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Performance Evaluation of Self-Organizing Relays in LTE

A Research Submitted in Partial fulfillment for the Requirements of theDegree of B.Sc. (Honors) in Electronics Engineering

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بسم الله الرحمن الرحيم

قال تعالى:

(اللَّهُ نُورُ السَّمَاوَاتِ وَالأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ
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اللَّهُ الأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ)

صدق الله العظيم

آية رقم 35 من سورة النور

Dedication

To Prophet Mohammed 'Peace be upon him'…

To our beloved parents...

To all Electronic EngineeringStudents...

Acknowledgement

First and for most, we would like to THANK GOD for giving us the strengthand courage through all the hard times and for blessing us with friends and family that always have been by other side and helping us when we needed it the most. Well, praising God goes without saying for us, for it will be a very long list of “Thank You God ...”, even if I had to mention very few of them.

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Thanks to all the Professors, Academic staff, class mates and friends at SUST,for all the knowledge and help we received from you; and for all the good times we has..

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Thank You very much.

Abstract

The increasing complexity of cellular network management and inhomogeneous Traffic patterns demand an enhanced level of automation in most of the network deployment and operational phases, it can not only simplify the complex network management tasks but also improve the user quality of experience by efficient resource utilization and minimizing the network response time to the network and environmental changes. In this thesis, we study the self-organized coverage and capacity optimization of cellular mobile networks using antenna tilt adaptations. We propose to use machine learning for this problem in order to empower the individual cells to learn from their interaction with the local environments. This helps the cells to get experienced with the passage of time and improve the overall network performance. We model this optimization task as a multi-agent learning problem using Fuzzy Q-Learning, which is a combination of Fuzzy Logic and Reinforcement Learning-based Q-Learning. Fuzzy logic simples the modeling of continuous domain variables and Q-learning provides a simple yet efficient learning mechanism. We study different structural and behavioral aspect of this multi-agent learning environment in this thesis and propose several enhancements for the basic FQL algorithm for this particular optimization tasks. Especially, we look into the effect of parallel antenna tilt updates by multiple agents (noise) to overcome the effect of noise environment on the learning convergence, the effect of selfish and We Develop this Work to get performance evolution in SINR, Data rate, Throughput, Spectrum efficiency and Delay Transmission.

المستخلص

التعقيد المتزايد للإدارة الشبكة الخلوية وأنماط حركة المرورغير متجانسةالطلبرفع مستوبالتشغيل التلقائي في أغلبنشرشبكةوالمراحل التنفيذية، فإنه لا يمكن تبسيطفقطمهام إدارةشبكة معقدةولكن أيضاتحسين نوعيةالمستخدممنالخبرة من خلالاستخدامالموارد بكفاءةوالتقليل منزمن الاستجابةالشبكة إلشبكةوالتغيرات البيئية .في هذه الأطروحة، ندرس التغطية والقدرة الأمثل للتنظيم الذاتي للشبكات المتنقلة الخلوية باستخدام التكيف في إمالة الهوائي .نقترح لاستخدام التعلم الآلي لهذه المشكلة من أجل تمكين الخلايا الفردية للتعلم من تفاعلها مع البيئة المحلية .وهذا يساعد الخلايا للحصول على الخبرة مع مرور الوقت وتحسين الأداء الكلي للشبكة.تم اعتماد تقنيه التغيظ (فظي)، الذي هو مزيج من المنطق الغامض، وبناء التعلم من التعزيز والتعلم .المنطق الضبابي البسيط نموذجة متغيرات نطاق مستمرة، ويقدم - التعلم آلية التعلم بطريقه بسيطة وفعالة .ندرس الجانب الهيكلي والسلوكي مختلفة في بيئة تعليمية متعددة ، واقتراح العديد من التحسينات لخوارزمية FQL الأساسية لهذه المهام الأمثل معينة .خاصة، ونحن نتطلع إلى تأثير موازية لضبط إمالة الهوائي من قبل البيئة (الضوضاء)للتغلب على تأثير البيئة ، تم الوصول الي نتائج هذا العمل للحصول على تطور الأداء في الاشاره المستقبله، معدل ارسال البيانات، الإنتاجية والكفاءة الطيف الترددي والتأخير في الزمن.

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List of Abbreviations

LTE : Long Term Evolution
4G : Fourth-Generation
CAPEX : CAPitalEXpenditures
OPEX : Operational EXpenditures
HetNets : Heterogeneous Networks
QoS : Quality-of-Service
SON : Self-Organizing Network
FQL : Fuzzy Q Learning algorithm
3GPP : Third Generation Partnership Project
DAS : Distributed Antenna Systems
eICIC : The enhanced Inter Cell Interference Coordination
CRE : Cell Range Expansion
ABS : Almost Blank Subframe
CDMA : Code Division Multiple Access
FDD : Frequency Division Multiplexing
TDD : Time Division Multiplexing
SAE : System Architecture Evolution
RAN : Radio Access Network
eNodeB : evolved NodeB
RNC : RadioNetwork Controller
HSPA : High Speed Packet Access
GPRS : General Packet Radio Service

SGSN : Gateway GPRS Support Node

S-GW : SAE Gateway

UE : User Equipment's

AGW : Access Gateway

MME : Mobility Management Entity

UPE : User Plane Entity

MIMO : Multiple Input Multiple Output

OFDM : Orthogonal Frequency Division Multiplexing

eNB : Evolved Node-B

BS : Base Station

MS : Mobile Station

UE : User Equipment's

RS : Relay Station

ICIC : Inter-Cell Interference Coordination

MDP : Markov Decision Process

OFDMA : Orthogonal Frequency Division Multiple Access

RACH : Random Access Channel

CCO : Coverage and Capacity Optimization

RL : Reinforcement Learning

LIST OF SYMBOLS

α - Degree of Truth of Fuzzy Rule

β - Learning Rate

γ - Discount Factor

µ - Degree of Membership

π - Action Policy

ρ - Reward Function

A - Set of All Possible Actions

a - Aggregated Action of All Activated Fuzzy Rules

ATc - Antenna Tilt of Cell c

E {...} - Expected Value

L - Fuzzy Label

q - Q-value of fuzzy rule and action pair

o - Action of Fuzzy Rule

P - State transition probability

r - Reward

s_c - Continuous Domain State of Cell c

E_C^{Center} - Center Spectral Efficiency of Cell c

SE_c^{edge} - Edge Spectral Efficiency of Cell c

SQ - State Quality

SQ_{avg} - State Quality Average of All Cells

Q - Q-value of continuous domain state-action pair

V - Value Function

X - Set of All Possible States

SE - Spectral Efficiency

UEs - Mobile user equipment’s

ATc - The current antenna tilt of the cell

$L^{n,m}$ - The mth label defined over the nth state vector component ts^n.

M	Total number of labels define for each fuzzy variable
P_{Rx}	Received power in dBm.
P_{Tx}	Transmitted power in dB
P_L	Pathloss in dB
SF	Shadow fading or large scale fading in dB.
G_{Ant}	Maximum antenna gain in dBi.
G_{Dir}	Directional gain of antenna.
φ	The horizontal angle between the main beam direction and the mobile user.
$\theta_{e_{tilt}}$	The electrical tilt angle and SLA_V is the side lobe attenuation.
G_{Ant} .	Received power calculation as
G_{Dir}	The directional gain
$G_H(\varphi)$	The horizontal antenna gain in dB.
G_V (θ)	The vertical antenna gain in dB.
φ& θ	The angles between the antenna and the mobile user in horizontal and vertical direction respectively.
FBR	The front to back ratio.
PR	Power Receiver in Mobile in (dB).
G	Antenna Gain
N	Noise in dB
I	Interference in dB
DR	Data Rate in dB
BW	Bandwidth in Hz
M	Type of modulation.[Number of bits per symbol].
C	Coding rate.
TH	Throughput in bit/sec
N	Number of Cells

ChapterOne

Introduction

1.1 Preface

In LTE-Advanced focus is on higher capacity:The driving force to further develop LTE towards LTE–Advanced - LTE Release10 was to provide higher bitrates in a cost efficient way and, at the same time, completely fulfill the requirements set by ITU for IMT Advanced, also referred to as 4G [1].

Relaying is one of the features being proposed for the 4G LTE Advanced system. The aim of LTE relaying is to enhance both coverage and capacity.The idea of relays is not new, but LTE relays and LTE relaying is being considered to ensure that the optimum performance is achieved to enable the expectations of the users to be met while still keeping OPEX within the budgeted bounds.

Relay stations are an important component of heterogeneous networks (HetNets) introduced in the LTE-Advanced technology as a means to provide very high capacity and QoS all over the cell area. In this project develops a self-organizing network (SON) feature to optimally allocate resources between backhaul and station to mobile links. Static and dynamic resource sharing mechanisms are investigated [2].

1.2 Problem statement

There are several problems faced LTE relay. Due to the variation in the capacity of base stations and the coverage area. The BSs in the network varies in parameter due to the network and environmental dynamics and that effects like (Overloaded Cells, Planning Errors / Changes in Terrain, or Failing BSs), all that also variations in user traffic patterns also create some congestion problems in the network and affect the Quality-of-Service (QoS) of the users. That need for network optimization engineer to either fine tune the results of these optimizations in the operational network or to adjust the parameters of the optimization algorithms.

1.3 Proposed Solution

Self-organizing for Coverage and Capacity Optimization helps to empower the cellular mobile in LTE. The cell Networks must be able to adjust the self, recover the problem, and return to the Target Coverage-Capacity Plan in LTE. Self-organizing network using fuzzy-Q-learning algorithm can provide such optimization.

1.4 Objectives

The objectives of this thesis are:

- To maximize the network capacity while ensuring that the targeted service areas remain covered.
- To simulate fuzzy Q learning algorithm (FQL) for antenna tilt adaptation to optimize coverage and capacity.
- To optimize coverage and capacity with minimal human intervention.

1.5 Methodology

Used fuzzy logic with MATLAB software to simulate FQL algorithm and test its effectiveness in the environment to optimize coverage and capacity(self-optimization). A MATLAB code will be written to simulate the system performance.

1.6 Thesis organization

The rest of the thesis is organized as follows:

Chapter Two: provide Background and review about the topic.

Chapter Three: provide a study of Fuzzy Q Learning algorithm in coverage & capacity optimization.

Chapter Four: Provide the simulation and discusses the results.

Chapter Five: Provide the conclusion of the work done and a list of recommendations.

Chapter Two

Literature Review

2.1 Introduction

It is not a hidden fact that, in today’s wireless and cellular networks, businesses and end users have clearly become dependent on mobility and the freedom of being always online. Smart phones, tablets and other devices are expected to be connected all the time and the applications on these devices are required to run smoothly. That is, for a mobile network to even be considered to have the minimum requirements from its users today, network problems like dropped calls, choppy videos and slow downloads should be out of the question. However, with the fast growth rate of wireless communication devices competing for spectrum, the mobile access networks that we have today will soon reach their maximum capacity. To address these high expectations, mobile network operators are employing new strategies in densely populated areas and commercial buildings where spectrum scarcity is highest. 3GPP has been working on LTE Advanced (Long Term Evolution - Advanced) in order to improve the spectral efficiency by employing Heterogeneous Networks (HetNets). HetNets improve the business model for mobile network operators and users by introducing network topologies which are less costly and are able to increase the capacity and coverage provided by the traditional macro cell mobile networks. HetNets are comprised of macro cells and low cost - low power base stations like picocells, femtocells, relays and other small cells along with WiFi-APs and distributed antenna systems (DAS). With HetNets a significant network capacity gain and uniform broadband experience can be provided to the users anywhere and at low cost, since the spectrum can be re-used across the multiple tiers in the network. However, HetNet deployments come with a lot of challenges and advanced interference control and management techniques are required to get the highest possible benefit from these networks. The enhanced Inter Cell Interference Coordination (eICIC) technique has been studied previously to address the interference problem that these small cells experience from macro cells. This thesis will concentrate on the performance improvement achieved when eICIC mechanisms are introduced to a simple HetNet. The eICIC approach as described in 3GPP's Release 10 involves two mechanisms, which this thesis also tries to take into consideration. These are the CRE (Cell Range Expansion) acheived through cell bias adjustments and ABS (Almost Blank Subframe) ratio. A discussion about the importance eICIC in SON - Self Organizing Networks will also be done [3].

LTE will allow wireless carriers to take advantage of greater download and upload speeds to increase the amount and types of content made available through mobile devices. As a step toward 4G mobile broadband wireless, the 3GPP body began its initial investigation of the Long-Term Evolution (LTE) standard as a viable technology in 2004.The LTE technology is expected to offer a number of distinct advantages over other wireless technologies. These advantages include increased performance attributes, such as high peak data rates and low latency and greater efficiencies in using the wireless spectrum [4].

- High spectral efficiency.
- Very low latency.
- Support of variable bandwidth.
- Interworking with other systems, e.g., cdma2000.
- FDD and TDD within a single radio access technology.
- Efficient multicast/broadcast.

2.1.1 LTE System Architecture

Together with radio access technology improvements, the core network is a part of this evolution as well, which is known as System Architecture Evolution (SAE). The LTE Radio Access Network (RAN) architecture consists of several eNodeBs (evolved NodeB). ENodeB is the base station, which controls the radio resource management functions. As an architectural evolution in LTE, eNodeBs are spread over the network coverage area consequently; the Radio Network Controller (RNC) of high speed packet access (HSPA) is removed from the architecture. Moreover, the Serving general packet radio service (GPRS) Support Node (SGSN) and Gateway GPRS Support Node (GGSN) are replaced by SAE Gateway (S-GW), resulting in smaller delays during the traffic flow as shown in figure (2-1).

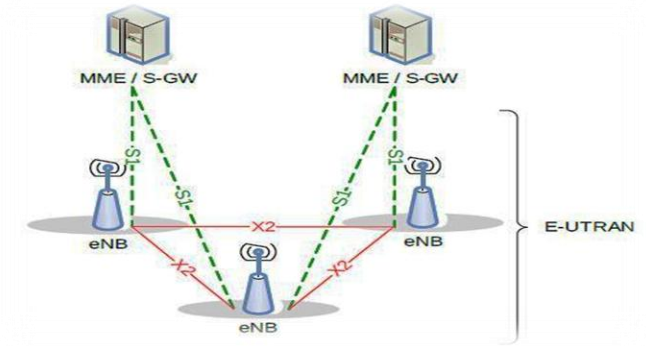


Figure 2.1: LTE Radio Access Network Architecture.

The eNodeBs are connected to each other via the interface called X2 and to the S-GWs via S1 interface. Besides controlling resource management tasks such as radio bearer control, radio admission control, radio mobility control

ENodeB executes transmission of paging messages, scheduling and dynamic allocation of resources to user equipment's (UE) for both uplink and downlink. An Access Gateway (AGW) is the node above eNodeB. ENodeBs can be connected to one or more a GWs in the radio network design. Furthermore, a GW is divided into two parts considering their functionalities, Mobility Management Entity (MME) and User Plane Entity (UPE) [5].

2.2 LTE relay

Relaying is one of the features being proposed for the 4G LTE Advanced system. The aim of LTE relaying is to enhance both coverage and capacity.

