Sudan University of Science and Technology
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Evaluating Macrocell Microcell

Handovers in LTE (4G)

October 2016

A thesis submitted as partial fulfillment of the requirements for the degree of B.Sc.(Honors) in Computer Systems and Networks

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Evaluating Macrocell Microcell Handovers in LTE (4G)

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الآية

(لَقَدْ جَاءَكُمْ رَسُولٌ مِّنْ أَنفُسِكُمْ عَزِيزٌ عَلَيْهِ مَا عَنِتُّمْ حَرِيصٌ عَلَيْكُم بِالْمُؤْمِنِينَ رَءُوفٌ رَّحِيمٌ(128)**فَإِن تَوَلَّوْا فَقُلْ حَسْبِيَ اللَّهُ لَا إِلَٰهَ إِلَّا هُوَ ۖ عَلَيْهِ تَوَكَّلْتُ ۖ وَهُوَ رَبُّ الْعَرْشِ الْعَظِيمِ (129))**

صدق الله العظيم

الإهداء

إلهي لايطيب الليل إلا بشكرك ولايطيب النهار إلا بطاعتك
.. ولاتطيب اللحظات إلا بذكرك .. ولا تطيب
الآخرة إلابعفوك .. ولا تطيب الجنة إلا برؤيتك. إلى من بلغ
الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي
الرحمة ونور العالمين .. سيدنا محمد صلى الله عليه وسلم
إلى من كلله الله بالهيبة والوقار .. إلى من علمنا العطاء
بدون انتظار .. إلى من نحمل أسمه بكل افتخار ..
نرجو من الله أن يمد في عمرك لترى ثماراً قد حان قطافها
بعد طول انتظار وستبقى كلماتك نجوم نهتدي
بها اليوم وفي الغد وإلى الأبد .. والدنا العزيز
إلى ملاكنا في الحياة .. إلى معنى الحب وإلى معنى الحنان
والتفاني .. إلى بسمة الحياة وسر الوجود
إلى من كان دعائها سر نجاحنا وحنانها بلسم جراحنا إلى
أغلى الحبايب
أمي الحبيبة
إلى من بهم نكبر وعليهم نعتمد .. إلى شمعة متقدة تنير
ظلمة حياتنا .. إلى من بوجودهم نكتسب قوة ومحبة
لا حدود لها .. إلى من عرفنا معهم معنى الحياة أخواني
إلى هذا الصرح العلمي الفتي والجبارجامعة السودان
للعلوم والتكنولوجيا, إلى كل من أشعل شمعة في دروبنا
وإلى من وقف على المنابر وأعطى من حصيلة فكره لينير
دربنا
إلى الأساتذة الكرام في كلية علوم الحاسوب وعلي رأسهم
الدكتوره :نعمه عز الدين عثمان
التي تفضلت بالإشراف على هذا البحث فجزاها الله
عنا كل خير فلها منا كل التقدير والاحترام

شكر وتقدير

الشكرلله عز وجل الذي أنار لنا ا لدرب، وفتح لنا أبواب
العلم
وأمدنا بالصبر والإرادة.

كل الشكر للأستاذه المشرفه الدكتوره :نعمه عزالدين
لتوجيهاتها ونصحها السديد
الشكر والإمتنان لكل الذين قدموا لنا يد المساعدة من
قريب
أو بعيد
ولكل من ساهم في إخراج هذا البحث إلى حيز التنفيذ
من أساتذة وإداريين بقسم نظم الحاسوب والشبكات.

المستخلص

من المتوقع أن تتحكم أنظمة الجيل الرابع في اتصالات الهاتف النقال في جميع مناطق التغطية في العالم. توفر هذه الأنظمة مختلف الخدمات للمستخدمين باختلاف أنواعهم والخدمات التي يطلبونها. تحدث عمليات النقل الرأسي بين طبقتين من الخلايا عندما يتم تحويل مستخدم من طبقة إلى الثانية. في هذا البحث، قمنا بدراسة أثر وسائط الشبكة على النقل الرأسي في خلية. تم ذلك باستخدام لغة ماتلاب في تطوير برنامج محاكاة يأخذ في الاعتبار طبقة خلايا ماكرو متراكبة مع طبقة خلايا مايكرو. قمنا بحساب عدة وسائط لقياس أداء الشبكة مثل التأخير واحتمالية اسقاط المكالمات المحولة واستخدام القنوات، ومن ثم مقارنة هذه الوسائط بالنسبة لمكالمات الماكرو والمايكرو. أظهرت النتائج أنه يمكن المحافظة على احتمالية اسقاط المكالمات المحولة بدرجة مقبولة عن طريق توفير احتياجات الخلية من قنوات وصفوف. كما أظهرت أن كفاءة أداء كل طبقة تعتمد على كمية المكالمات في كلٍ منهما. في حالة معاملة مكالمات كل طبقة بنفس الأولوية تكون الكفاءة في الأداء متشابهة.

Abstract

Fourth Generation (4G) systems are expected to operate the global mobile network coverage area. They provide various services for different user types and their requirements. Vertical handovers occur between two layers of cells when a user is switched from one layer to another. This research details the influence of network parameters on vertical handover performance in a cell. It is done using a MATLAB simulation considering a macrocell – microcell environment. We calculate

different network performance parameters such as delay, handover dropping probability and channel utilization and compare them for macrocell and macrocell traffic. Our results show that the handover dropping probability can be maintained in acceptable levels by providing sufficient channel and queue requirements. They also show that the performance of each layer depends on the amount of traffic in each layer. If the two traffic types are treated with equal priority in the system, their performance is similar.

Abbreviation	**Description**	**Page**
AVB	Available Bandwidth	16
BL	Battery Level	16
BS	Base Station	11
Coo	Cost of operation	16
DES	Discrete-Event Simulation	17
GPS	Global positioning system	6
GSM	Global System for Mobile Communications	7
GUI	Graphical User Interface	36
GPRS	General Packet Radio Service	8
3GPP	3rd Generation partnership project	21
HSCSD	High Speed Circuit Switched Data	8
HSDPA	High-Speed Downlink Packet Access	8
HeNB	home e node B	24
ITU-R	International Telecommunication Union – Radio communication Sector	9
IMT-Advanced	International Mobile Telecommunications Advanced	9
LTE	Long Term Evolution	9

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Chapter One

Introduction

1.1 Overview

Mobile systems are divided into generations according to their data rates and services, the First Generation Systems (1G), Second Generation Systems (2G),Third Generation Systems (3G), Enhances Second Generation Systems (2.5G), and Fourth Generation Systems (4G), Fourth Generation Systems have recently emerged providing high quality video services to large number of users.

The handover is the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. It has two types with respect to connections: soft handover and hard handover, there are several types of handover algorithms based on the parameter they use such as signal strength, speed and interference. This project considers the strength of the signal for the handover decision. Vertical handover happens between two overlapped cells of different sizes. This project evaluates hard handovers happening in overlapped in 4G systems.

1.2 Problem Statement

In 4G systems, macrocell and microcell are overlapped and are used to provide service for users. Each layer serves users according to some parameters (mobile speed, requested service, channel availability).

Handovers occur between two layers. The problem with vertical handovers is not having sufficient resource for users. In some cases, the traffic entering a cell from a different layer might consume all the resources, with the expense of quality of service for users entering the cell from the same layer. This project evaluates the effect of multi layer traffic on network performance.

1.3 Objectives

The aim of this research is to study the influence of performance parameters such as (arrival rate, total number of channels, mobile average speed) on handover performance (handover blocking and dropping probability).And to evaluate the performance of macrocell and microcell handover request and how they influence each other.

1.4 Research Methodology

The research uses discrete event driven simulation to evaluate the vertical handover system. It uses a M/M/C queue to serve the requests for channels in the cell. The simulation is developed using MATLAB.

1.5 Scope

This research considers handover cells only. It does not take into account new call requests generated at microcells and macrocells.

1.6 Organization of the Thesis

There are six chapters in this research. The second chapter describes mobile systems and generations, handovers and types of it and explains vertical handovers. Chapter three literatures Review. Chapter four describes the methods and tools that were used to evaluate the handover system and the design of the system. The fifth chapter shows the results and discussions of the project .The sixth chapter shows the conclusions, recommendations and references.

Chapter Two

Background of Mobile Systems

2.1 Introduction

This chapter explains mobile system, handovers, handover algorithms and vertical handovers, simulation modeling, experiment environment.

2.2 Background of Mobile Systems

Mobile devices are the prevalent computing device in many parts of the world, and over the next few years it is expected that mobile Internet usage will outpace desktop usage worldwide.

Mobile phones are nowadays inexpensive, easy to use, and comfortable. Their importance can be illustrated through the following additional features: The mobile phones are the complete lifesavers as they can help in emergency if we get stuck in unknown areas, it is can easily write daily schedules, contacts of friends, appointments, notes and they even remind us of the important events or meetings.

Number of mobile users around the world has become more than half the population, as studies have proved that mobile users increase at a rate of more than half a year due to the smart use of technology in mobile device applications in it.

Mobile phones are no longer just devices only for voice telephony, but goes beyond to exchange multimedia messages such as graphics, video, use e-mail and the Internet. And given the enormous potential in the smart phone has become possible to exploit this potential by multiple applications benefit the user.

A mobile application is a software application designed to run on mobile devices such as smart phones and tablet computers. Most such devices are sold with several apps bundled as pre-installed software, such as a web browser, email client, calendar, mapping program, an app for buying music, other media and more apps. Some pre-installed apps can be removed by an ordinary uninstall process, thus leaving more storage space for desired ones. Where the software does not allow this, some devices can be rooted to eliminate the undesired apps [1].

2.2.1 Mobile Systems

A mobile operating system is an operating system for smart phones, tablets or other mobile devices. While computers such as the typical laptop are mobile, the operating system that they use is not considered mobile .This is because they were originally designed for bigger stationary desktop computers that historically did not have or need specific mobile features.

Mobile operating systems combine features of a personal computer operating system with other features useful for mobile or handheld use this includes: a touch screen, cellular, Bluetooth,Wi-Fi,GPS (Global positioning system) mobile navigation, camera. All of these features are considered essential in modern mobile systems [2].

2.2.2 Mobile System Generations [3]

Mobile systems are divided into generations according to their data rates and services. Following is a brief explanation of each generation, where their evolution is shown in Figure 2-1.

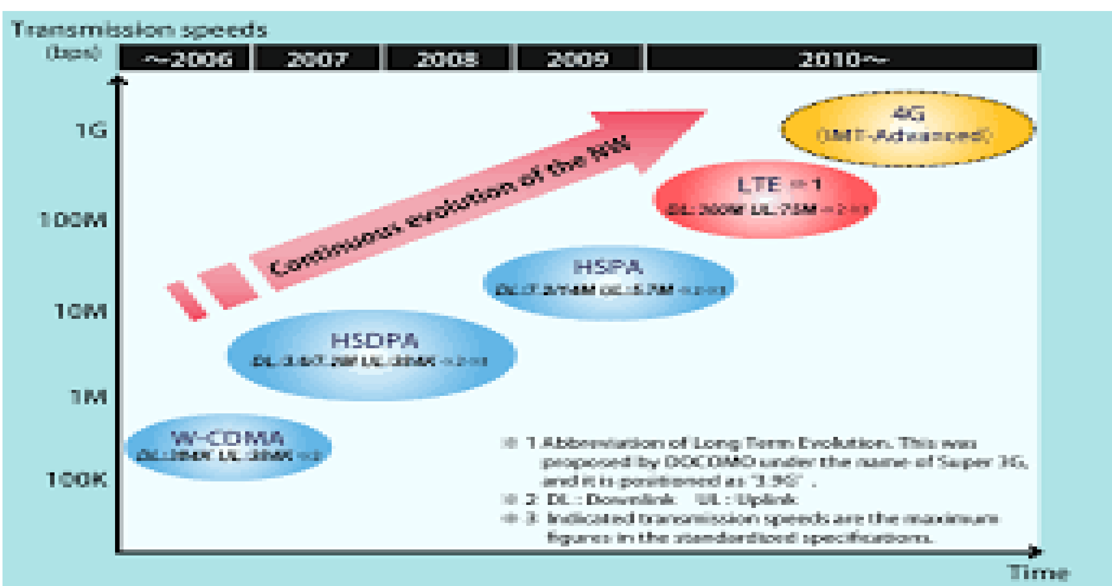


Figure 2- Evaluation of Mobile System Generations

1. **First Generation Systems (1G)**

These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunication. The cells used in 1G were large hexagon – shaped cells with a radius of about 30 kilometers.1G system suffered from many limitations including: limited capacity, lack of security and roaming.

2. **Second Generation Systems (2G)**

Second generation 2G cellular telecom networks were commercially launched on the GSM (Global System for Mobile Communications) standard in Finland.2G introduced data services for mobile, starting with SMS(Short Massage Services) text messages. 2G technologies enabled various mobile phone networks to provide the services such as MMS (Multimedia Messages Service).

3. **Enhanced Second Generation Systems(2.5G)**

The bridging technology between 2G and 3G,based on existing 2G technologies, focused on increasing the maximum data rates, it work base on packet switched networks.'2.5G' systems introduced enhance the data capacity of GSM and mitigate some of its limitations, these systems add packet data capability to GSM network and the most important technologies are GPRS (General Packet Radio Service) and High Speed Circuit Switched Data (HSCSD): uses multiple time slots per user.

4. **Third Generation Systems (3G)**

Is the third generation of mobile telecommunications technology. It is based on a set of standards used for mobile devices and mobile telecommunications such as The Universal Mobile Telecommunications System (UMTS). It uses services and networks that comply with the International Mobile

Telecommunications-2000. 3G famous applications include: mobile Internet access, fixed- wireless Internet access, video calls and mobile TV.

5. **Enhances Third Generation Systems (3.5G)**

3.5G is a grouping of a number of mobile telephony and data technologies designed to provide better performance than 3G systems. They come as an intermediate step towards deployment of full 4G capability.

The technologies include:

- High-Speed Downlink Packet Access(HSDPA)
- Evolved HSPA-
- 3GPP Long Term Evolution(LTE)

6. **Fourth Generation Systems (4G)**

4G is the fourth generation of cellular wireless standards. It is an enhancement of the 3G and 2G families of standards. In 2008, the ITU-R (International Telecommunication Union –Radio communication Sector) organization specified the IMT-Advanced (International Mobile Telecommunications Advanced) requirements for 4G standards, setting peak speed requirements for 4G service at 100 Mbit/s for high mobility communication and 1 Gbit/s for low mobility communication .The goal of 4G is to allow everyone to access the Internet anytime and every where and to increase user data rates and services at a reduced cost.

A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smart phones, and other mobile devices. It is also expected to provide facilities such as ultra-broadband Internet access, IP telephony, gaming services, and multimedia.

4G candidate systems include:

- Mobile WiMAX standard (first used in South Korea in 2007).
- The first-release Long Term Evolution (LTE) standard (in Norway and Sweden since 2009).

It was expected that 4G systems will be put in practice in 2012. However, non of the candidate systems is considered 4G yet. Instead, they are referred to as 3.9G and beyond 3G.

2.2.3 Security and Privacy in 4G

In the development of 4G Networks, security measures must be established that enable data transmission to be as safe as possible.

The network should support security to protect data that is transmitted across the network from hackers and other security violations.

One of the main goals of 4G networks is to provide services across a wide geographic area seamlessly. At the same time, smaller local area networks will run different operating systems. The heterogeneity of these wireless networks exchanging different types of data complicates the security and privacy issues. Furthermore, the encryption and decryption methods being used for 3G networks are not appropriate for 4G networks.

To overcome these security and privacy issues, two approaches are followed. The first is to modify the existing security and privacy methods so that they are applicable to heterogeneous 4G networks. The other approach is to develop new dynamic reconfigurable, adaptive, and lightweight mechanisms [4].

2.2.4 Quality of Service in 4G

With respect to network quality, many 4G telecommunications providers are promising that there will be enhanced connectivity. They also promise to maximize the quality of transmitted data across the network [5].

2.3 Handovers in Mobile Systems

2.3.1 Handover Definition

In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service [6].

Handovers occur when the signal strength between the mobile and the serving Base Station (BS) falls below a certain level due to the mobile distance from the base station or the level of interference.

2.3.2 Handover Objectives

1. Maintaining continuous connection for users whilst providing the network quality of service (QoS) at all times.
2. Decreasing the interference by reducing the transmitted power, and hence increasing the useful signal.

3. Insuring equal distribution of traffic among cells to administrate resources, avoid congestion and balance the load between cells.
4. Clearing outlining of cells' boundaries and coverage areas.

2.3.3 Types of handover

Handovers are categorized with respect to frequencies, Systems, Connections and handover technique

2.3.3.1Types of Handovers with respect to frequencies:

1. Intra-frequency Handover: when the frequency does not change following the handover.
2. Inter-frequency Handover: when the handover leads to change in the frequency.

2.3.3.2 Types of Handovers with respect to systems:

1. Intra-system Handover: within the same mobile system.
2. Inter-system Handover: when the handover leads to a change in the mobile network.

2.3.3.3Types of handovers with respect to connections [7]

1. Hard Handover

Is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before the connection to the target is made. For this reason such handovers are also known as "break-before-make". Hard handovers are intended to last for the minimum time possible. So that the call disruption is short. The call disruption caused by hard handover can be observed by the caller as a click during the call.

2. **Soft handover**

In soft handover the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handover is called “make-before-break”. The time interval, during which the call maintains the two connections in parallel, may be brief or substantial. Soft handovers may involve using connections to more than two cells; as connections to three, four or more cells can be maintained by one phone at the same time. When a call is in a state of soft handover, the signal of the best channel is used for the call. Alternatively, all the signals can be combined to produce a clearer copy of the signal. This type has more advantage.

3. **Softer handover**

When the soft handover is performed both in the downlink (forward link) and the uplink (reverse link), the handover is called softer. Softer handovers are possible when the cells involved in the handover have a single cell site.

2.3.3.4 Types of handovers with respect to handover technique

1. Network controlled handover.

The concept of network controlled handovers is commonly used in cellular technologies. With multi-mode terminals, using layer-2 techniques, this concept can only be applied inside each technology, which impairs the full exploitation of multi-access support.

2. Mobile phone assisted handover.

A mobile assisted handover (MAHO) is a process used in GSM cellular networks where a mobile phone assists/helps the cellular base station to transfer a call to another base station. It is a technique used in mobile telecom to transfer a mobile phone to a new radio channel with stronger signal strength and improved channel quality.

3. Mobile controlled handover.

In mobile-controlled handover, each MS is completely in control of the handover process. This type of handover has a short reaction time (in the order of 0.1 seconds). MS measures the signal strengths from surrounding BSs and interference levels on all channels. A handover can be initiated if the signal strength of the serving BS is lower than that of another BS by a certain threshold.

2.4 Handover Algorithms

2.4.1 Umbrella handover algorithm

The umbrella handovers are utilized in order to make handovers between different network layers or cell sizes. For example, handover between macrocells and microcells.

In order to be effective, the umbrella handover algorithm should also take into account other parameters such as the speed of the mobile.

For example, it is more desirable to assign faster moving mobiles to the macro cells and provide service to stationary mobiles from the microcell to minimize the number of handovers in the area [8].

2.4.2 Traffic based handover algorithm

In order to balance the load between cells, a specified number of handovers from one specified cell can be performed. This allows distributing callers from acongested cell to neighbor cells with less number of active connections, which leads to improving the overall performance.

Before the decision for a handover is made, it is important to ensure that the drop in the measured signal level is not due to momentary fading and that the mobile is actually moving away from the serving base station.

The base station monitors the signal level for a certain period of time before a handover is initiated [9].

Information about the vehicle speed can also be computed from the statistics of the received short-term fading signal at the base station.

2.5 Vertical Handover (VHO)

Vertical handover is a network node that automatically changes its connection type to access a supporting infrastructure. When a computing device could connect to the Internet via two different network technologies, it is automatically connected to the available network. This switching from one network to the other is called vertical handover.

Vertical handover enable the phone to select the higher bandwidth at lower costs for networks like wide local area networks. It also provides extended coverage for cellular networks [10].

2.5.1 Reasons for Vertical Handover

1. Cost/Capacity/Coverage.
2. Benefit of utilizing the higher bandwidth and lower cost.
3. Multiple Cellular technologies are generally available at the same coverage area.
4. Better mobility support and larger coverage.

2.5.2 Challenges in Vertical Handover

1) Multi-mode devices
2) Power consumption
3) Quality of Service QoS
   - Available capacity
   - Security
4) Timing
5) The business model
6) Session continuity

2.5.3Input parameters for Vertical Hanover

- Available Bandwidth (AVB)
- Speed of mobile terminal (SMT)
- Number of Users (NU)
- Received Signal Strength (RSS)
- Battery Level (BL)
- Cost of operation (C)

- Traffic Type (TT)

2.5.4 Vertical Handover Process

Vertical handover have three main phases:

Initiation: mobile terminal (or network controller) must know which wireless networks are reachable.

Decision: selection, through a VHO algorithm, of the access point, on the basis of proper performance metrics (Received Signal Strength Indicator (RSSI), network connection time, available bandwidth, power consumption, cost, security level, user preferences).

Execution: signaling operations to re-establish connection and carry out data transfer [11].

2.5.5 Limitations of vertical handover

1) It handles all the connections in the same manner. When all TCP/IP connections automatically transfer from one interface to another, in this situation only one wireless interface (the best one) is used at that moment.

2) An incorrect handover decision may degrade the quality of service or break off the current call.

2.6 Simulation modeling

A simulation is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world. Simulation modeling is used to help designers and engineers understand whether, under what conditions, and in which ways a part could fail and what loads it can withstand [12].

2.6.1 Types of simulation

There are two types of simulation with respect to observation periods and how the system's state evolves over time:

Continuous Event simulation

Continuous Simulation refers to a computer model of a physical system that continuously tracks system response according to a set of equations typically involving differential equations .It is assumed that the number of people in the system and number of servers busy can take any continuous value. These assumptions make it possible to model using stock and flow structure of system dynamics approach .

Discrete-Event Simulation (DES)

A discrete-event simulation (DES) models the operation of a system as a discrete sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system. Between consecutive events, no change in the system is assumed to occur, thus the simulation can directly jump in time from one event to the next.

2.6.2 M/M/c queuing model

In queuing theory, a discipline within the mathematical theory of probability, the M/M/c queue (or Erlang–C model) is a multi-server queuing model. In Kendall's notation it describes a system where arrivals form a single queue are governed by a Poisson process, there are *c* servers and job service times are exponentially distributed. It is a generalization of the M/M/1 queue which considers only a single server. The model with infinitely many servers is the M/M/∞ queue.

