Adaptive Algorithm for Resource Allocation in Cellular Grid

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August 2018

Adaptive Algorithms for Resource Allocation in Cellular Grid

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A dissertation submitted in partial fulfillment of the requirements for the degree of

MASTER OF OPERATIONAL COMMUNICATION

In the College of Information Communication Technology

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August 2018

DECLARATION

I declare that this Dissertation contains my own work except where specifically acknowledged.

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Signed………………………………………..

Date…………………………………………..

Certificate

This is to certify that the project work entitled "Adaptive Algorithm for Resource Allocation in cellular Grid " is a record of original work done by ***UKURIKIYEYESU DIEUDONNE*** *with Reg no:* ***216358841*** *in partial fulfillment of the requirement for the award masters of science in information systems of College of Science and Technology, University of Rwanda during the academic year 2017-2018*

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Acknowledgments

I, first of all, thank my beloved family and my Supervisors Dr. Gaurav Bajpai and Dr. Didacienne Mukanyiligira for their invaluable assistance and support to my studies.

My sincere acknowledgment addresses to the authorities of the UNIVERSITY OF RWANDA - COLLEGE OF SCIENCE AND TECHNOLOGY, more especially to the School of ICT, though I acquired multitudes of knowledge having permitted me to carry out this Thesis.

I kindly express my acknowledgment to my fellow classmates for their moral and encouragements; they have listened and given me advice. They are my blessings.

I acknowledge all those who directly or indirectly support me either economically or morally throughout in my studies.

Thank you all!!

ABSTRACT

Nowadays, the use of mobile devices is increasing at a high rate. Mobile device users are competing to use allocated resources by the service provider during the insufficient availability of resources to serve their demand. Some users are not satisfactorily served due to the competition in the sharing of allocated resources due to low processing power, low or no signal availability.

This problem can be addressed by creating the Cellular Grid. The devices in the cellular grid will address the issue by optimizing resource sharing and provisioning. This will be achieved by exploiting existing connectivity technologies Bluetooth, Near Field Communication (NFC), Radio-frequency identification (RFID), Bluetooth Low Energy (BLE), Wi-Fi (wireless fidelity) in the cell to support some cellular services.

This research shall focus on design and development of algorithms that shall allow the cellular grid to provide better connectivity. Further, this research will also show demonstrate the efficient utility of available resources thus increasing the better service for the users in the cell.

Keywords: Cellular Grid, Bluetooth, Near Field Communication, RFID, Bluetooth Low Energy, Wi-Fi, Grid computing.

LIST OF SYMBOLS AND ACRONYMS

TL:DR :Too long; Didn't read

NA : Not Applicable

VoIP :Voice Over Ip Internet Protocol

VoWIFI : Voice Over Wireless Fidelity

RSSI : Received Signal Strength Indicator

RSRP : Reference Signal Received Power

CDMA : Code Division Multiple Access

UMTS :Universel Mobile Télécommunications System

EV-DO :Evolution Data Optimized

3G **:** Third Generation

4G LTE **:** Forth Generation Long Term Evolution

SDMS : Systems development method

D2D : Device to Device Communication

BS : Base Station

MANET : Mobile Adhoc Network

UE : User Equipment

RBs : Radio Base Station

BLE **:** Bluetooth Low Energy

DSS : Direct Sequence Spread Spectrum

SNR **:** Signal to Noise Ratio

FHS **:** Frequency Hope Spectrum

OFDM **:** Orthogonal Frequency Division Multiplexing

CDMA **:** Code Division Multiple Access

PANs **:** Personal Area Networks

LANs **:** Local Area Networks

NANs **:** Neighborhood Area Networks

WANs **:** Wide Area Networks

IoT : Internet of Things

RB **:**Resource block

Raid **:** Redundant Array of Independent Disks

IMEI : International Mobile Equipment Identity

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Chapter 1 General Introduction

1.1 Introduction

Nowadays mobile users have too many complaints against their service providers that they are not provided with enough resources. Due to much love of money, service providers are much interested in increasing the number of users, and less care for the services offered to the users.

Users keep moving from one Base Station to another. There is a probability that you will find a huge number of users accumulated at one base station. The cellular system has the maximum number of users that are allowed to be present. So, when the number of users increases beyond the maximum number, the new users are not able to use the resources, lowering the quality of service [1].

Another thing is that those users in the cell have different capabilities like device's receiver sensitivity and device's processing power. Those devices compete for the channel. Devices with high receiver sensitivity have a high probability of competing and use the resources. The devices with low receiver sensitivity also face a problem of utilizing the allocated resources, thus lowering the quality of service. Low receiver sensitivity may also be as a result of signal fading in the area. Signal fading happens results as the signal propagates from the transmitter to the receiver, loses strength due to the nature of the area and obstacles between them. So, the signal takes different paths thus resulting to the fading of the signal [2] [3]. This may result the receiver to receiver too weak signal to support communication

There is a possibility brought by grid computing, whereby a device can utilize resources of another device.

By exploiting and integrating together the existing connectivity technologies such as Bluetooth, Near Field Communication (NFC), Radio-frequency identification (RFID), Bluetooth Low Energy (BLE), Wireless Fidelity (Wi-Fi) in the cell may support some cellular services.

By combining these mentioned above communication technologies and make a grid, the available resources can be well utilized by allowing other new devices to use the resources.

1.2 Motivation

This research thesis is highly motivated to conduct this research as he will be able to avail resources to a large number of users.

The research is interested to bring the concept of Grid computing to address cellular communication problems.