The idea of relays is not new, but LTE relays and LTE relaying is being considered to ensure that the optimum performance is achieved to enable the expectations of the users to be met while still keeping OPEX within the budgeted bounds.

2.2.1 Need for LTE relay technology

One of the main drivers for the use of LTE is the high data rates that can be achieved. However all technologies suffer from reduced data rates at the cell edge where signal levels are lower and interference levels are typically higher. The use of technologies such as MIMO, OFDM and advanced error correction techniques improve throughput under many conditions, but do not fully mitigate the problems experienced at the cell edge.

As cell edge performance is becoming more critical, with some of the technologies being pushed towards their limits, it is necessary to look at solutions that will enhance performance at the cell edge for a comparatively low cost. One solution that is being investigated and proposed is that of the use of LTE relays.

2.2.2 LTE relay basics

LTE relaying is different to the use of a repeater which re-broadcasts the signal. A relay will actually receive, demodulates and decodes the data, apply any error correction, etc to it and then re-transmitting a new signal. In this way, the signal quality is enhanced with an LTE relay, rather than suffering degradation from a reduced signal to noise ratio when using a repeater. For an LTE relay, the UEs communicate with the relay node, which in turn communicates with a donor eNB. Relay nodes can optionally support higher layer functionality, for example decode user data from the donor eNB and re-encode the data before transmission to the UE. The LTE relay is a fixed relay - infrastructure without a wired backhaul connection, that relays messages between the base station (BS) and mobile stations (MSs) through multihop communication. There are a number of scenarios where LTE relay will be advantageous.

- Increase network density: LTE relay nodes can be deployed very easily in situations where the aim is to increase network capacity by increasing the number of eNBs to ensure good signal levels are received by all users. LTE relays are easy to install as they require no separate backhaul and they are small enabling them to be installed in many convenient areas, e.g. on street lamps, on walls, etc.

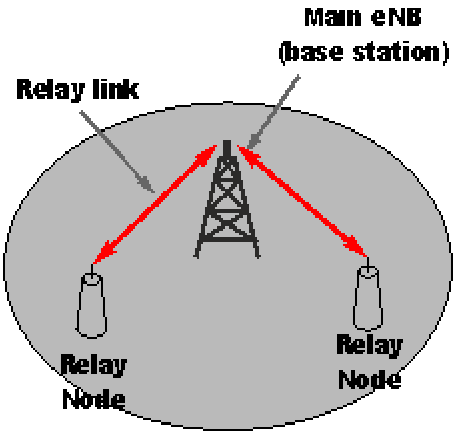


Figure 2.2: LTE relay used to increase network density

- Network coverage extension : LTE relays can be used as a convenient method of filling small holes in coverage. With no need to install a complete base station, the relay can be quickly installed so that it fills in the coverage blackspot.

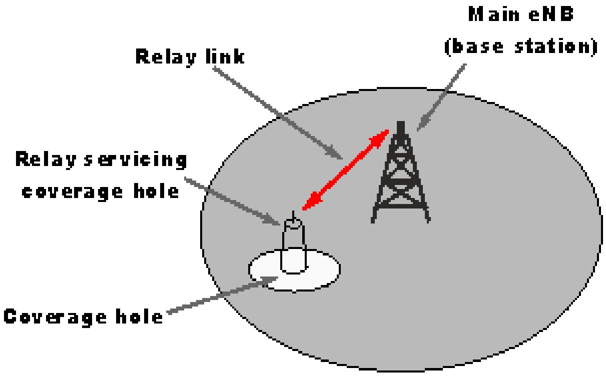


Figure 2.3: LTE relay coverage extension - filling in coverage hole

Additionally LTE relay nodes may be sued to increase the coverage outside main area. With suitable high gain antennas and also if antenna for the link to the donor eNB is placed in a suitable location it will be able to maintain good communications and provide the required coverage extension.

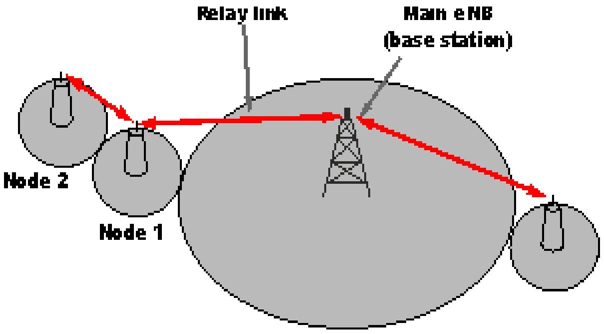


Figure 2.4: LTE relay coverage extension - extending coverage

It can be noted that relay nodes may be cascaded to provide considerable extensions of the coverage.

- Rapid network roll-out: Without the need to install backhaul, or possibly install large masts, LTE relays can provide a very easy method of extending coverage during the early roll-out of a network. More traditional eNBs may be installed later as the traffic volumes increase.

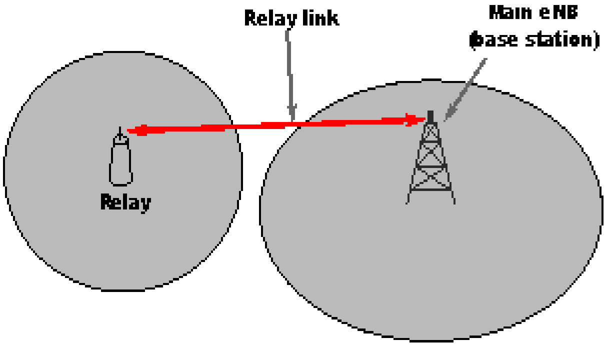


Figure 2.5: LTE relay to provide fast rollout & deployment

2.2.3 LTE relaying full & half duplex

LTE relay nodes can operate in one of two scenarios:

- Half-Duplex: A half-duplex system provides communication in both directions, but not simultaneously - the transmissions must be time multiplexed. For LTE relay, this requires careful scheduling. It requires that the RN coordinates its resource allocation with the

UEs in the uplink and the assigned donor eNB in the downlink. This can be achieved using static pre-assigned solutions, or more dynamic ones requiring more intelligence and communication for greater flexibility and optimisation.

- Full Duplex: For full duplex, the systems are able to transmit and receive at the same time. For LTE relay nodes this is often on the same frequency. The relay nodes will receive the signal, process it and then transmit it on the same frequency with a small delay, although this will be small when compared to the frame duration. To achieve full duplex, there must be good isolation between the transmit and receive antennas.

When considering full or half duplex systems for LTE relay nodes, there is a trade-off between performance and the relay node cost. The receiver performance is critical, and also the antenna isolation must be reasonably high to allow the simultaneous transmission and reception when only one channel is used.

2.2.4 LTE relay types

There is a number of different types of LTE relay node that can be used. However before defining the relay node types, it is necessary to look at the different modes of operation.

One important feature or characteristic of an LTE relay node is the carrier frequency it operates on. There are two methods of operation:

- Inband: An LTE relay node is said to be "Inband" if the link between the base station and the relay node are on the same carrier frequency as the link between the LTE relay node and the user equipment, UE, i.e. the BS-RN link and the BS-UE link are on the same carrier frequency.

- Outband: For Outband LTE relay nodes, RNs, the BS-RN link operates of a different carrier frequency to that of the RN-UE link.

For the LTE relay nodes themselves there are two basic types that are being proposed, although there are subdivisions within these basic types:

- Type 1 LTE relay nodes: These LTE relays control their cells with their own identity including the transmission of their own synchronisation channels and reference symbols. Type 1 relays appear as if they are a Release 8 eNB to Release 8 UEs. This ensures backwards compatibility. The basic Type 1 LTE relay provideshalf duplex with Inband transmissions.

There are two further sub-types within this category:

  - Type 1.a: These LTE relay nodes are outband RNs which have the same properties as the basic Type 1 relay nodes, but they can transmit and receive at the same time, i.e. full duplex.
  - Type 1.b: This form of LTE relay node is an inband form. They have a sufficient isolation between the antennas used for the BS-RN and the RN-UE links. This isolation can be achieved by antenna spacing and directivity as well as specialised digital signal processing techniques, although there are cost impacts of doing this. The performance of these RNs is anticipated to be similar to that of femtocells.

- Type 2 LTE relay nodes: These LTE relaying nodes do not have their own cell identity and look just like the main cell. Any UE in range is not able to distinguish a relay from the main eNB within the cell. Control information can be transmitted from the eNB and user data from the LTE relay.

Table 2.1: Summary of Relay Classifications & Features in 3GPP Rel.10

LTE Relay Class	Cell ID	Duplex Format
Type 1	Yes	Inbandhalf duplex
Type 1.a	Yes	Outband full duplex
Type 1.b	Yes	Inband full duplex
Type 2	No	Inband full duplex

There is still much work to be undertaken on LTE relaying. The exact manner of LTE relays is to be included in Release 10 of the 3GPP standards and specifications [6].

2.3 Self-organizing network

Aiming at reducing (CAPEX) and (OPEX), self-organizing functions have highly automatic features requiring minimum manual intervention.

It consists of self-configuring, self-optimizing, and self-healing functionalities. Figure2.6 depicts a basic framework for these functionalities [7]. Self-configuration provides the capabilities for newly deployed eNBs to finish the configuration with automatic installation procedures for obtaining the basic configuration information to operate the system. This process works in preoperational state, which is known as the state from when the eNB is powered up and has backbone connectivity until the RF transmitter is switched on. The use cases for self-configuration include automatic configuration of physical cell identity, neighbor-list configuration, and coverage capacity-related parameters [8]. Self-optimization offers the benefits of the dynamic optimization in the operational state, which is known as the state where the RF interface is switched on, as shown in Figure 2.7. This functionality reduces the workload for site visit and analysis of network performance manually, resulting in reduction of OPEX. The main use cases for self- optimization are coverage and capacity optimization, energy savings, mobility robustness optimization, mobility load balancing optimization, RACH optimization and interference reduction [2]. The introduction of self-healing process is to solve or mitigate the faults that could be solved automatically by activating proper recovery actions in the operational state. It includes not only the automatic detection as well as localization of the failure, but also the recovery and the compensation actions. The use cases of self-healing are cell outage detection, cell-outage compensation, cell outage recovery, and return-from-cell-outage compensation [9].

2.3.1 SON Architecture

Regarding the SON entity allocation, there are three basic ways to implement the SON architecture, namely centralized SON, decentralized SON and hybrid SON, as shown in Figure (2.6) & (2.7) [10]

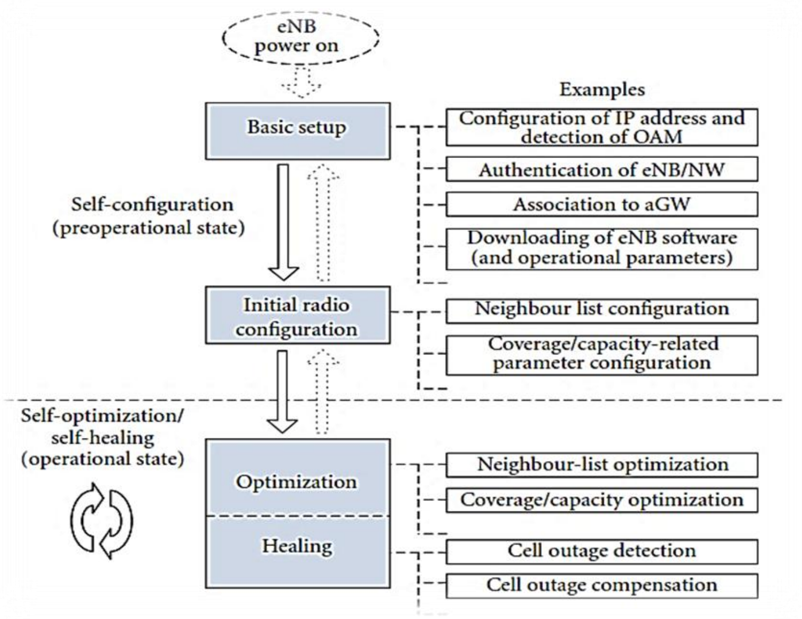


Figure2.6: Basic framework for SON functionalities

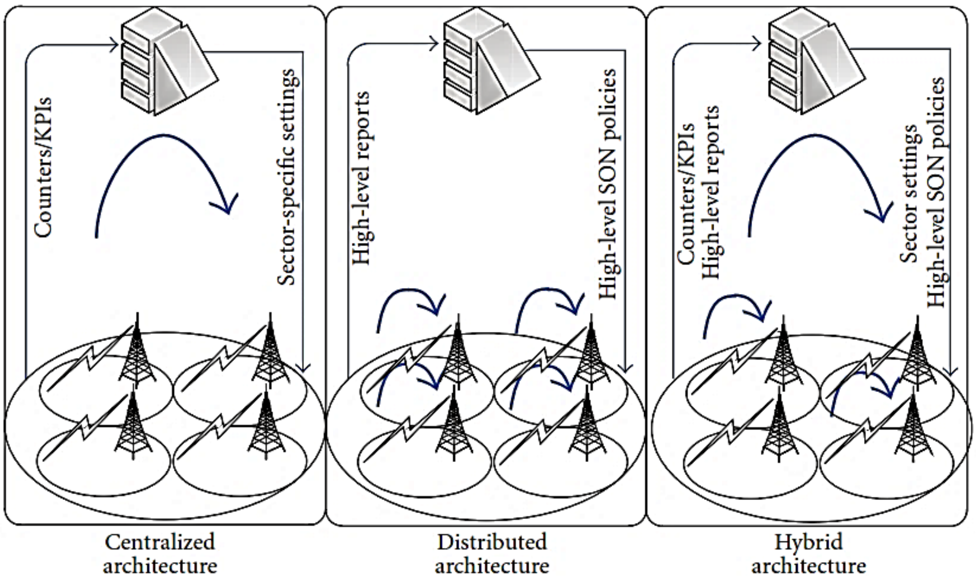


Figure 2.7: SON Architectures

2.3.2 Self-Organizing Relays in LTE networks

Self-organizing networks (SON) mechanisms have been introduced in the Long Term Evolution (LTE) standard in order to empower the network by embedding autonomic mechanisms, namely self-configuration, self-optimization and self-healing ([2], [11]). These mechanisms aim at simplifying the network management, at reducing its cost of operation and at increasing its performance. Within release 10 of 3GPP, enhancement of SON features have been introduced into the LTE-Advanced technology, such as the enhancement of mobility robustness and load balancing self-optimization.

Dynamic self-optimization targets on-line network implementation of SON mechanisms with short time resolution (e.g. seconds to minutes) for adapting the network to new operation conditions such as traffic variations. The requirements for SON solutions to be adopted in radio access networks are the classical goodness criteria in optimization and control: existence of optimal solutions, convergence to an optimal solution, speed of convergence, monotonic improvement of the goodness of the solution, stability and robustness to noise. Previous work on on-line network optimization include the popular utility-based approach used in [12], [13] and [14]. Reinforcement learning has been investigated for example in [15].

LTE-Advanced introduces the concept of Heterogeneous Network (HetNet) as a mean to increase network capacity.

