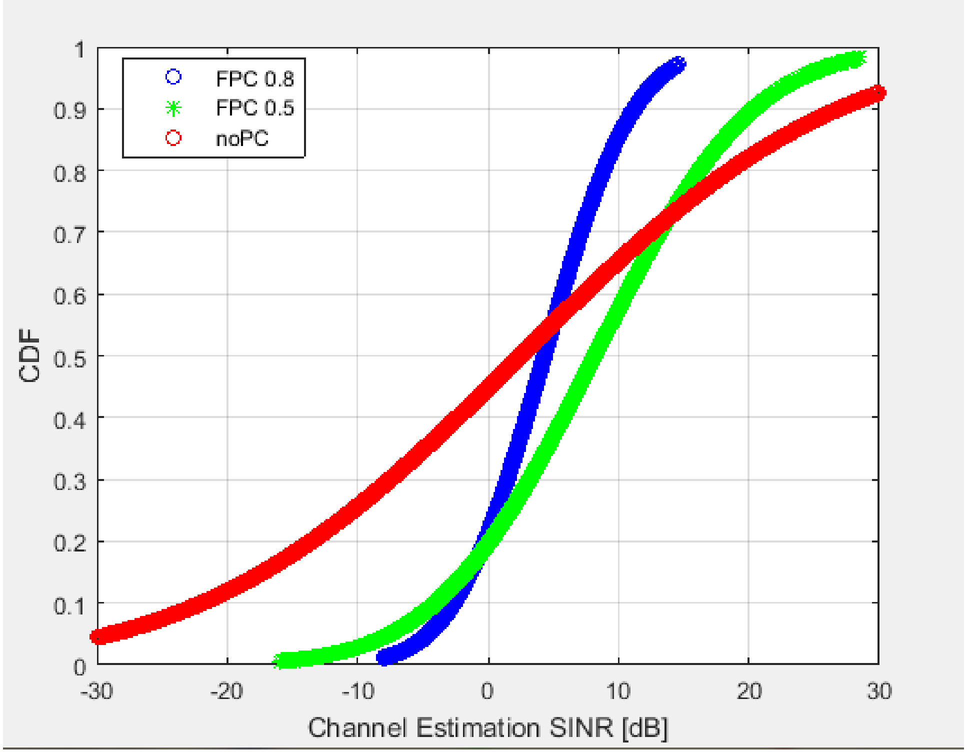

Figure 4.2: CDF of the channel estimation SINR with M=128 And R3.

In fig.3 we observe that depending on the value of p_0 and optimal value of α these parameters are able to specify the values required to provide the highest CSE value.

when p_0 = -120 dBm the value of α=0.9 ,

when p_0 = -100 dBm the value of α=0.75,

when p_0 = -80 dBm the value of α=0.7,

when p_0 = -40 dBm the value of α=0.3,

when p_0 = -20 dBm the value of α=0.2

when p_0= -60 dBm and α=0.5 we observe the maximize the CSE .

With full compensation of the large scale fading attenuation, this specific FPC configuration s outperformed by baseline noPC in the CSE.