2.7 Experiment environment

There are a number of handover types in the system, shown in Figure 2-1

1. Handovers moving out of the current macrocell into a neighbor macrocell.
2. Handovers moving from a neighbor macrocell into the current macrocell.
3. Handovers from a microcell into the macrocell.
4. Handovers from the macrocell into a microcell
5. Handovers moving out of the current microcell into a neighbor microcell.
6. Handovers moving from a neighbor microcell into the current microcell.

This research, consider the handover explained 2 and 3, since they are served from the resources of the cell of interest. As for other handover types, they are handled by resource from other cells.

Figure 2-2 Handover Types

Chapter Three

Literature Review

3.1 Introduction

This chapter illustrates the handover schemes in overlaid macro femto cellular networks, and discuses a novel approach for mobility management in LTE femto cells, and a survey discussed various existing handover decision algorithms for the integrated macrocell-femtocell network, also it simulates femtocell scenarios with features and models compliant with 3GGP specifications using LTE-sim frame work. Then the tools and techniques which are used in the project.

3.2 Handover schemes in overlaid macro femto cellular networks

Femtocells are the small, low power base stations deployed inside the homes or buildings to provide better coverage in those regions and to increase the capacity of the networks

The femtocells have emerged out as a promising solution to improve the network coverage indoors and to offload the traffic from already overloaded macrocells.

In this study, a few works on the handovers in femtocell overlaid macrocell have been described. The objectives for handover are proposed which include throughput, energy efficiency, and reduction in unnecessary handovers, network load balancing, interference management and network security. The comparison of existing handover techniques has been done against the stated objectives.

The comparison indicates the need of an efficient handover technique that tries to cover all the objectives. To achieve all of them is certainly difficult but more number of objectives achieved leads to improve the quality of service to user [13].

3.3 A novel approach for mobility management in LTE femtocells

LTE is an emerging wireless data communication technology to provide broadband to internet access. Femtocells are included in

3GPP (3rd Generation partnership project) since Release 8 to enhance the indoor network coverage and capacity. The main challenge of mobility management in hierarchical LTE structure is to guarantee efficient handover to or from/to/between femtocells.

This study focused, on different types of handover and comparison performance between different decision algorithms.

A speed based handover algorithm for macro-femto scenario is proposed with simulation results.

The paper showed the mathematical complexity of the renowned approaches for handover techniques and comparisons of the simulation result of the handover algorithm to others, the main aim was to create a speed based algorithm.

The preliminary simulation results showed a better result than the signal strength based and speed based handover techniques and showing lower number of handover attempts in the cell centre areas. However, the proposed algorithm is not very energy efficient and does not perform well in the cell edge area compared to other handover algorithm [14].

3.4 Mobility management in integrated macrocell femto cell network- A Survey

Support of femtocell is an integral part of latest wireless communication technologies to achieve high capacity demand and high data rate.

For successful deployment of femtocells, smooth integration of femtocell network in macrocell network and seamless communication between them is required.

This survey article discussed various existing handover decision algorithms for the integrated macrocell-femtocellnetwork.

A number of handover management algorithms are studied and advantages, disadvantages of proposed algorithms are discussed [15].

The study covered the following algorithms:

Handover decision algorithm based on RSSI and Wireless Transmission Loss

Handover decision algorithm based on UE movement pattern

Handover decision algorithm based on UE Speed

Handover decision algorithm based on traffic type

Handover decision algorithm based on Received signal strength & Quality

Handover decision algorithm using SON concept

Handover decision algorithm using Proximity concept

When developing a vertical handover algorithm, the main features to focus on are:

1- Handover decision parameters

2- System model assumptions

3- QoS requirements

4- Features of algorithms

3.5 System level simulation for two tier macro-femto cellular networks

LTE-Simulation (LTE-sim) is an object-oriented open source simulator which incorporates a complete protocol stack that can be used for simulating two-tier macro- femto scenarios.

In this study, simulates femtocell scenarios with features and models compliant with 3GPP specifications.

The simulation are developed using LTE-sim framework.

The femtocell scenario can be used for investigating performances in a wider range that can differ in terms of network layouts (i.e., number and position of base stations, building, and streets), system load (i.e., number of users and applications) and so on [16].

3.6 Performance analysis of handover strategies in femtocell network

Femtocells, also known as HeNB (home e node B) are the network technology in the Long Term Evolution (LTE) network that are implemented in order to fulfill the upcoming demand of high data rates.

There are three types of access mode:

1- Open Access mode
2- Closed Access mode

3- Hybrid Access mode

This study analyzed the performance analysis of handover strategies in femtocells networks under hybrid access mode to minimize the unnecessary handovers.

The handover strategy was evaluated based on the specific stay time interval 'T' and UE (user equipment) velocity.

The simulation results showed that the proposed algorithm minimized the number of handovers and decreased the unnecessary handover probability.

The results also proved to be better when compared with the traditional strategy

This study considers femtocells, which are indoor miniature cells that serve stationary mobiles. Therefore the mobile speed or the requested service does not play an influential parameter in the handover decision. The main reason for a handover to occur is the mobile exiting the coverage area of the femtocell.

[17].

3.7 Tools and Techniques

MATLAB

Matrix laboratory is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

In 2004, MATLAB had around one million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics [18].

Chapter Four

System Design

4.1 Introduction

This chapter illustrates the design of the system. It explains the model inputs and outputs, the experiment environment and the simulation description.

4.2 System design

This project used discrete event driven simulation to evaluate the vertical handover system. The model of the system evolves over time by an arrive or depart event and the state variables change instantaneously at separated points in time.

In this project, the basic entities in the queuing network model are service centers, which represent channels, and customers, which represent call requests.

This project used M/M/c queue to hold vertical handover requests when no channels are available to handle the requests immediately (from the c total channels). The queuing model id described as follows:

- Arrivals are randomly generated and follow an exponential distribution with a mean value of λ .
- Service times have an exponential distribution with parameter μ in the M/M/c queue. This represents the call duration.
- There are *c* servers, which are the channels that are used to make calls, and serve from the front of the queue. If there are less than *c* requests, some of the servers will be idle. If there are more than *c* requests, they are placed in the queue.
- The queue is of size N, so all requests that exceed the system capacity (c+n) will be droped.

4.3 Model Inputs

The inputs of the model are:

Request arrival rates:

A call request in the system is a handover call moving from a neighbor cell into the current cell.

This call can be entering from a macrocell with a rate λ_a ,or from a microcell in a different layer with a rate λ_i .

Total channels:

A server here is a channel, which is the resource provided by the cell for the mobile user to send and receive signals for a service (a call for example). There is a total of c available channels in the cell which are fairly granted to macrocell and microcell users.

Service Demand:

The service demand of a customer at the server is the total amount of time the customer requires in service. The average service time is $\frac{1}{\mu}$, where μ is the service rate.

Queue Length:

The queue length N is the average number of customers in the queue.

4.4 Model Outputs

The outputs of the model are:

Utilization:

The utilization of a server is the proportion of time the device is busy, or, equivalently, the average number of customers in service there.

Throughput:

The average number of served customers per unit time.

Mean queue delay:

The average time a customer waits in the queue.

Dropping probability:

It's the probability that the call is dropped due to the system reaching its full capacity. (The system capacity is calculated from the queue size N plus the total channels c).

4.5 System Scenario

Figure 4-1 Handover Requests

This system, consider two layers of overlapped cells shown in Figure 4-1

1. A layer of macrocells that provides service to mobile users who are moving at a high speed.
2. A layer of microcells that accommodates slow moving and stationary mobile users.

The system considers two types of customers:

1. Handover requests from neighboring macrocell.
2. Handover requests from a microcell in different layer.

The cell has a number of c channels which are given to call requests on demand, there are arrivals from macrocell and microcell, as shown in Figure 4-2

Figure 4-2 Macrocell System Components

There are three cases happen in the system:

1. The user request will be immediately served.
2. The user request will be delayed in a queue.
3. The user request will be dropped.

Case One

If the servers are available, the user will enter immediately to the channel to be served as shown in Figure 4-3

Figure 4-3 Service without Delay

Case two

If all servers are busy, in another call requests the user call request will be delayed and placed in the queue until there is an available channel as shown in Figure 4-4.

Figure 4-4 Service with Delay

Case three

If all servers are busy, in another call requests the user call request, and also the queue is full the user call request will be dropped as shown in Figure 4-5.

Figure 4-5 Service Dropped

4.6 Simulation description

The general methodology that is applied in the simulation is described in the flow chart show in Figure 4.2

The simulation starts by initializing the parameters and input them in the program. The next step is accepting a handover requests then check the queue, if the queue is full or not. If the queue is full, then the request will be dropped. In the case that the queue is empty or not full. The simulation checks if there is an available channel or not. If no channel is available, the request will be placed in the queue until a channel is available. Otherwise, the request will immediately be served. In all cases, statistics are calculated to evaluate the performance of the current request as well as the system in whole, and to update system state variables. After that, the simulation checks if the maximum number of requests is reached. If not, it accepts a new request, otherwise, the simulation terminates.

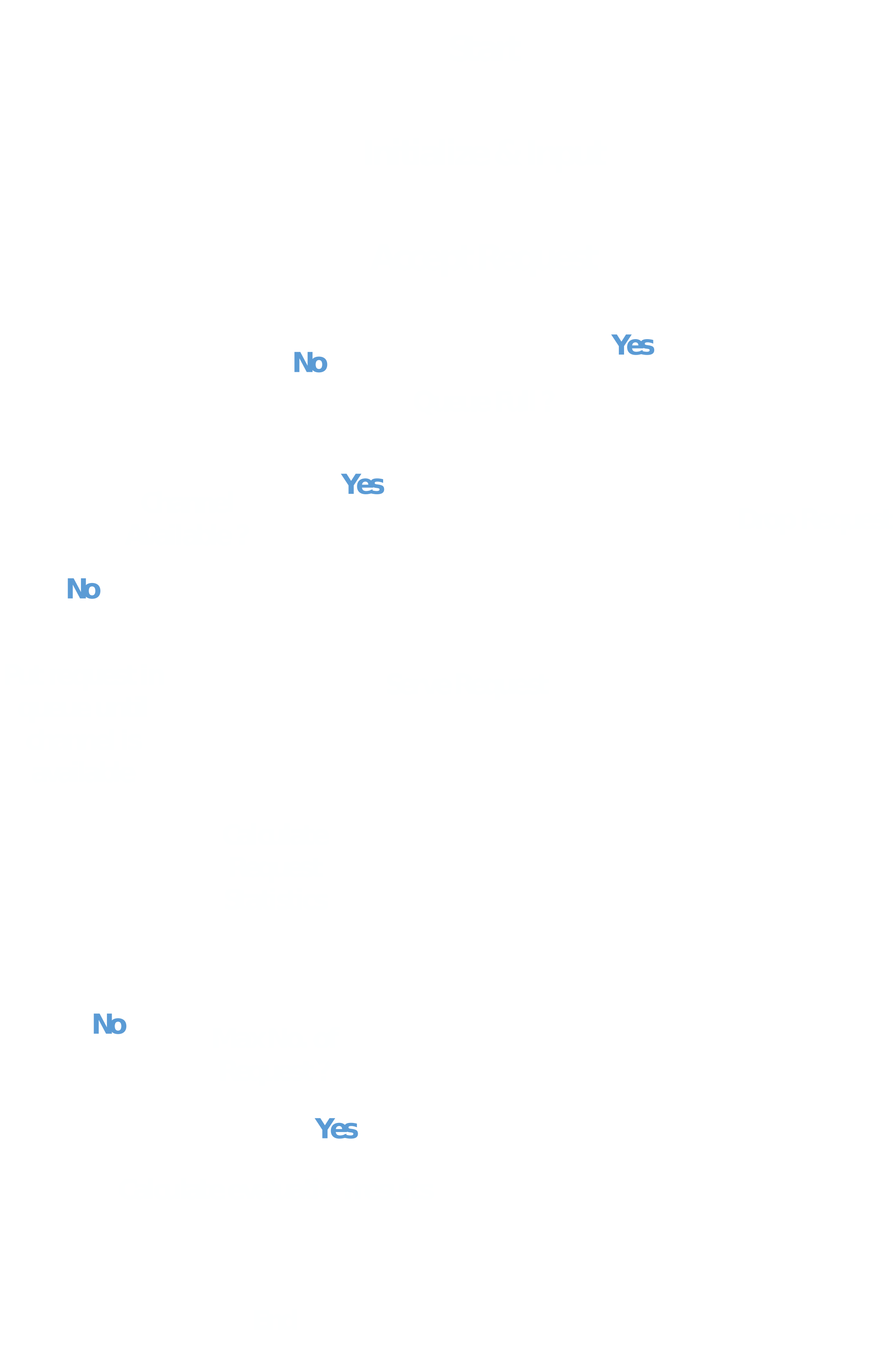


Figure 4-6 Simulation Flowchart

Chapter Five

Results

5.1 Introduction

The implementation of the explained simulation is developed using MATLAB environment. And developed a Graphical User Interface (GUI) to enable the input of multiple parameters and obtain the outputs immediately. The requested inputs to run the simulation are the arrival rates, service time, number of channels, queue size, and the total number of users. The simulation is run and the outputs are calculated and displayed. These outputs are the throughput, served requests (successful HO) and the rejected requests (dropped HO). The simulation generates figures for the mean delay, utilization, and the dropping rate for both macrocell and microcell requests. A separate widow enables evaluating the system with different number of channels, queue sizes, and arrival rates, while other parameters are fixed. Here, the results will give the mean delay, utilization and the dropping rate for the different values entered.

5.2 Implementation

The user enters the input values and run the simulation. The simulation initializes output and temporary variables. Then it repeatedly generates the random numbers to simulate arrival and service events. The throughput is theoretically calculated using Erlang C equation. It is calculated a second time from the simulating by looping for each user and deciding if the user is blocked or served with respect to the availability of channels and queue space. The Grade of Service is calculated by the equation:

$$GoS = \frac{No\ of\ Dropped\ users \times 100}{Total\ number\ of\ user}$$

The delay of the users is calculated by adding the current holding time to the delay of the previous user:

Delay = service time + previous delay

When different values of parameters are considered (number of channels, queue size or arrival rate), the simulation is executed each time with a value, and the result is displayed in figures for comparison.

Table 5.1 lists the inputs values used in the evaluation.

Parameter	Input value
Macrocell arrival rate	70 call/sec
Microcell arrival rate	50 call/sec
Service time	15 seconds
Total number of channels	15
Total number of users	100
Queue size	50

Table 5.1 Simulation inputs

5.3 Simulation Results and Evaluation

Scenario one

In this section, demontration by results the outcomes of evaluation. The simulation runs after entering the input as shown in Figure 5-1. The results are mathematically calculated and displayed on the interface.Simulation results are displayed in figures . An example of the resultes shown in the following subsections.

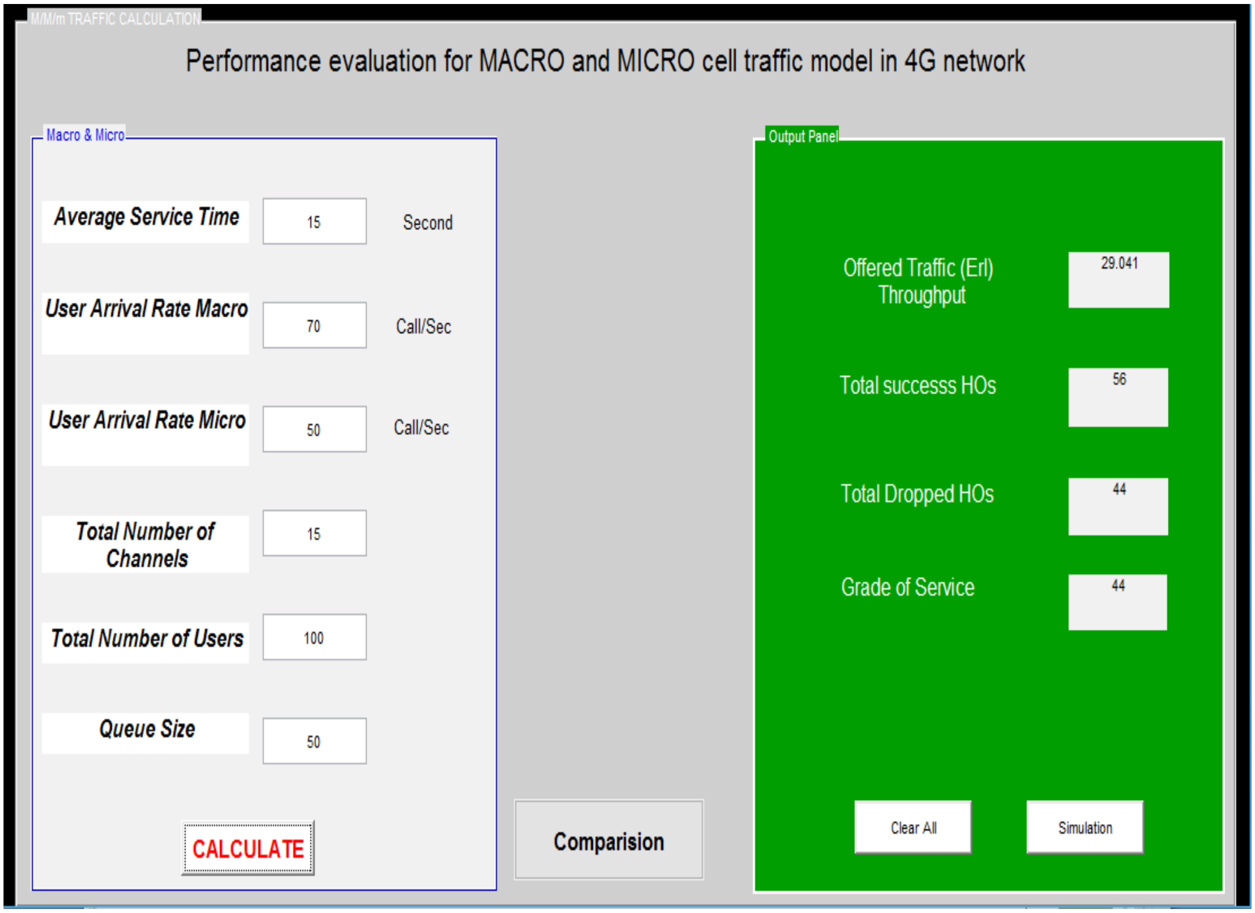


Figure 5-Main interface

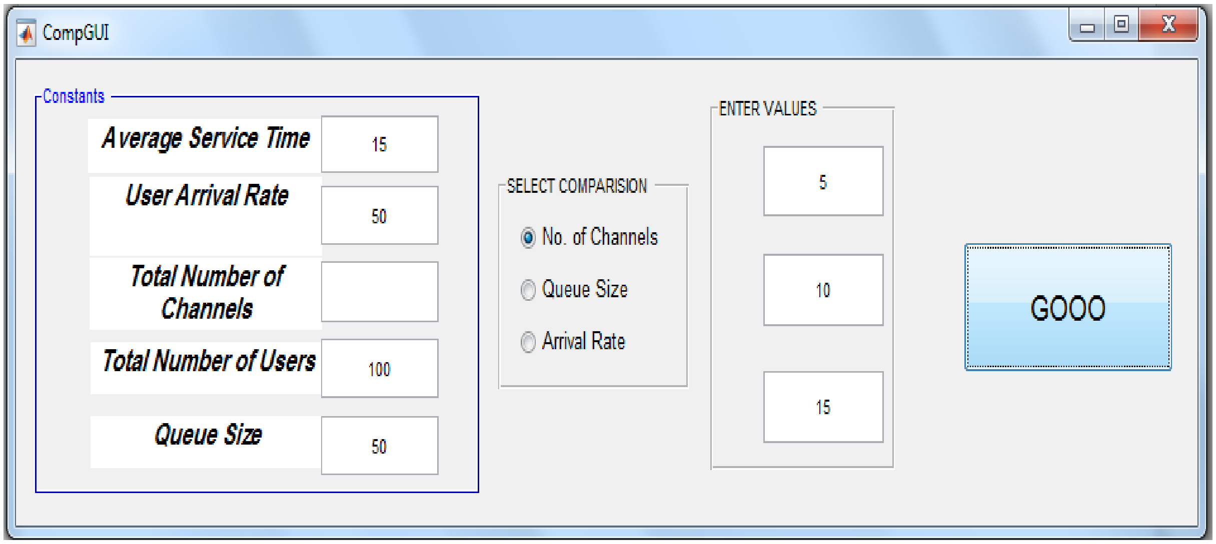
5.3.1 Mean delay measurements

1) Mean delay having different number of channels

Assume that:

- The service time is 15 second.
- The user arrival rate is 50call/sec.
- The total number of users in the system is 100.
- The queue size is 50.

- The number of channels has different values which are: 5, 10, 15.



When the number of channels increases, more requests are served immediately reducing the delay as shown in Figure 5-2.