HetNets comprise low power nodes deployed in high traffic areas to increase capacity, namely microcells, femtocells and Relay Stations (RSs). Autonomous resource management in HetNets is among the important and challenging research avenues in SON for next generation radio access networks, encompassing load balancing, Inter-Cell Interference Coordination (ICIC), mobility management, and other self-optimizing resource allocation mechanisms.

This paper focuses on self-optimizing RSs. RSs are linked to the microcell by a wireless link which replaces the wired backhaul. We will use the term “station” to refer to a Base Station (BS) or a RS indifferently. Radio resources have to be shared between the BS to RSs links and the stations to users links. The resource allocation which maximizes the system capacity depends on system parameters such as traffic and RSs placement. Both static and dynamic mechanisms areinvestigated in this work.

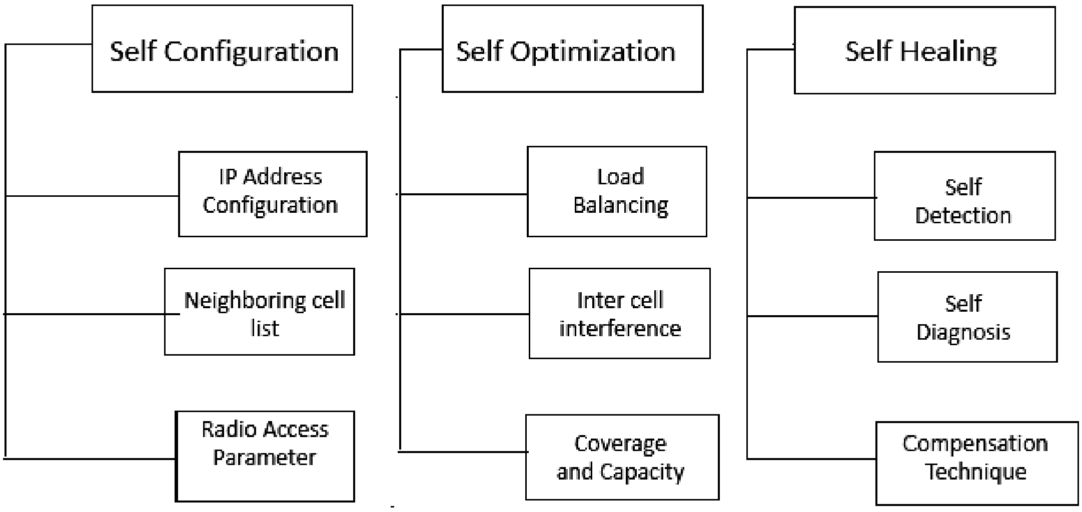


Figure 2.8:Self Organizing Network

2.3.3 Reasons for self-optimizing networks

One of the major elements within SON optimization techniques that can be used. As the environment for the base station, eNB may change after installation and configuration; there is a need to continue to optimise the operation on a regular basis.

Some of the reasons for a change in the environment may be:

Change in propagation characteristics: SON optimization of the network can help take out the effects of any changes to the propagation conditions. These could arise from new buildings going up, or coming down etc. Even changes resulting from leaves falling in autumn can have a significant effect.

Change in traffic patterns: As time progresses usage patterns may change. This could result from increased concentrations of users, from new housing, changes resulting from more people being on holiday, schools being on vacation, or any one of many hundreds of reasons. These can result in further optimisation being required to re-asses the best operational characteristics for the base station, eNB.

Change in deployments: There could be many reasons for the change in deployments in the area. Other base stations, eNBs could have been optimised and changed their characteristics, alternatively new base stations may have been deployed and their operation could affect that of others.

These reasons all mean that to obtain the optimum the performance, it is necessary to optimise the network on a regular basis [16].

2.3.4 Types of self-optimizing network functionality

There are a number of areas where self-optimisation of the network is undertaken [16].

- Mobility robustness optimisation
- Mobility load balancing and traffic steering
- Energy saving
- Coverage and capacity optimisation

2.3.5 Mobility robustness optimisation

The mobility robustness optimisation functionality is included within the self-optimising network routines to enable robust mobility and handovers within the mobile network. There are a number of aims for the mobility robustness optimisation:

Minimise dropped calls: Dropped calls are one of the major causes of customer dissatisfaction and therefore this is a key driver. To improve the perceived quality of the network, reducing the rate of dropped calls is essential.

Minimise unnecessary handovers: Unnecessary handovers lead to inefficient use of network resource and the increased chance of a dropped call. Often many unnecessary handovers take place as a "ping-pong" between two cells as the signal level especially at the cell border varies between the two cells where small changes in position can lead to multiple handovers between the same two cells.

Minimise idle mode problems: When coming out of an idle mode it is necessary for the handset to be able to quickly setup the connection.

Minimise radio link failures: Radio link failures occur at many times. Obviously the first step is to ensure good coverage so that the failures do not occur, but also if they do occur to have in place a capability to quickly re-establish the connection.

There are a great many factors that affect the mobility robustness within the SON self-optimisation. Cell changes are one major issue, and they are initiated dependent upon signal strength indications. As cell handover is the key issue it is necessary to categories the two main types of handover, and to understand their operation. In this way solutions and their methods can be better understood:

Intra-frequency handover: This form of handover is one that takes place between two cells or sectors using the same carrier frequency. This form of handover needs to take place when the strength of a new cell is greater than that of the existing cell. As they are all on the same frequency it is relatively easy for the handset or UE to monitor the strength of existing and neighbouring cells. This is particularly important because for large cells in particular the overlap between cells can be small, and when moving it is possible to transition from one cell area to another. Fast action is therefore needed if the link is not to be lost, although this can lead to more handovers along the cell borders.

Inter-frequency handover This form of handover takes place when the carrier frequency is changed. It makes monitoring the strength of adjacent channels more difficult because the handset needs to monitor multiple channels, but reduces issue with interference apparent at the edges of the cell when two or more cells use the same frequency. Again, fast action is needed to ensure the handover is initiated in time to retain the link before the handset or UE falls out of range of the current cell. However inter-frequency handovers are less prone to interference and can therefore be required less suddenly.

These forms of cell handover give an insight into some of the problems that can occur with handover.

To minimise the number of problems that occur, SON self-optimization processes provide a number of capabilities that can reduce the handover issues:

The SON self-optimization solution should better optimise the cell boundaries to gain a better idea of where they occur, and to try to limit the pin-pong effect.

Carry out optimisation of cell boundaries more often to accommodate any changes that may arise from new cells being added, changes in propagation characteristics resulting from a variety of occurrences from the construction or demolition of buildings to the propagation changes cause by seasonal issues such as leaves on trees, etc.

Improve measurements capability and statistics analysis of the self-optimisation solution relating to handover so that more accurate decisions can be made.

Decentralise the handover decision making to enable swifter and more accurate decisions to be made.

2.3.6 Load balancing

The aim of the load balancing elements of the SON optimization are to try to level out the data hotspots as much as possible. Some cells are likely to be more heavily loaded than others and methods are used to try to even the load out, proving the most effective service for users while maintaining overall capacity while keeping investment to reasonable levels.

With data usage rising exponentially, management of the data load is a key element of SON self-optimisation. However load balancing and traffic steering require sophisticated routines within the SON self-optimization elements to be able to make complex decisions regarding the optimum solutions for any given case.

Some of the key processes within the load balancing and traffic steering software include the following:

To make the data traffic more even over the network and thereby reduce and data hotspots the SON optimisation should enable traffic to be moved from highly loaded cells to less loaded neighbours within the limitations of coverage and interference.

To offload traffic from the macro cells to the smaller low power cells such as HeNB or Wi-Fi. In this way better use is made of the macro cells.

To ensure optimum performance, any handsets or UEs that are moving should not be handed down to smaller cells as they will soon move out of range requiring a large number of handovers. The self-optimisation software should be able to detect signs of movement.

2.3.7 Energy saving

With general green issues and costs both acting as drivers, energy saving is becoming an increasingly important feature for SON self-optimization network functionality. Energy savings are motived by the need to reduce carbon dioxide emissions as well as cost savings from the reduced power consumption.

Energy savings are achieved with both the UE, handset and within the network. Obviously different strategies are used for both, although many of the fundamental concepts are the same.

As far as SON optimization is concerned the major energy savings can be made within the network, and in particular within the eNBs.

Energy savings can be made in many ways within a self-optimizing network. Traditionally not a lot of functionality has been added to networks to provide energy savings, but as traffic drops dramatically over night there are significant opportunities for energy savings.

There are a number of options that can be implemented to provide an energy self-optimizing network:

Reduce active carries for off-peak times: Many base stations transmit a number of carriers to enable the data capacity requirements to be met. During off peak periods, the number of carriers that are active could be reduced with the resultant reduction in power required.

Sleep mode: In some areas it may be possible to put some base-stations into a sleep mode and increase the coverage of others. In business areas where there is a very high level of usage during the day, at night usage may be next to zero. Similarly at weekends the same effect would be noted.

Accordingly it may be possible to put some base-stations, eNBs to sleep over night or at other times, and increase the coverage or more fully utilise an umbrella cell. Care would need to be taken with this strategy not to reduce the coverage and leave holes that may provide an annoyance to any users that may be around. Typically sleep mode should be a mode from which the base station, eNB could quickly be awoken.

Local generation: While most base stations utilise mains / grid for their power source, more options are now available for local generation. This has been particularly applicable to developing countries where power supplies may not be as easy to provide. However, this is now more of an option for many especially with renewable energy sources such as wind and solar. While the costs of renewable energy are not cheap, the carbon footprint of the network may become a standard which could be adopted. No doubt with more development further energy saving solutions can be added to the network.

2.3.8 Coverage and capacity optimisation

The concept behind this element of the SON self-optimisation is to adapt parameters such as antenna tilts, transmitter power levels and the like to maximise coverage while optimising the capacity by ensuring the inter-cell interference levels are minimised.

The coverage and capacity optimization, CCO, aspect of the self-optimizing network can create some significant advantages, although it is very time consuming and expensive to manage manually.

There are a number of ways in which it can be achieved:

Adjustment of antenna parameters: In order to provide CCO using an adjustment of the antenna parameters, a Remote Electrical Tilt, RET antenna is required. Previous generations of base stations only enabled manual adjustment of the antennas. Now it has become viable for them to be electrically steered. The adjustment is generally the angle if tilt. Moving it upwards increases the boundaries of the cell, although care has to be taken to ensure that coverage is maintained close to the antenna tower.

The adjustment can be made either mechanically or electrically.

However when a system is installed with electrical tilt, sometimes mechanical tilt is also needed to give a wider range because the electrical tilt is limited.

The antenna tilt needs to be carefully adjusted. If it is lowered too much, then the cell boundaries will be brought inwards and coverage holes may appear causing issues with handover. If it is adjusted too high, then the coverage will be extended and it may result in interference levels rising at the cell borders where signals from the adjacent cell will also be received if they use the same channel. Accordingly the self-optimization and adjustment needs to take in these requirements.

Adjustment of power level parameters: While antenna adjustments may be the most obvious solution, self-optimization and adjustment may also be applied to the power levels. In many respects, base station transmitter power optimization is more challenging than using antenna tilt and control. There are issues with amplifier behaviour and also issues with reciprocity with the handsets. It is possible to increase the transmitted power so that the handset receiver can receive the base station further away, but it may not be possible for the handset to increase its power sufficiently to match any improvements especially at the cell edge where it may already be operating close to its maximum level [17].

Chapter Three

Methodology

3.1 Over view:

Q Learning is a practical form of Reinforcement Learning (RL), which is an important subfield of machine learning. RL is a type of learning involving an agent learning behavior that achieves a goal by directly interacting with its uncertain environment and by properly utilizing past experience derived from previous actions. Moreover, we combine the fuzzy rule with the Q-Learning to deal with the realistic problem whose input and output variables are continuous. The complete process is presented in figure 3.1.

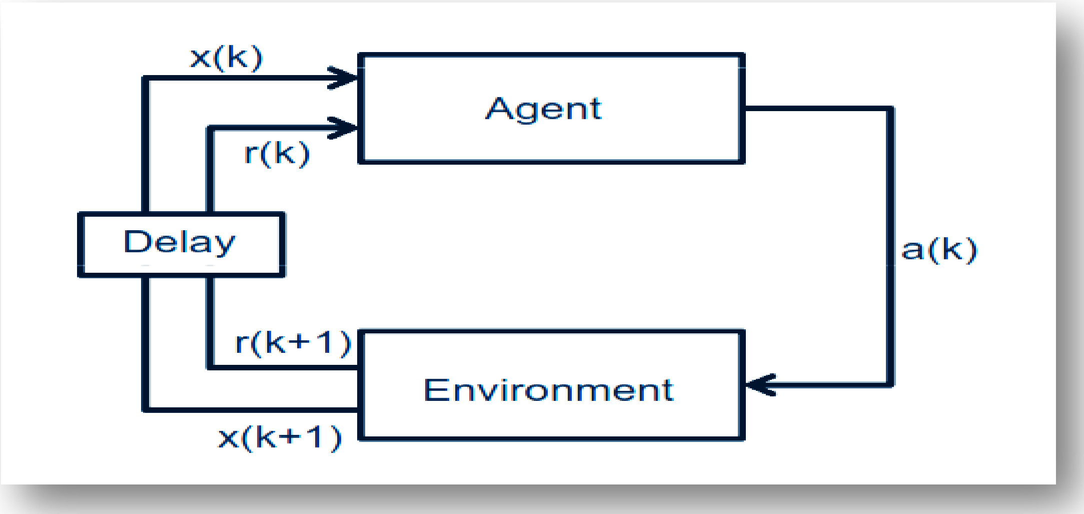


Figure 3.1: Reinforcement Learning (RL) system

It solves the learning problem by estimating a Q-value function or the Q-function for each state action pair. This Q-function defines the quality of choosing an action $a \in A$in state $x \in X$in terms of its long-term expected reward.

$$Q^{\pi}(X_k,a_k)=\mathrm{E}\{r(x_k,a_k)+\gamma . r\left(x_{k_{+1}}, a_{k+1}\right) + \gamma^2 . r\left(x_{k_{+2}}, a_{k+2}\right) + + ... + \gamma^k . r\left(x_{k_{+m}}, a_{k+m}\right) + ...\}. \qquad (3.1)$$

Which is similar to the value function as defined in Equation 3.2, but here we explicitly calculate the value of each action in every state. Similarly, the Q-function can be shown to follow the Bellman Equation as:

$$Q^{\pi}(X_{\kappa}, a_{\kappa}) = E\{r_k + \gamma . Q^{\pi}(x_{k+1}, a_{k+1})\} \text{ (3.2)}$$

In addition, the optimal Q-values, which define the expected reward of selecting an action in state s and then following the optimal policyπ^*:

$$Q^{\pi^*}(x_k, a_k) = \max_{\pi}\{Q^{n}(x_k, a_k)\} \quad \text{(3.3)}$$

In addition, it can be iteratively calculated as

$$Q^{\pi^*}(x_{\kappa}, a_{\kappa}) = E\{r(x_{\kappa}, a_{\kappa}) + \gamma \max_{a_k+1}\{Q^{\pi}(x_{k+1}, a_{k+1})\}\} \text{ (3.4)}$$

Q Learning tries to learn the optimal Q-function in an online fashion by incrementally improving its estimate$\hat{Q}(x_k, a_k)$.

$$\hat{Q}(x_k, a_k) = Q^*(x_k, a_{\kappa}) - e(x_k, a_k) \quad \text{(3.5)}$$

Where $e(x_k, a_k)$ is difference between the optimal and estimated value

$$e(x_{\kappa}, a_k) = Q^*(x_k, a_k) - \hat{Q}(x_k, a_k) = \Delta\hat{Q}(x_k, a_k) \text{ (3.6)}$$

This difference between the optimal and estimated value can be used to incrementally improve the estimate as the learning agent become more and more experienced as follow:

$$\hat{Q}_{k+1}(x_k, a_k) = \hat{Q}(x_k, a_k) + \beta_k . \Delta\hat{Q}(x_k, a_k)$$

$$=\hat{Q}(x_k, a_k) + \beta_K . \{Q^*(x_k, a_k) - \hat{Q}(x_k, a_k)\}$$

$$=\hat{Q}(x_k, a_k) + \beta_k . \left\{r_\kappa + \gamma . \max_{a_{k+1} \in A} \{\hat{Q}_k(x_{k+1}, a_{k+1})\} - \hat{Q}_k(x_k, a_K)\right\} (3.7)$$

Where β is the learning rate and describe how much impact the new information has on the old estimate for $\beta = 0$ no learning is done and for $\beta = 1$ the new value completely overwrites the old estimate.