1.3 Background of the study

In communication technology, there have been many evolutions. As technology is advancing, there are many innovations that have been taken place just to improve on quality of service in telecommunication. The introduction on Wireless communication (1G) in 1980's, aimed to replace wired communication as there were many limitations that wanted to be handled as a wired technology was too expensive and could not cover many places. After first Generation there came the second generation, Third Generation, and Fourth Generation just to solve problems that were discovered in their previous generations. As these changes and innovation took place, one of the problems that were to be addressed was how resources are allocated to users. The problem of resource sharing has become the big issue in the telecommunication area. In recent days a lot of research is being done on D2D communication whereby devices can communicate with another one without the intervention of Base station [4], but there are minimum requirements required for it to be possible. The way D2D communication operates has proven to be a good approach even though it has some problems that have not yet fixed as discussed in literature review. The emerging of Grid computing technology has solved some issues whereby resources can be shared. So, by combining all these approaches can yield into something interesting [5].

Researchers have developed many algorithms such as non-linear program [6] that is feasible in solving optimization problems, brute-force search algorithm [7] that insists to use whatever way that can be the best in finding the solution, Evolutionary algorithm, genetic algorithm [8] that helps in solving problems that might not possible to find a solution. It helps to solve problems that are potentially huge search spaces and navigating them. All these algorithms were designed just to help in device discovery in D2D communication.

1.4 Problem statement

The base station (BS) has a fixed number of channels which can serve a fixed number of users at particular time. Users can increase but the number of channels is fixed. So, when the number of users becomes more than the specified maximum numbers that base station can accommodate results into a bad quality of service.

1.5 Objective of research

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1.5.1 Main objective

The main objective of this research is to analyze the existing techniques used in cellular communication to allocate resources in D2D communication. Determine how connectivity technologies can be used in the cellular grid to accommodate a large number of users in the cell.

1.5.2 Specific objectives

The specific objectives were as follows:

1. To analyze the existing schemes and methods of resource allocation for devices in the cell.
2. To make an analysis on how wireless connectivity technologies operate.
3. Develop algorithms for how devices should adopt when they want to communicate in the cellular grid.

4. Simulating and testing the improvement brought by a cellular grid.

1.6 Proposed solution

The devices that face the problem of low quality of services due to different factors like low receiver sensitivity due to place where they are located, will be aided by those with a good quality of services in a cellular grid, to make communication better.

1.7 Justification

At the end of this research, there will be an optimized algorithm that will allow users to share the allocated resource with the help of existing connectivity technology in the cellular grid. Devices that cannot communicate using cellular channel shall utilize the channel with the help of other devices with the channel.

1.8 Scope and limitation of the research

There are many services that are offered in cellular communication. This research will be limited to the sharing of data. Voice call will not be supported.

1.9 Organization of the study

This research is organized as follows.

Chapter One gives the introduction of the research which includes a short background of the domain that was studied and proposed problem with its solution.

Chapter Two discusses related researches that were carried out before, the gaps ion them and how this research fill those gaps.

Chapter Three is the research methodology. This gives the overview of the research methods that were used during this course of this work. It also presents the systems requirement for the research.

Chapter Four presents a system analysis and design that includes all the theory that was used.

Chapter Five provides results by interpreting data using charts.

Chapter Six finalizes the research with a conclusion and suggests recommendations for future work.

1.10 Hardware and software requirements

1.10.1 Hardware requirements

Laptop machine with specifications

- Core i3Processor.
- Frequency 2.7GHZ.
- 2GB RAM,
- Hard Disk Storage Space 500GB HDD

1.10.2 Software requirements

- Window 7 with 64-bit Operating System,
- JDK 8.0.1
- MatLab 12.

1.11 The conclusion of Chapter One

In this chapter, the researcher has given an introduction, motivation, background of the study, a detailed problem statement has been given, proposed solution, scope, and limitation of the research, how this research is organized and why he is interested in working on this project.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In recent years, researches were made just to make cellular communication easy. Among technologies that are involving boosting cellular communication is D2D communication. Different research studies have been done, giving insight into the use of D2D communication in cellular mobile systems. This chapter will put much emphasis on showing recent researches that were done on D2D communication, introduce more about resource allocation for Device-to-Device Communication. It will show researches that were done on Grid computing. Further, it will also provide literature review in a few theories that are going to be used in this thesis research work.

2.2 D2D communication in a cellular network

Several authors have worked on ways and algorithms on how resources are allocated to the devices in the D2D communication.

According to the definition D2D [9] communication as direct communications between mobile devices without necessarily to transfer data through a base station (BS). The author found that the most useful processes in D2D communications are device discovery that finds devices located nearby. In order to determine the proximity of devices, each device transmits a discovery message periodically, and other devices check if the message can be received successfully. Their system model is based on network-assisted but distributed-control D2D communications.

It is assumed that the devices that need to establish this kind of communication are orthogonal [10].

While discovery parameters can be provided by the network, each device selects its own resource for discovery message transmissions. It is explained that when a device starts the discovery process, it may perform carrier sensing for each RB (Resource Block) available in a single discovery period and select the RB with the least amount of interference to maximize the discovery range. If the measured interference power at a transmitter for the selected RB is lower than a predefined carrier sensing threshold, then the RB can be used for periodic discovery message transmissions with the assumption that a desired discovery range *R* can be satisfied. Otherwise, the discovery period needs to be increased so that a greater number of RBs can be included in an enlarged discovery period and the density of transmitters per RB can be reduced. This focuses on the device discovery but it does not show how devices shall be connected, how system capacity can be enhanced to accommodate more users on the network so as to provide better QoS (Quality of Service) to the users.