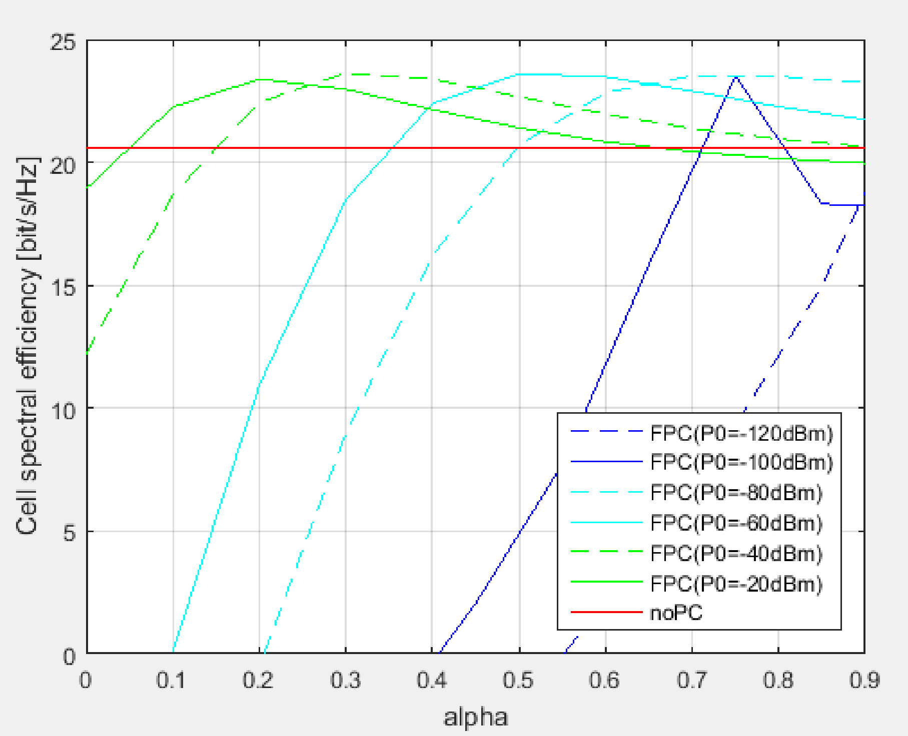

Figure 4.3: Average cell spectral efficiency for different values of $P_0$and α With M=128, and R3.

In fig.4 we able different value for p_0 and α ,observe to get a maximize the CBT must be choose the lower value of p_0 and a higher value of α .

when p_0= -20 and α= 0.2

when p_0= -40and α= 0.1

when p_0= -60 and α= 0.3

when p_0= -80 and α= 0.4

when p_0= -100 and α= 0.5

when p_0= -120 and α= 0.6 that is more favorable for the CBT.

With full compensation of the large scale fading attenuation, this specific FPC configuration s outperformed by baseline noPC in the CBT.

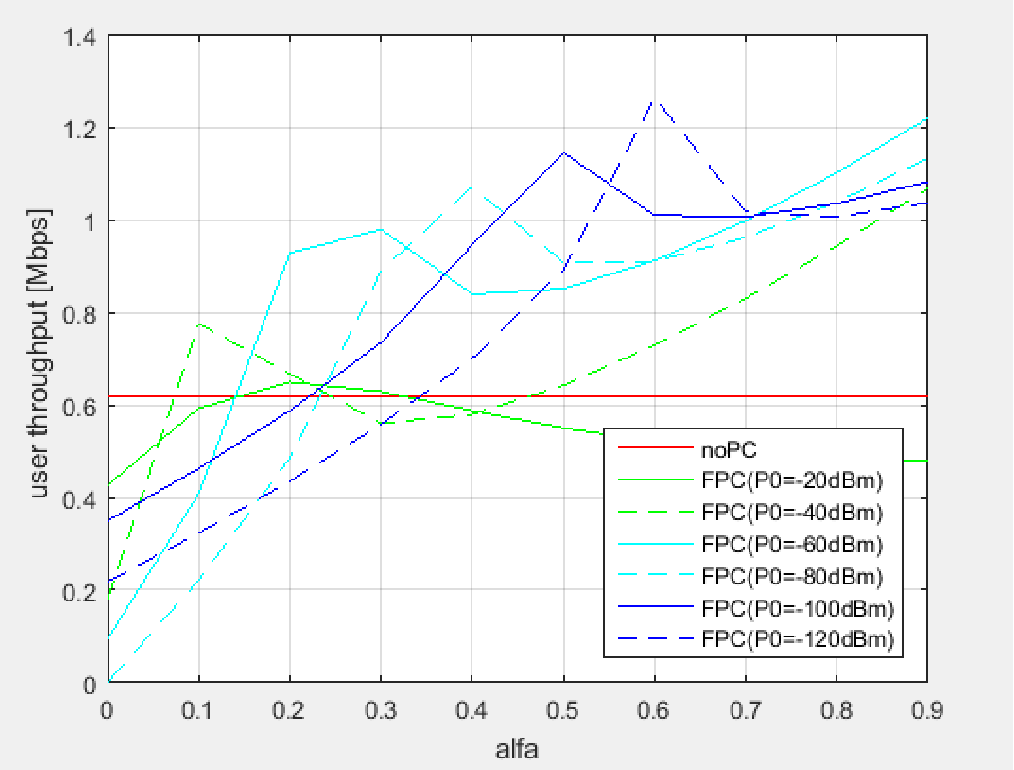

Figure 4.4: The UE throughput for different values of $P_0$and α With M=128, and R3.