3.2 Q-Learning Algorithm Steps

The general Q-Learning algorithm is an iterative process of estimating the Q- function and follows the following steps

1. Initialize the estimates of Q-values: $\hat{Q}\ (x, a)$:= 0$\forall x \in X, a \in A$
2. Observe the current state $x = \ x_k$
3. Select an action a_k and execute it
4. Receive the immediate reward r_k
5. Observe the new state x_k+1
6. Update the estimate $\hat{Q}(x_k, a_k)$as described in 3.7
7.$x \Leftarrow x_k$+1
8. Repeat steps from three to seven until the terminal condition is met

3.3 Fuzzy Q-Learning

Reinforcement Learning problems are generally modeled as finite state Markov Decision Process (MDP), which requires that the system can be represented as a set of finite states. As a result, it is feasible to calculate Q-value for each state action pair. However, it becomes extremely difficult if the state or action space is continuous. For example, in our thesis, coverage and capacity of cellular mobile networks was usually based on the received signal strength, which are continuous in nature. State definitions based on these continuous variables would make it impossible to maintain the Q-values for each state-action pair. Moreover, using fixed thresholds for partitioning the continuous variables into discrete variables leads to abrupt transitions, which may lead to very different actions for two very closely related states.

Fuzzy logic can overcome this problem by providing the required abstraction and yet allowing a smooth transition from one state to another. Fuzzy logic uses fuzzy sets, which have elements with graded degree of membership compared to the classical set theory where the elements' membership is measured in binary terms i:e: either the element belongs to or does not belong to the set. This graded membership allows smooth transition between different sets because as the value of fuzzy variable changes, the degree of membership to a particular set can gradually decrease while its membership to another set can increase at the same time.

Fuzzy Q-Learning (FQL) is a combination of fuzzy logic and Q-Learning and tries to overcome the problems of each while benefiting from the strong points of each. Fuzzy logic provides a flexible framework for optimization problems and Q-learning can provide the learning and fine tuning mechanisms where supervised learning is not possible.

3.3.1 FQL controllers (FQLC)

FQL controllers (FQLC) represent the control system for the optimization of a RL problem. For our studies, we assume a distributed architecture where each cell has its own FQLC and tries to optimize its performance using it, as shown in Figure 3.2. The major components of the FQLC were described in the following sections:

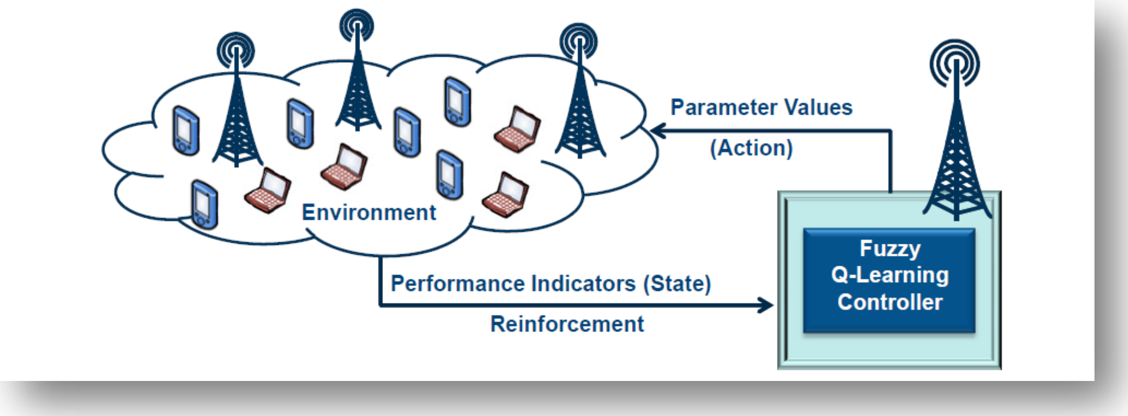


Figure 3.2: Distributed FQLC for CCO

3.3.1.1 States

States are used to describe different conditions of an environment. In cellular mobile networks, the performance is usually measured in terms of network Key Performance Indicators (KPIs). These KPIs represent various statistics of the BS and mobile user activity and can be used to represent the current operational state of a network.

For the CCO by antenna tilt adaptation, we consider the Spectral Efficiency (SE) statistics to measure the coverage and capacity performance of an antenna tilt configuration. SE represents the transmitted information per unit bandwidth and therefore clearly indicate the spectrum usage efficiency. The higher the value of SE, higher the transmitted data rates achievable. In an operational network, spectral efficiency can be derived from the Signal to Interference plus Noise Ratio feedbacks from the mobile user equipment's (UEs) over a sufficiently large period so that the optimization area is adequately covered. Therefore, we define our input state vector as follows:

$$s_C = [ATc \quad SE_C^{Center} \quad SE_c^{edge}] \quad (3.8)$$

Where, ATc is the current antenna tilt of the cell c ∈ C, the set of all cells in the network. SE_C^{Center} and SE_c^{edge} are the central and edge spectral efficiencies respectively of cell c. As LTE utilizes a re-use one frequency allocation scheme among the cells, so the users at the cell edge experience significant inter-cell interference. Therefore, it is important to not just look at the peak SE, but its distribution within the cell. For this reason, we look at two distinct SE metrics to represent the state of a cell.

3.3.1.2Actions and Policy

Actions are the possible steps that the FQLC can take in any state. As the optimization parameter under study is antenna tilt so we define the FQLC actions as the change to be applied to the current antenna tilt value. The optimization target for FQLC is now to learn an action policy that represent a mapping from states $s_c \in$ S to output actions $a_c \in$ A, where A is the set of all possible actions for that state:

$$\pi_c : s_c \rightarrow a_c$$

3.3.1.3 Membership Functions

Fuzzy logic is based on Fuzzy Set Theory introduced by LotfiZadeh. Fuzzy Sets are sets whose elements have degrees of membership. Unlike traditional set theory, where the elements of a set have binary membership, fuzzy set theory allows gradual assessment of the membership of an element to a set. This is achieved with the help of a Membership Function valued in the real unit interval [0,1]. A membership function represents the extent to which a statement is true generally known as the degree of truth as shown in figure 3.3.

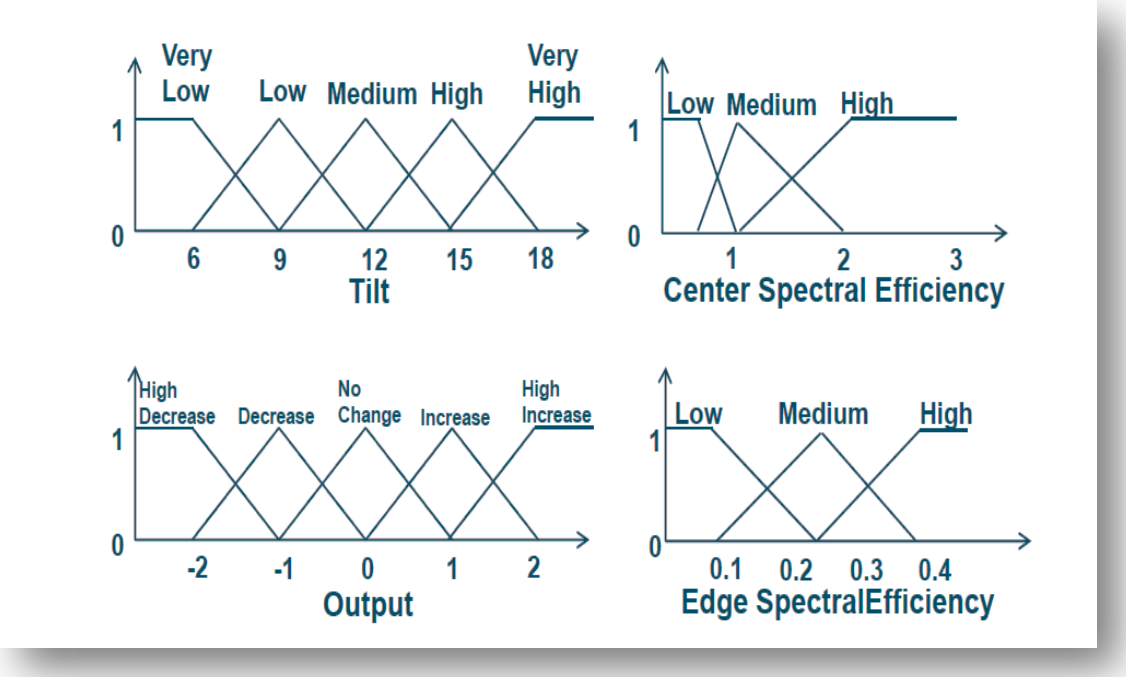


Figure 3.3: Membership Functions

Therefore, a fuzzy set consists of two things: a linguistic label or name of the fuzzy set, which describes some behavior of its contents and the associated membership function, which represent the degree of truth for each element.

For designing an FQLC, each variable of the input state vector s^n and output action a is discretized using a finite number of Fuzzy Sets. Each fuzzy set has its own label and associated membership function denoted by $\mu L^{n,m}(s^n)$, where $L^{n,m}$ is the mth label defined over the nth state vector component ts^n. A value of zero means state variable s^n does not belong to this label and one means it is fully a member of this label. The labels used for our state and output variables are shown in Figure 3-4. Antenna downtilt and output variables have five labels each, whereas SE^{Center} and SE^{Edge}have three labels each. For membership functions we use strict triangular membership functions, so that, for each value of the variable the sum of degrees of membership of all fuzzy labels is equal to one.

$$\Sigma_{m=1}^{M}\mu(s_m^n) = 1 \quad (3.9)$$

Where, M is the total number of labels define for each fuzzy variable. For example, for a downtilt value of 7 degrees the membership value is 0.667 for fuzzy label Very Low and 0.333 for fuzzy label Low.

3.3.1.4 Reinforcement Signal

In RL methods, the environment provides the agent with the feedback about its actions in the form of Reinforcement Signals (RS). These RS help the learning agent to characterize which actions produce better results in which states. As we describe the state of our CCO problem as a vector of current tilt, center SE and edge SE, we define a term State Quality (sQ_c) to describe the cumulative effect of both center and edge SE of a cell. sQ_c is defined as the weighted sum of center and edge SE. Higher SQ_c means better spectral efficiency distribution in the cell and thus higher achievable throughput.

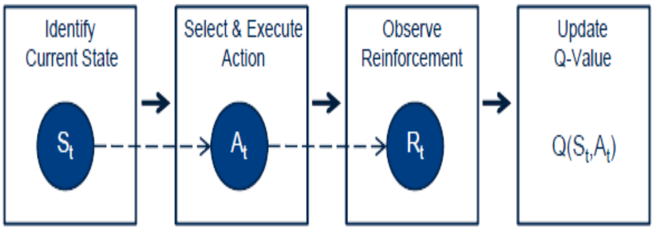
$$SQ_c = SE_c^{center} + w \cdot SE_c^{edge} \qquad (3.10)$$

3.4 Fuzzy Q-Learning Algorithm

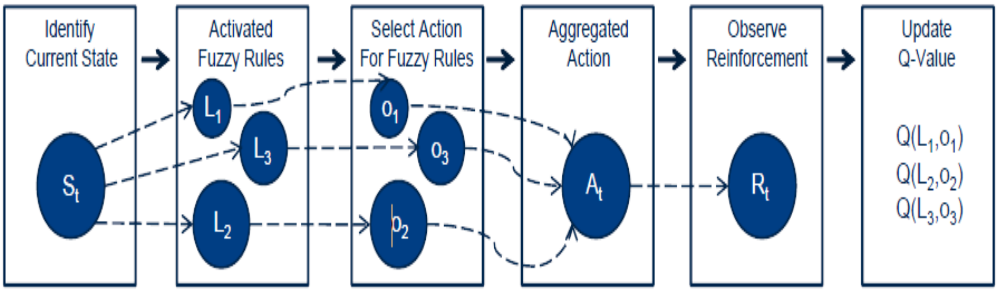
Similar to Q-learning the optimization target for FQL is also to find the optimal policy that maximizes the long-term rewards for the learning agent. This is done by iteratively improving the estimated q-values for each state action pair as described in Equation 3.7. However, the major difference is that in FQL the q-values are actually learned for the discrete states defined by the modal vector or rules of the FIS instead of the actual continuous domain state variables. Therefore, FQL algorithm is slightly different from the Q-learning algorithm.

The FQL algorithm starts with the identification of its current state based on the degree of truth of each FIS rule, defined by the product of the membership values of the corresponding fuzzy labels for each rule:

$$\alpha_i\ (s) = \Pi_{n+1}^{N} \mu L_i^{n,m} (s^n) \qquad (3.11)$$



(a) Q-Learning



(b) Fuzzy Q-Learning

Figure 3.4: Comparison between Q-Learning and Fuzzy Q-Learning

3.5 Mathematical Equations

The Mathematical Equations that's used in simulation in MATLAB are:

3.5.1 Propagation Mode

In LTE while the transmit power is under the control of the transmitter, the received power is affected by a number of environmental factors and device characteristics. For the accuracy of the simulation studies, it is vital to have accurate propagation models for the calculation of received power as all other metrics of system performance like SINR, capacity, coverage, etc are calculated from it. Typically, the relation between transmit and received power is expressed as:

$$P_{Rx}=P_{Tx} - P_L - SF - +G_{Ant} + G_{Dir} \quad (3.12)$$

Where:

P_{Rx} = the received power in dBm.

P_{Tx} = the transmitted power in dBm.

P_L= the pathloss in dB.

SF = shadow fading or large scale fading in dB.

G_{Ant} =the maximum antenna gain in dBi.

G_{Dir} = the directional gain of antenna.

3.5.2 Pathless

Path loss (PL) defines the degradation in power with respect to the distance between the transmitter and the receiver.