Cellular operators may offer such cheap access to spectrum with controlled interference enabled by D2D communication as an underlay to the cellular network.

Provides the concept of D2D illustrated in the Figure-1 below [11].

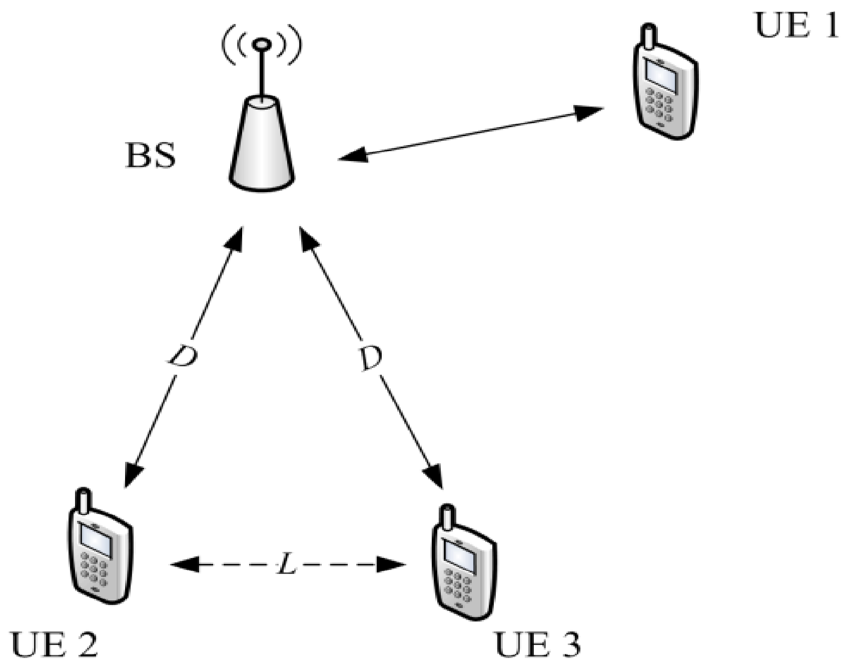

Figure 1: D2D Concept

This way of allocating devices only aimed at devices that have the ability to participate in that communication. It was not considered that there can be a problem whereby some device capabilities cannot be a problem to participate in the communication.

2.3 D2D and ad-hoc networks

D2D communication is not a new concept, take an example of Bluetooth, it can be used to send files to each other, meaning that this is a kind of D2D communication. In the usual cellular system, if two cellular users want to communicate with each other, the messages start from the sender and go through the base station (BS) and then reach the receiver. Things become different if D2D communication is introduced. The messages can then go directly from the sender to the receiver without bothering the base station. But since the D2D communication is cellular-based, it is controlled by the base station. This means that the base station knows when the communication starts and ends.

An ad-hoc network is explained [12]as a decentralized type of wireless network that does not depend on a pre-existing infrastructure, such as routers in wired networks or access points in managed, infrastructure wireless networks. Instead, each node participates in routing by forwarding data for other nodes, and so the determination of those nodes forward data is made dynamically based on the network connectivity. A Mobile Adhoc Network (MANET) is an autonomous collection of mobile routers and associated hosts connected by bandwidth-constrained wireless links.

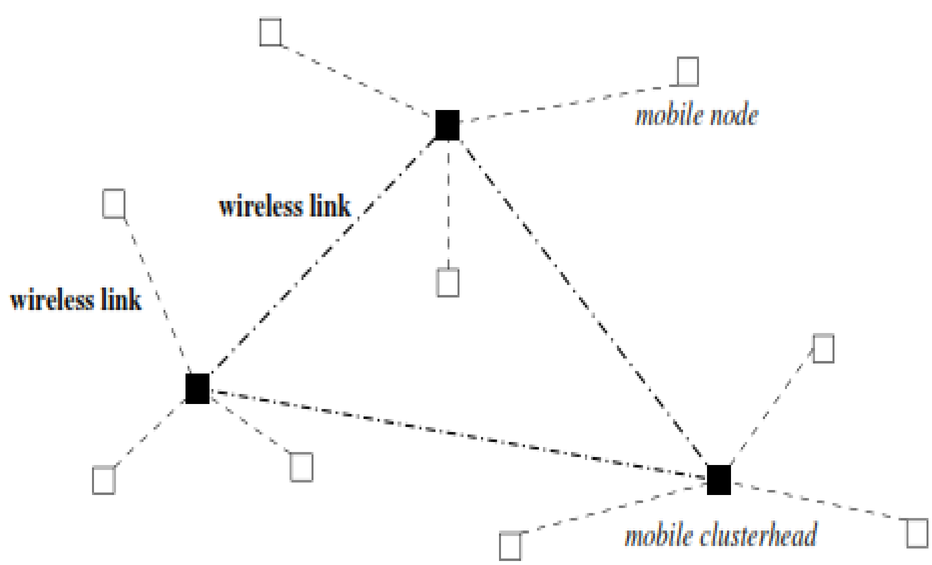

Figure 2: A Mobile Ad-hoc Network (MANET)

The network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion or may be connected to the larger Internet. *Figure 2*shows the mobile ad-hoc network.

This kind of communication differs from D2D communication in the way that D2D communication is cellular based. As shown in *Figure 1* and *Figure 2,* it shows how D2D differ from Ad-hoc network. Table from [11]shows key differences between cellular and ad-hoc networks.