In fig.5 and fig.6 we report the average CSE and CBT versus α in a different setup, which consider M=64, both R1 and R3. In fig.5 We Observe that α=0.4 good choses for P_0=-60 and α=0.9 for P_0=-100 . In fig.6 We Observe that α=0.4 good choses for P_0=-60 and α=0.8 for P_0=-100. We observe in fig.5 and fig.6 noPC R3 is higher than R1 and this is because pilot contamination is limiting more the system performance with R1 than R3.

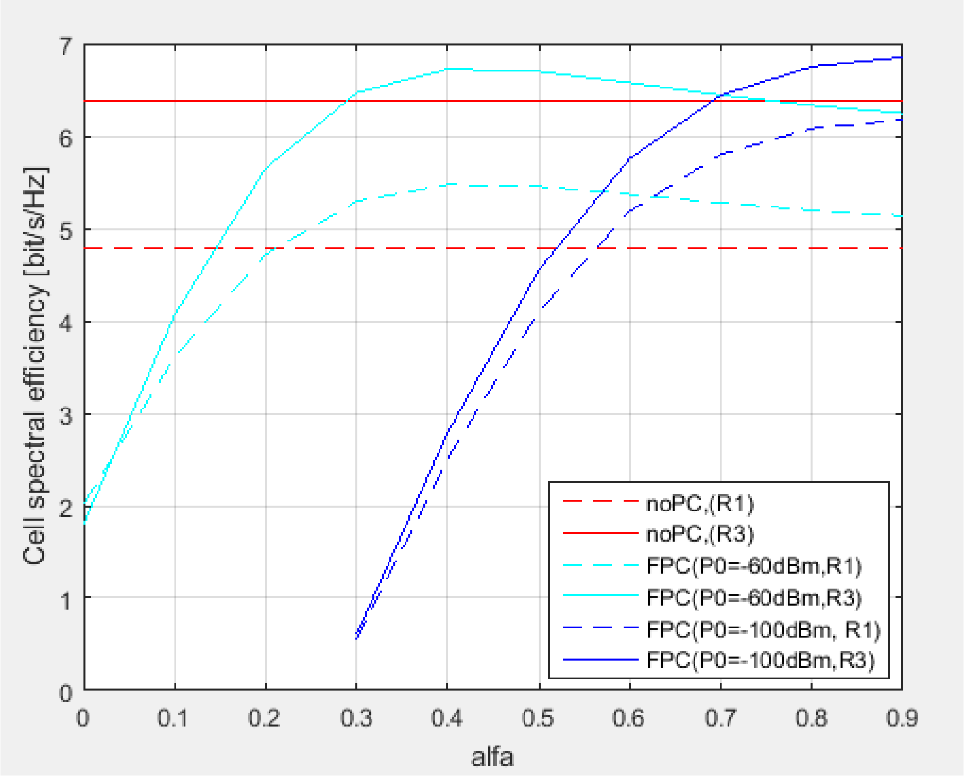

Figure 4.5: Average cell spectral efficiency for different values of $P_0$and α With M=64, comparing R1 against R3.