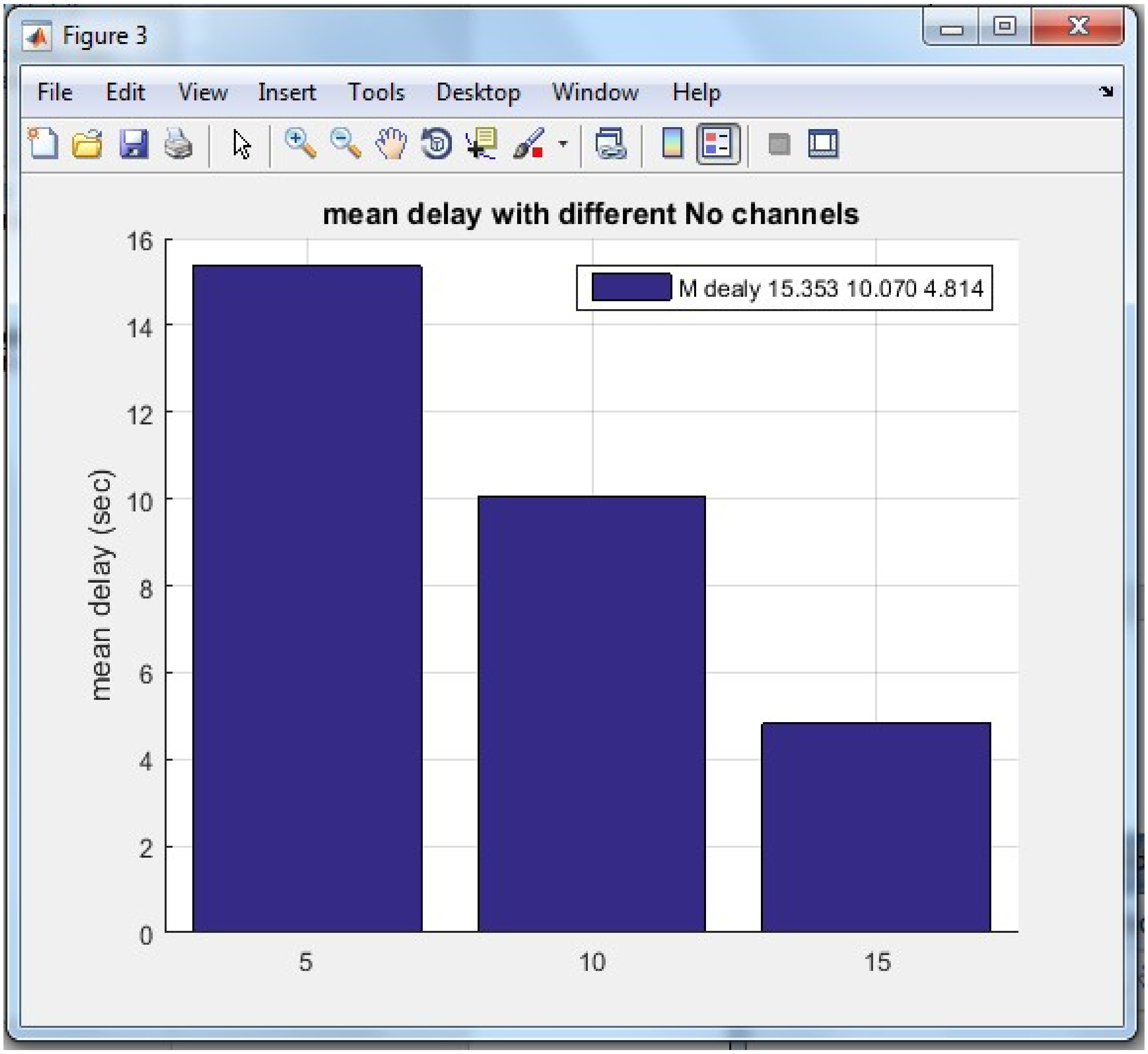
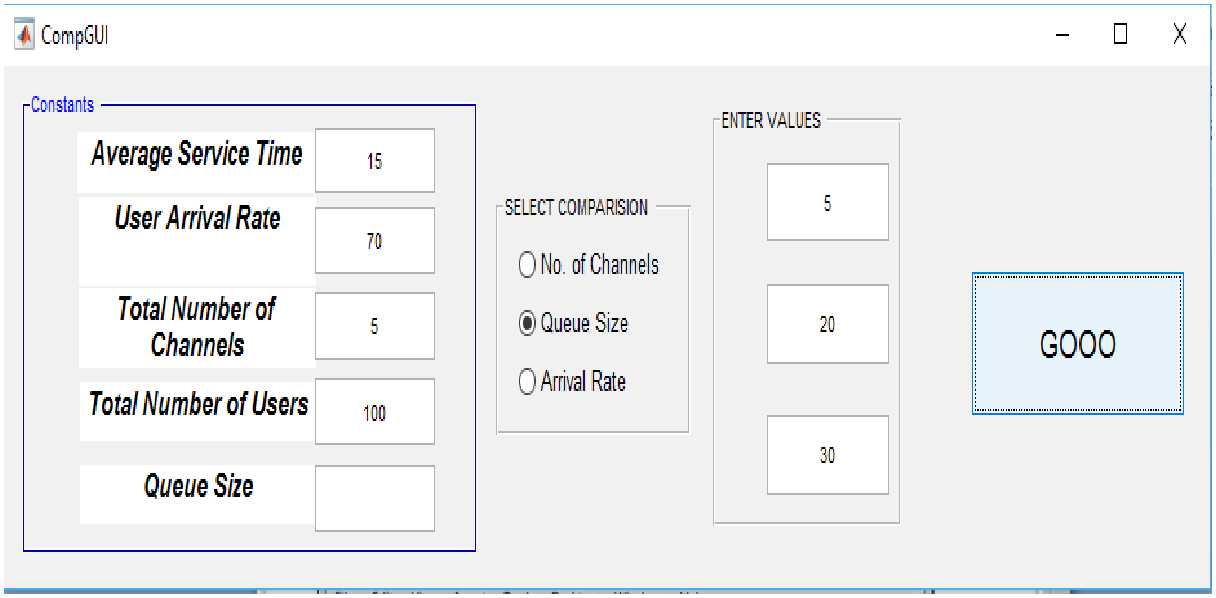


Figure 5- Mean delay having different number of channels

2) Mean delay having different Queue size

Assume that:

- The service time is 15 second.
- The user arrival rate is 70 call/sec.
- The total number of channels is 5.
- The total number of users in the system is 100.
- The queue size has different values which are: 5, 20, 30.



When the queue size is increase the mean delay is increases also, as shown in Figure 5-3.

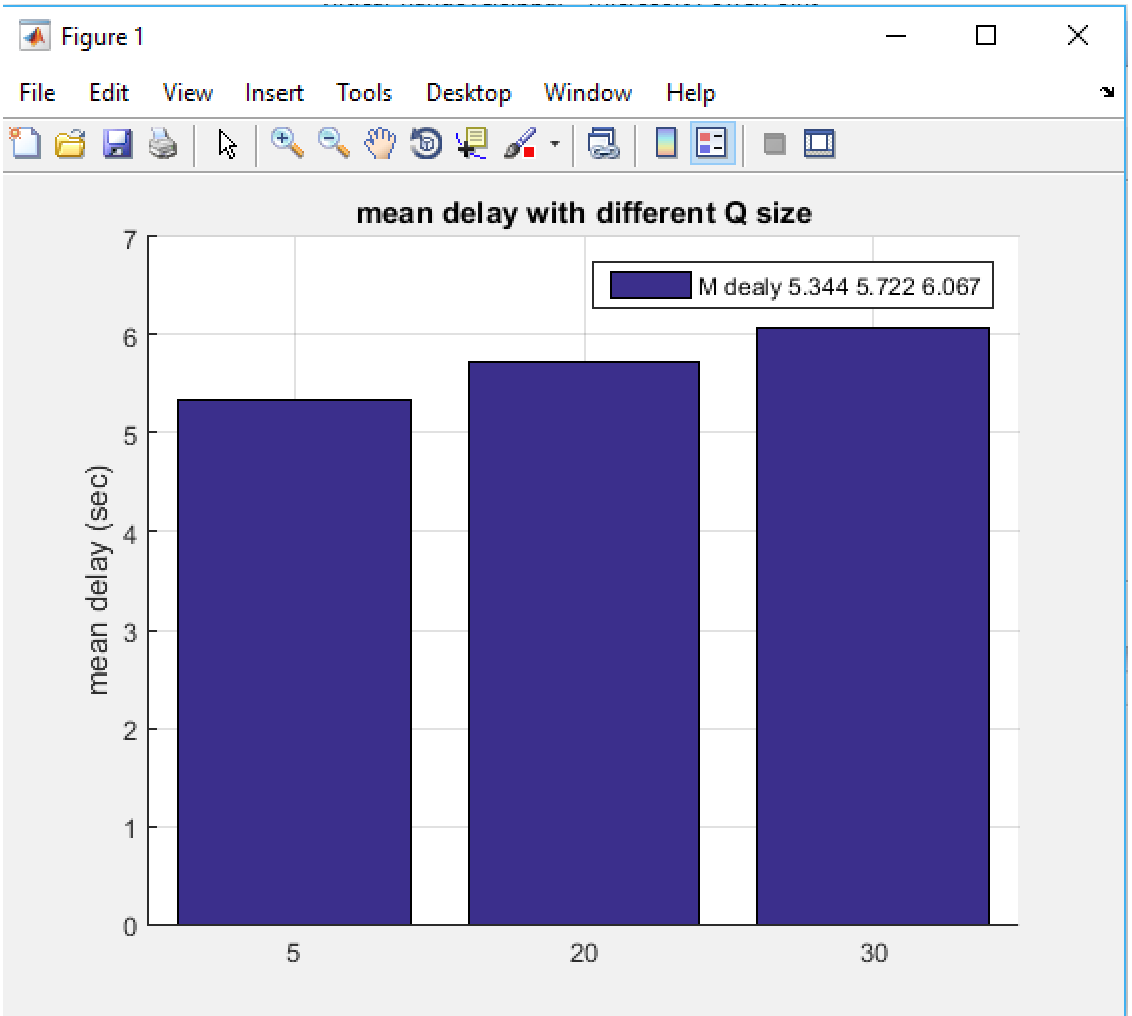


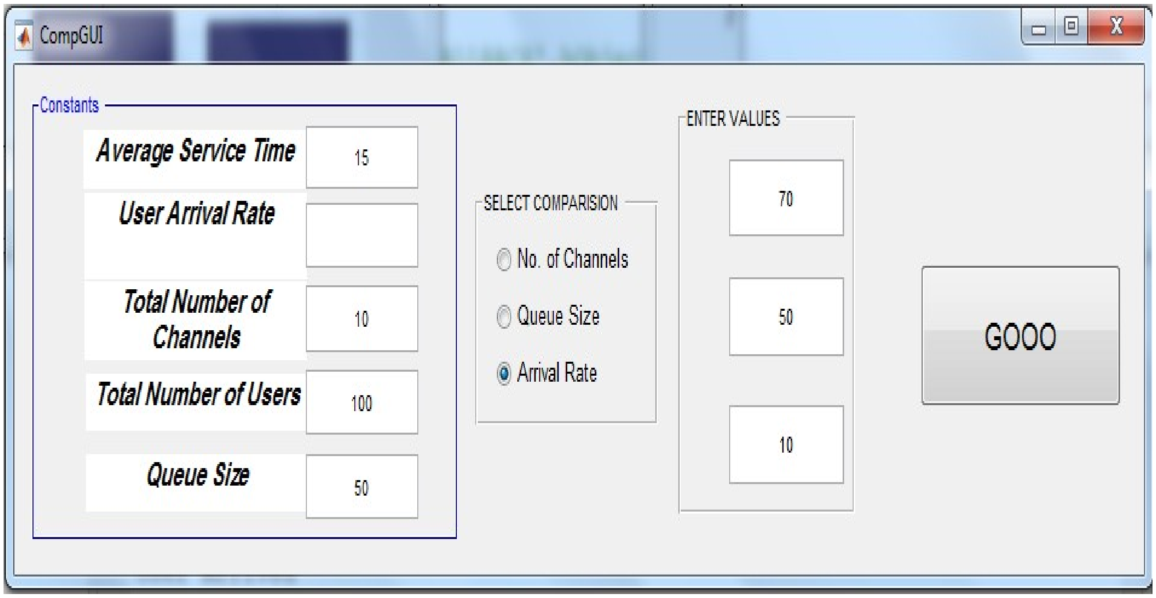
Figure 5-Mean delay having different Queue sizes

3) Mean delay having different arrival rates

Assume that:

- The service time is 15 second.
- The user arrival rate has different values which are: 70, 50, 10 call/sec.
- The total number of channels is 10.
- The total number of users in the system is 100.

- The queue size is 50.



When the arrival rates increases, more requests are placed in the queue. Therefore, the mean delay increases also as shown in Figure 5-4.

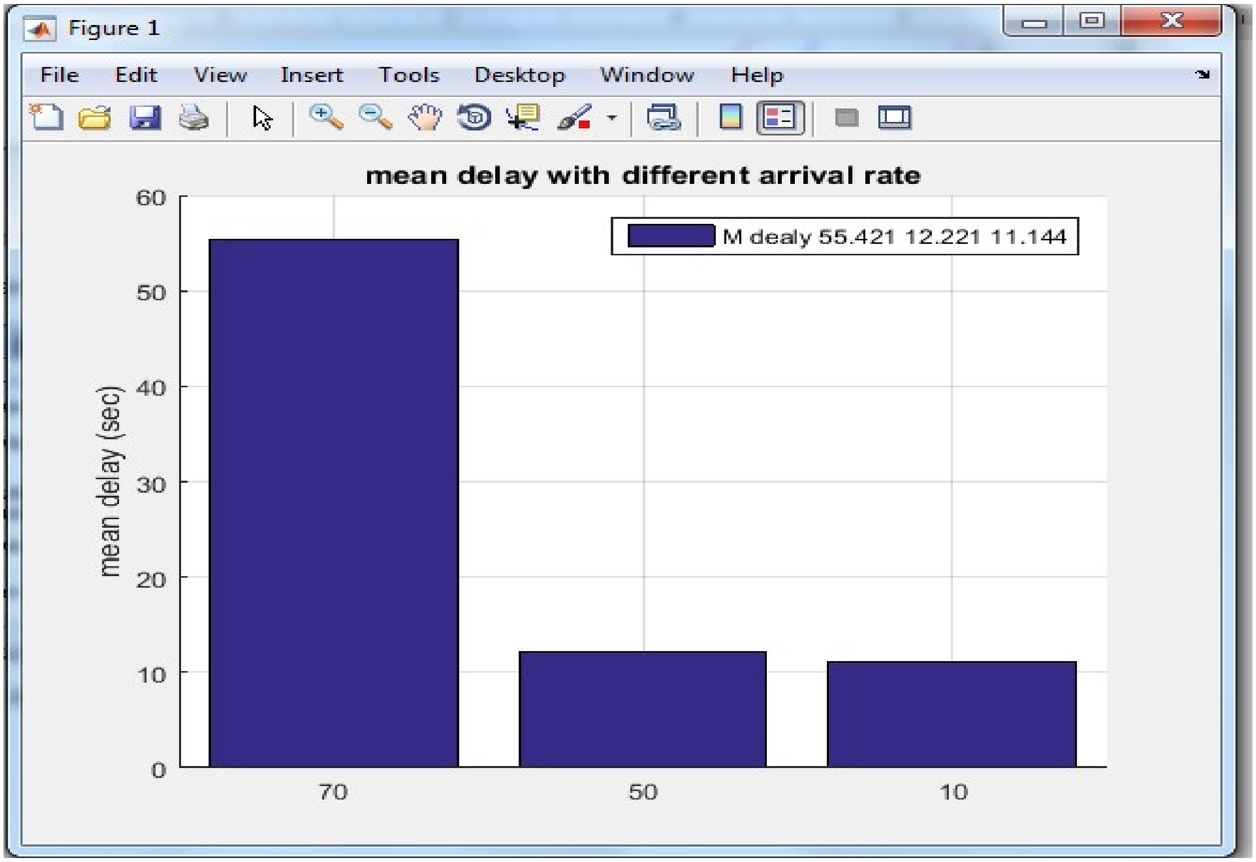


Figure 5-Mean delay having different arrival rates

5.3.2 Dropping probability measurements

1) Dropping probability having different number of channels

When increasing the number of channels, more requests are served, reducing the number of rejected calls due to unavailable resources.

The dropping probability decreases by increasing the number of channels as shows in Figure 5-5.

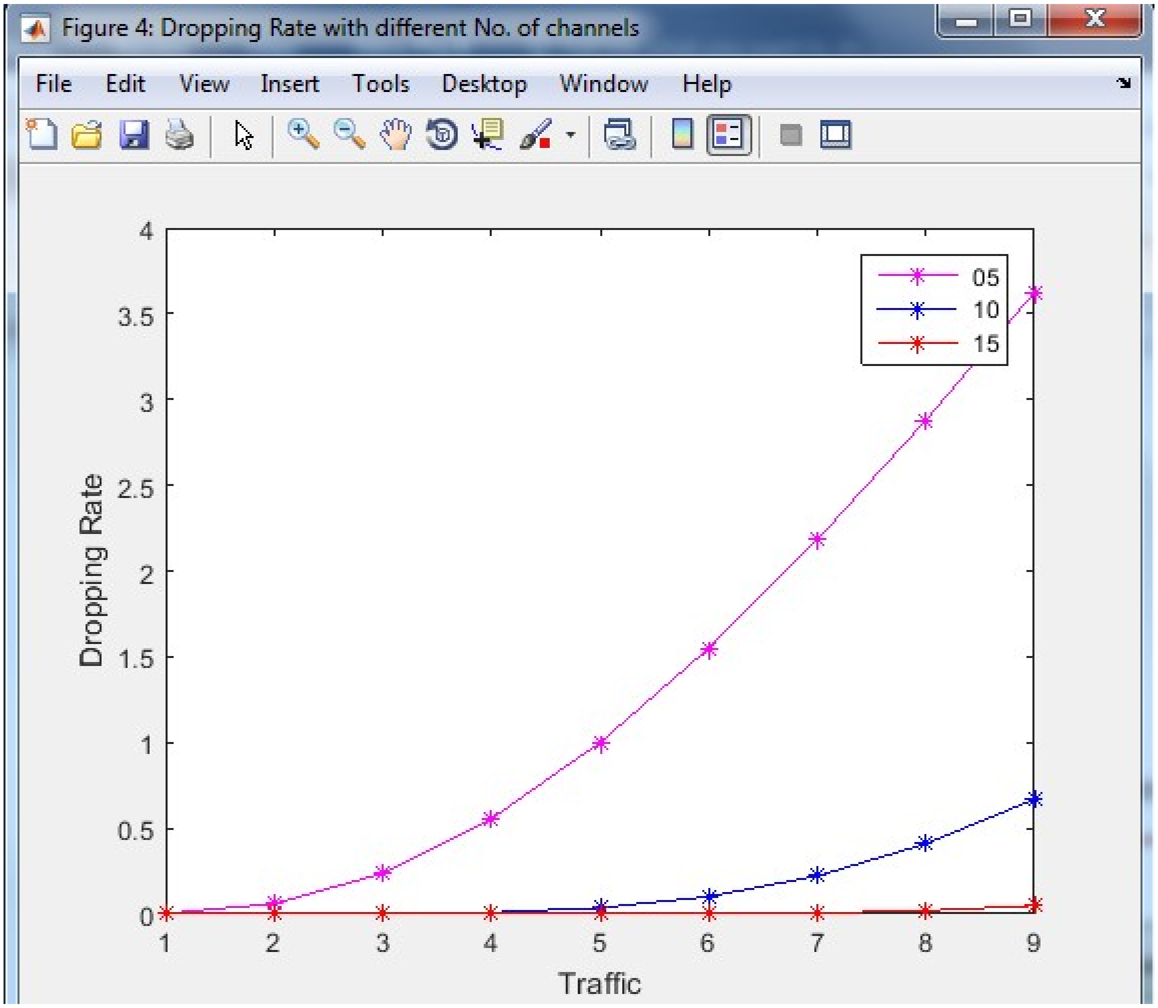


Figure 5-Dropping Probability having different number of channels

2) Dropping probability having different Queue sizes

The dropping probability is reduced by increasing the queue size, because the queue can handle a larger number of arrivals as can be seen in Figure 5-6.

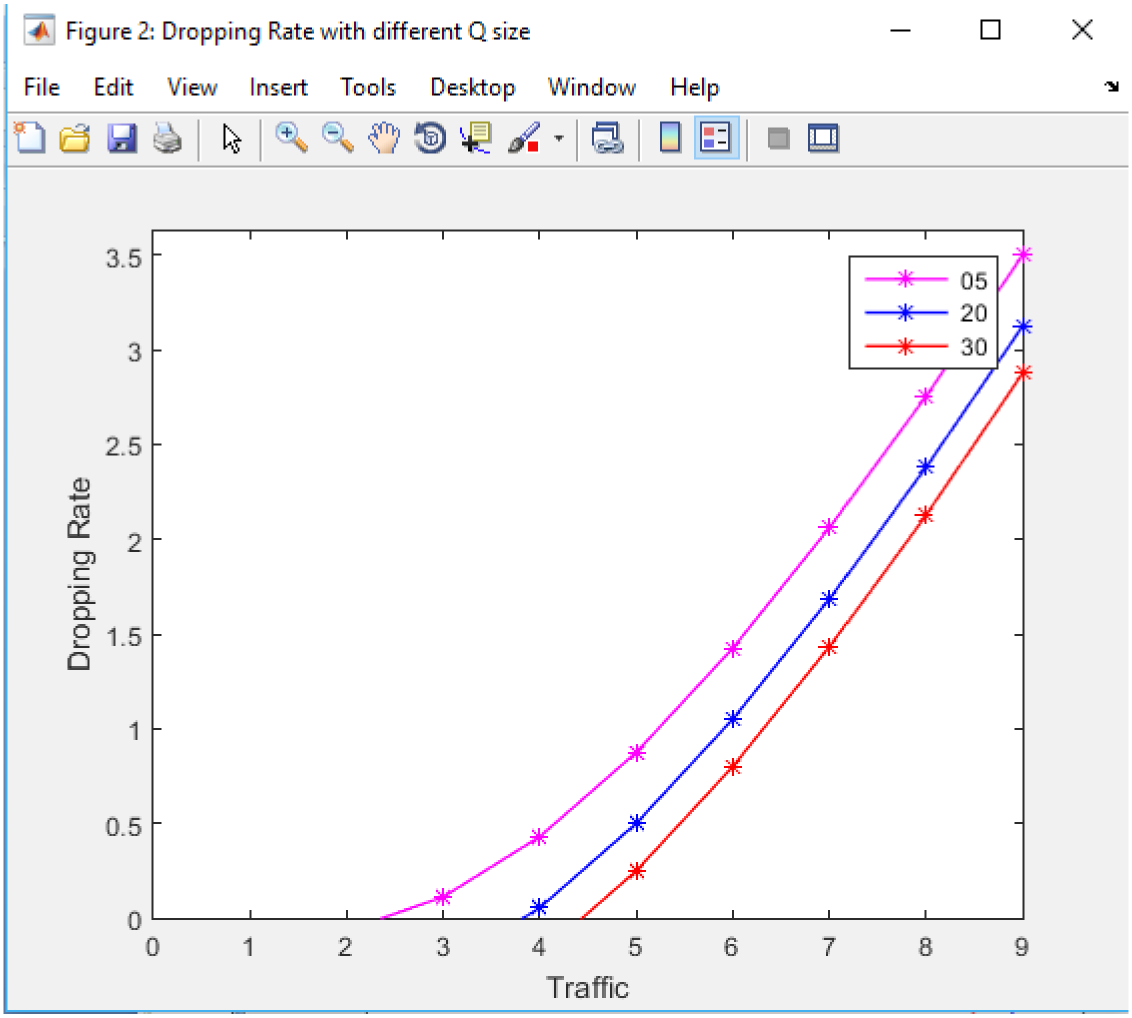


Figure 5-Dropping Probability having different Queue sizes

3) Dropping probability having different arrival rates

The Dropping probability increases with increasing the arrival rate, because when arrivals increases the queue reaches its maximum capacity and the rest of the calls are dropped. Figure 5-7 shows this increase.