PL = 128.1 + 37.6•log (d) (3.13)

3.5.3 Horizontal Pattern

The horizontal antenna pattern is models as:

$G_H(\varphi)=-min[12(\frac{\varphi}{\varphi 3dB})\text{^}2, FBR_H]$ (3.14)

Where, φ, $-180° \leq \varphi \leq 180°$ is the horizontal angle between the main beam direction (0° direction) and the mobile user.

φ3dB = the horizontal half power beam width.

3.5.4 Vertical Pattern

Similarly, vertical antenna pattern is defined by:

$$G_V(\theta) = -\max[12(\frac{\theta-\theta_{e_{tilt}}}{\theta_{3\,dB}})\text{\textasciicircum}2, SLA_V]\ (3.15)$$

Where, θ, −90° ≤ θ ≤ 90°, is the elevation angle with respect to the horizontal plane (θ = 0° means horizontal direction).

$\theta_{e_{tilt}}$ = the electrical tilt angle and SLA_V is the side lobe attenuation.

3.5.5 Antenna Gain

Directional antennas are utilized instead of Omni-directional antennas. Directional antennas allow transmission of radio signals in a particular direction with higher gain and therefore, can reduce the inter-cell interference in other directions. The maximum antenna gain is the gain of a directional antenna over the isotropic antenna and is included in Equation 3.13 for received power calculation asG_{Ant}. The directional gain G_{Dir} refers to the relative strength of the radiated power depending on the vertical and horizontal location of the mobile user with respect to the location of the BS antenna.

In this thesis, a 3D antenna model defined by 3GPP is utilized, which includes both horizontal and vertical antenna radiation pattern. The gain at any position is calculated as the sum of both radiation patterns:

$$G_{Dir} = G\ (\varphi, \theta\ ) = -\min\ \{-\ [G_H(\varphi) + G_V(\theta)], FBR\} \qquad (3.16)$$

Where, G_H (φ) = the horizontal antenna gain in dB.

G_V (θ) = the vertical antenna gain in dB.

φAnd θ = the angles between the antenna and the mobile user in horizontal and vertical direction respectively.

FBR = the front to back ratio.

3.5.6 Signal to Interference Noise Ratio (SINR)

The signal to interference is very importance in mobile station and it relate with data rate, spectrum efficiency, throughput, and delay. And its calculate by power receiver, antenna gain, interference, distance and noise. Eq. 3.17 calculate the Signal to interference noise ratio (SINR).

$$SINR = (PT + G) - (N + I) \quad (3.17)$$

Where

SINR =Signal to interference noise ratio in (dB)

PR = power Transmit in Mobile in (dB).

G = gain antenna.

N = noise in (dB).

I = interference in (dB).

3.5.7 Data Rate (DR)

Data rate is the average number of bits per unit time unit (bits/second). Equation (3.18) calculates the Data rate (DR).

$$DR = \mathrm{Bw} * \mathrm{M} * \mathrm{C} \qquad (3.18)$$

Where:

DR = data rate in (dB).

BW= Bandwidth in (Hz).

M = type of modulation. [Number of bits per symbol].

C = coding rate.

3.5.8 Throughput (TH)

Throughput System throughput is defined as the total number of bits correctly received by all users and can be mathematically expressed Equation 3.19 calculate the Throughput (TH)

$$\mathrm{TH} = \sum_{n=1}^{n} \left(\mathrm{DR}(n) + \mathrm{DR}(n) + \mathrm{DR}(n)\right) \frac{\mathrm{Bits}}{\mathrm{second}} \quad (3.19\ )$$

Where:

TH = Throughput in (bit/sec).

N = number of user.

3.5.9 Spectral Efficiency (SE)

Spectral Efficiency: refers to the information rate that can be transmitted over a given bandwidth in a given system(bit/s/Hz), Equation 3.20 calculate the Spectral Efficiency (SE)

$$SE = \frac{\mathrm{DR}}{Bw} \qquad (3.20)$$

Where:

SE = Spectral Efficiency in (bit/s/Hz).
DR = Data rate in (bit/sec).

BW = Bandwidth in (Hz)

3.5.10 Delay Transmission (DT)

Delay transmission: System delay gives the average of the total queuing delay of all packets in the buffers at the eNBs in the system.

System delay can be mathematically expressed Equation 3.21 calculate the Delay transmission (DT)

$$DT = \frac{\text{data}}{DR}\ \text{Sec} \qquad (3.21)$$

Where*:*

DT = Delay transmission *in (*sec*).*

Data = data transmit in (bit/sec).

DR = Data rate in (bit/sec).

Chapter four

Simulation and Result

4.1 Over View:

To optimize coverage and capacity in LTE network Fuzzy Q learning algorithm is used and it’s implemented in MATLAB software. Single cell scenario and selfish learning approach were applied. Signal to noise ratio, antenna gain, data rate, throughput, transmission delay, spectral efficiency; coverage and capacity were optimized using the algorithm.

Table 4.1: simulation parameters

Parameter	**Values**
Bandwidth	20MHz
Time	1s
Number of eNBs	1
Number of UEs	100
Number of TX antennas	1
Number of Rx antennas	1
Modulation	QPSK, 16QAM, 64QAM
Gain	15 dB
Power cell centre	46 dBw
Power cell edge	67 dBw
Noise ratio	10 to 15 dB
Power transmit	46 dBw
Vertical angle	-90 to 90
Horizontal angle	-180 to 180
Inter-Site Distance (ISD)	500 m
Antenna Max. Gain	15 dB
Antenna Height	35 m
Half Power Beam width (Vertical)	12.6 dB
Backward Attenuation (Vertical)	20 dB
Half Power Beam width (Horizontal)	70 dB
Backward Attenuation (Horizontal)	25 Db

4.2 Simulation Results

The simulation results are shown in the following section in the form of line graphs:

4.2.1 Horizontal Antenna Pattern

The next figure 4.1 illustrate the horizontal antenna pattern where the horizontal angle between the main beam direction (0- direction) and the mobile user is between [-180° to 180°] as is shown in the figure that the best propagation and power transmit of antenna is in zero angle and less in the other angles, due to that zero angle is used in our simulation in the regular scenario.

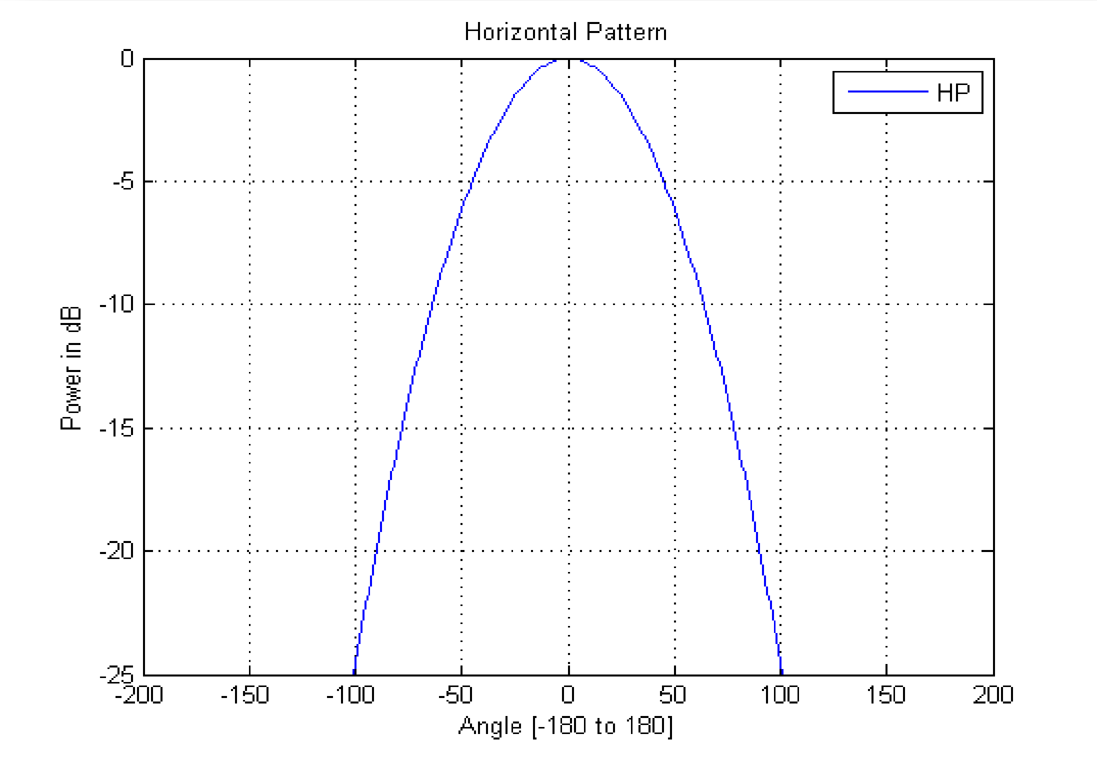


Figure 4.1: horizontal antenna pattern

4.2.2 Vertical Antenna Pattern

The next figure 4.2: shows the vertical antenna pattern where is the elevation angle with respect to the horizontal plane (ϴ=0° means horizontal direction) is between [-90° to 90°] verses the power, as is shown in the figure below the best propagation and power transmit of antenna is when the angle is increased in the other degrees, 25◦ angle has been used in our simulation in the regular scenario as the best angle for our antenna tilt adaptation.

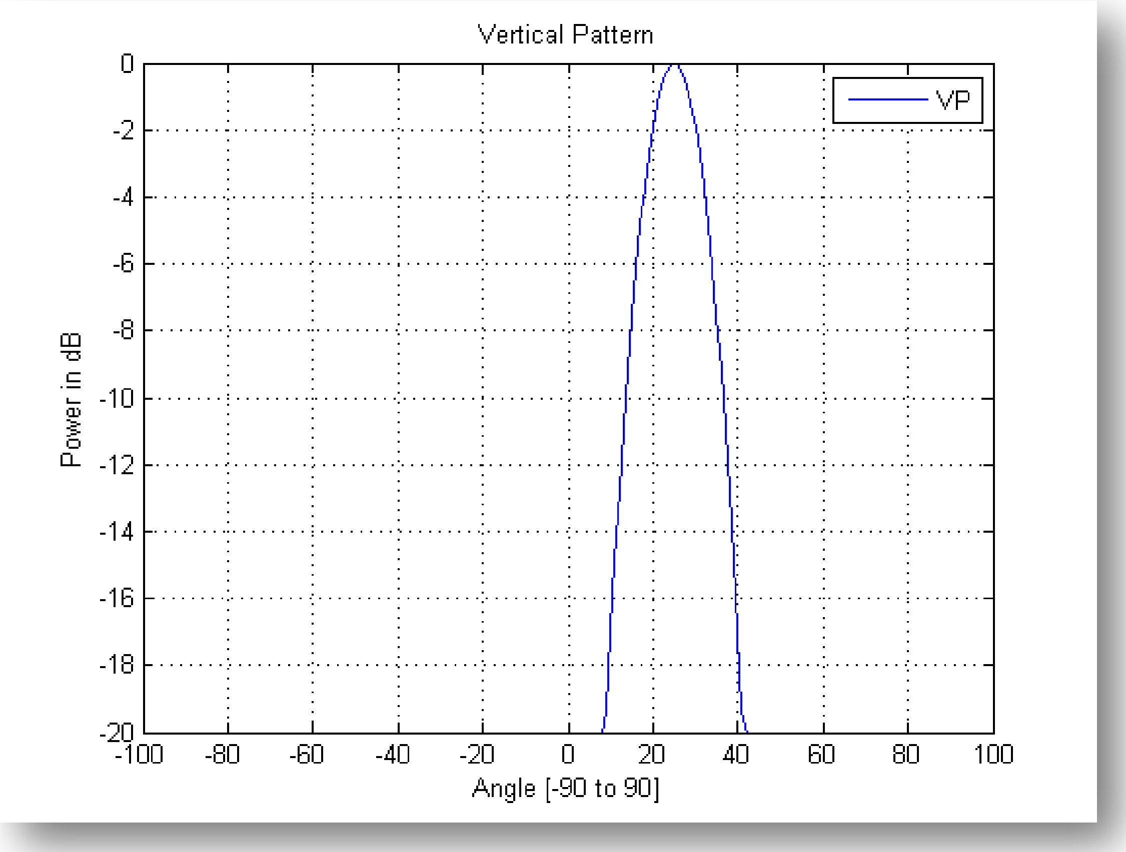


Figure 4.2: vertical Antenna Pattern

4.2.3 SINR Before & After Optimizing

The next figure 4.3: shows the relationship between the Signal to Interference Noise Ratio before and after optimization by using FQL.

It optimize the SINR by control the gain of antenna vertical to overcome the effect of noise, the figure shows that the maximum SINR when using FQL optimization.

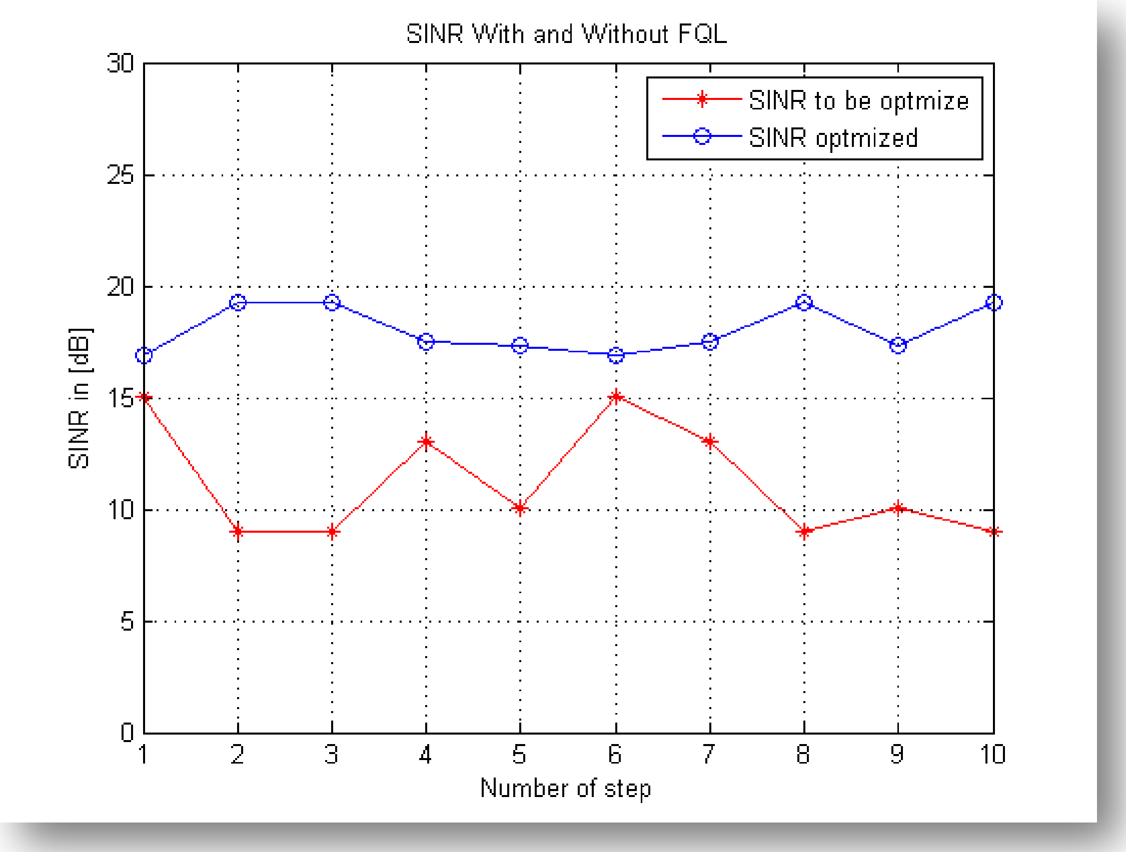


Figure 4.3: SINR before and after optimization

4.2.4 Data Rate Before and After Optimization

The next figure 4.4: shows the relationship deferent in the Data Rate before and after optimization by using FQL and very clear that the Data Rate is peter and optimized with the varied in the environments of propagation. The figure shows that the Data Rate before and after optimization.