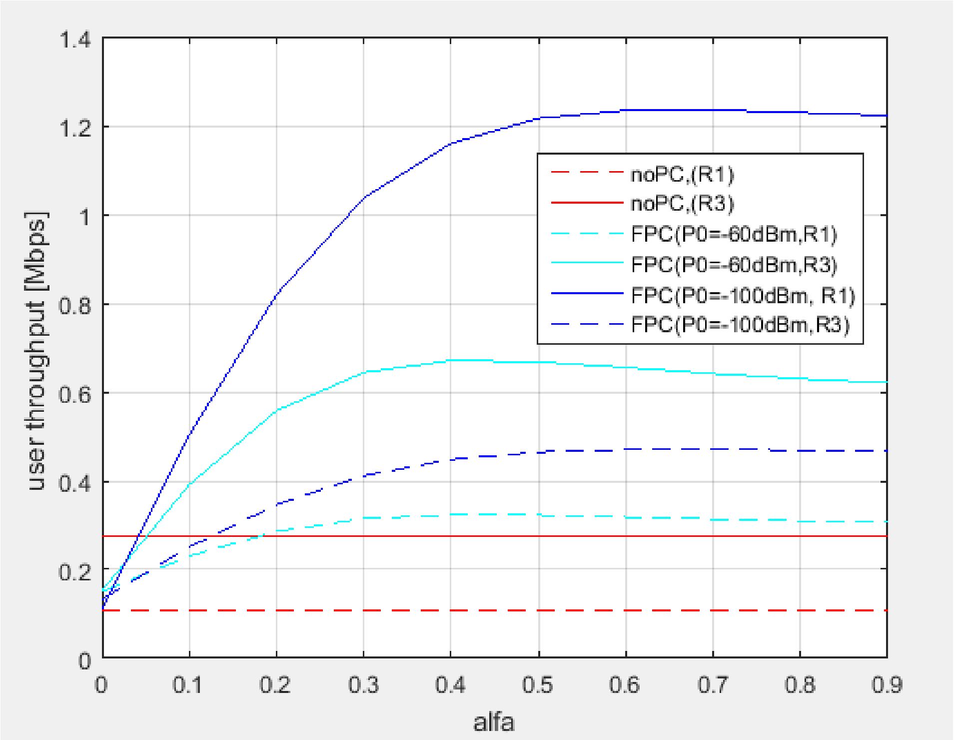

Figure 4.6: The UE Throughput for different values of $P_0$and α With M=64, comparing R1 against R3.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION:

5.1 Conclusion

The research is focused on the power control of a 5G cellular system. the power control is specified to function both with open loop and closed loop mechanisms. The open loop functioning is based on the Fractional Power Control technique which is designed to allow for full or partial compensation for the path loss. The uplink power control is an important issue in improving many problems related to transmitting power and using concept of FPC to provides huge gains and improve the throughput, interference and spectral efficiency when compared to a baseline scheme with all the users transmitting at maximum power. There are two parameters to tuning the power transmit per UE it is α and $P0$ we have concluded that the configuration with P0=−60dBm andα= 0.5 represents a good solution for the cell spectral efficiency, whereas better performance in the cell border throughput can be obtained with P0= −120dBm and α= 0.6. Finally, we have observed that FPC becomes essential in interference limited systems. A higher value of in α traduces less difference in the uplink SNR, it guarantees more fairness among the UEs, but needs to be coupled with a lower value of $P0\ in$ order to avoid a strong level of interference in the network. Thus, FPC supports different deployment scenarios. FPC enables tradeoff between the cell edge throughput and cell center throughput. It also decreases inter cell interference and reduces the power consumption at the UE.

5.2 Recommendation

- We recommend in future work test the effect the uplink fractional power control in path loss and energy efficient.
- We used MATLAB simulation so we could not determine environment system setup, we recommend in future work to use reality show program like the OPNET network simulator.

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APPENDICES A-C

Appendix A: CDF of the UE transmit power $\boldsymbol{p_k}$ with M=128 And **R3**

```
clc;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% I0 =-157;%dBm/Hz
distance=unidrnd(R,1,mobiles);


%------------------------------------------
lamda=(3*10^8)/f;
%for j=1:t
for i=1:mobiles
    alfa(i)=(i-1)*0.0001;
%-------------------------------------
lr(i)=20*log10((4*pi*distance(i))/lamda);%dBm - Path loss
pl(i)=lr(i)+Atheta+SF;


%-------------------------------------------------------------
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgc(i)=1/pl(i);%path gain calculation
psdc(i)=Poc+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%-------------------------------------------------------------
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgd(i)=1/pl(i);%path gain calculation
psdd(i)=Pod+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%-------------------------------------------------------------
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgf(i)=1/pl(i);%path gain calculation
psdf(i)=Pof+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

end


wpc=mean(psdc);
wepc= std(psdc(:));
cdpc=cdf('Normal',psdc,wpc,wepc);
wpd=mean(psdd);
wepd= std(psdd(:));
cdpd=cdf('Normal',psdd,wpd,wepd);
wpf=mean(psdf);
wepf= std(psdf(:));
cdpf=cdf('Normal',psdf,wpf,wepf)
```