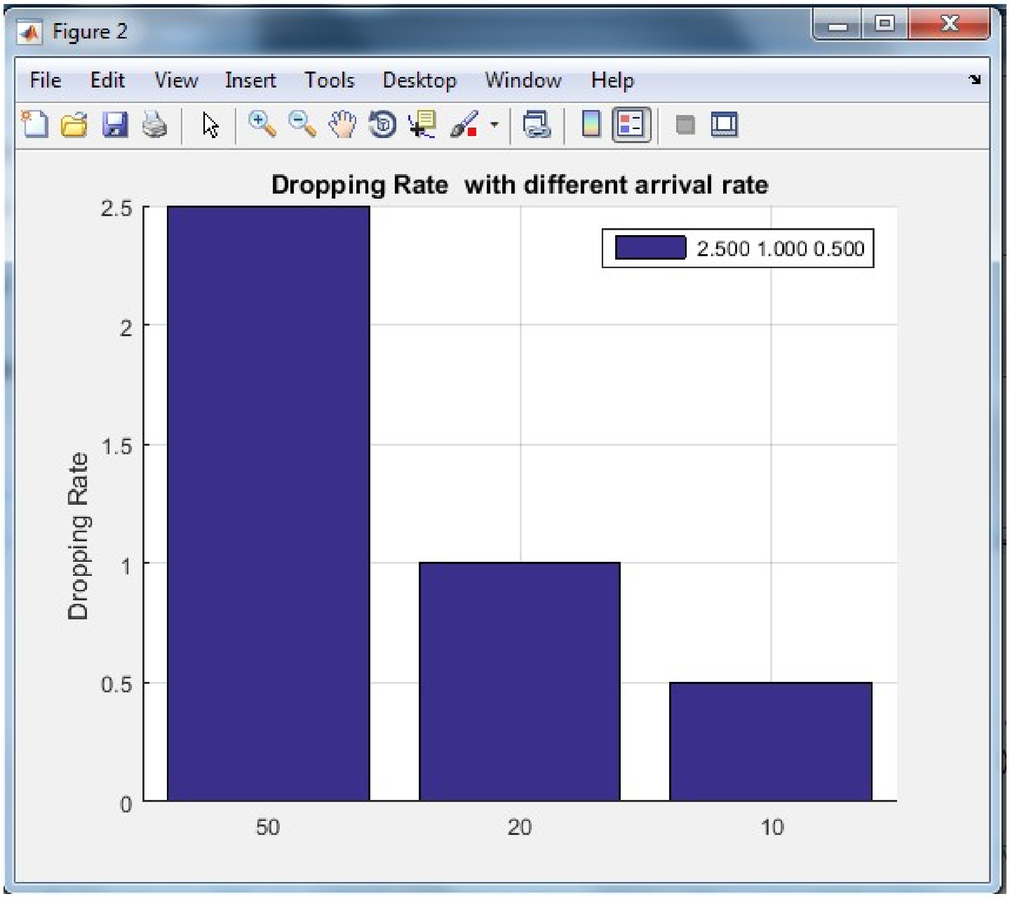


Figure 5- Dropping Probability having different arrival rates

5.3.3 Macrocell-Microcell evaluation

1) Mean delay

Macrocell and microcell calls experience the same delay as can be seen in Figure 5-8.

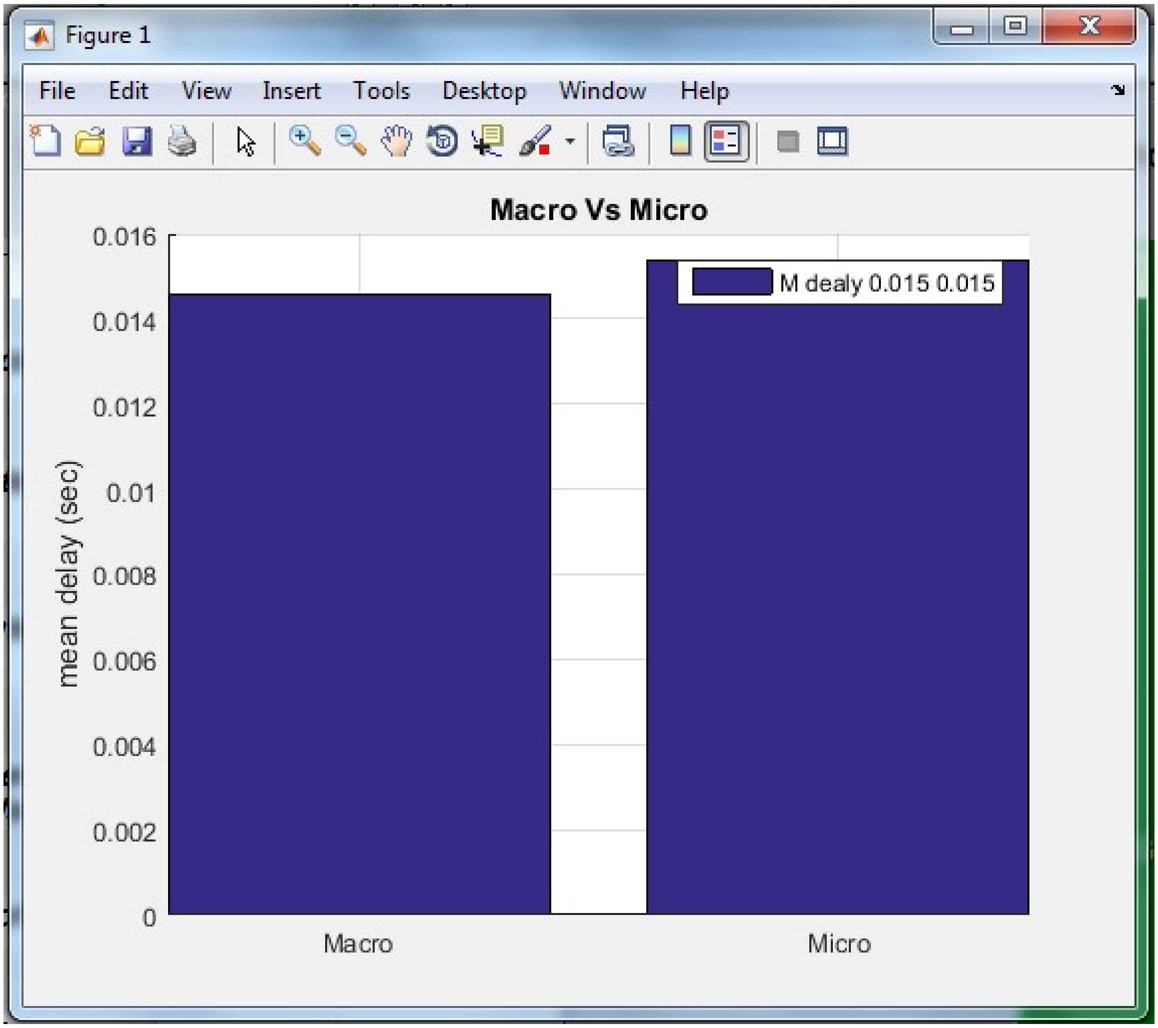


Figure 5-Mean delay results

2) Dropping probability

The Dropping probability is the same for the two cells macrocell and microcell as Figure 5-9 confirms.

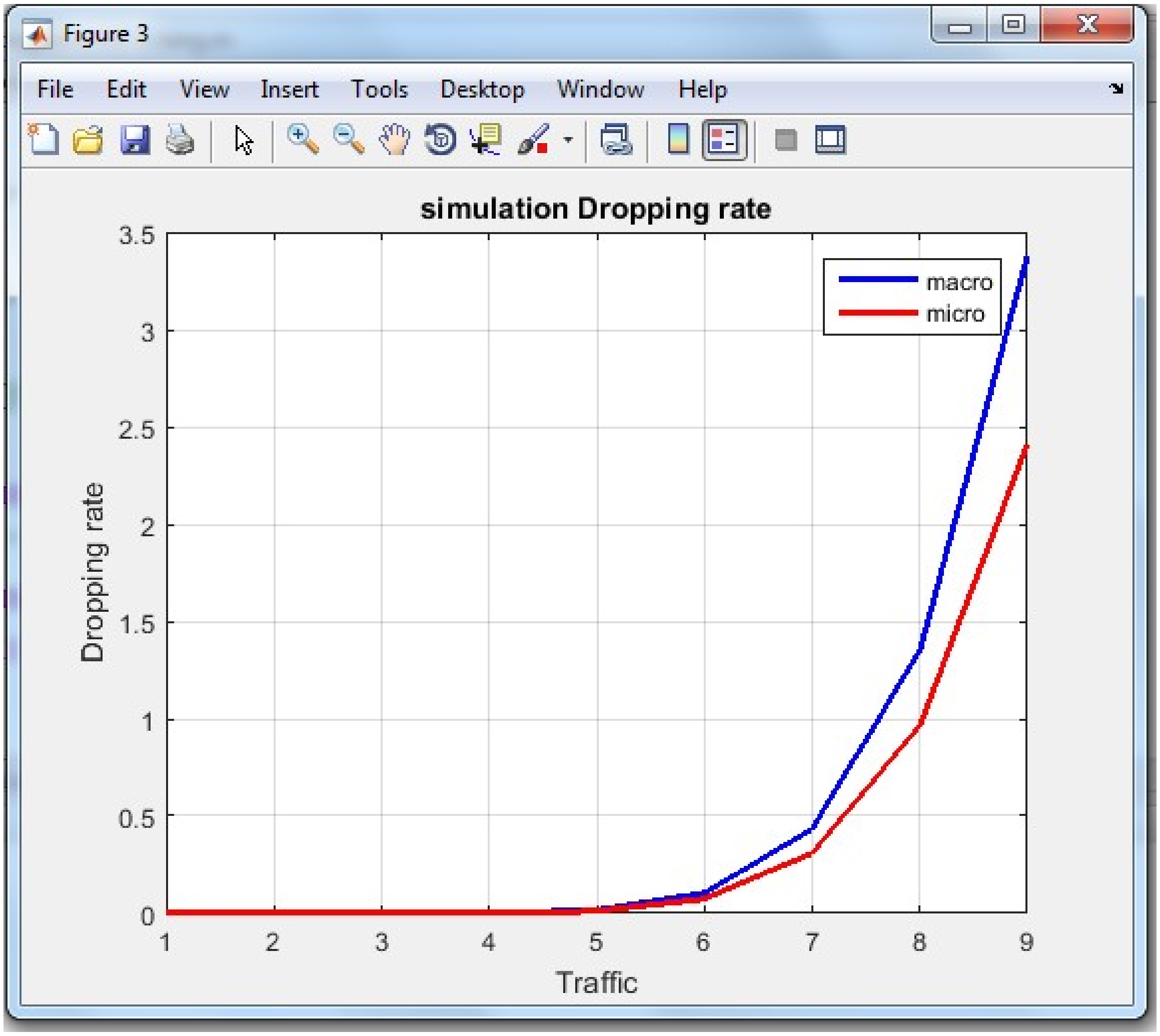


Figure 5-Dropping Probability for macrocell and microcell

3) Utilization

The utilization is similar for both cells as shows in Figure 5-10.

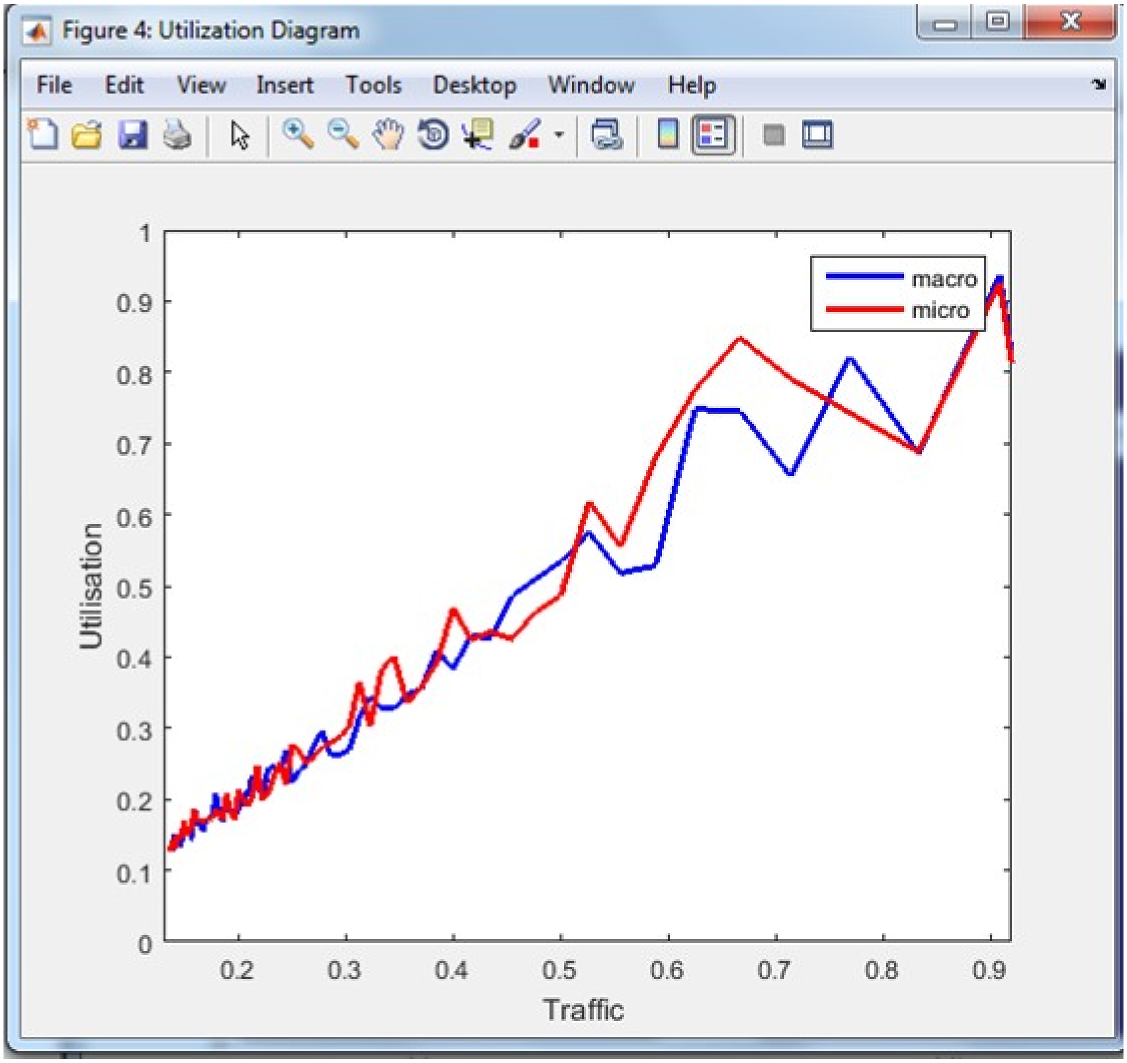


Figure 5- The Utilization for macrocell and microcell

Scenario two

Table 5.2 lists the inputs values used in the evaluation.

Parameter	Input value
Macrocell arrival rate	50 call/sec

Microcell arrival rate	50 call/sec
Service time	20 seconds
Total number of channels	20
Total number of users	150
Queue size	50

Table 5.2 Simulation inputs

An example of the resultes shown in the following subsections.

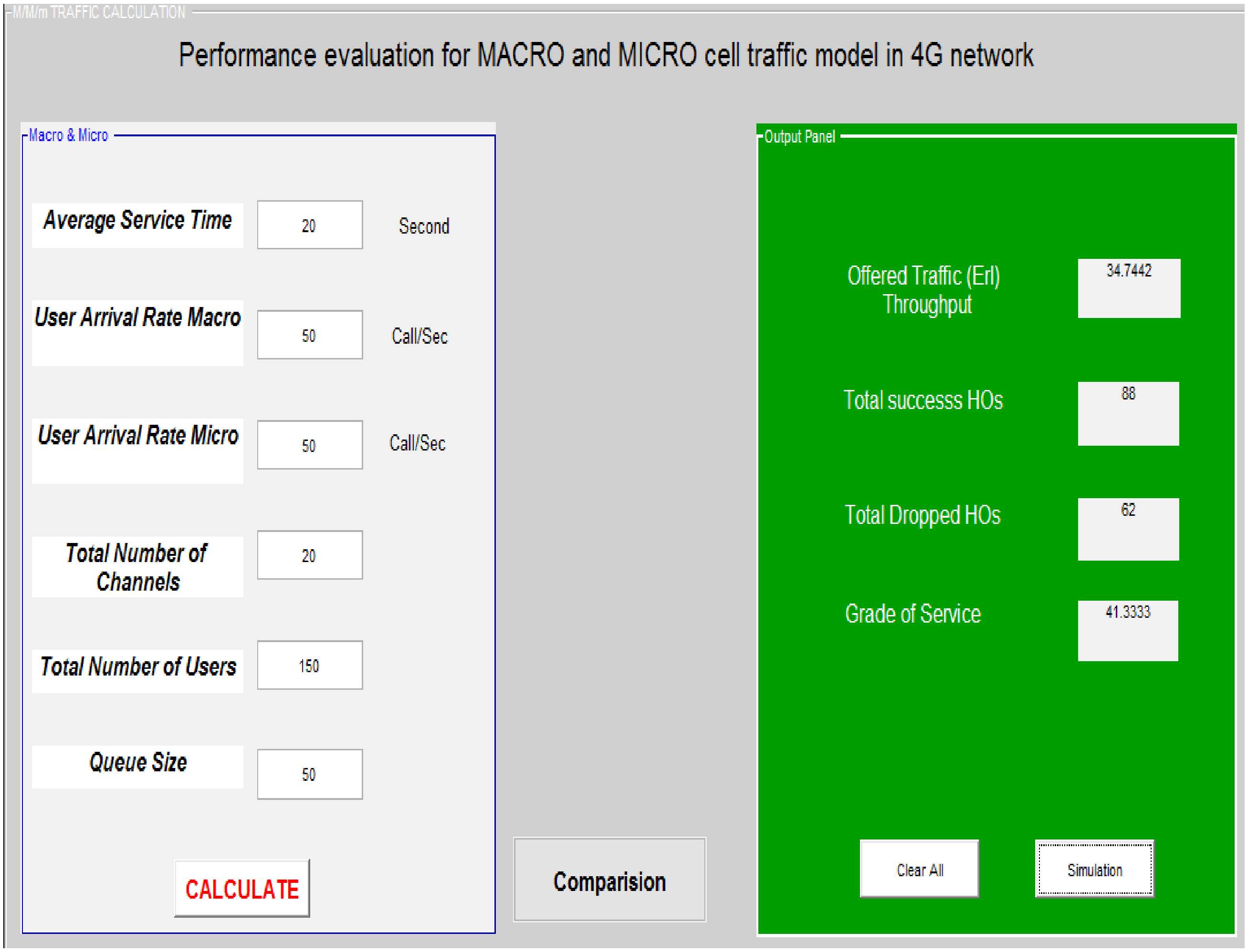


Figure 5-1 Main interface

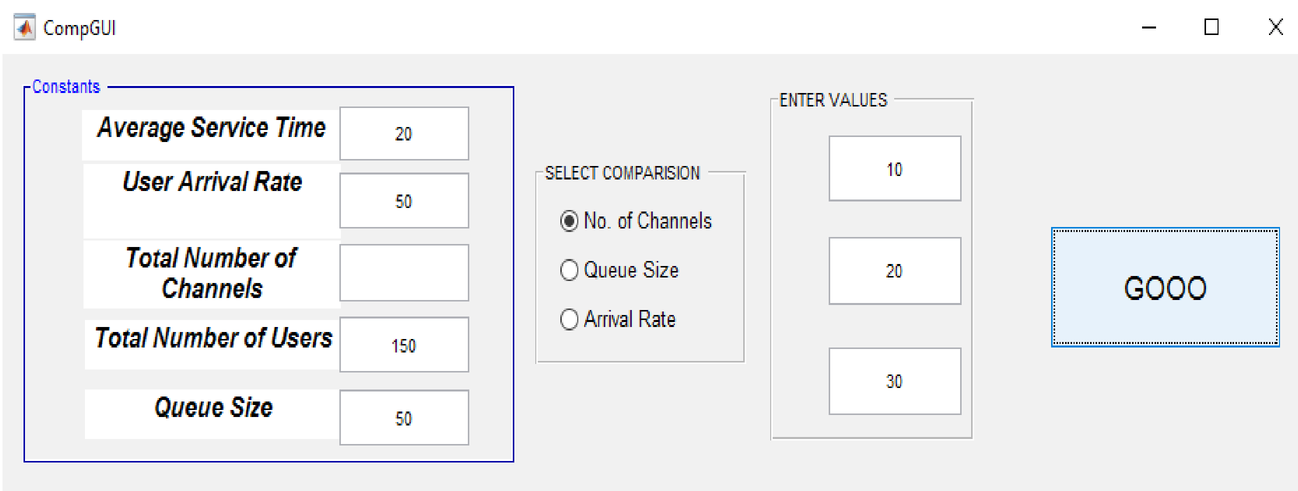
5.3.4 Mean delay measurements

1) Mean delay having different number of channels

Assume that:

- The service time is 20 second.
- The user arrival rate is 50call/sec.

- The total number of users in the system is 150.
- The queue size is 50.
- The number of channels has different values which are: 10, 20, 30.



When the number of channels increases, more requests are served immediately reducing the delay as shown in Figure 5-12.