Table 1: Differences between cellular and ad-hoc network

CELLULAR NETWORKS	AD HOC WIRELESS NETWORKS
Fixed infrastructure-based	Infrastructure-less
Single-hop wireless link	Multi-hop wireless links
Guaranteed bandwidth	Shared radio channel (more suitable for best-effort data traffic)
Centralized routing Centralized routing	Distributed routing Distributed routing
Circuit-switched	Packet-switched (evolving toward emulation of circuit switching)
Seamless connectivity (low call drops during handoffs)	Frequency path break due to mobility
High cost and time of deployment	Quick and cost-effective deployment

2.4 Resource Allocation in D2D communication

Researchers tried to use Device centric Resource Allocation scheme, to resolve the huge task that was done by Base station to allocate resources. This paper has proposed three steps through that resources can be allocated by themselves [13].

These three steps are:

"In the first step, devices maintain their resource occupancy matrix by exchanging the neighboring information.

In the second step, a resource block is selected based on resource allocation scenarios.

In third steps, the resource block is allocated based on the priority on the BS side."

This scheme does not much depend on the BS side hence reducing load, time consumption and improves the overall throughput.

This scheme is better, as discussed in above paragraphs but, it only allows devices in the same proximity. Otherwise, communication is not possible through this scheme where devices are distant.

The following points aim to discuss how to efficiently allocate resources for Overlay D2D communication. The problems that were to be solved were,

1) Traffic offloading from the eNB(Evolved Node B)to the local area network

2) system-capacity and Frequency-efficiency enhancement due to spatial reuse and

3) eNB (Evolved Node B)coverage extension via UE-to-UE (user equipment) relaying.

It was found that there were many challenges during the implementation of D2D communication such as efficient utilization of the cellular spectrum by both D2D Links and cellular links [14].

The researcher stated the critical issue for Overlay D2D being the minimization of RBs required for D2D communication with reliability constraint. These problems were addressed by the following algorithms

1. *Guide for Minimum Overlay Partition*
2. *Heuristic Allocation Algorithm*
3. *Design Insight*

The researchers were able to save up to 18.6% RBs, improve the throughput per RB by up to 23.4%, and reduce the computation time by up to 67.9%.The drawback of this scheme was that it only allows users who are in the same coverage area with the base station.

The study that aimed to mix both underlay and overlay D2D communication just to improve the way resources are allocated was made. This was aided by using Heterogeneous networks where the devices that can be possible for them to use other connectivity technologies can use them instead of overloading base station while they can communicate using other technologies. In the research, it was stated that D2D mode can be used by any two users in close proximity for efficient communication, in this communication macrocell or core network is not involved. For D2D communications both licensed and unlicensed spectrum can be used [15].

They tried to solve the problem by combining both having a macro cell, small cell, relay and D2D communication by designing the way communication will be set accordingly.

But the problem of this scheme is that the communication could be possible only when the devices that need to establish communication to be in the coverage that technology intended to user needs.

The way resources are allocated using the technique called Typical Random Technique as it was found as a useless as it arises some problems of interference was opposed. This led to the introduction of anew algorithm called Multi-armed bandit solver, also known as Online Learning Algorithm. This was helping to show the correct transmission power suitable for D2D candidates to communicate without much interference [16].

This scheme gives the proper way to allocate resources between devices in the same location and does not give favor to devices that are not candidates of D2D communication.

The explanation of the advantages of using D2D is discussed. It statesthat despite these benefits brought by this emerging technology have also some side effects like interference. Research works have been conducted just to eliminate those problems in order to overcome the problems and keep enjoying the benefits. They found that allowing the D2D pair to communicate and allowing the resources to be used by another pair could result in interference. By using existing algorithms such as evolutionary algorithm, genetic algorithm9 and10, researchers have introduced a graph coloring with chaos genetic to address this problem just to locate where the D2D pair is feasible before the allocation of resources [17].

This research only embarked on underlay D2D communication neglecting overlay that can be used to enhance this technology.

The discussed benefits of using Multi-Hop D2D communication are covering the gap that was left behind in the previous researches. In this research explains how to introduce the scenario of multi-hop communications, and discuss that how to build multi-hop communication, how D2D Users Equipment (UEs) is distributed and how to reduce the outage probability in D2D enabled cellular network [18].

This technology does not support heterogeneity communication between devices that can be offered by the use of the grid.

It is supported that using Single Hop D2D communication is good as it takes the advantage of reuse, proximity, and hop gains. It urges that also this can be improved by using Multi-hoped D2D communication. Although it hard to design algorithms to comply with such technology, they have proven how useful it is.

They achieved this by designing algorithms that help to

1. Propose and analyze heuristic mode selection and resource allocation strategies that are applicable in cellular networks integrating MH D2D communications and

2. Develop a utility optimal distributed PC scheme that considers both the achievable rates along MH (Multi hop) paths and the overall energy consumption.

The problem with this is, that the technology does not support heterogeneity communication between devices that can be offered by the use of the grid [19].

An algorithm that can be used to share data between devices using multi-hop network was discussed [20]. This is because devices may not be able to connect due to the distance between them. D2D communication has many factors to be fulfilled for it to be possible. Then one of the devices can act as a relay to transport data between devices. Here, they also considered the selection of mode also depending on social factor. This was achieved by providing A Power-efficient and Social-aware Relay Selection (PSRS) algorithm to solve the above problem.

This algorithm does not help devices that are not in the same proximity and cannot be used to communicate using different technologies.