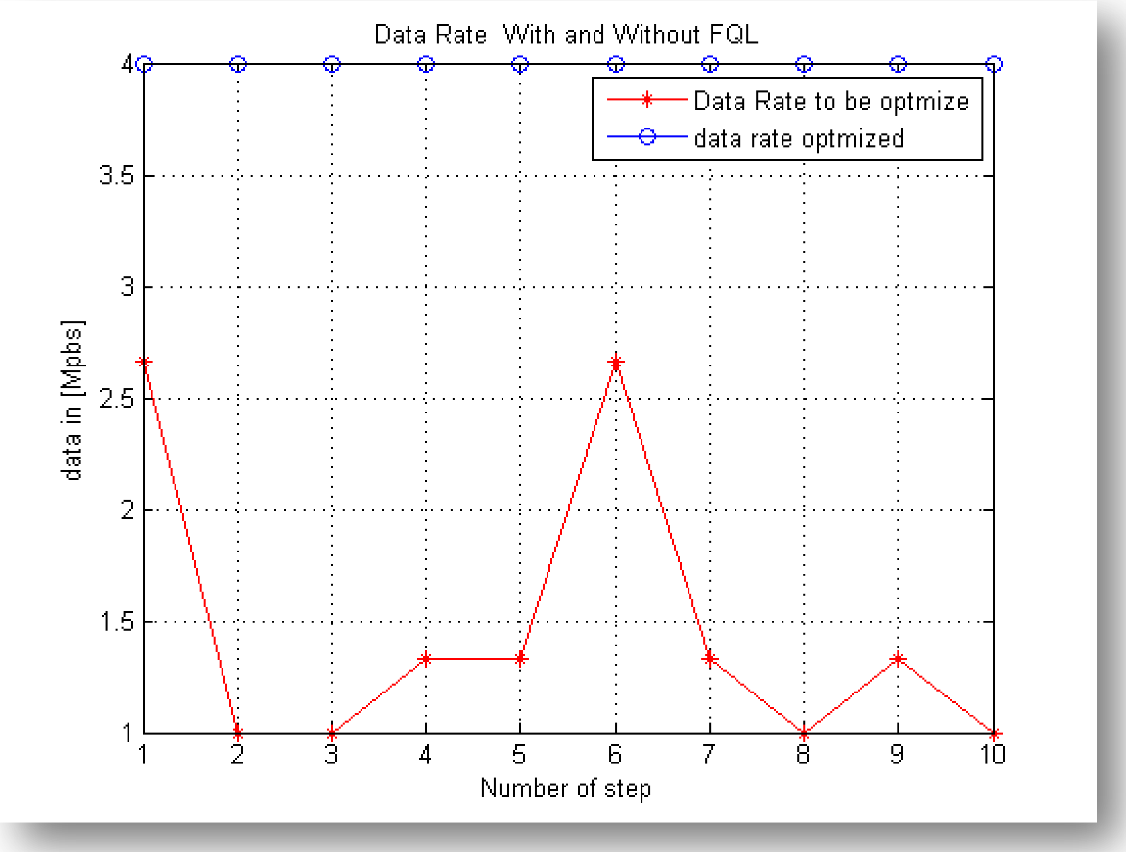


Figure 4.4: Data Rate before and after optimization

4 .2.5 Spectral Efficiency Before and After Optimization

The next figure 4.5: shows the relationship and deferent in the spectral efficiency before and after optimization by using FQL and very clear that spectral efficiency is peter and optimized with the varied in the environments of propagation. The figure shows that the spectral efficiency before and after optimization.

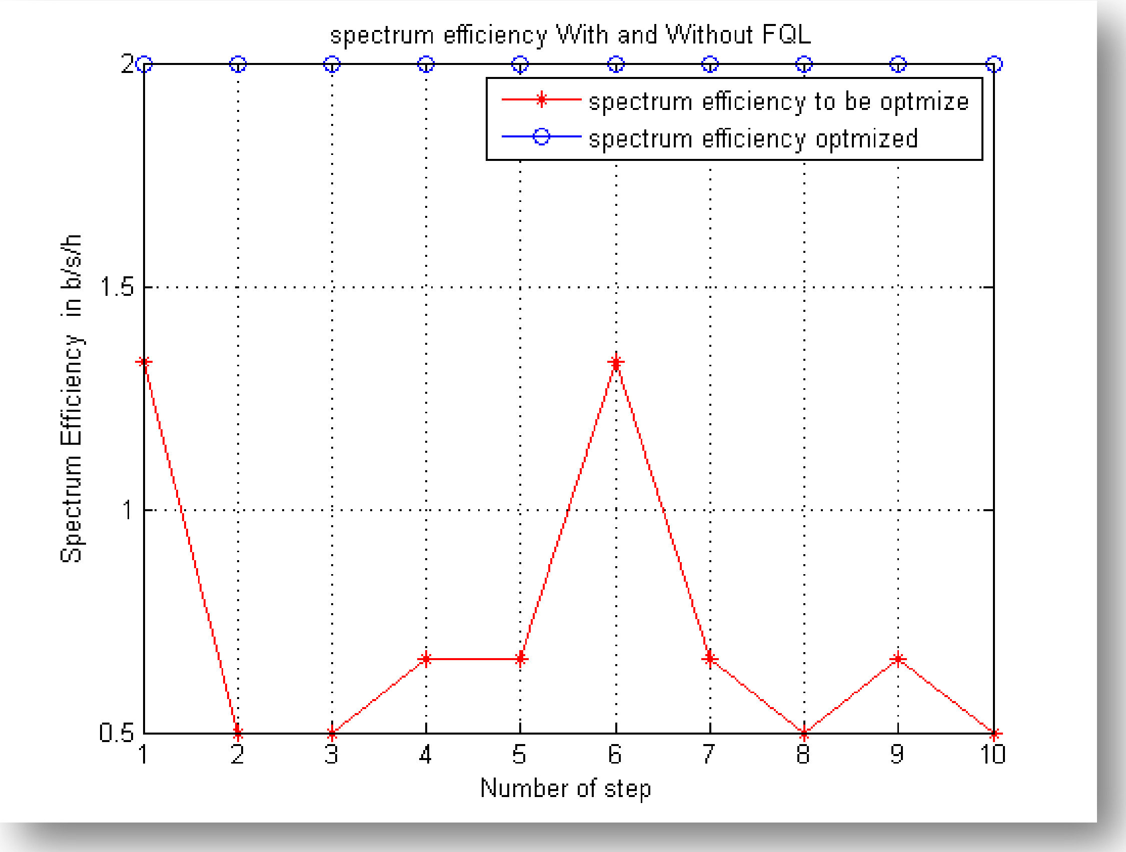


Figure 4.5: The spectral efficiency before and after optimization

4.2.6 Delay Transmission Before and After Optimization

The next figure 4.6: shows the relationship and deferent in the Delay Transmission before and after optimization by using FQL and very clear that Delay Transmission is peter and optimized with the varied in the environments of propagation. The figure shows that the Delay Transmission before and after optimization.

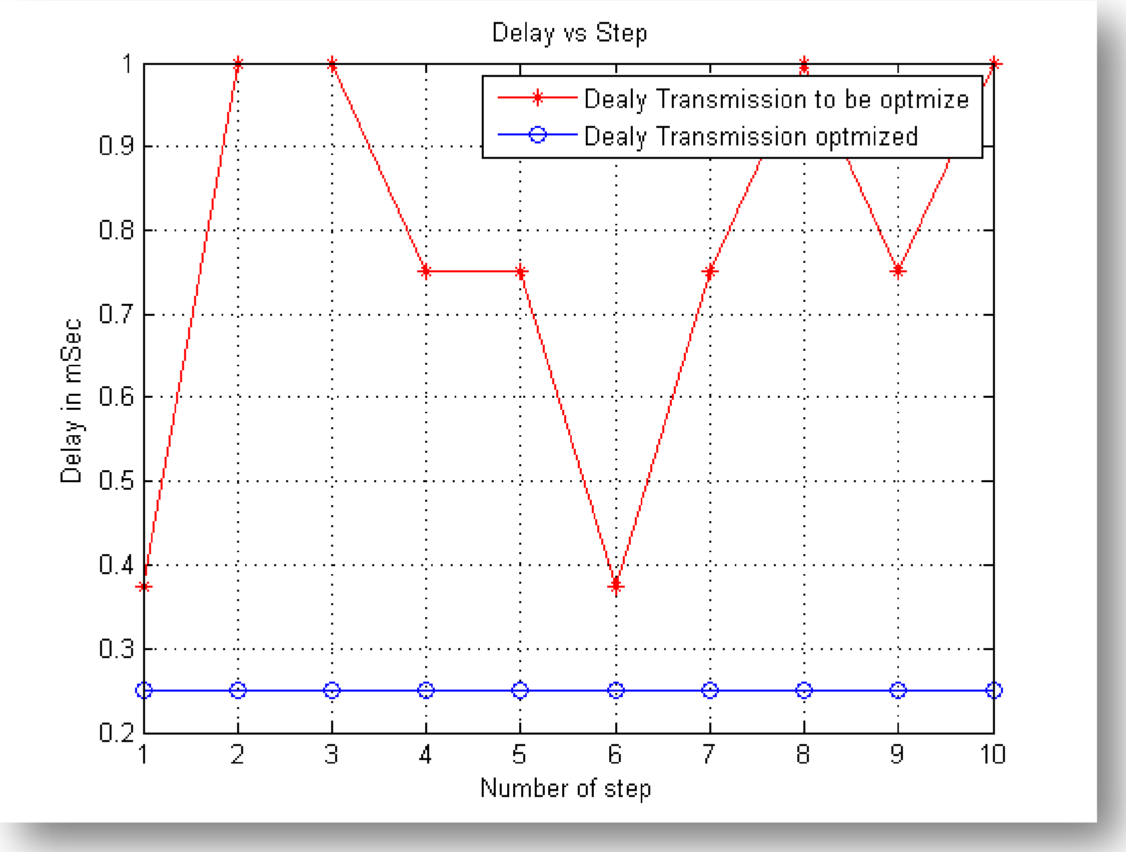


Figure 4.6: Delay Transmission before and after optimization

4.2.7 Coverage With and Without FQL

The next figure 4.7: shows the relationship and deferent in the Coverage before and after optimization by using FQL and very clear that Coverage is peter and optimized with the varied in the environments of propagation. The figure shows that the Coverage before and after optimization.

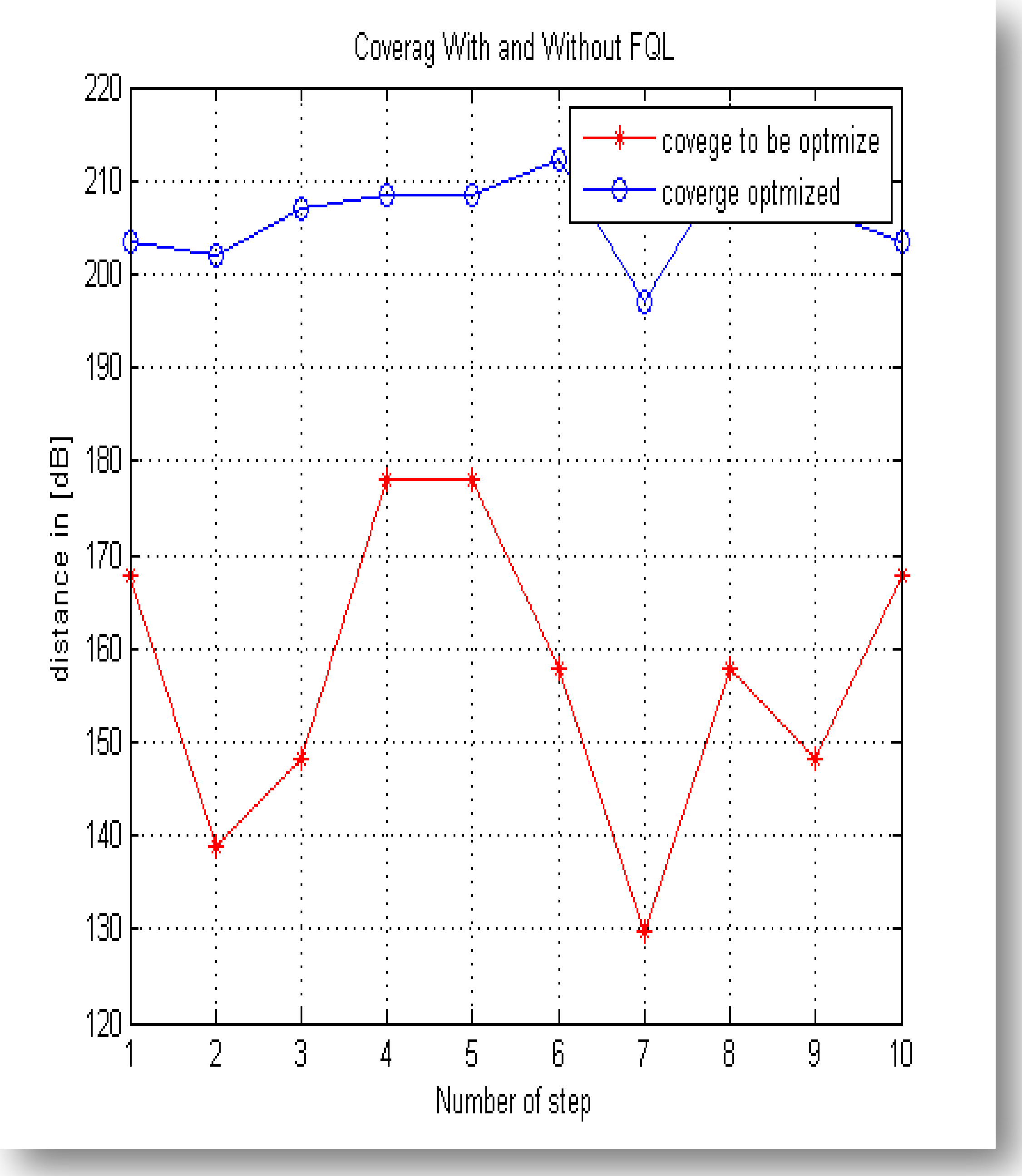


Figure 4.7: Coverage before and after optimization

4.2.8 Capacity with and without FQL

The next figure 4.8: shows the relationship and deferent in the Capacity before and after optimization by using FQL and very clear that Capacity is peter and optimized with the varied in the environments of propagation. The figure shows that the Capacity before and after optimization.