Appendix B: CDF of the channel estimation SINR with M=128 And R3

```
distance=unidrnd(R,1,mobiles);

%-------------------------------------------
lamda=(3*10^8)/f;

for i=1:mobiles
    alfa(i)=(i-1)*0.0001;
%PL=20*log10((4*pi*d)/lamda); eguation of path loss in dbm
lr(i)=20*log10((4*pi*distance(i))/lamda);%dBm - Path loss
pl(i)=lr(i)+Atheta+SF;% fading attenuation between UE k and its
anchor BS

%-------------------------------------------------------------

%psd=Po+alfa*pl+10*log(N);%[dBm]- using path loss
pgc(i)=1/pl(i);%path gain calculation
psdc(i)=Poc+(alfa(i)*pl(i))+10*log(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxc(i)=psdc(i)*pgc(i);%psdrx=psdtx/pl
sc(i)=rxc(i)/(I+n);%


%-------------------------------------------------------------

%psd=Po+alfa*pl+10*log(N);%[dBm]- using path loss
pgd(i)=1/pl(i);%path gain calculation
psdd(i)=Pod+(alfa(i)*pl(i))+10*log(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxd(i)=psdd(i)*pgd(i);%%psdrx=psdtx/pl
sd(i)=rxd(i)/(I+n);%


%-------------------------------------------------------------

%psd=Po+alfa*pl+10*log(N);%[dBm]- using path loss
pgf(i)=1/pl(i);%path gain calculation
psdf(i)=Pof+(alfa(i)*pl(i))+10*log(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxf(i)=psdf(i)*pgf(i);%%psdrx=psdtx/pl
sf(i)=rxf(i)/(I+n);%


end


wsc=mean(sc);
wesc= std(sc(:));
cdsc=cdf('Normal',sc,wsc,wesc);
wsd=mean(sd);
wesd= std(sd(:));
cdsd=cdf('Normal',sd,wsd,wesd);
```

```
wsf=mean(sf);
wesf= std(sf(:));
cdsf=cdf('Normal',sf,wsf,wesf);
```