2.5Grid computing technique to improve D2D communication

The evolution of Grid computing is explained. It shows that Grid computing has become a new approach for a high performance distributed computing infrastructure. It describes that Grid computing plays a great role when the focus on resource sharing, coordination manageability, and high performance [21].

This research was only done by ignoring mobile resources and intends to devices that are connected using the same technology.

The grid is described as an extremely large virtual network system that allows participants to access the resources such as processors databases of many different machines distributed over the world. This paper discusses architecture, open sources software that can be used in the grid [22].

This approach can be found as an opportunity to improve D2D communication.

The possibility of mobile grid computing was examined. The factors and opportunities are shown. Some of the opportunities shown are

1. Mobile devices are always connected
2. Most of the devices have high computing power.

It also shows the challenges for it to not succeed like power, platform, network and social factors. These challenges are overcome by designing a good Mobile Grid architecture. This is an opportunity to enhance D2D communication when Grid technology is included [23].

The architectural shift from 4G to 5G was shown. It states as technology changes mobile devices has also to be designed to be able to comply with the technology. As technology changes, new improvements also exist. So, devices that use different technology access to services differently. Devices with latest technologies have better services compared to the rest [24].

Devices with low processing power can benefit those that are using the better technology through the grid.

There are different techniques that are used in Grid computing Architecture that can bring a great opportunity in using grid computing in cellular communication.

RAIDO

Raid (Redundant Array of Independent Disks) is the technique that breaks the file and then spreads it in all disk drives in the RAID group. This technology helps to back up the data in case one of the disks fails; it automatically loads data from another one. In Network Attached Storage can NAS integrates RAID subsystem to aggregate the storage capacity, I/O performance and reliability based on data striping and distribution [25] Raid Systems has offered an attractive alternative IO SLED, promising improvements of an order of magnitude, performance, reliability, power consumption, and scalability [26].

Due to its benefits, it can bring much support in grid computing.

Load Balancing

In Grid computing, gas gained another advantage of load balancing where by the submitted jobs can be re-allocated and in case the resource manager has become overloaded. Load balancing can also enhance the improvement in heterogeneity, scalability and adaptability [27] [28]**.**

Optimization

In Grid computing, there is need to coordinate and provide resource sharing on networks located at different places. So in doing this, the job scheduling on the environment becomes crucial. The Algorithm “Bio-Inspired Heuristic” was developed to address the optimization problem that result due to heterogeneity and complexity of resources. This gives Grid computing a great opportunity to address optimization problems that may rise in cellular grid [29].

Grid computing optimization has become a hot topic where by some Algorithms were developed including bees Algorithm. The bee’s algorithm intended to investigate a multi objective

Scenario of Economic/Environment Power Dispatch Problem. It was found that optimization in parallel computing is difficult rather than grid computing. This is because in parallel computing the algorithm is not feasible due to the complexity of algorithm. So this becomes an added value factor to use cellular Grid as optimization problems were studied and solved [30].

Queuing Model.

In grid computing, there are various jobs which are being submitted to grid server. Those jobs have to be services. The time which is taken for the jobs to reach to server is arrival rate and the time taken by the server to serve the jobs is service rate. So as there is a big number of jobs being submitted to the server, there is a need to have a queuing model that will design how jobs have to be serviced. Some models were proposed like, *Markovian time queing models* $M(t)/M/s/s$ and $M(t)/M(t)/s/s$ [31] M/M/1 and M/M/m were studied and proved to be a better scheduling approach in Grid computing [32].

Resource Manager:

In grid computing, there is a need to track how resources are being utilized. Each device has IMEI(International Mobile Equipment Identity) as the unique identifier of every mobile device [33].

During resource allocation in cellular grid, this number helps to inform the grid the mobile number associated with it such that in case that number gets back on the network during handover, will have to refund resources utilized when it was not being served by the base station.

2.6Wireless technologies to support D2D cellular grid

2.6.1 Wireless technologies

It is shown that as that in the fast-growing of the Internet of Things, applications for personal devices to industrial instruments connect wirelessly to the internet. The wireless devices can communicate at a distance offered by the technology being used. They are classified into four categories namely

1. Personal Area Networks (PANs) covering 10 m.,
2. Local Area Networks (LANs) covers 100 m,
3. Neighborhood Area Networks (NANs) that can cover more than 25 km., and
4. Wide Area Networks (WANs) covering a range of 100 m.

According to wireless technologies can be adopted in a cellular grid to underutilize the resources offered by the base station [34].

2.6.2 Bluetooth Low Energy (BLE)

It was found that BLE is gaining a wide range of applications. This technology supports the communication range of 50 meters. And can go beyond 100 meters. This technology can handle other interference on the same frequency as was tested o the IEEE 803.11 technology. This technology is characterized by the following features.

1. 1 Mbps Data Rate (RF modulation symbol rate)•
2. 128bitAESCCMSecurity.
3. Ultra Low Power Consumption (around1μAwhensleep-ingand<20mAmaximumconsumption).
4. Low Latency (6msfromnon-connectedstate).

This technology can be found as a solution to support cellular communication once put in the grid [35].

2.6.3 Wireless Fidelity (Wi-Fi).

Wi-Fi technology is described as one of the successful wireless networks that are based on a serial standard of IEEE 802.11.It is quite popular for providing different data services [36].

This is a useful technology as its physical layer uses DSSS (Direct Sequence Spread Spectrum), FHSS (Frequency hope Spread Spectrum), OFDM (Orthogonal Frequency Division Multiplexing), and IR (Infrared). The aadvantages, features, and architecture were discussed. It has a wide range of applications offered. This technology can help to enhance cellular grid, as Mobile devices support this technology.