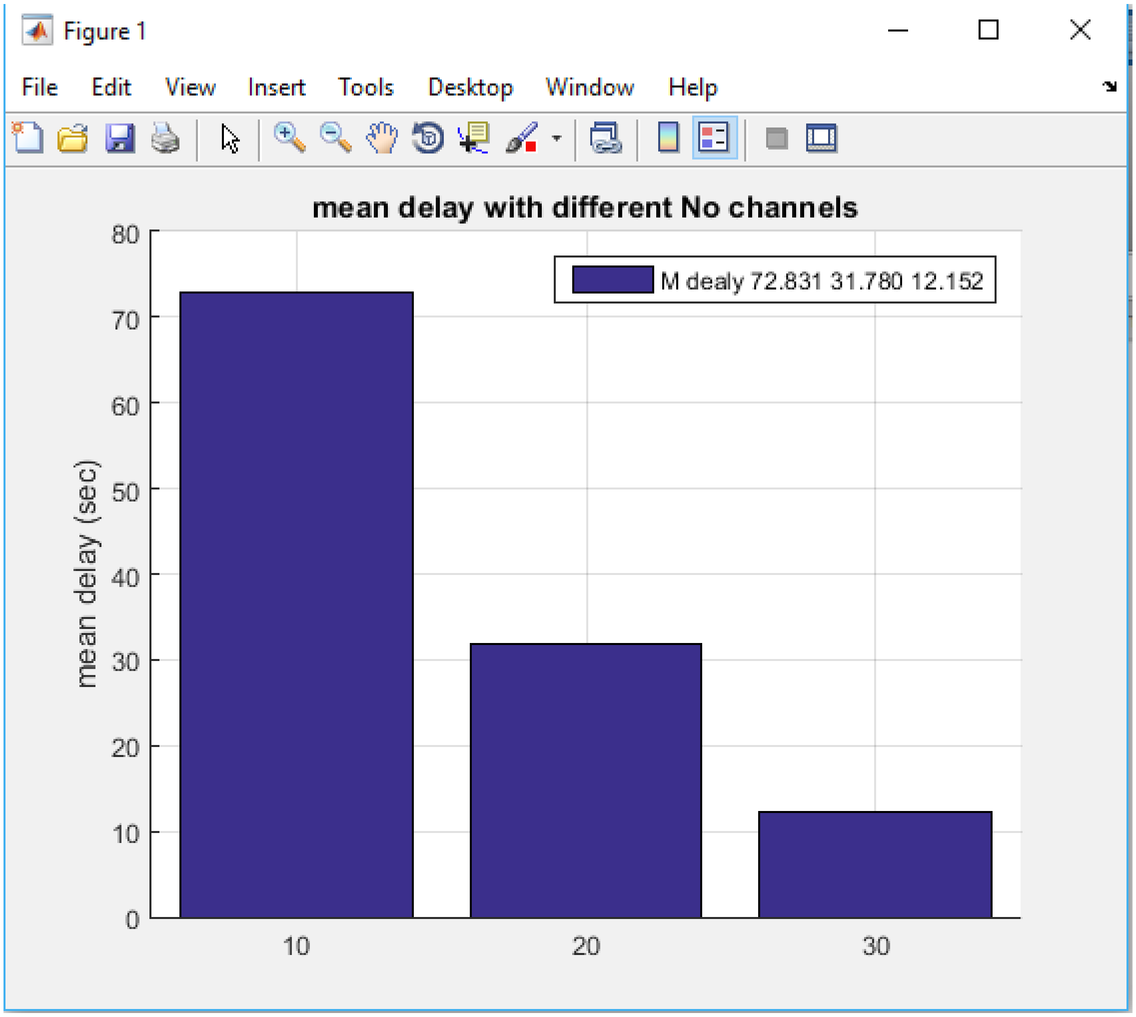
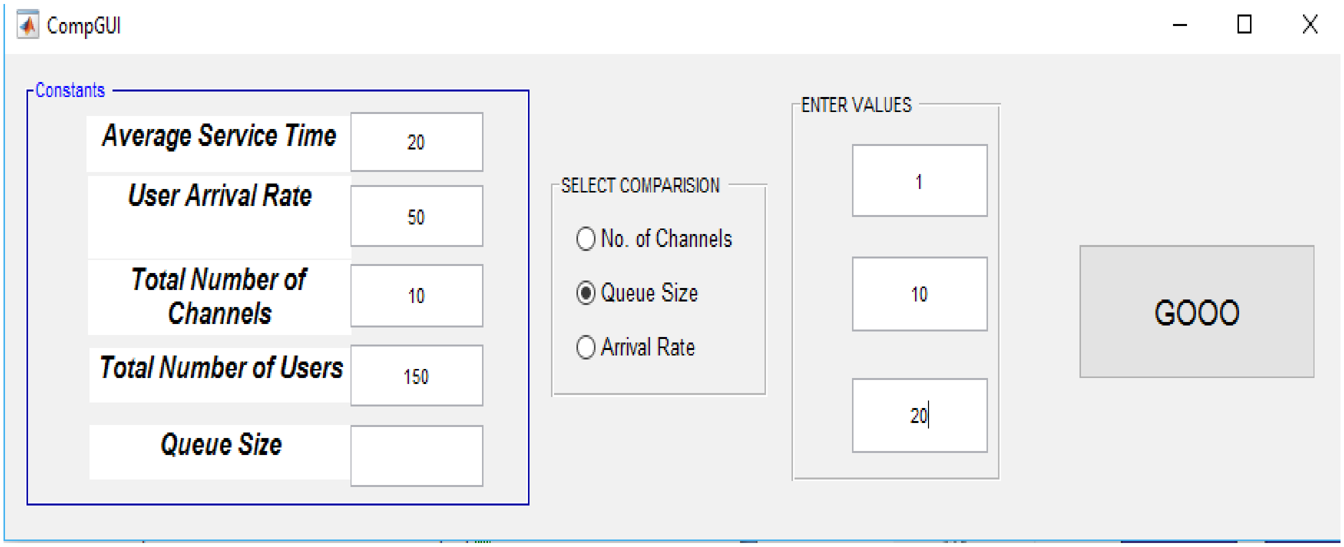


Figure 5-12 Mean delay having different number of channels

2) Mean delay having different Queue size

Assume that:

- The service time is 20 second.
- The user arrival rate is 50 call/sec.
- The total number of channels is 10.
- The total number of users in the system is 150.
- The queue size has different values which are: 1, 10, 20.



When the queue size is increase the mean delay is increases also, as shown in Figure 5-13.

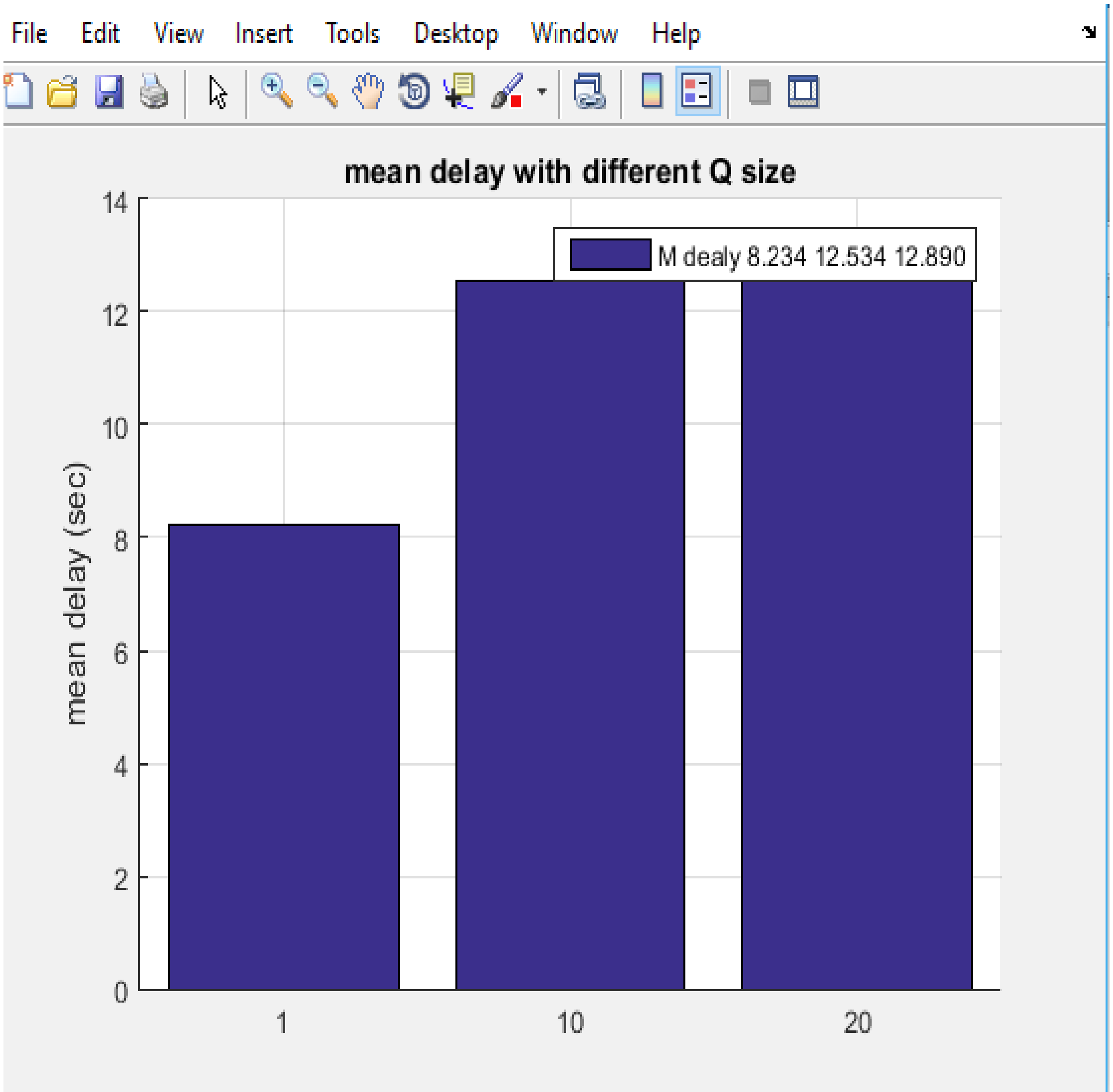


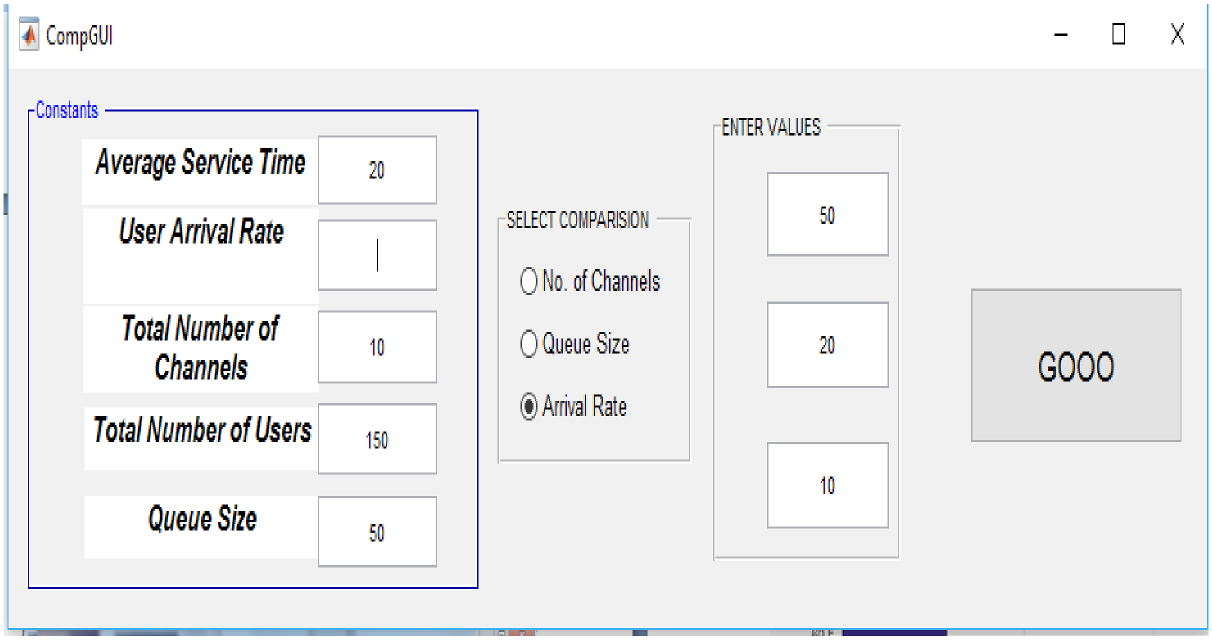
Figure 5-1 Mean delay having different Queue sizes

3) Mean delay having different arrival rates

Assume that:

- The service time is 20 second.
- The user arrival rate has different values which are: 50, 20, 10 call/sec.
- The total number of channels is 10.

- The total number of users in the system is 150.
- The queue size is 50.



When the arrival rates increases, more requests are placed in the queue. Therefore, the mean delay increases also as shown in Figure 5-14.

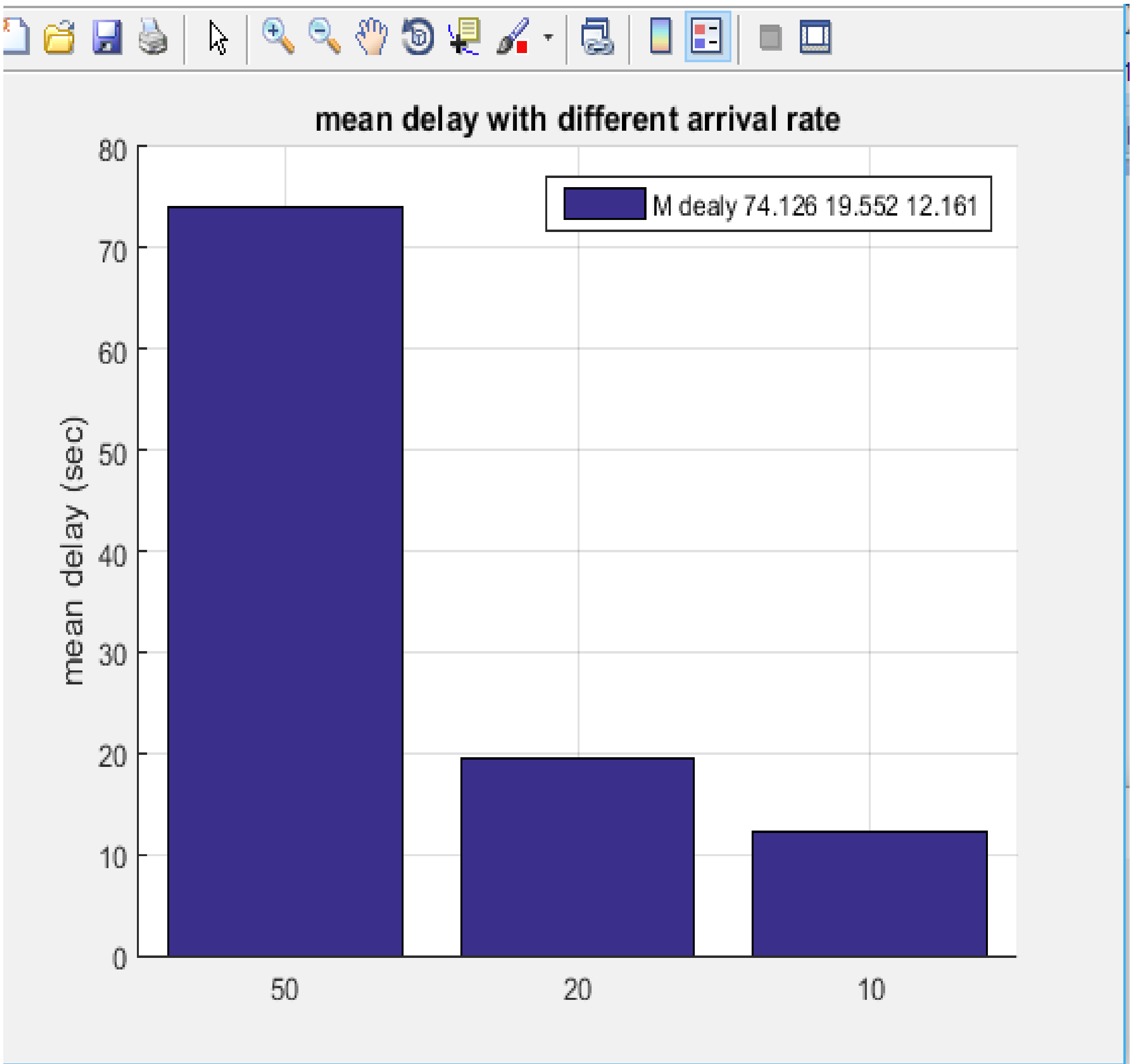


Figure 5-1 Mean delay having different arrival rates

5.3.5 Dropping probability measurements

1) Dropping probability having different number of channels

When increasing the number of channels, more requests are served, reducing the number of rejected calls due to unavailable resources. The dropping probability decreases by increasing the number of channels as shows in Figure 5-15.

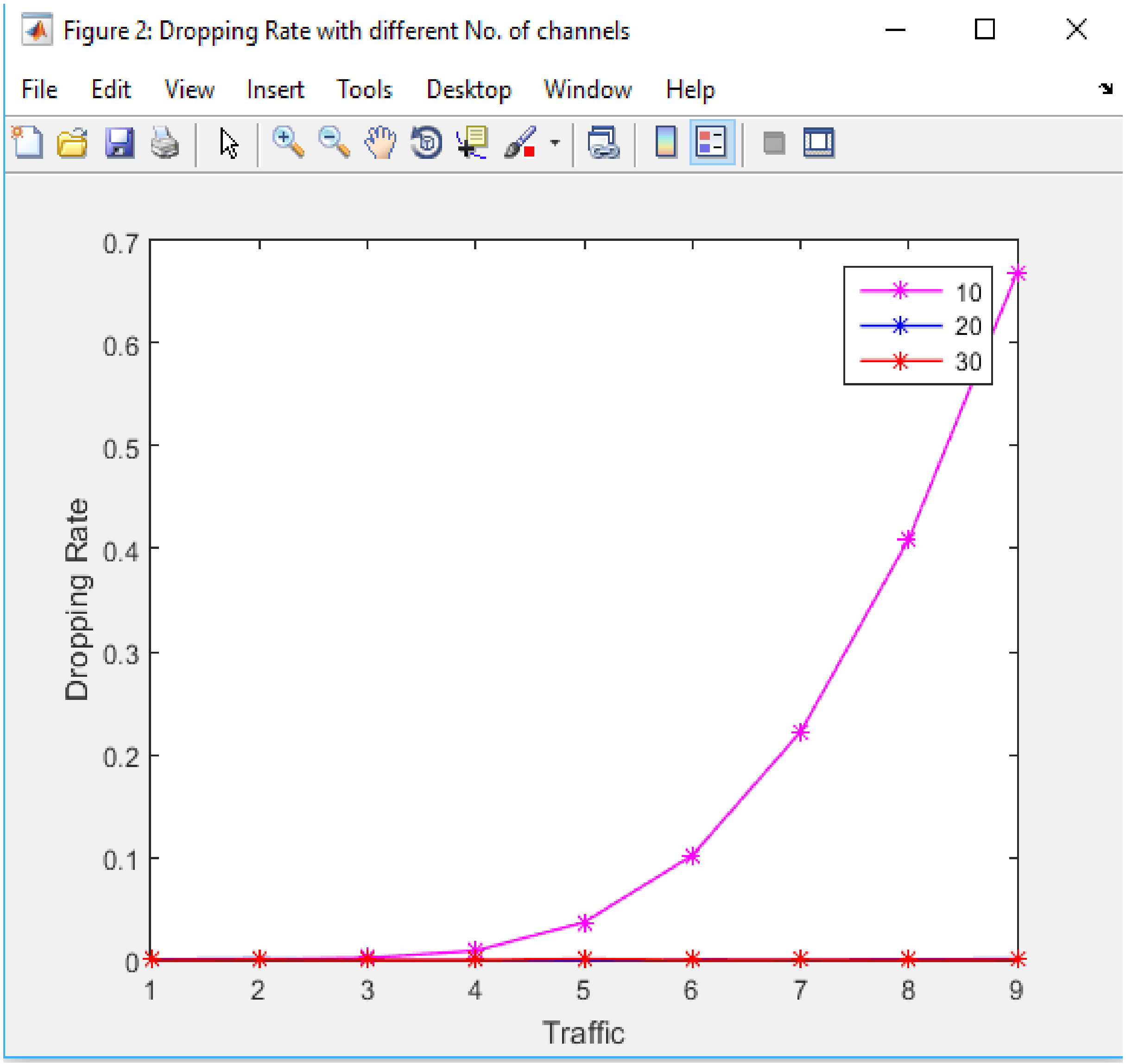


Figure 5-1 Dropping Probability having different number of channels

2) Dropping probability having different Queue sizes

The dropping probability is reduced by increasing the queue size, because the queue can handle a larger number of arrivals as can be seen in Figure 5-16.

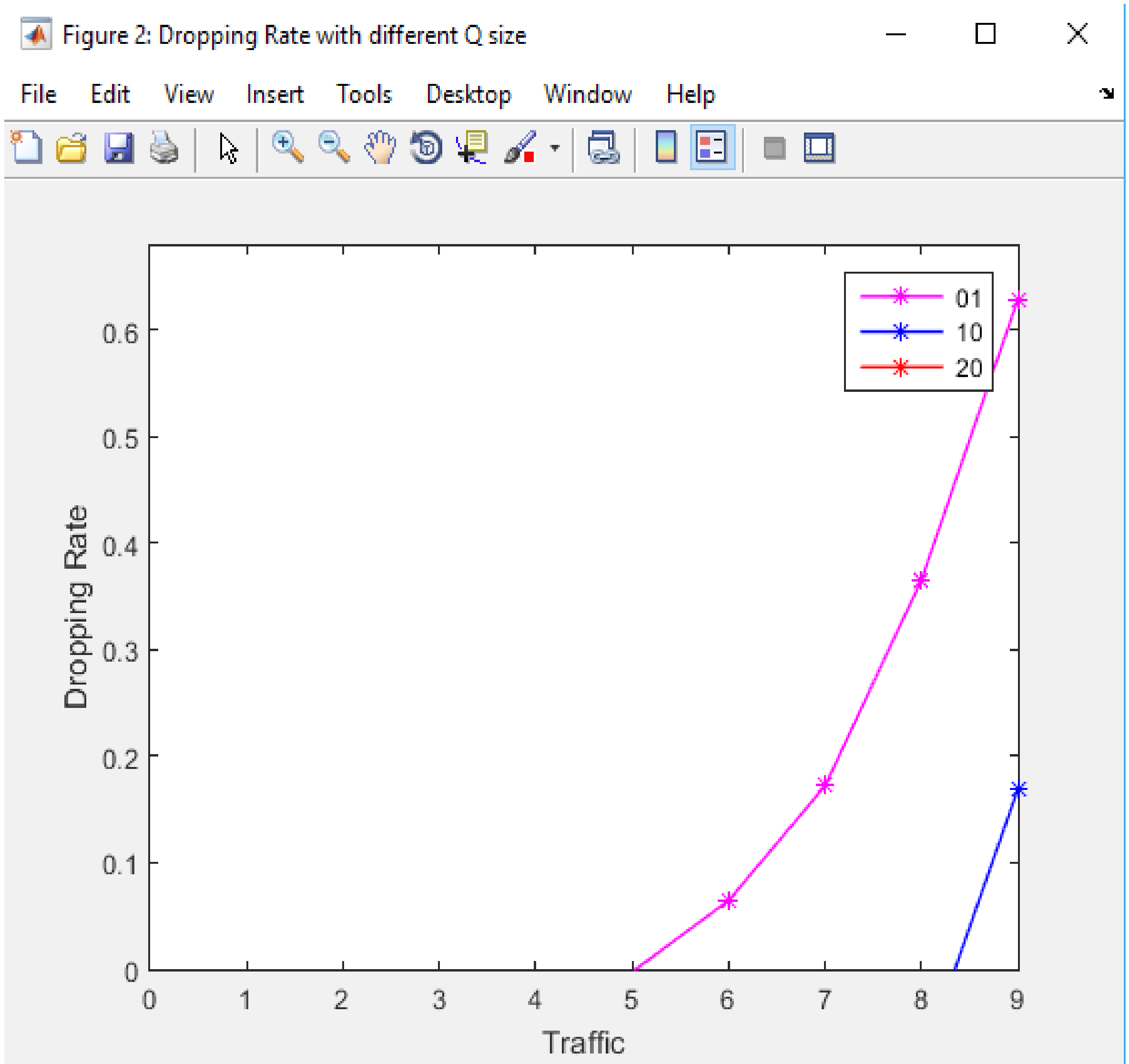


Figure 5-1 Dropping Probability having different Queue sizes

3) Dropping probability having different arrival rates

The Dropping probability increases with increasing the arrival rate, because when arrivals increases the queue reaches its maximum capacity and the rest of the calls are dropped. Figure 5-17 shows this increase.