Appendix C: Average cell spectral efficiency for different values of P_0 and α with M=128, and R3. The UE throughput for different values of $P_0$and α With M=128,and R3. Average cell spectral efficiency for different values of $P_0$and α With M=64, comparing R1 against R3. The UE Throughput for different values of $P_0$and α With M=64, comparing R1 against R3

```
%------------------------------------------

%for j=1:t
for i=1:mobiles
    alfa(i)=(i-1)*0.1;
%-------------------------------------
lr(i)=32.25+(20*log10(fc))+(20*log10(d));%dBm - Path loss
pl(i)=lr(i)+SF+Atheta;




%-------------------------------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pga(i)=1/(pl(i).^(alfaa-1));%path gain calculation
psda(i)=Poa+(alfaa*pl(i));%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxa(i)=psda(i)*pga(i);%psdrx=psdtx/pl
rxai(i)=psda(i)*(1/(pl(i).^(alfa(i)-1)));%psdrx=psdtx/pl
sa(i)=rxa(i)/(I+n);%
sai(i)=rxai(i)/(I+n);
cfa(i)=(bweff*v*M*bwprb*log2(1+(sa(i)/seff)));%[Bps] throuput
SEA(i)=cfa(i)/BW;%specrum effieciency
cfaR1(i)=(bweff*v*MR1*bwprb*log2(1+(sa(i)/seff)));%[Bps] throuput R1
SEAR1(i)=cfaR1(i)/BW;%specrum effieciency R1
 cfaR3(i)=(bweff*v*MR3*bwprb*log2(1+(sa(i)/seff)));%[Bps] throuput
R3
SEAR3(i)=cfaR3(i)/BW;%specrum effieciency R3
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgb(i)=1/(pl(i).^(alfa(i)));%path gain calculation
psdb(i)=Pob+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxb(i)=psdb(i)*pgb(i);%psdrx=psdtx/pl
sb(i)=rxb(i)/(I+n);%
cfb(i)=(bweff*v*M*bwprb*log2(1+(sb(i)/seff)));%[Bps] throuput
SEB(i)=cfb(i)/BW;%specrum effieciency
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgc(i)=1/(pl(i).^(alfa(i)));%path gain calculation
psdc(i)=Poc+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxc(i)=psdc(i)*pgc(i);%psdrx=psdtx/pl
sc(i)=rxc(i)/(I+n);%
cfc(i)=(bweff*v*M*bwprb*log2(1+(sc(i)/seff)));%[Bps] throuput
SEC(i)=cfc(i)/BW;%specrum effieciency
%-------------------------------------------------------------
```

```
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgd(i)=1/(pl(i).^(alfa(i)));%path gain calculation
psdd(i)=Pod+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxd(i)=psdd(i)*pgd(i);%%psdrx=psdtx/pl
sd(i)=rxd(i)/(I+n);%
cfd(i)=bweff*v*M*bwprb*log2(1+(sd(i)/seff));%[Bps]throuput
SED(i)=cfd(i)/BW;%specrum effieciency
cfdR1(i)=bweff*v*MR1*bwprb*log2(1+(sd(i)/seff));%[Bps]throuput
SEDR1(i)=cfdR1(i)/BW;%specrum effieciency
cfdR3(i)=bweff*v*MR3*bwprb*log2(1+(sd(i)/seff));%[Bps]throuput
SEDR3(i)=cfdR3(i)/BW;%specrum effieciency
%-------------------------------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pge(i)=1/(pl(i).^(alfa(i)));%path gain calculation
psde(i)=Poe+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxe(i)=psde(i)*pge(i);%psdrx=psdtx/pl
se(i)=rxe(i)/(I+n);%
cfe(i)=(bweff*v*M*bwprb*log2(1+(se(i)/seff)));%[Bps] throuput
SEE(i)=cfe(i)/BW;%specrum effieciency
%--------------------------------------
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgf(i)=1/(pl(i).^(alfa(i)-1));%path gain calculation
psdf(i)=Pof+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxf(i)=psdf(i)*pgf(i);%%psdrx=psdtx/pl
sf(i)=rxf(i)/(I+n);%
cff(i)=(bweff*v*M*bwprb*log2(1+(sf(i)/seff)))/2;%[Bps] throuput
SEF(i)=cff(i)/BW;%specrum effieciency
cffR1(i)=(bweff*v*MR1*bwprb*log2(1+(sf(i)/seff)))/2;%[Bps] throuput
SEFR1(i)=cffR1(i)/BW;%specrum effieciency
cffR3(i)=(bweff*v*MR3*bwprb*log2(1+(sf(i)/seff)))/2;%[Bps] throuput
SEFR3(i)=cffR3(i)/BW;%specrum effieciency
%--------------------------------------
%psd=Po+alfa*pl;%[dBm]- using path loss
pgg(i)=1/(pl(i).^(alfa(i)-1));%path gain calculation
psdg(i)=Pog+(alfa(i)*pl(i))+10*log10(50);%[dBm] - using path gain

%si=psd(i)/(I+n);%SINR ot user i
rxg(i)=psdg(i)*pgg(i);%%psdrx=psdtx/pl
sg(i)=rxg(i)/(I+n);%
cfg(i)=(bweff*v*M*bwprb*log2(1+(sg(i)/seff)))/2;%[Bps] throuput
SEG(i)=cfg(i)/BW;%specrum effieciency
end

wsa=mean(sai);
wesa= std(sai(:));
cdsa=cdf('Normal',sai,wsa,wesa);
wsd=mean(sd);
wesd= std(sd(:));
cdsd=cdf('Normal',sd,wsd,wesd);
wsf=mean(sf);
wesf= std(sf(:));
cdsf=cdf('Normal',sf,wsf,wesf);
```

```
cdpa=0:1:9;
wpd=mean(psdd);
wepd= std(psdd(:));
cdpd=cdf('Normal',psdd,wpd,wepd);
wpf=mean(psdf);
wepf= std(psdf(:));
cdpf=cdf('Normal',psdf,wpf,wepf);
```