2.7Mathematical Formulas

2.7.1 Probability theories

In probablity, when events depend on others are called conditinal probability, that determines the probability of a certain depends on the occurance of the other event. In a communication in order to tranfer information, depends on many factors. For example. In order to send a message, the following factors have to be considered.The device to be used must be available, Network coverage,Airtime,Receiverthat fullfills all requirements mentioned but a few.

So, this kind of probability is calculated as

P(A and B)=P(A).P(B|A) [37]**…….Equation-1**

Where,

P(A and B)=Probability of A intesection B. Event A to happen at the same time as Event B happens.

P(A)=Probability of Event A to happen

P(B)=Probability of Event B to happen

P(A|B)= probability of event A given that event B has occurred.

2.8Signal Strength indifferent Modes of Communication

In Mobile communications, According to INS (Industrial and Enterprise IoT solutions), they explain ranges of how **Signal Strength** varies in RSSI (Received Signal Strength Indicator) in (3G, CDMA/UMTS/EV-DO) and Reference Signal Received Power (RSRP)for 4G LTE [38], [39].

The measurements are described in the tables below. For 3G cellular connections, RSSI and EC/IO is what to look at.

Table 2: RSSI vs. Signal Strength for 3G

RSSI	Signal Strength
>-70dBm	Excellent
-70dBm to -85dBm	Good
-86dBm to -100dBm	Fair
<-100dBm	Poor
-110dBm	No Signal

Table 3: EC/IO vs. Signal Quality for 3G

EC/IO (dB)	Signal Quality
0 to -6	Excellent
-7 to -10	Good
-11 to -20	Fair to Poor

For 4G LTE, RSRP (Reference Signal Received Power), RSRQ (Reference Signal Received Quality), and SINR are the metrics to check.

Table 4: RSSP vs. Signal Strength for 4G

RSRP	Signal Strength
>-90dBm to -105dBm	Excellent
-90dBm to -105dBm	Good
-106dBm to -120dBm	Fair
<120dBm	Poor

Table 5: RSRQ vs. Signal Quality for 4G

SINR value	Throughput

>-9dB	Excellent
-9dB to -12dB	Good
<-13Db	Fair to Poor

Table 6: SINR value vs. Throughput for 4G LTE

SINR value	**Throughput**
>10	Excellent
6 to 10	Good
0 to 5	Fair
<0	Poor

2.8.1 Wi-Fi Signal Strength

Table 7 specifies the acceptable Signal Strengths in Wi-Fi [40].

Table 7: Acceptable Signal Strengths in Wi-Fi.

Signal Strength	**TL;DR** (Too long; Didn't read)	**Explanation**	**Required for**
-30 dBm	Amazing	Max achievable signal strength. The client can only be a few feet from the AP to achieve this. Not typical or desirable in the real world.	N/A
-67 dBm	Very Good	Minimum signal strength for applications that require very reliable, timely delivery of data packets.	VoIP/VoWiFi, streaming video
-70 dBm	Okay	Minimum signal strength for reliable packet	Email, web

		delivery.	
-80 dBm	Not Good	Minimum signal strength for basic connectivity. Packet delivery may be unreliable.	N/A
-90 dBm	Unusable	Approaching or drowning in the noise floor. Any functionality is highly unlikely.	N/A

2.8.2 Bluetooth

In Bluetooth, Signal Strength decreases with every 1 m, whereby in every 1m signal strength decreases by a value of 10dBm [41].

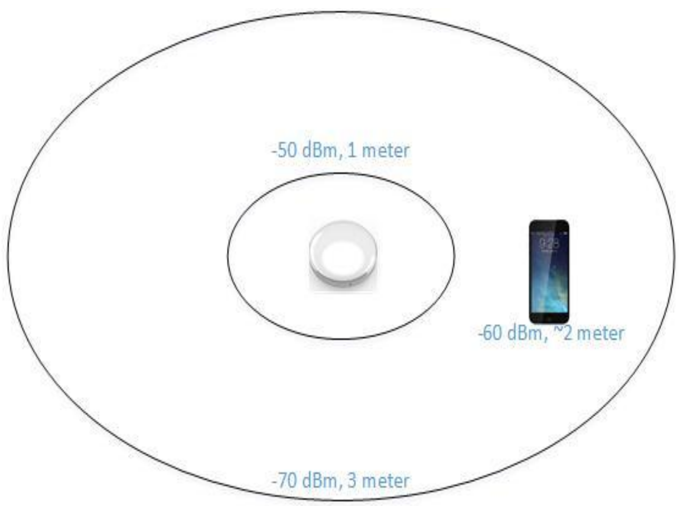

Figure 3: Signal Strength Variation with Distance in Bluetooth Technology

2.9Conclusionof Chapter Two

In this chapter, the detailed background study was given in each subsection. Key definition and related information were detailed in this chapter.

Generally, this chapter has discussed the schemes that are used in the allocation of resources in D2D communication. It has also shown the gap in each scheme. It has discussed also gaps and opportunities in mobile grid computing. The opportunities offered by the grid can help to cover the gaps in D2D communication.

Chapter 3: RESEARCH METHODOLOGY

This section gives an overview of the research methods that were used during the course of this work. It highlights the methods and approaches used and show how the analyzed results were presented throughout the whole project. Mainly scientific methods for conducting research were used however both qualitative and quantitative approaches were rarely used as data analysis was part of this research. The experimental research approach was also considered as several simulation results were presented and these resulted from several experiments that were conducted but this research approach lies under scientific research methods and this indicates that scientific type of research covers almost the whole project and other methods were just used for clarification.