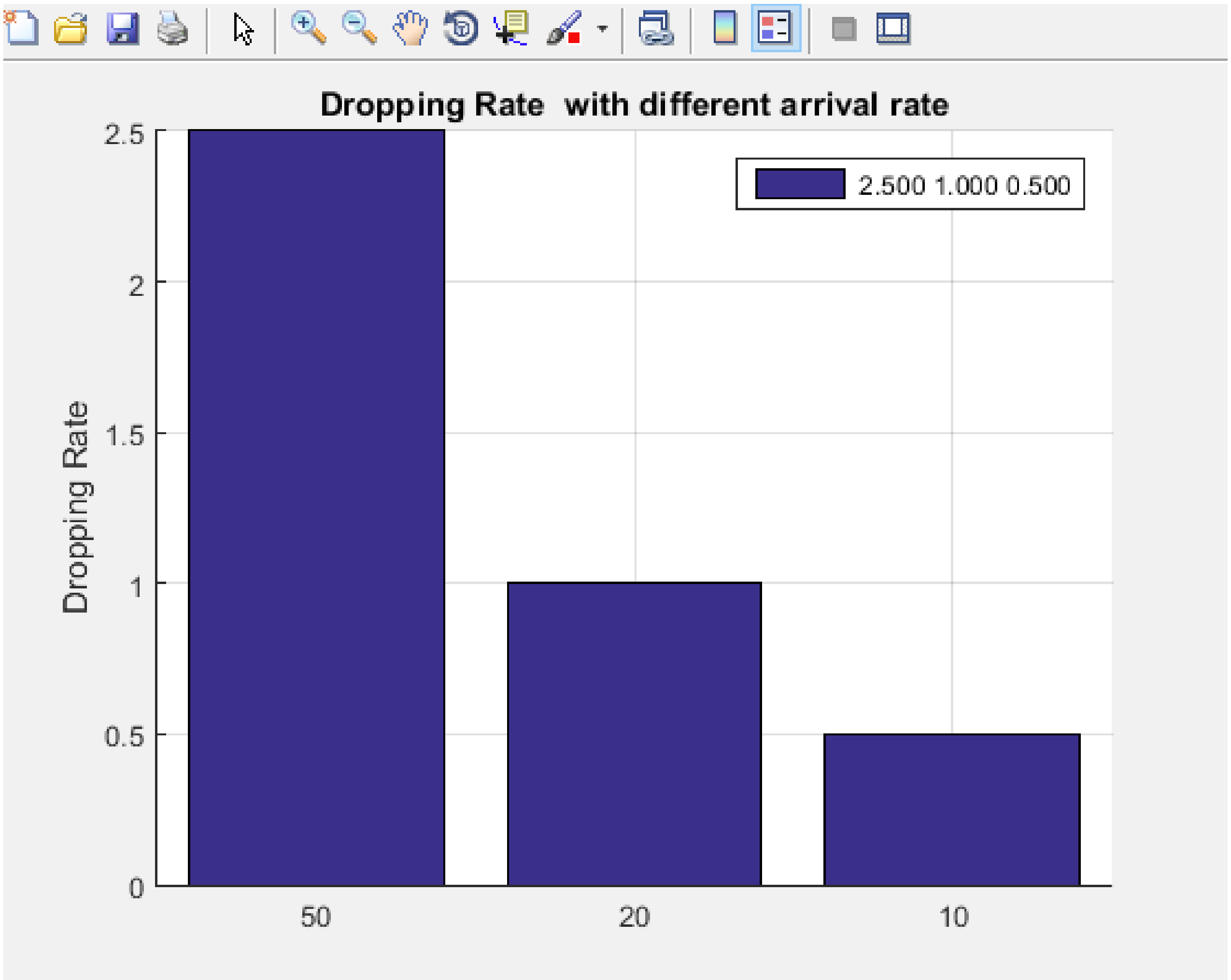


Figure 5-1 Dropping Probability having different arrival rates

5.3.6 Macrocell-Microcell evaluation

1) Mean delay

Macrocell and microcell calls experience the same delay as can be seen in Figure 5-18.

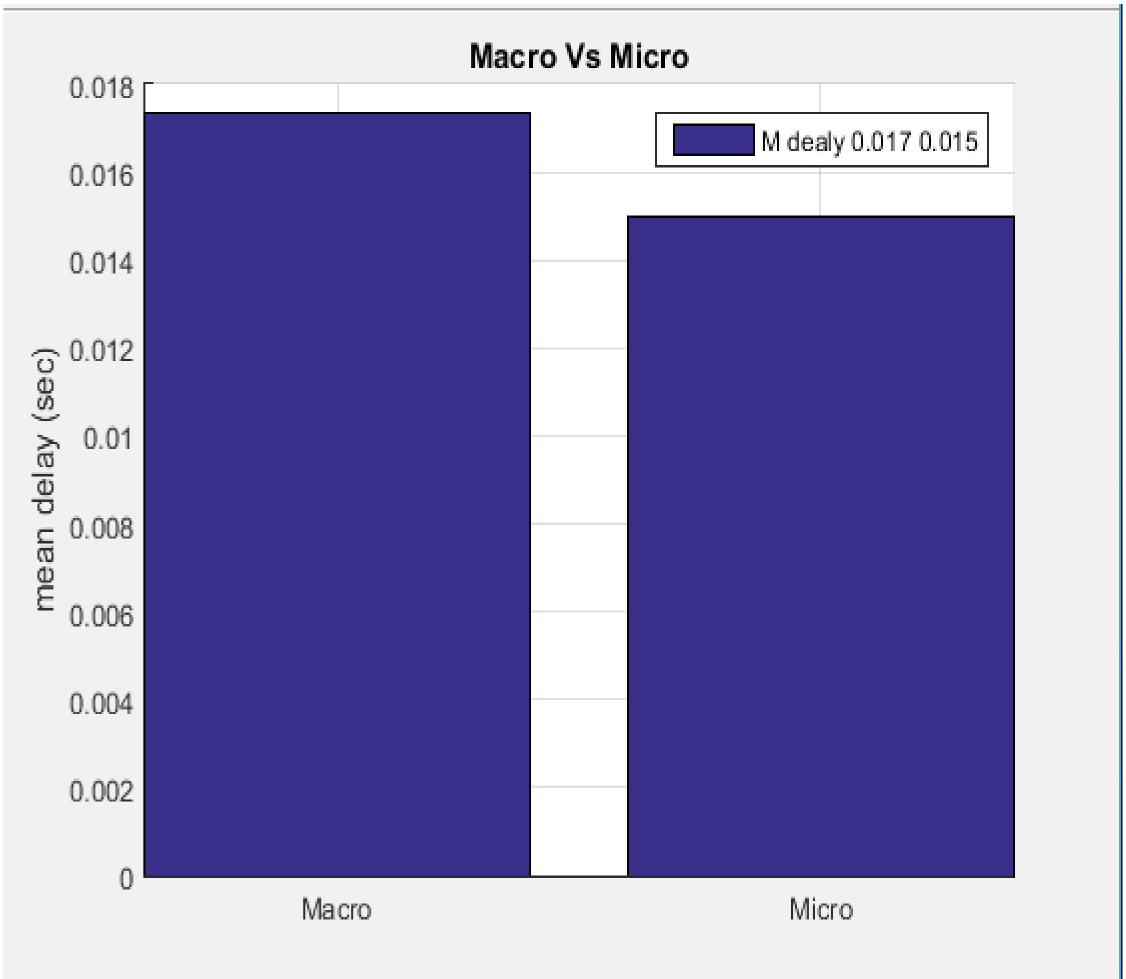


Figure 5-1 Mean delay results

2) Dropping probability

The Dropping probability is the same for the two cells macrocell and microcell as Figure 5-19 confirms.

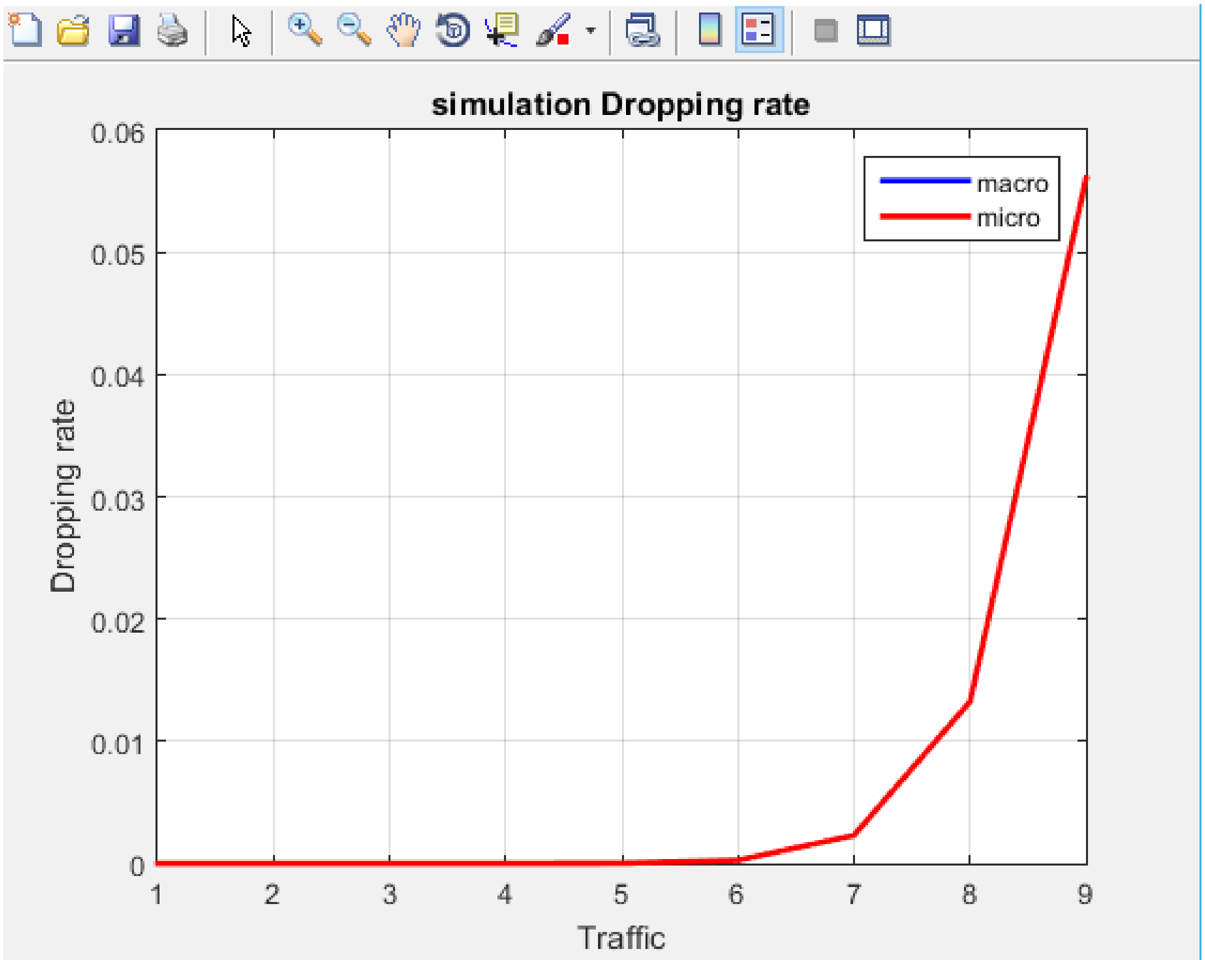


Figure 5-1 Dropping Probability for macrocell and microcell

3) Utilization

The utilization is similar for both cells as shows in Figure 5-20.

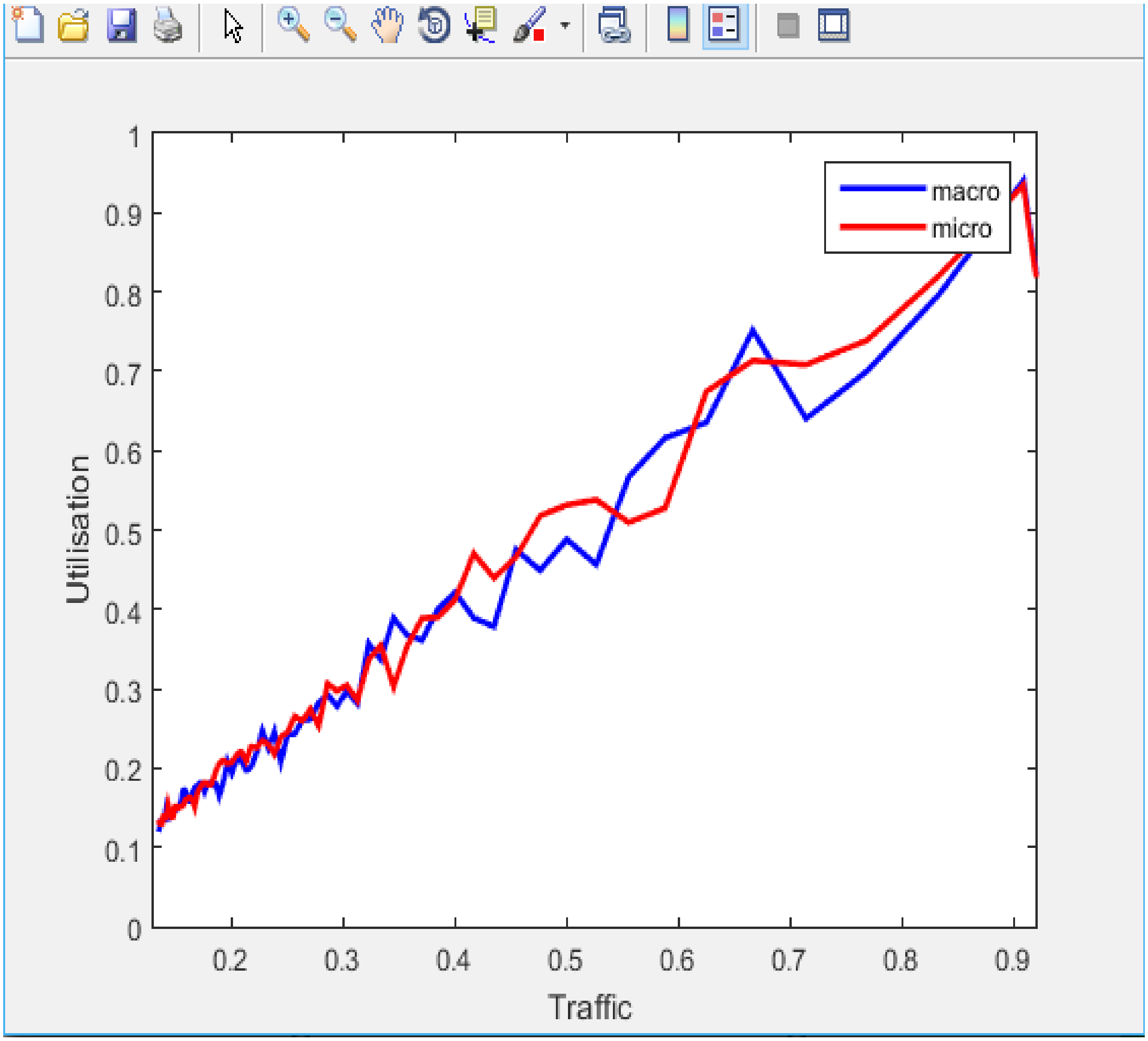


Figure 5- The Utilization for macrocell and microcell

Scenario three

Table 5.3 lists the inputs values used in the evaluation.

Parameter	**Input value**
Macrocell arrival rate	70 call/sec

Microcell arrival rate	70 call/sec
Service time	30 seconds
Total number of channels	30
Total number of users	200
Queue size	60

Table 5.3 Simulation inputs

An example of the resultes shown in the following subsections.

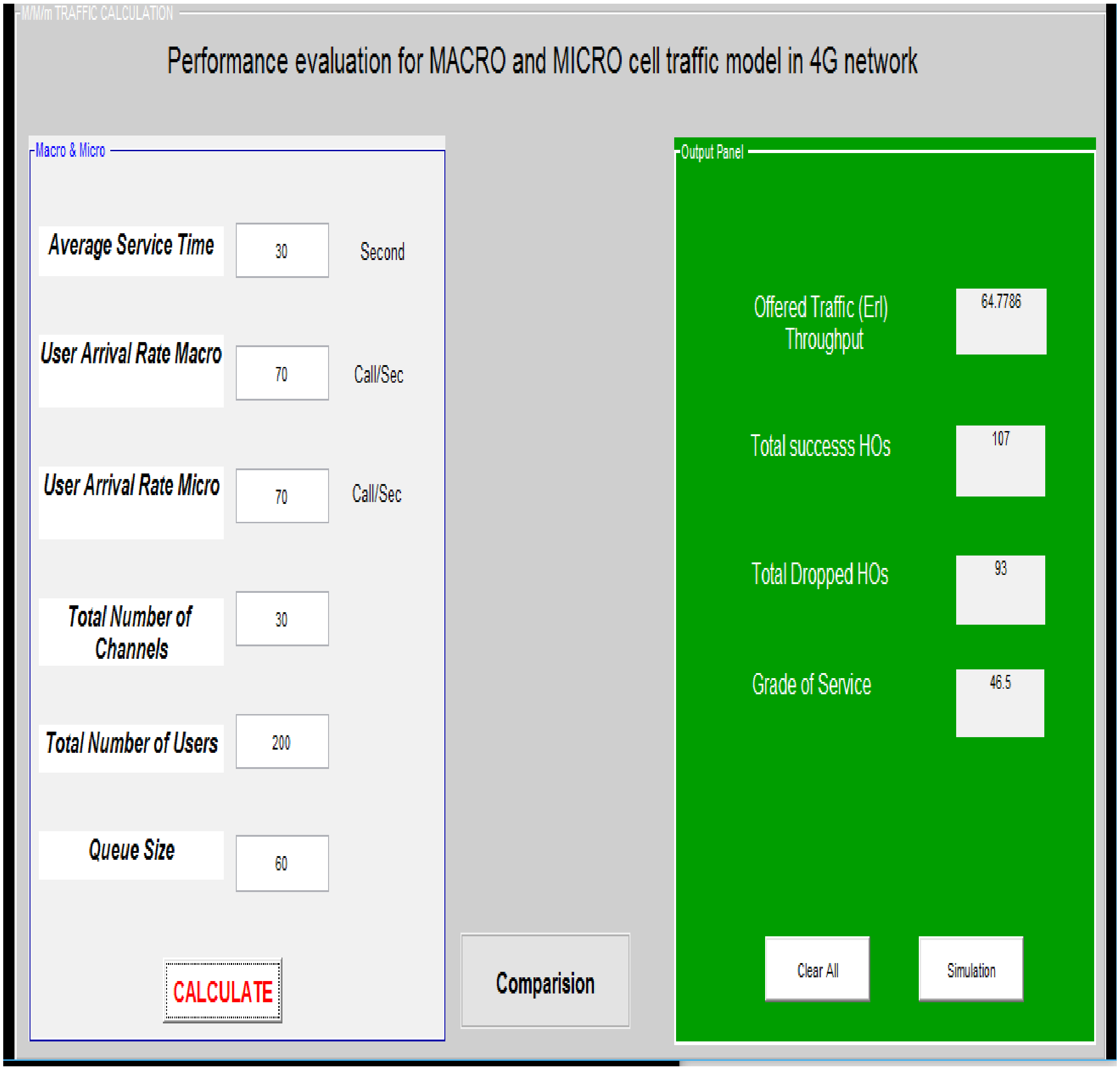


Figure 5-21 Main interface

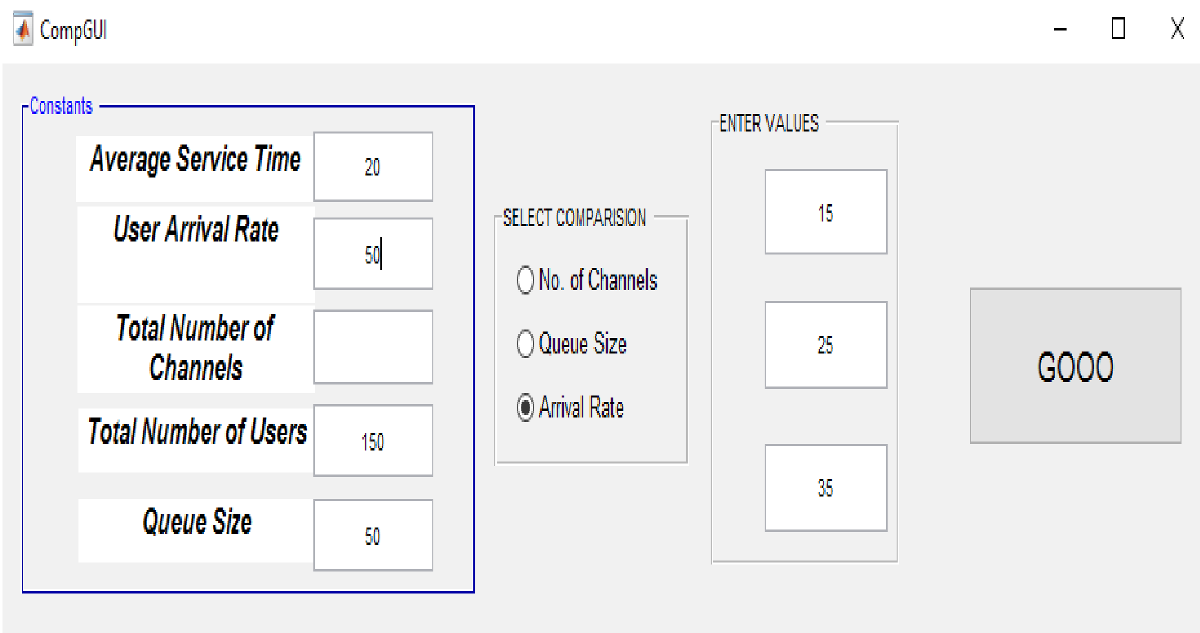
5.3.7 Mean delay measurements

1) Mean delay having different number of channels

Assume that:

- The service time is 20 second.