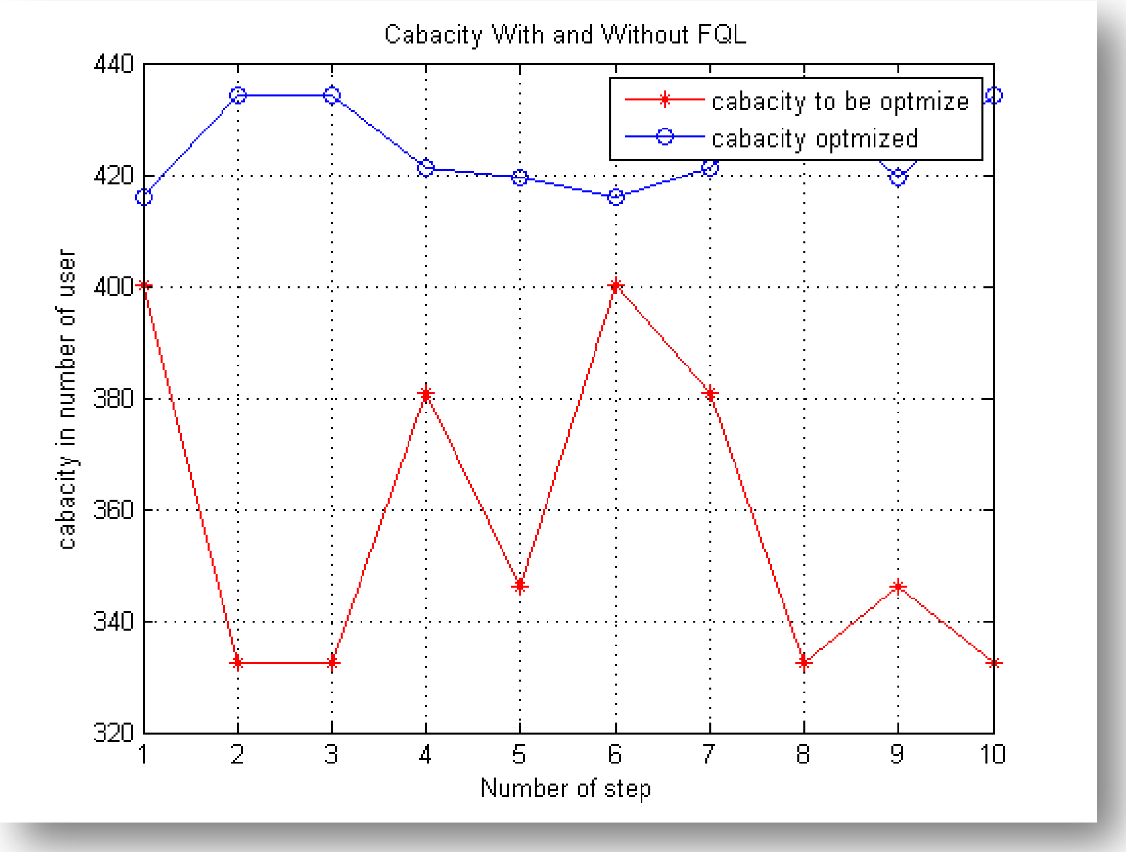
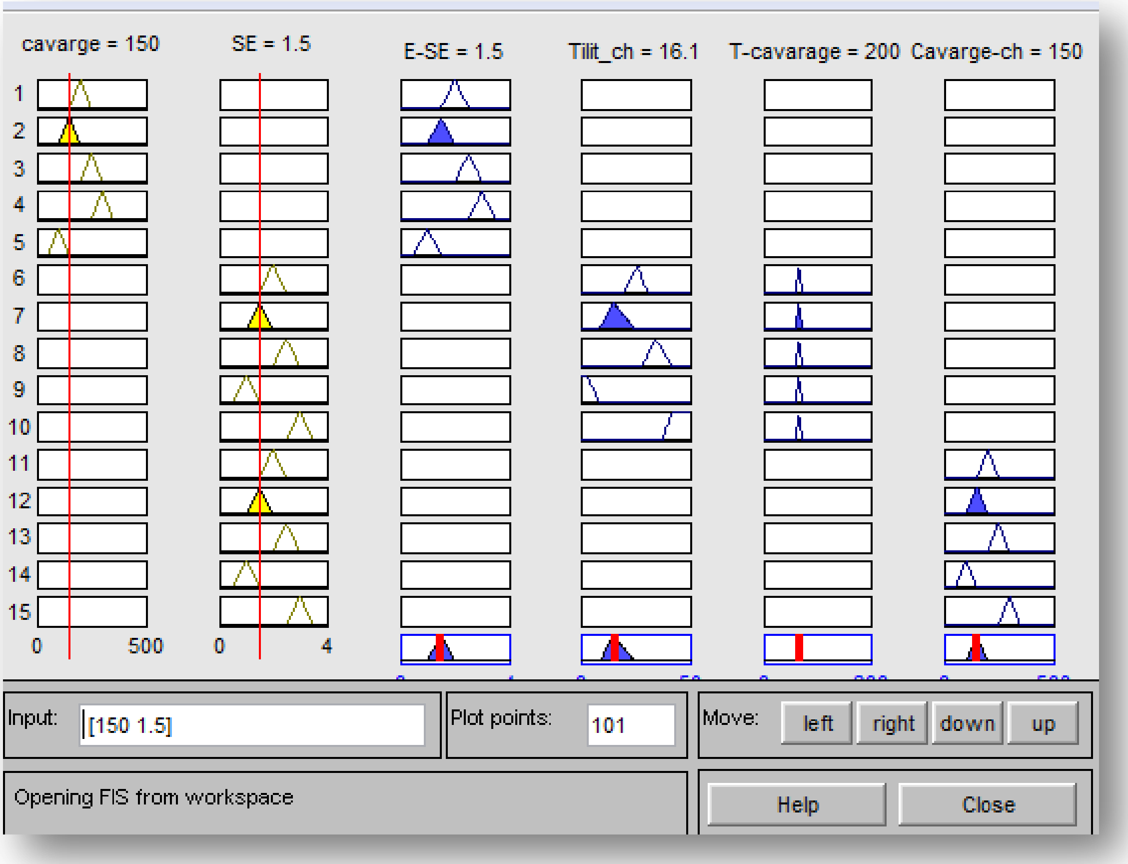


Figure 4.8: Capacity before and after optimization

4.2.9 First Fuzzy Inference System (FIS):

Figure shows in the first column the tilt angle that's changed by the environment (16.1), coverage (150) and its spectral efficiency measurement at the edge (1.5) the output value is the feedback that will return the coverage value to the target, which is 200 Meter °.



Input: [150 1.5]

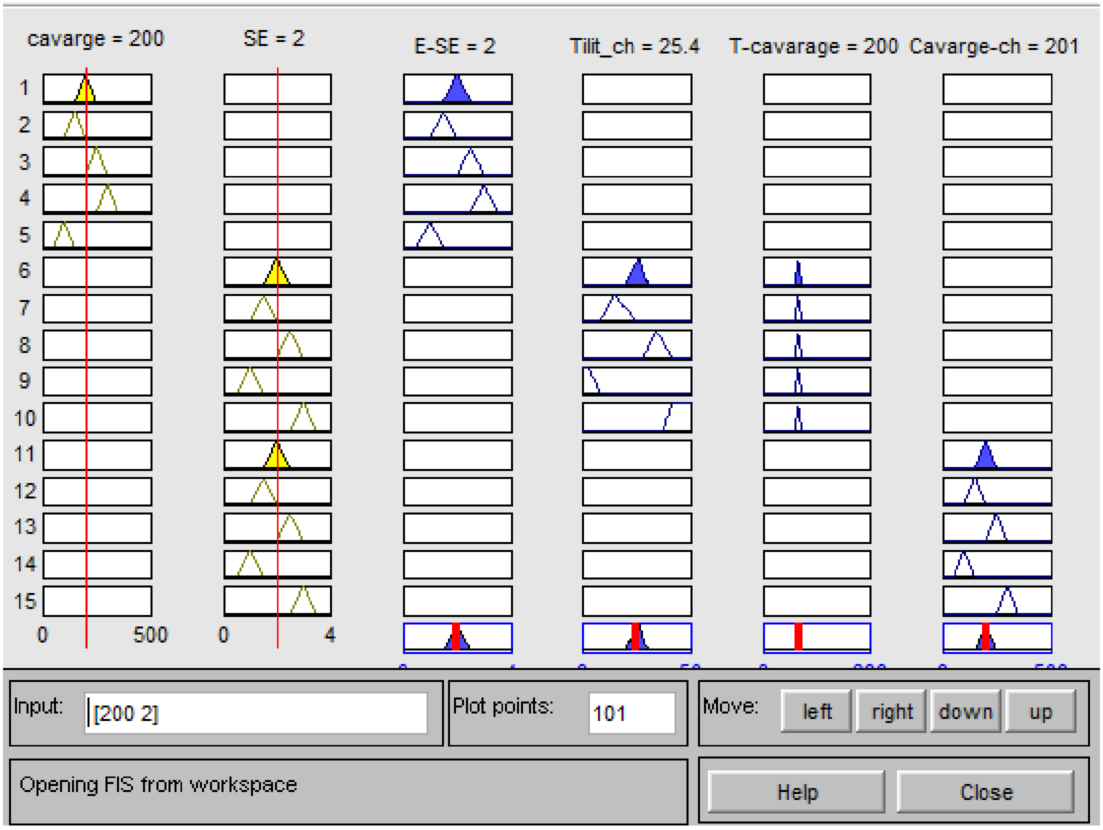
Plot points: 101

Opening FIS from workspace

Figure 4.9: first FIS

4.2.10 Second Fuzzy Interference System

Figure shows in the first column the tilt angle that’s changed by the environment (25), coverage (200) and its spectral efficiency measurement at the edge (2) the output value is the feedback that will return coverage value which is 200 Meter.



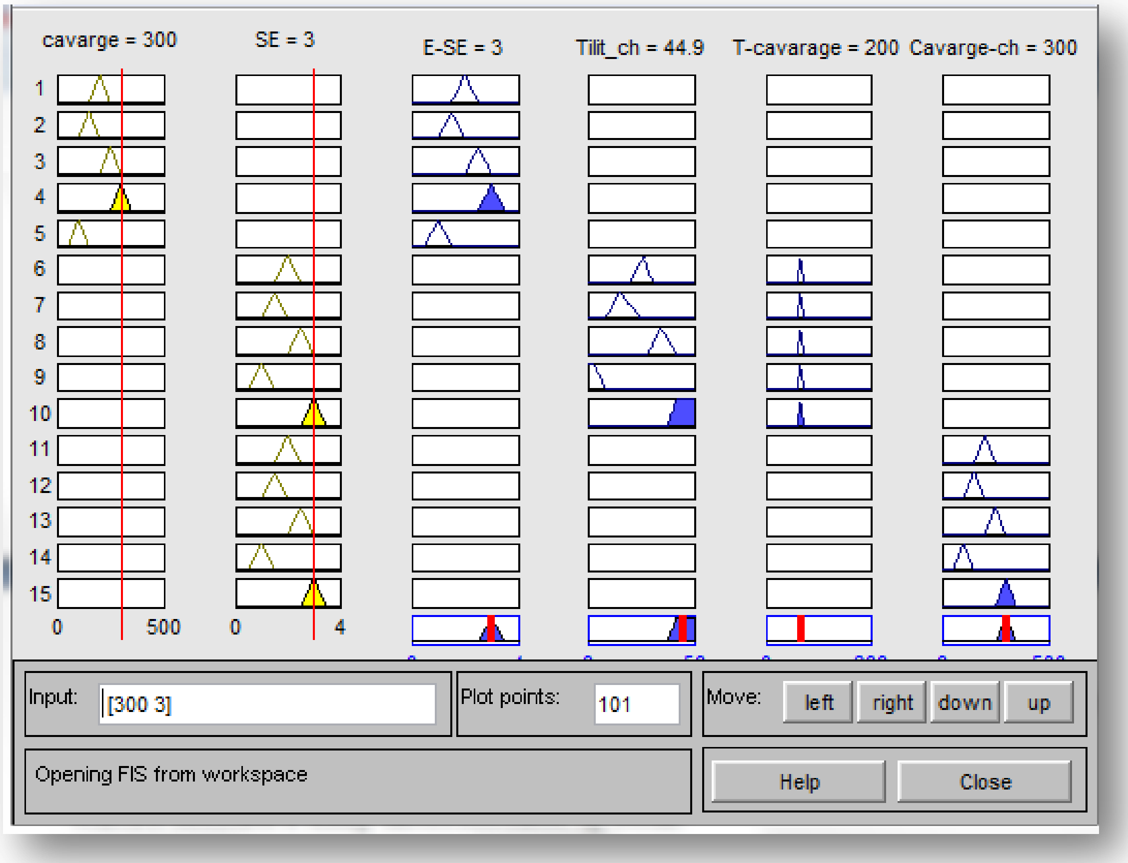
cavarge = 200
SE = 2
E-SE = 2
Tilit_ch = 25.4
T-cavarage = 200
Cavarge-ch = 201

Input: [200 2]
Plot points: 101
Opening FIS from workspace

Figure 4.10: Second FIS

4.2.11 Third Fuzzy Inference System (FIS)

Figure shows in the first column the tilt angle that’s changed by the environment (44), coverage (300) and its spectral efficiency measurement at the edge (23) the output value is the feedback that will return coverage value which is 200 Meter.



Input: [300 3]

Plot points: 101

Opening FIS from workspace

Figure 4.11: Third FIS

Chapter Five

Conclusion and Recommendation

5.1 Conclusion:

The Coverage and capacity in long term evolution suffers from different factor environment effects, the self-organizing network technique (SON) has been widely studied to decrease these effects, MATLAB software was used to implement FQL algorithm and to prove that FQL algorithm is effective in the environment to optimize coverage and capacity, The results showed that adding SON technique can make such an improvement to the optimization of the system.

Self-organization in future mobile network is powerful technique which in future going to decrease operating capital and personnel even with increased complexity.

5.2 Recommendation

A lot of work has been done in this thesis but there is still room for improvement:

- More self-organizing network algorithms can be studied in order to enhance the coverage and capacity optimization in LTE network .also practical implementation with highly accurate calculation can be achieved.
- In our future work, variants of the algorithms will be developed to enhance the cooperation between SON entities especially when abrupt changes happen. Moreover, it would be an interesting future research to extend the current work to heterogeneous networks.

References:

[1] Available: http://www.3gpp.org/technologies/keywords-acronyms/97-lte-advanced. Available: lastseen(25.8.2016)

[2] 3GPP, “Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRAN); Overall description; Stage 2,” 3rdGeneration Partnership Project (3GPP), TS 36.300, Sep. 2008.