3.2 Development Research approaches

This part describes the overview of the research approaches and the steps involved in system development from the step of gathering the ideas to the final step of simulations and getting the result.

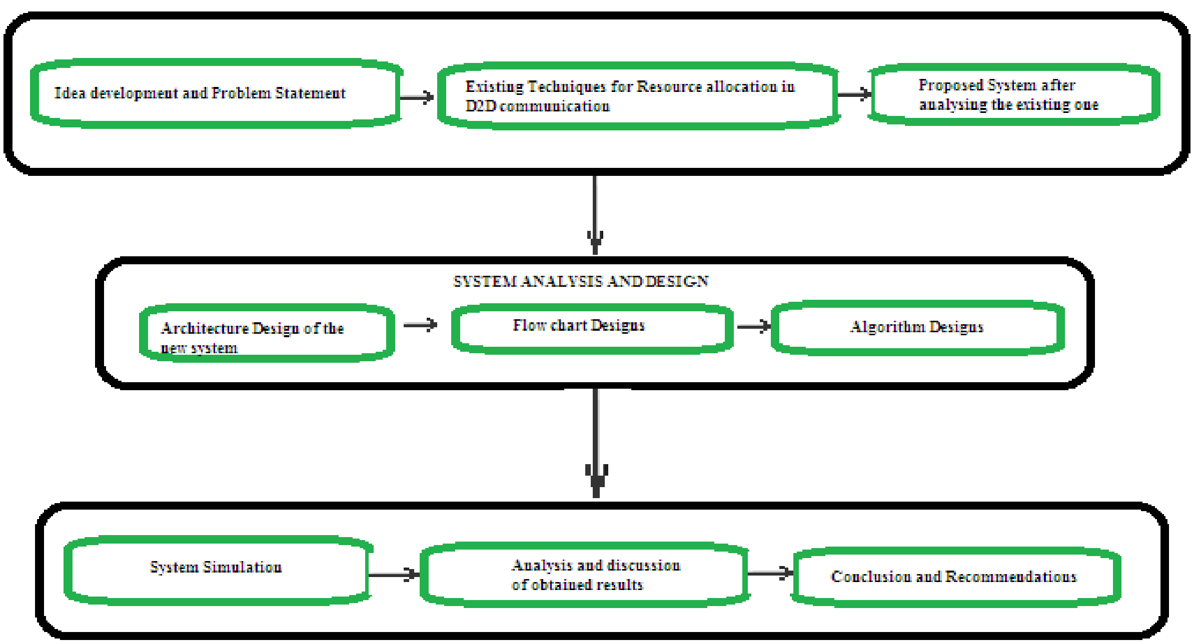

Figure 4: Overview of Research approaches development

The development approach in this research thesis has two types:

- The algorithm and flowcharts Design approach.
- The simulation approach.

In this research thesis, the existing systems are analyzed and propose the new one where the same formula was used in the proposed algorithm and was developed based on the probability model. Several flowcharts were designed to show the flow of information.

3.2.1 Scientific research methods

During the course of this research, several scientific methods were used to conduct this research. The existing schemes were found in qualitative research methods and design, analysis, and simulation an experimental approach was used. It began with random ideas and slowly we come up with the objectives, statement of the problem and proposed a solution. In the existing schemes, this helped to come up with knowledge about the research ideas. In this case, the existing schemes seized the opportunity to discover the existing knowledge and to propose the solution to the stated problem.

To be specific, a quantitative approach was taken to evaluate how other existing schemes work, their weaknesses in order to find what should be done to improve its performance. Several ideas were developed and considered like the idea of using the grid to allow low signal strength devices to communicate with other devices.

3.2.2 Experimental approach

The experiments were done in different cases such as 3G and 4G by considering each case using Cellular Grid and not using Cellular Grid using different parameters. The algorithm used to generate outputs is also demonstrated. This research has also defined the situations when a mobile grid will be applicable.

3.3 System Development Methodology

3.3.1 Prototyping Model

For the research methodology of this project, the chosen software development life cycle was Prototyping model that a systems development method (SDM) in which a prototype (an early approximation of a final system or product) is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved from which the complete system or product can now be developed.