- The user arrival rate is 50call/sec.
- The total number of users in the system is 150.
- The queue size is 50.
- The number of channels has different values which are: 15, 25, 35.



When the number of channels increases, more requests are served immediately reducing the delay as shown in Figure 5-22.

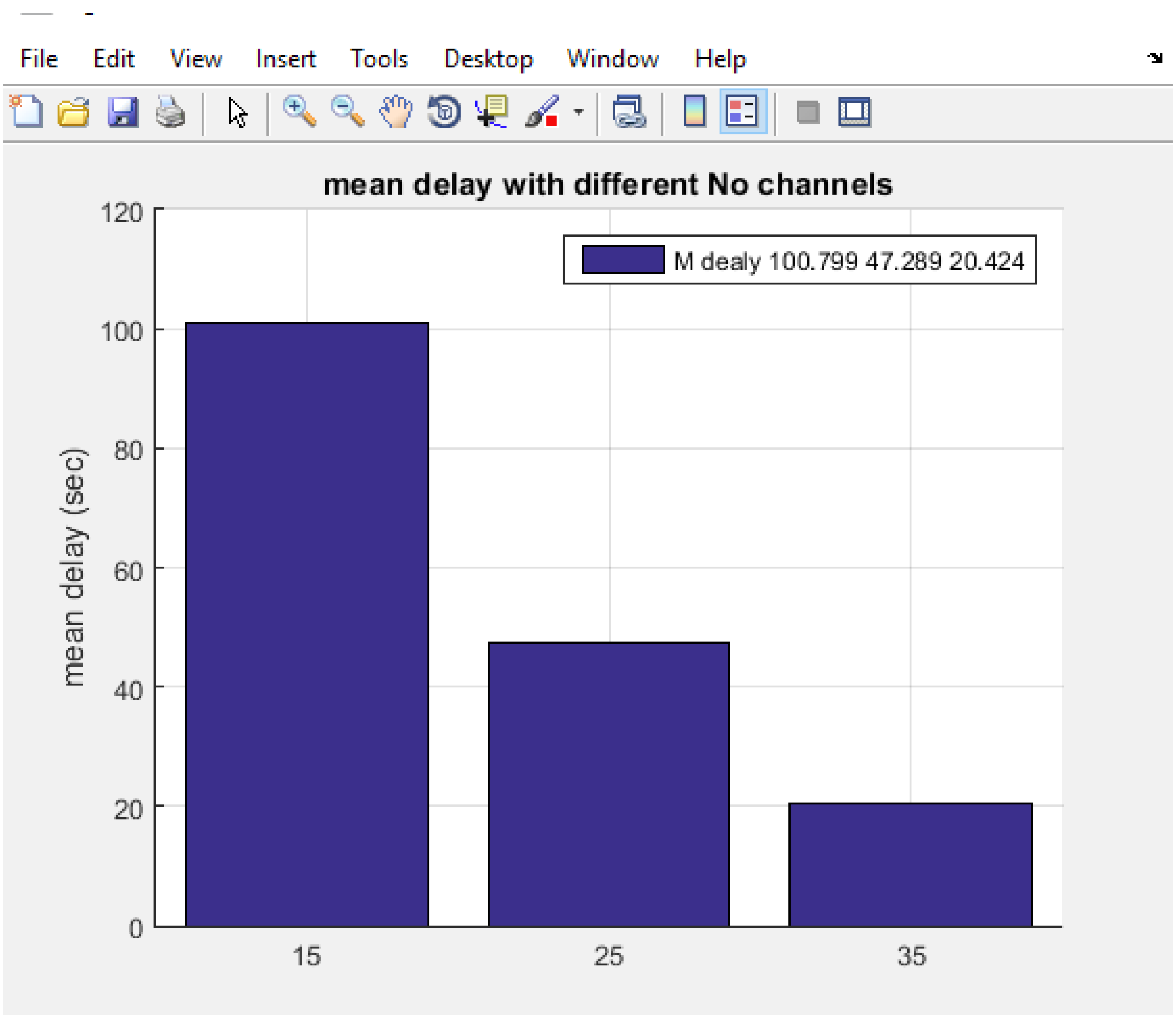


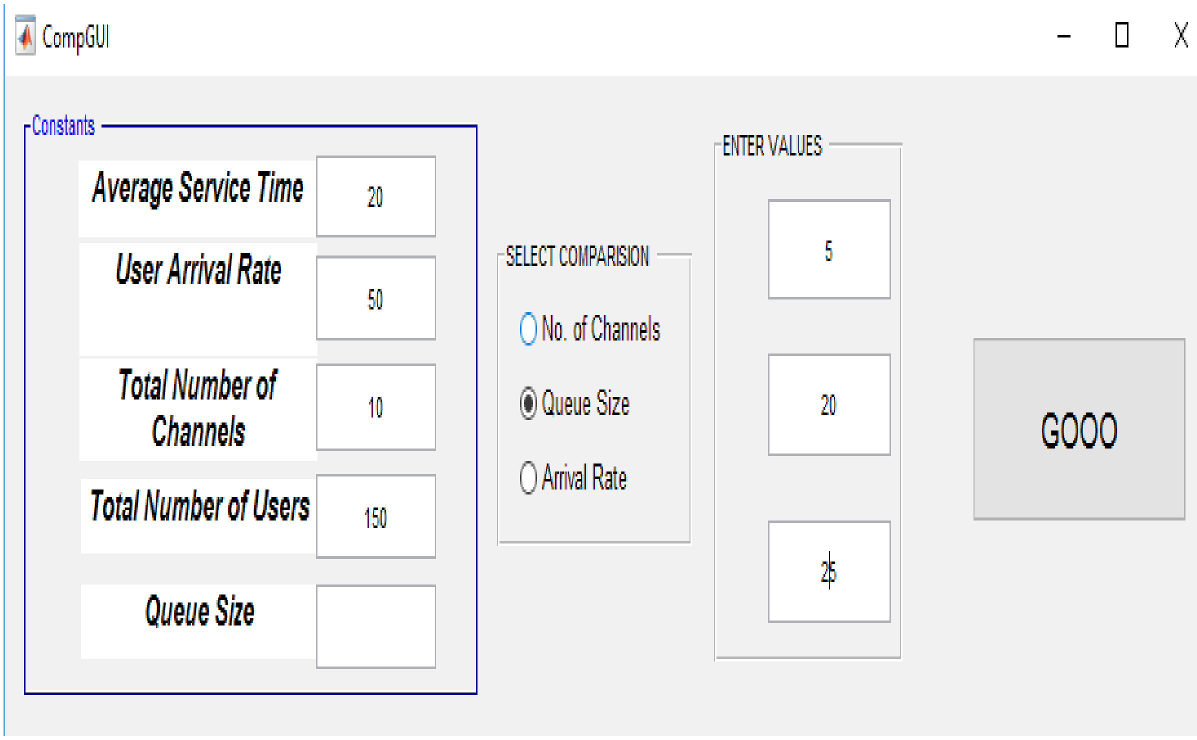
Figure 5-22 Mean delay having different number of channels

2) Mean delay having different Queue size

Assume that:

- The service time is 20 second.
- The user arrival rate is 50 call/sec.
- The total number of channels is 10.
- The total number of users in the system is 150.

- The queue size has different values which are: 5, 20, 25.



When the queue size is increase the mean delay is increases also, as shown in Figure 5-23.

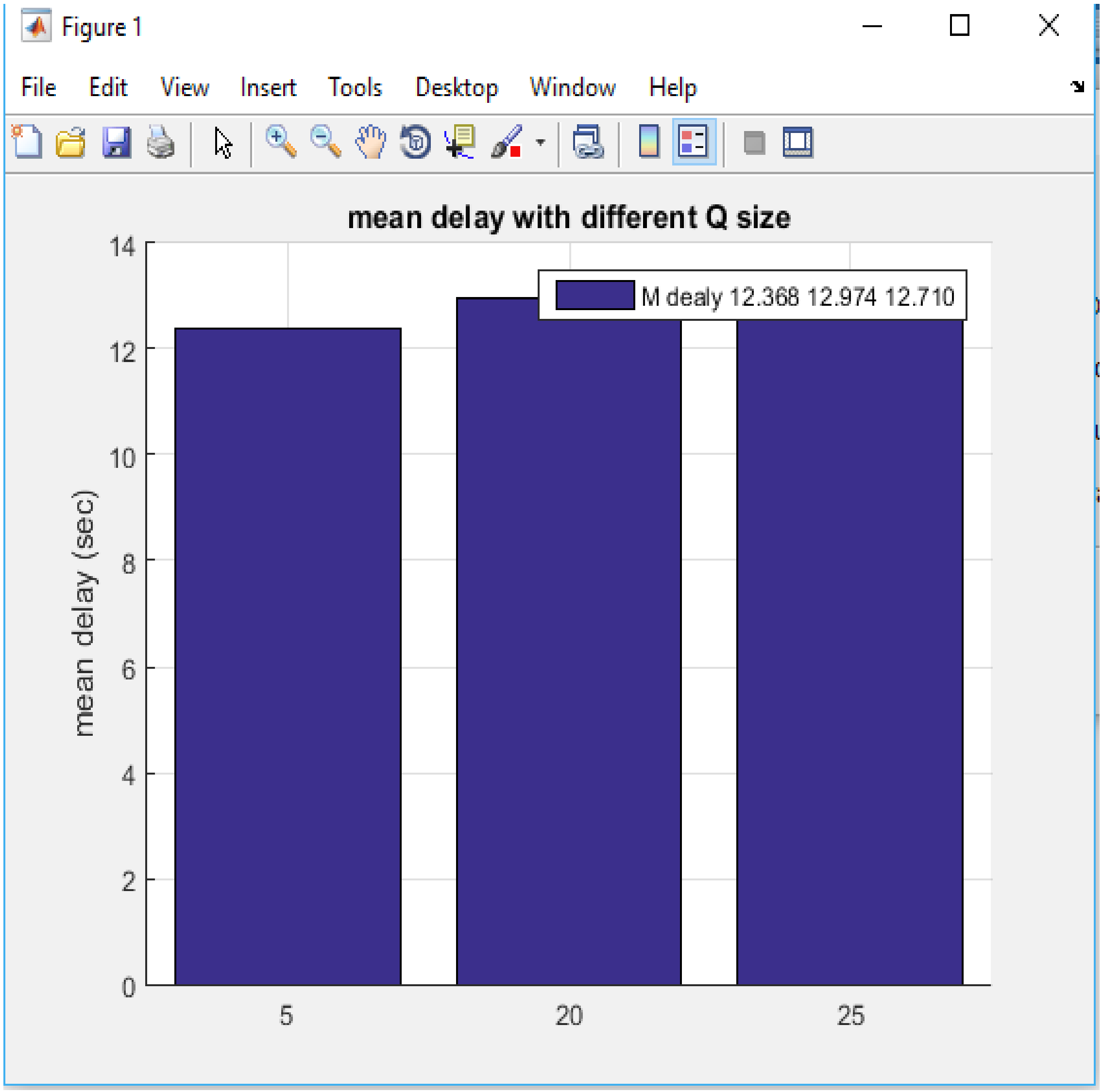


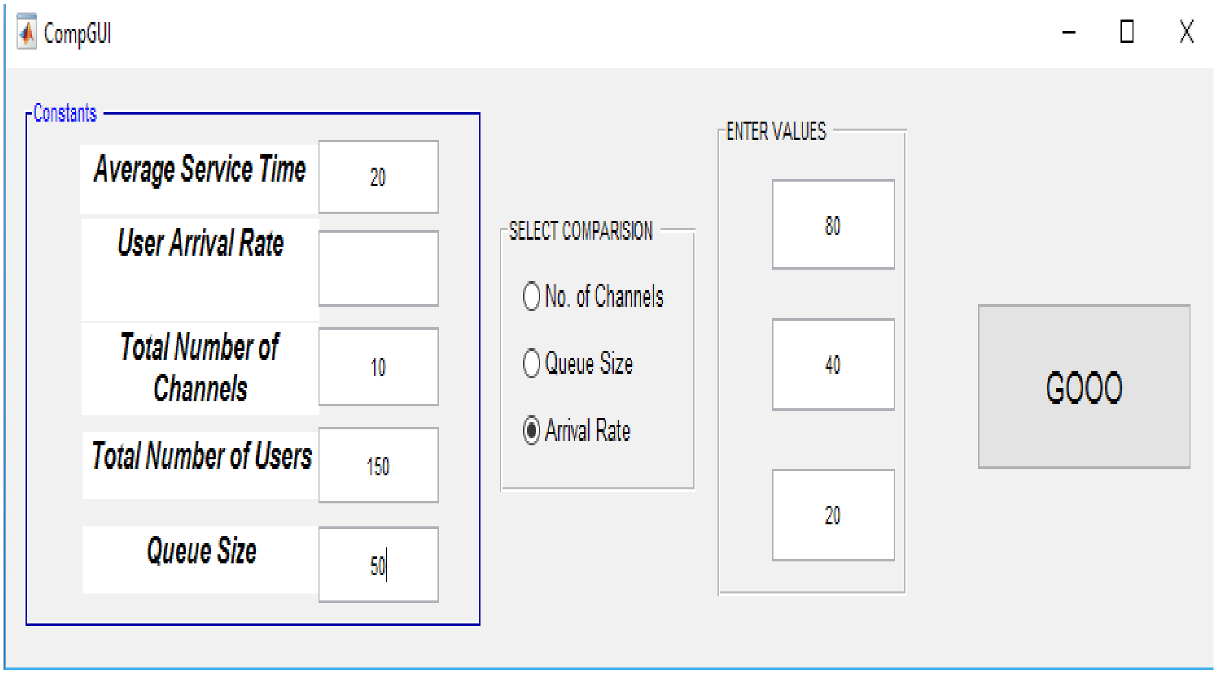
Figure 5-2 Mean delay having different Queue sizes

3) Mean delay having different arrival rates

Assume that:

- The service time is 20 second.
- The user arrival rate has different values which are: 80, 40, 20 call/sec.
- The total number of channels is 10.

- The total number of users in the system is 150.
- The queue size is 50.



When the arrival rates increases, more requests are placed in the queue. Therefore, the mean delay increases also as shown in Figure 5-24.

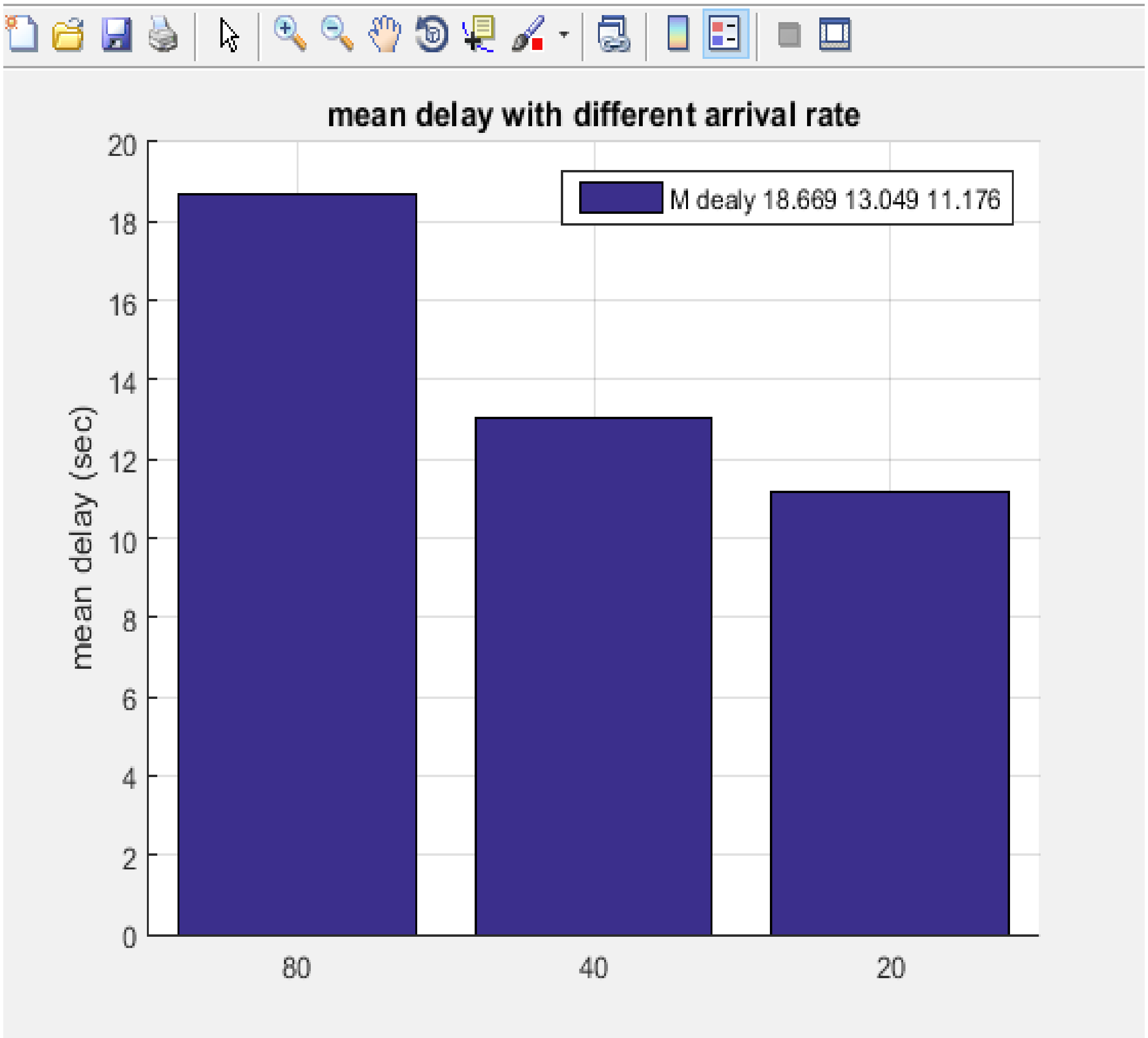


Figure 5-2 Mean delay having different arrival rates

5.3.8 Dropping probability measurements

1) Dropping probability having different number of channels

When increasing the number of channels, more requests are served, reducing the number of rejected calls due to unavailable resources.

The dropping probability decreases by increasing the number of channels as shows in Figure 5-25.

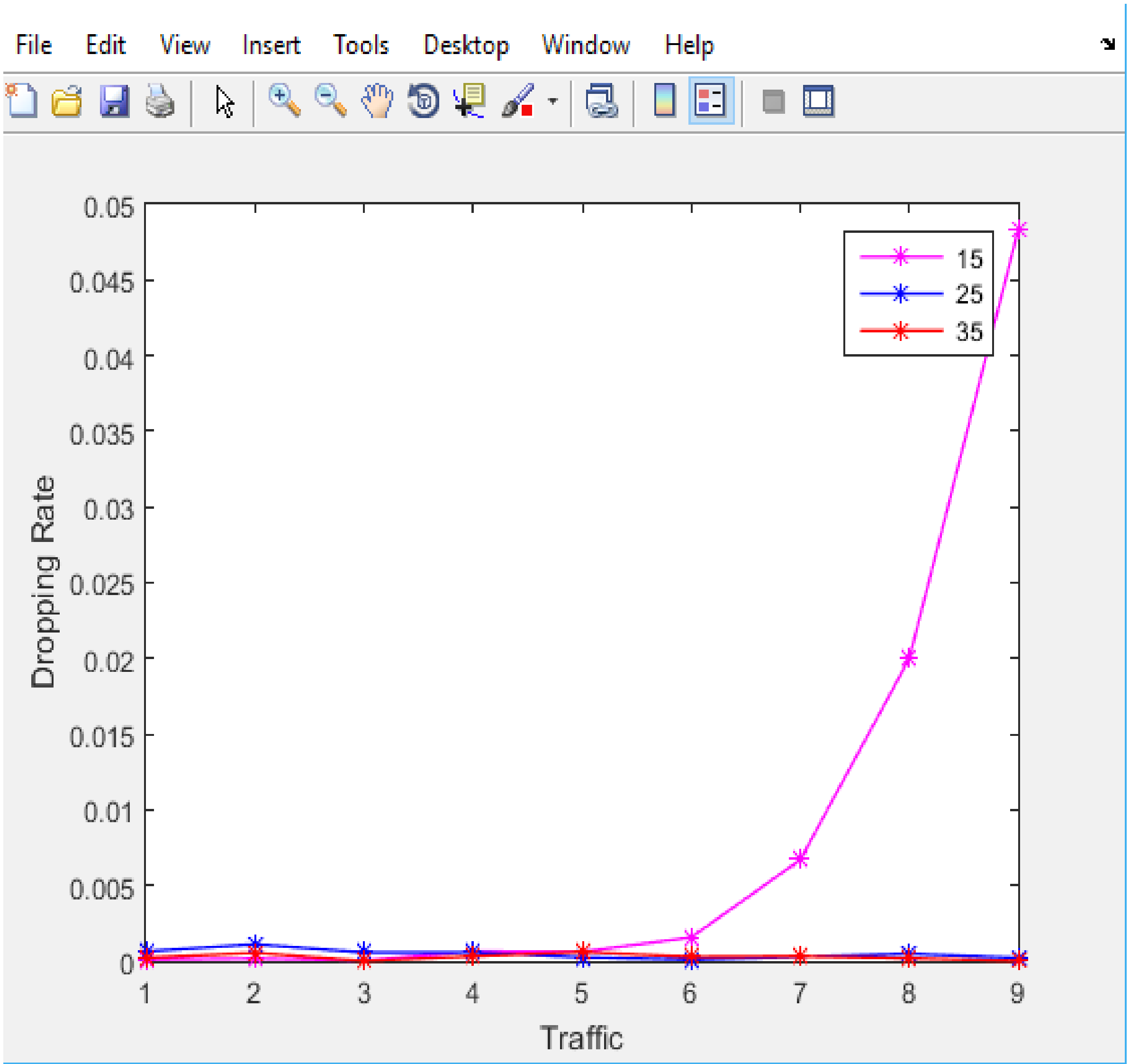


Figure 5-2 Dropping Probability having different number of channels

2) Dropping probability having different Queue sizes

The dropping probability is reduced by increasing the queue size, because the queue can handle a larger number of arrivals as can be seen in Figure 5-26.