[3] AnimutDemekeTsegaye. "Self OrganizingNetworks(SON). UIO: Department of Informatics University of Oslo (Autumn 2014)

[4] Ali-Yahiya and Tara. "Introduction to Mobile Broadband Wireless."Understanding LTE and its Performance. (2011. 3-15)

[5] Kim and Hyun Sook, . "method and terminal for determining handover for traffic offloaded onto wlan." . (24 .Jul. 2014)

[6] Available: http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/4g-lte-advanced-relaying.php. Last seen(10.9.2016)

[7] 3GPP TS 36.300E-UTRA and E-UTRAN; Overall description; Stage 2 (Release 9)V9.9.0, December 2011.

[8] 3GPP TR 36.902E-UTRA; Self-configuring and self-optimizing network (SON) use cases and solutions (Release 9)V9.3.1, March 2011.

[9] 3GPP TS 32.541SON; Self-healing concepts and requirements (Release 10)V2.0.0, March 2011

[10] 3G AmericasThe benefit of SON in LTE: self-optimization and self-organizing networksJuly 2011

[11] 3GPP “Evolved Universal Terrestrial Radio Access Network (EUTRAN); Self-configuring and self-optimizing network (SON) use cases and solutions,” 3rd Generation Partnership Project (3GPP), TR 36.902, Sep. 2008. [Online]. Available: http://www.3gpp.org/ftp/Specs/htmlinfo/ 36902.htm

[12] A. Stolyar and H. Viswanathan, “Self-organizing dynamic fractional frequency reuse for best-effort traffic through distributed inter-cell coordination,” in INFOCOM 2009, IEEE, apr.2009, pp. 1287 –1295.

[13] R. Combes, Z. Altman, and E. Altman, “Self-organizing fractional power control for interference coordination in ofdma networks,” in IEEE ICC 2011, 2011.

[14] R. Combes, M. Haddad, Z. Altman, and E. Altman, “Self-optimizing strategies for interference coordination in ofdma networks,” in IEEE ICC 2011 PlaNet Workshop, 2011.

[15] M. Dirani and Z. Altman, “A cooperative reinforcement learning approach for inter-cell interference coordination in ofdma cellular networks,”in Modeling and

Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2010 Proceedings of the 8th International Symposium on, may. 2010, pp. 170 –176.

[16] Swati Bairagi, SauravVerma, ChaitanyaKaul" Review on Self Organization in Next Generation Mobile Network", International Journal of Computer Applications (0975 –8887), Volume 114 –No. 13, March 2015.

[17]Available:http://www.radio-electronics.com/info/cellulartelecomms/self-organising-networks-son/self-optimisation-optimization.php. Last seen(20.9.1016)

Appendix

Appendix Code A

```
clearall,clc, close all
Learning_Snapshot_Frequency=1; %1 SEC
all_Learning_Snapshot=10
%eNB Parameters
Max_Tx_Power=46; %dBm
ISD=500; %Inter_Site_Distance=500 %METER
Antenna_Height=35; %METER
Antenna_Max_Gain=15; %dB
Bw= 2; % Mega
%Distance 0-500 meters uniform random distribution
%path
loss%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%
d=.6; %kelo meter
PL_edge = 128.1 + 37.6.*10*log(d);
%antenna gain*********************
%Horizontal
Pattern%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
FBRH=25;  %Backward Attenuation
ebselom=-180:1:180;
ebselom3dB=70;  %Half Power Beamwidth
GHH= -min((12*(ebselom./ebselom3dB).^2),FBRH);
%plot Horizontal Pattern******************************
figure
plot(ebselom,GHH);
grid
ylabel('Power in dB')
xlabel('Angle [-180 to 180]')
title('Horizontal Pattern')
legend('HP')
%Vertical
Pattern%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%
THETA=-90:1:90;
%THETA=-180:1:180;
SLAV=20;  %Backward Attenuation
THETAetilt=25;
THETA3dB=12.6;  %Half Power Beamwidth
GVV = -min(12*((THETA-THETAetilt)./THETA3dB).^2,SLAV)
%THETAetilt=-18
% plot Vertical Pattern******************************
figure
plot(THETA,GVV);
grid
ylabel('Power in dB')
```

```
xlabel('Angle [-90 to 90]')
title('Vertical Pattern')
legend('VP')
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%
GV = max(12*((15-THETAetilt)./THETA3dB).^2,SLAV)
GH= -min((12*(1./ebselom3dB).^2),FBRH);
%SINR%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%
GDIR=-min(-(GH+GV),FBRH); %GAIN DIRCTION
PRX=Max_Tx_Power+Antenna_Max_Gain+GDIR;
%noise
noise=randi([1 8],1,10)
SINR=PRX+PL_edge-noise%shuod be 41

for n=1:10

if   ( SINR(n) >=-10 & SINR(n) < 0 )
THETAetilt=40
elseif ( SINR(n) >=0 & SINR(n) < 2 )
THETAetilt=39
elseif ( SINR(n) >=2 & SINR(n) < 4 )
THETAetilt=38
elseif ( SINR(n) >=4 & SINR(n) < 6  )
THETAetilt=37
elseif ( SINR(n) >=6 & SINR(n) < 8  )
THETAetilt=36
elseif ( SINR(n) >=8 & SINR(n) < 10 )
THETAetilt=35
elseif ( SINR(n) >=10 & SINR(n) < 12  )
THETAetilt=34
elseif ( SINR(n) >=12 & SINR(n) < 14  )
THETAetilt=33
elseif ( SINR(n) >=14 & SINR(n) < 16 )
THETAetilt=32
elseif ( SINR(n) >=16 & SINR(n) < 18  )
THETAetilt=32
elseif ( SINR(n) >= 16.4 & SINR(n) < 18.2  )
THETAetilt=30
elseif ( SINR(n) >=18 & SINR(n) < 25 )
THETAetilt=29
end;
GH_u= -min((12*(1./ebselom3dB).^2),FBRH);
GV_u(n) = max(12*((15-THETAetilt)./THETA3dB).^2,SLAV)
GDIR_u(n)=-min(-(GH_u+GV_u(n)),FBRH); %GAIN DIRCTION
PRX_u(n)=Max_Tx_Power+Antenna_Max_Gain+GDIR_u(n);
SINR_abdate(n)=PRX_u(n)+PL_edge-noise(n);
if   ( SINR(n) >=-10 & SINR(n) < 0 )
M1(n)=2; %4QAM
C1(n)=1/8;
```

```
elseif ( SINR(n) >=0 & SINR(n) < 5 )
M1(n)=2;%4QAM
C1(n)=1/5;
elseif ( SINR(n) >=5 & SINR(n) < 10 )
M1(n)=2;%4QAM
C1(n)=1/4;
elseif ( SINR(n) >=10 & SINR(n) < 15  )
M1(n)=2;%4QAM
C1(n)=1/3;
elseif ( SINR(n) >=15 & SINR(n) < 20  )
M1(n)=4;%16QAM
C1(n)=1/3;
elseif ( SINR(n) >=20 & SINR(n) < 25 )
M1(n)=4;%16QAM
C1(n)=2/3;
elseif ( SINR(n) >=25 & SINR(n) <30  )
M1(n)=4;%16QAM
C1(n)=3/4;
elseif ( SINR(n) >=30 & SINR(n) < 35  )
M1(n)=4;%16QAM
C1(n)=4/5;
elseif ( SINR(n) >=35 & SINR(n) < 40 )
M1(n)=6;%32QAM
C1(n)=2/3;
elseif ( SINR(n) >=40 & SINR(n) < 45  )
M1(n)=6;%32QAM
C1(n)=2/3;
elseif ( SINR(n) >= 45 & SINR(n) < 50  )
M1(n)=6;%32QAM
C1(n)=3/4;
elseif ( SINR(n) >=50 & SINR(n) < 55  )
M1(n)=6;%32QAM
C1(n)=4/5;
end;
DR(n)=Bw*M1(n)*C1(n);
if   ( SINR(n) >=-10 & SINR(n) < 0 )
M2(n)=2;%4QAM
C2(n)=1/8;
elseif ( SINR_abdate(n) >=0 &SINR_abdate(n) < 5 )
M2(n)=2;%4QAM
C2(n)=1/5;
elseif ( SINR_abdate(n) >=5 &SINR_abdate(n) < 10 )
M2(n)=2;%4QAM
C2(n)=1/4;
elseif ( SINR_abdate(n) >=10 &SINR_abdate(n) < 15  )
M2(n)=2;%4QAM
C2(n)=1/3;
elseif ( SINR_abdate(n) >=15 &SINR_abdate(n) < 20  )
M2(n)=4;%16QAM
C2(n)=1 /2;
elseif ( SINR_abdate(n) >=20 &SINR_abdate(n) < 25 )
```

```
M2(n)=4;%16QAM
C2(n)=2/3;
elseif ( SINR_abdate(n) >=25 &SINR_abdate(n) <30  )
M2(n)=4;%16QAM
C2(n)=3/4;
elseif ( SINR_abdate(n) >=30 &SINR_abdate(n) < 35  )
M2(n)=4;%16QAM
C2(n)=4/5;
elseif ( SINR_abdate(n) >=35 &SINR_abdate(n) < 40 )
M2(n)=6;%32QAM
C2(n)=1/2;
elseif ( SINR_abdate(n) >=40 &SINR_abdate(n) < 45  )
M2(n)=6;%32QAM
C2(n)=2/3;
elseif ( SINR_abdate(n) >= 45 &SINR_abdate(n) < 50  )
M2(n)=6;%32QAM
C2(n)=3/4;
elseif ( SINR_abdate(n) >=50 &SINR_abdate(n) < 55  )
M2(n)=6;%32QAM
C2(n)=4/5;
end;;
DR_update(n)=Bw*M2(n)*C2(n);


end;
SE=DR/Bw;
SE_update=DR_update/Bw;
DT=1./DR
DT_update=1./DR_update;
figure
plot(SINR,'r*-')
holdon
plot(SINR_abdate,'bo-')
grid
xlabel('Number of step')
ylabel('SINR in [dB]')
title('SINR With and Without FQL')
legend('SINR to be optmize','SINR optmized')
axis([1 10 0 30])
%data rate
figure
plot(DR,'r*-')
holdon
plot(DR_update,'bo-')
grid
xlabel('Number of step')
ylabel('data in [Mpbs]')
title('Data Rate  With and Without FQL')
legend('Data Rate to be optmize','data rate optmized')
%axis([1 10 1 10])
% spectrum efficiency
```

```
figure
plot(SE,'r*-')
holdon
plot(SE_update,'bo-')
grid
xlabel('Number of step')
ylabel('Spectrum Efficiency  in b/s/h')
title(' spectrum efficiency With and Without FQL')
legend('spectrum efficiency to be optmize ','spectrum
efficiency optmized')
%axis([1 10 1 10])
%   Delay
figure
plot(DT,'r*-')
holdon
plot(DT_update,'bo-')
grid
xlabel('Number of step')
ylabel('Delay in mSec')
title(' Delay vs Step')
legend('Dealy Transmission to be optmize ','Dealy
Transmission optmized')
%axis([1 10 0 1])
%destance
figure

d=((.5*SINR.*(SINR-2))+(SINR))+50
d_update=(11.*SINR_abdate)+15
plot(d,'r*-')
holdon
plot(d_update,'bo-')
grid
xlabel('Number of step')
ylabel('distance in [dB]')
title('Coverag With and Without FQL')
legend('covege to be optmize','covergeoptmized')
%copacity
figure
C = log2(1 + SINR)*100
C_update = log2(1 + SINR_abdate)*100
plot(C,'r*-')
holdon
plot(C_update,'bo-')
grid
xlabel('Number of step')
ylabel('cabacity in number of user')
title('Cabacity With and Without FQL')
legend('cabacity to be optmize','cabacityoptmized')
```

Appendix Code B

```
[System]
Name='ss'
Type='mamdani'
Version=2.0
NumInputs=2
NumOutputs=4
NumRules=15
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='sum'
DefuzzMethod='centroid'

[Input1]
Name='cavarge'
Range=[0 500]
NumMFs=6
MF1='Very-Low':'trimf',[50 100 150]
MF2='LOW':'trimf',[100 150 200]
MF3='Medium':'trimf',[150 200 250]
MF4='Very-High':'trimf',[250 300 350]
MF5='High':'trimf',[200 250 300]
MF6='mf6':'trimf',[300 350 400]

[Input2]
Name='SE'
Range=[0 4]
NumMFs=6
MF1='Low':'trimf',[1 1.5 2]
MF2='Very-High':'trimf',[2.5 3 3.5]
MF3='Very-Low':'trimf',[0.5 1 1.5]
MF4='Mediame':'trimf',[1.5 2 2.5]
MF5='High':'trimf',[2 2.5 3]
MF6='mf6':'trimf',[3.001 3.501 4.001]

[Output1]
Name='E-SE'
Range=[0 4]
NumMFs=6
MF1='Low':'trimf',[1 1.5 2]
MF2='Very-Low':'trimf',[0.5 1 1.5]
MF3='Mediam':'trimf',[1.5 2 2.5]
MF4='Very-High':'trimf',[2.5 3 3.5]
MF5='High':'trimf',[1.99974603174603 2.49974603174603
2.99974603174603]
MF6='mf6':'trimf',[3 3.5 4]

[Output2]
Name='Tilit_ch'
Range=[0 50]
NumMFs=5
MF1='Very-Low':'trapmf',[-166.7 -166.7 3.233 8.267]
```

```
MF2='High':'trimf',[28.103544973545 34.143544973545
41.643544973545]
MF3='Very-High':'trapmf',[37.5 41.67 166.7 166.7]
MF4='LOW':'trimf',[8.67 14.74 24.75]
MF5='Medium':'trimf',[19.4 26.3 30.3571428571429]

[Output3]
Name='T-cavarage'
Range=[0 600]
NumMFs=5
MF1='Low':'trimf',[80 160 180]
MF2='Mediam':'trimf',[180 200 220]
MF3='High':'trimf',[220 230 240]
MF4='Very-Low':'trapmf',[-2000 -2000 70 80]
MF5='Very-High':'trimf',[240 240 600]

[Output4]
Name='Cavarge-ch'
Range=[0 500]
NumMFs=6
MF1='Very-low':'trimf',[50 100 150]
MF2='Low':'trimf',[100 150 200]
MF3='Mediam':'trimf',[150 200 252]
MF4='High':'trimf',[200 250 299.6]
MF5='Very-High':'trimf',[250 300 350]
MF6='mf6':'trimf',[300.26455026455 350.26455026455
400.26455026455]

[Rules]
3 0, 3 0 0 0 (1) : 1
2 0, 1 0 0 0 (1) : 1
5 0, 5 0 0 0 (1) : 1
4 0, 4 0 0 0 (1) : 1
1 0, 2 0 0 0 (1) : 1
0 4, 0 5 2 0 (1) : 1
0 1, 0 4 2 0 (1) : 1
0 5, 0 2 2 0 (1) : 1
0 3, 0 1 2 0 (1) : 1
0 2, 0 3 2 0 (1) : 1
0 4, 0 0 0 3 (1) : 1
0 1, 0 0 0 2 (1) : 1
0 5, 0 0 0 4 (1) : 1
0 3, 0 0 0 1 (1) : 1
0 2, 0 0 0 5 (1) : 1
```