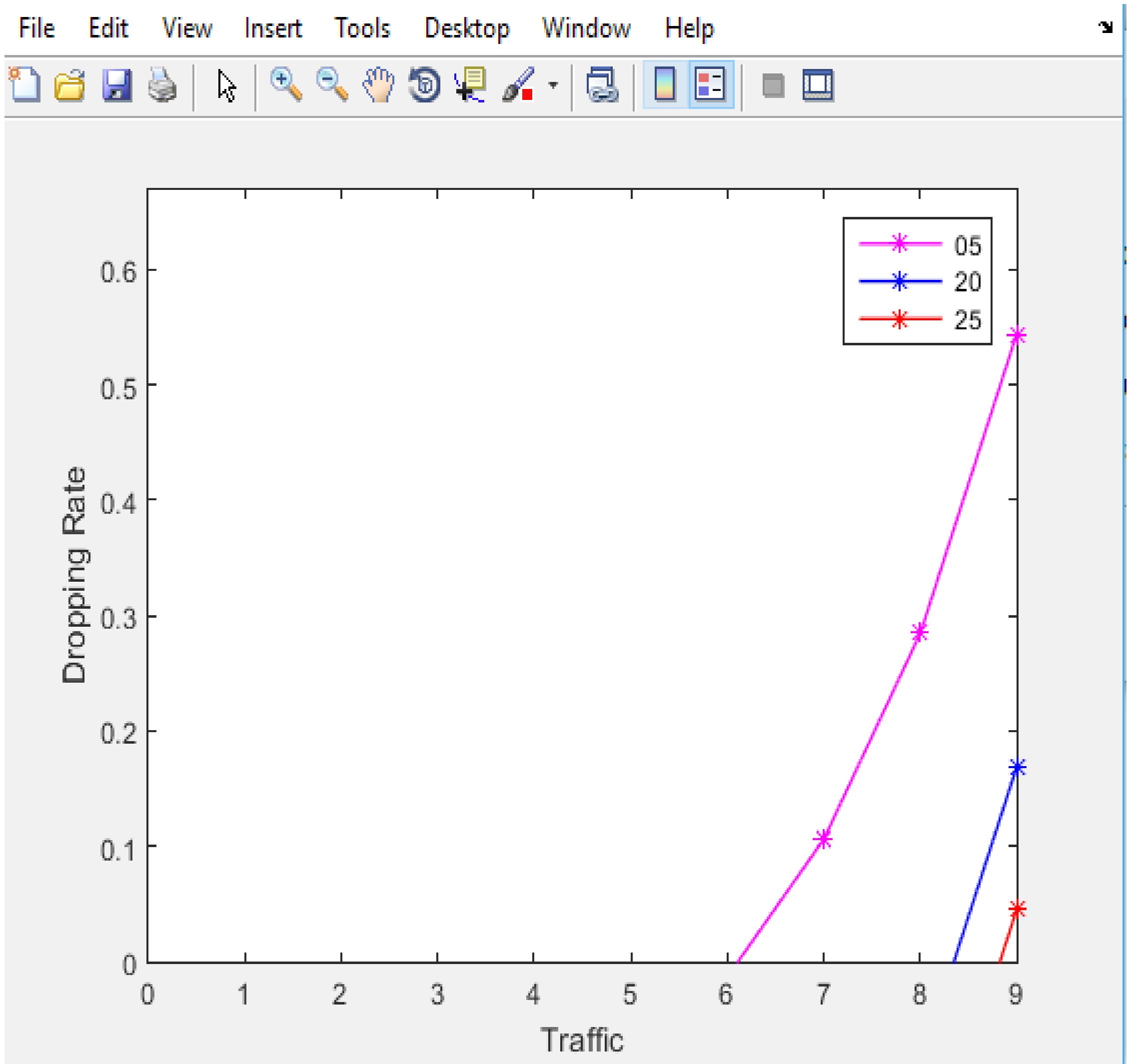


Figure 5-2 Dropping Probability having different Queue sizes

3) Dropping probability having different arrival rates

The Dropping probability increases with increasing the arrival rate, because when arrivals increases the queue reaches its maximum capacity and the rest of the calls are dropped. Figure 5-27 shows this increase.

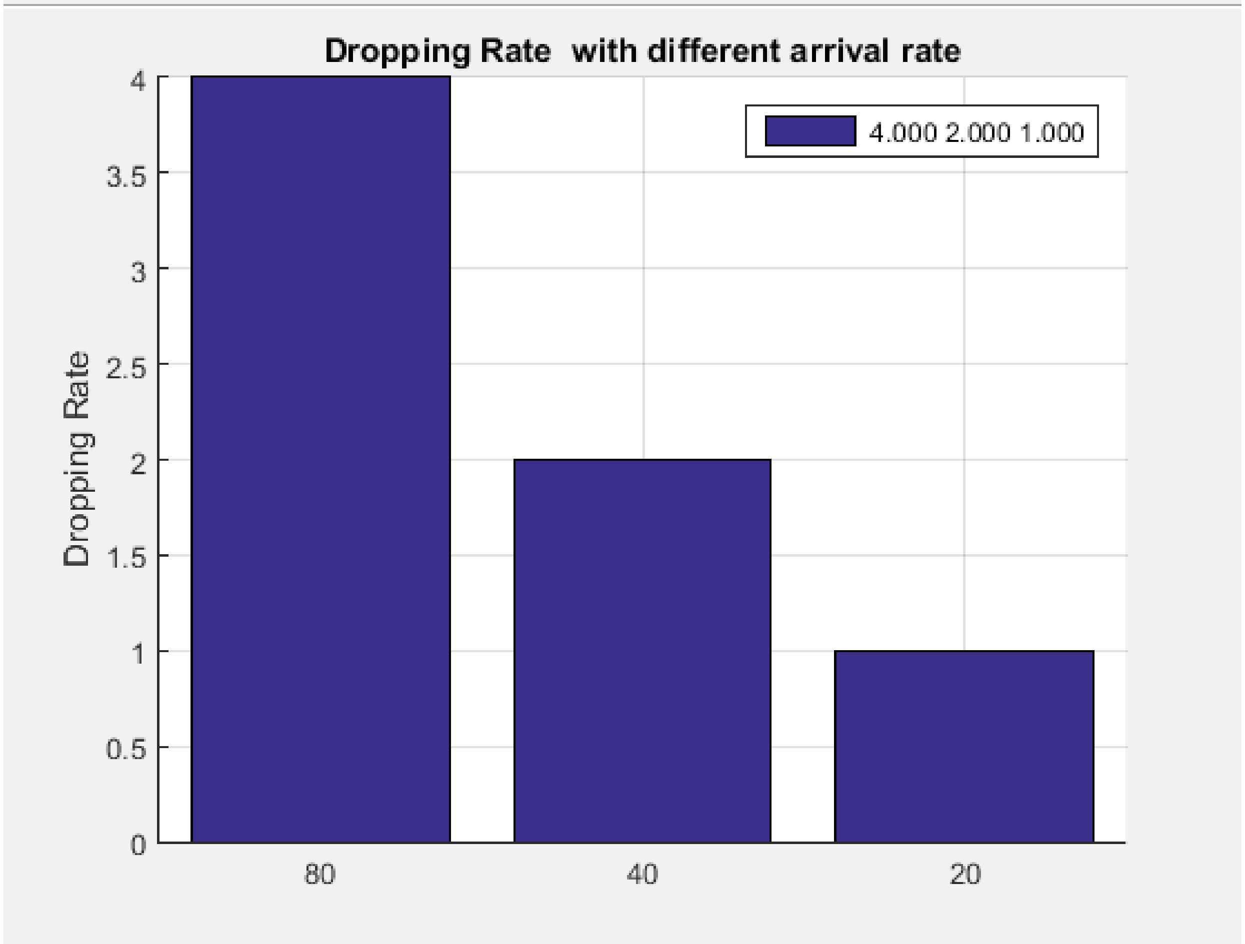


Figure 5-2 Dropping Probability having different arrival rates

5.3.9 Macrocell-Microcell evaluation

1) Mean delay

Macrocell and microcell calls experience the same delay as can be seen in Figure 5-28.

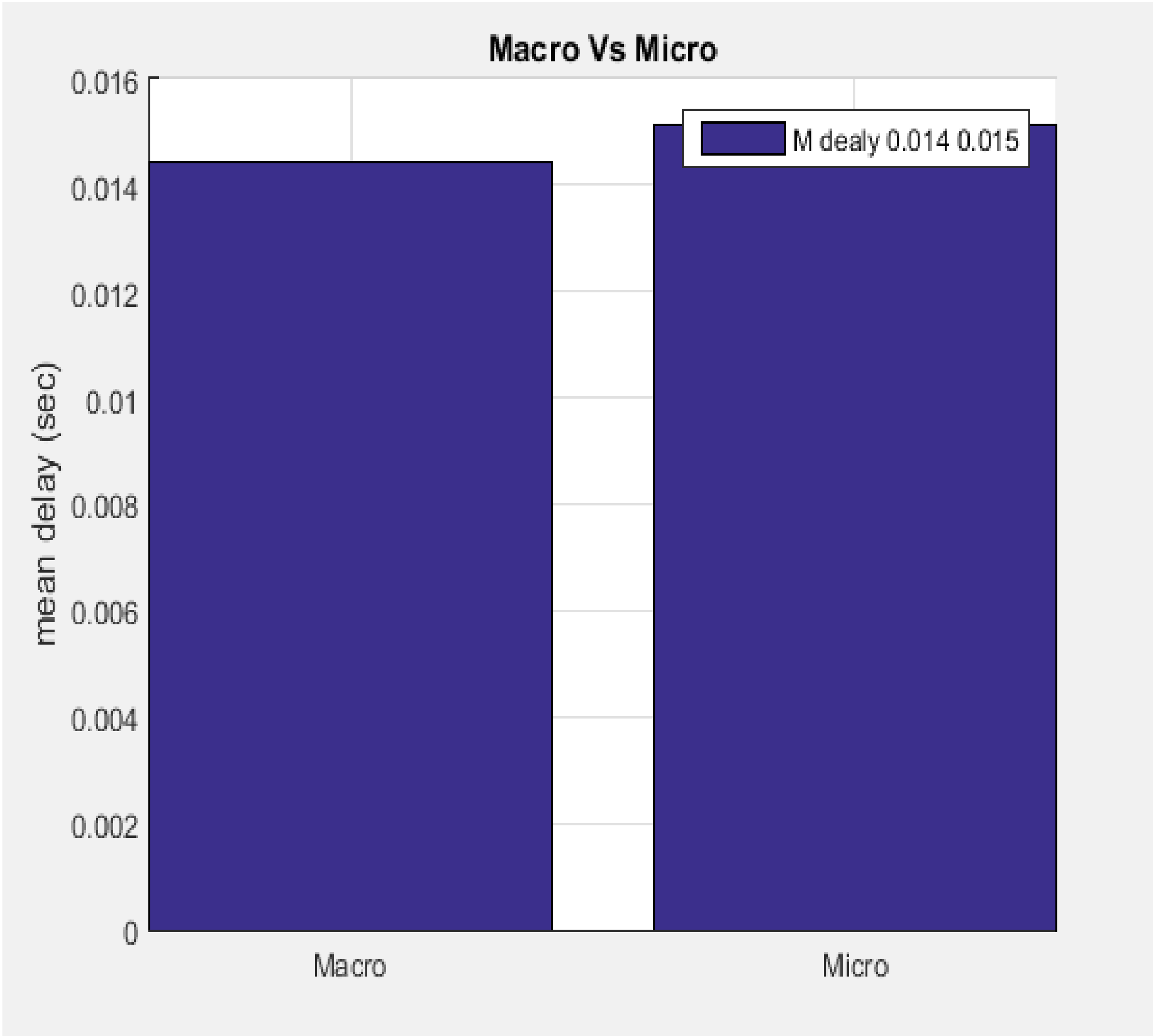


Figure 5-2 Mean delay results

2) Dropping probability

The Dropping probability is the same for the two cells macrocell and microcell as Figure 5-29 confirms.

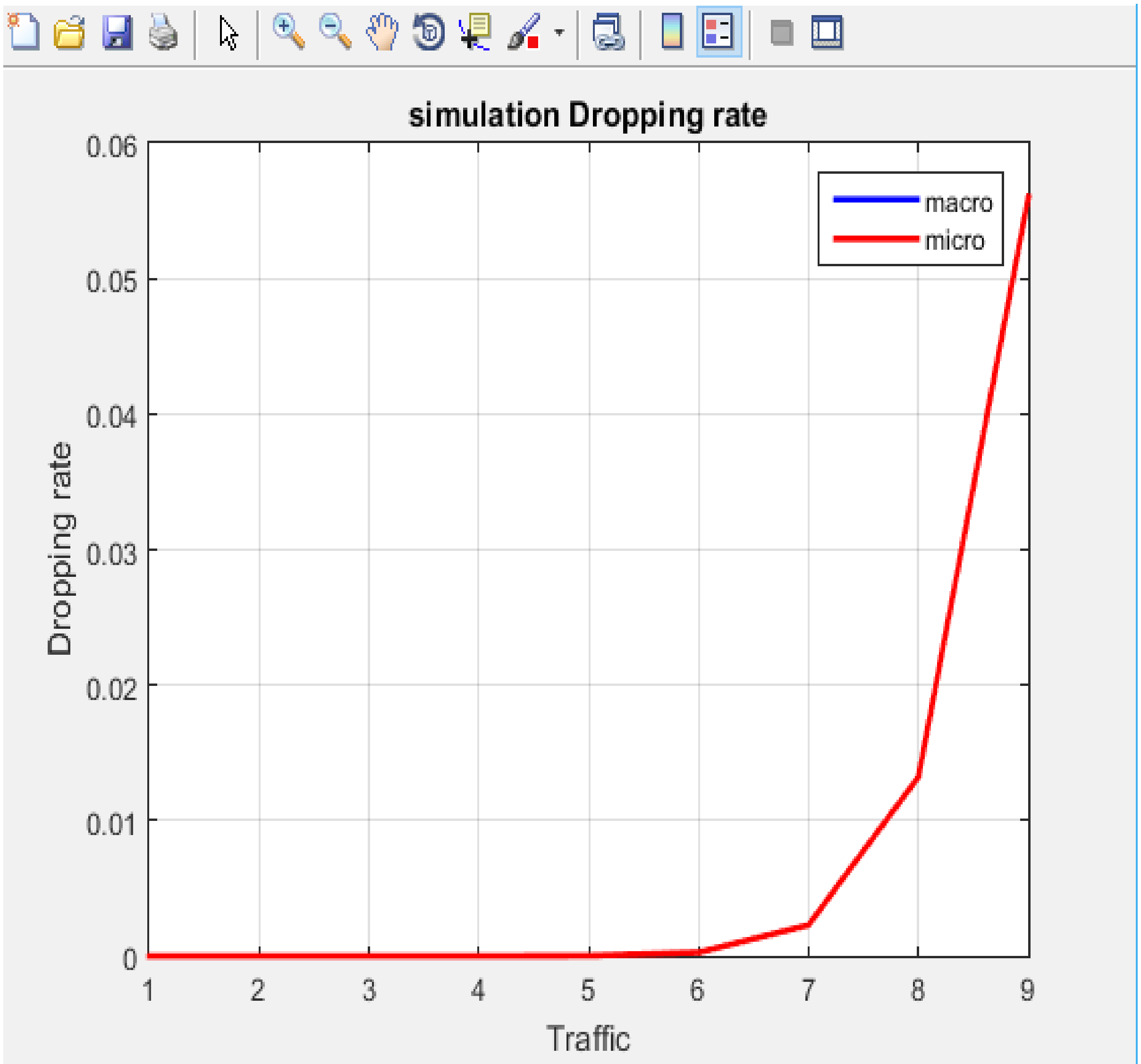


Figure 5-2 Dropping Probability for macrocell and microcell

3) Utilization

The utilization is similar for both cells as shows in Figure 5-30.

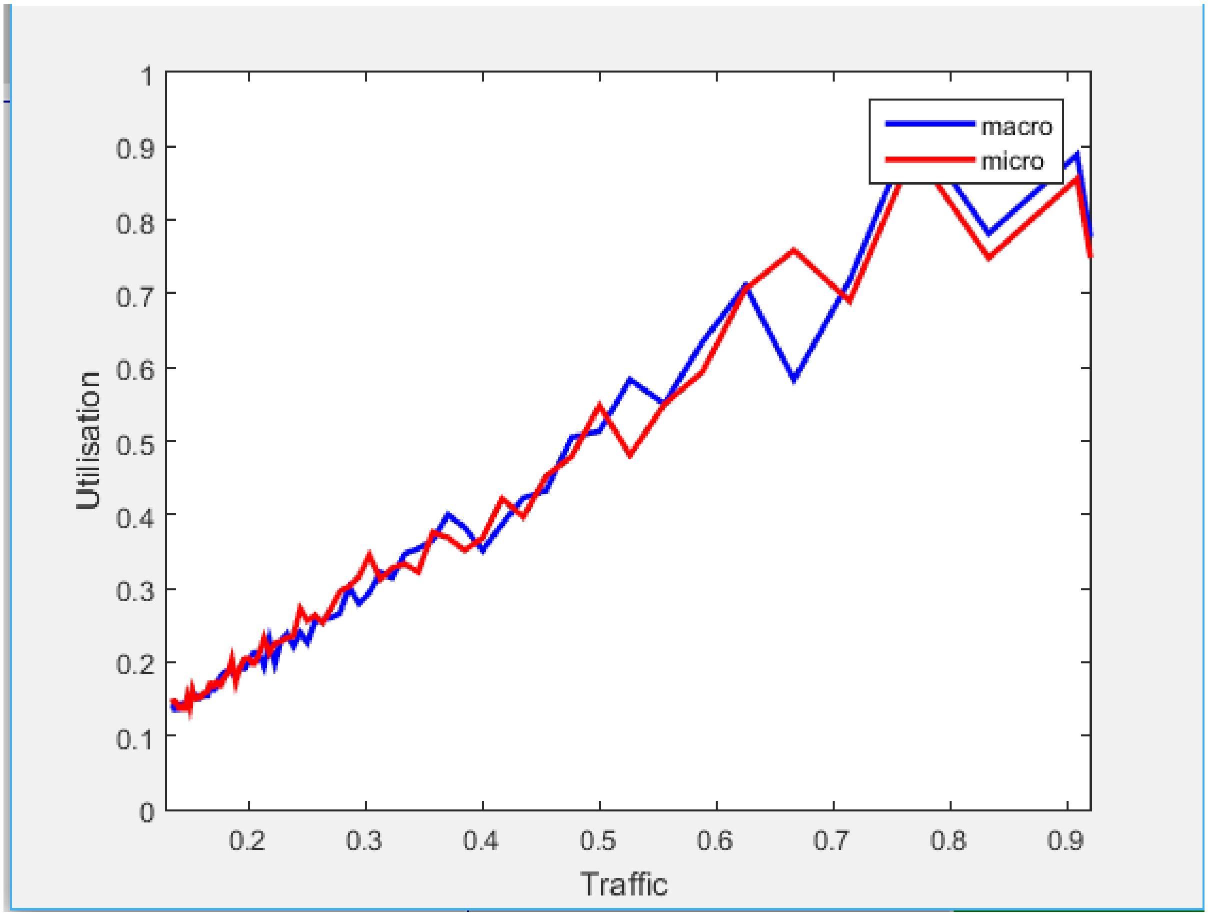


Figure 5- The Utilization for macrocell and microcell

5.4 Summary

After the vertical handover evaluation has completed, it found that the mean delay increases with the increase in the queue size, and the arrival rate, but decreases when having more channels in the cell.

The handover dropping probability increases when the arrival rate increases, however, it is reduced when increasing the queue size and number of channels.

The performance of macrocell and microcell traffic is similar, as they are both treated with the same priority in the cell.

Chapter six

Conclusion and Recommendations

6.1 Introduction

This chapter presents the conclusions of the research and recommendations for further work.

6.2 Conclusion

Global wireless networks enable mobile users to communicate regardless of their locations. One of the most important issues is location management in a highly dynamic environment because mobile users may roam between different wireless networks, network operators, and geographical regions. This project has considered the interconnection of users between different cells which is the process of handover and considered that over 4G networks, practically. This issue has been modeled by assuming that a system consists of a layer of macrocells and a layer of microcells, where vertical handover occur between the two layers.

The simulation model is designed and implemented using MATLAB environment, which allows multiple features and comprehensive platform for such studies. The system is constructed by using a friendly Graphical User Interface (GUI), which allows the users to enter multiple input values to get different evaluation results. The system allows the user to run a simple comparison for the system between the behavior of the macro and micro cells by entering the service time, arrival rate of each, number of channels, total number of users, and the queue size. The outputs show the throughput, successful and dropped handovers, and the Grade of service. The second GUI interface allows to compare the behavior of the network model under different parameter values. These are the number of channels, queue size, and the arrival rate.

From the results it has been proven that with increasing the number of channels the mean delay and the dropping rate are decreased. Increasing the queue size doesn't effect the mean delay but may decreases the dropping rate. Finally, by increasing the arrival rate, the mean delay is increased and the dropping rate is also increased.

6.3 Recommendations

- The evaluation can consider having a higher priority for traffic from one layer over the other layer.
- The work can be extended to have traffic from multiple cells and consider new calls.
- Including inter system handovers between 3G and 4G for example.

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