3.3.2 Steps of Prototyping Model

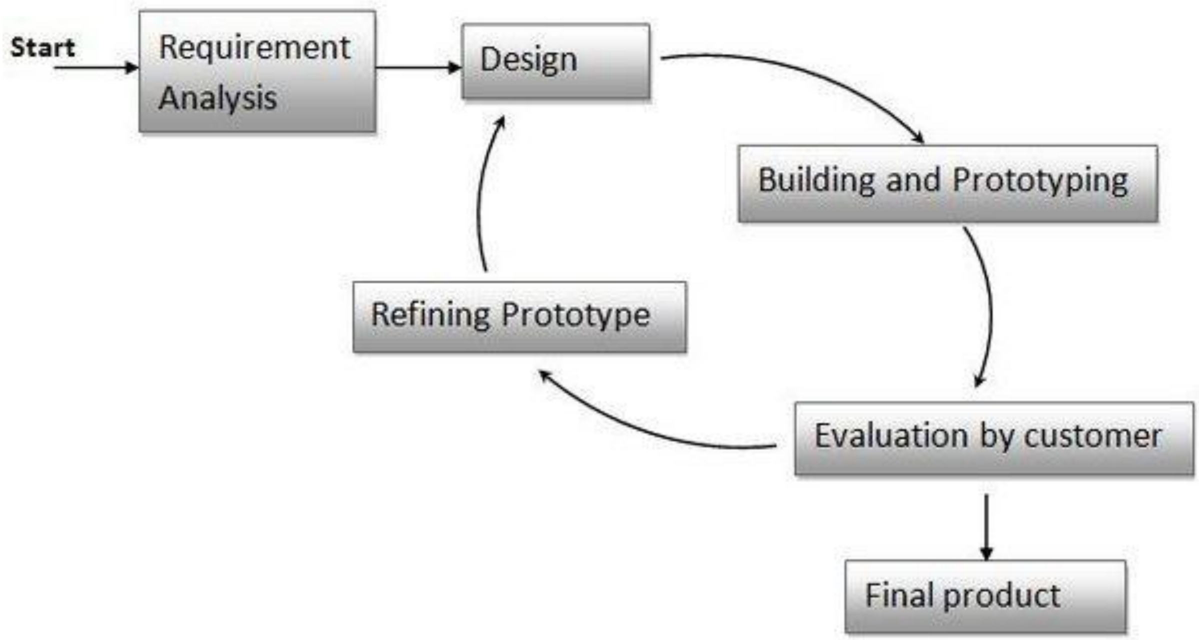

Figure 5: Steps of used SDM

3.4Requirements analysis

For this thesis, activities began on with requirements analysis on how devices can communicate with each other using mobile cellular Grid. The details of the new system were defined in details and the users were interviewed in order to know the requirements of the system.

1. **Quick design:** After knowing the requirements that will help the design of an adaptive algorithm that will support Resource allocation in cellular Grid, a quick design for the system was created that is shown in chapter 4, It is not a detailed design and

includes only the important aspects of the system, that gives an idea of the system to the user. This quick design helped in developing the prototype means algorithms.

2. **Building and prototyping:** All the Information gathered from quick design phase has been modified to form the first prototype (resource efficient algorithm for D2D communication and simulation results) which represented the working model of the required system. It is in this phase where also the simulation tools stated to be identified and are used.

3. **User evaluation:** Next step was to present the first prototype for the user evaluation of the prototype to recognize its strengths and weaknesses such as what is to be added or removed. Comments and suggestions were collected as more simulations were being made.

4. **Refining prototype:** After evaluating the prototype and if the client is not satisfied, the current prototype was refined according to the requirements or comments or suggestions from the first presentation. A new prototype has been developed with the additional information provided by the user. The new prototype has been evaluated just like the previous prototype. This process continued until all the requirements specified by the user are met. A final system has been developed on the basis of the final prototype when the user was satisfied with the developed prototype.

5. **Last in the used SDM is Engineer product:** Once the requirements were completely met, the user has accepted the final prototype hence, final simulation results and algorithms were delivered to the end users.

3.5 Data Collection Methods

The following methods have been used during data collection: Interview and Documentation as my research methods. Through this, raw data on the new system ware collected**,** where information on the current system was obtained.

3.5.1 Documentation

In this method, the researcher went to the library to search for books that contain the subject related to this topic. Not only the books used but also some electronic books (from the internet), the projects that were done, class notes, different journals, and papers.

3.5.2 Interview

In this method, the researcher went on the ground asking different users to different users about the existing issue. The researcher recorded different views from users.

3.5.3 Observation

In this method, the researchers went on the ground and saw what was happening. One observation was that two people were in the same location that experiences the problem of low signal strength. Between the two, one was able to communicate but others were not able to communicate. Another observation was that in a place where there are a big number of people, experiences low qualities of services whereby some devices can communicate but others cannot.

The researcher also observed that if we take two mobile devices, it will be found that maybe they have the number of network status bars but differ in signal strength.

3.6 Proposed system requirements

3.6.1Functional Requirements

Adaptive Algorithm for resources allocation in cellular Grid possesses the following functional requirements such as:

1. Searching devices in the grid.
2. Establish a connection to the devices in the grid.
3. Sending Data to the next device.
4. Calculating the device's signal strength.
5. Choosing the right technology to connect through the grid.

3.6.2 Non-Functional Requirements

The following are also the nun-functional requirements of the developed Adaptive Algorithm for resources allocation in cellular Grid.

- Displaying grid connection status.
- Notification messages for a successful message deliverance.
- Buttons that directs the user what to do.
- Usability: This system should be used by any user, should not be a computer literate.
- Recoverability: When there something that is not working well this project, it can be easily recovered.
- Compatibility: This application should be able to run in all 3G and above mobile devices

3.6.3 Hardware and Software Requirements

Hardware requirement: The following are minimum hardware requirements for running Adaptive Algorithm for Resource Allocation in Cellular Grid:

1. Computer with 4 GB RAM
2. 500 GB free space of Hard Disk
3. Core i3

Software requirement:

1. Windows 7 Operating System
2. Java 1.8.
3. MatLab version 12

3.7 Design process

The design of the new proposed Adaptive Algorithm for resources allocation in cellular Grid was an important phase after gathering the requirements and conducting the feasibility study. The design was specifically done after analyzing the existing schemes and then proposes a new scheme that was intended to archive our objectives. As it was done in chapter 5, this scheme performed better than the existing scheme hence our goal was achieved.

3.8 Conclusion of Chapter Three

This chapter of methodology covers the approach to carry out the research, methods of data collection, a summary of data and its analysis and the processes to be undertaken when designing and simulating of the systems. By this stated methodology, it's believed that the problem encountered in Adaptive Algorithm for resources allocation in cellular Grid is going to be addressed. The proposed system analysis and design is going to be explained in the next chapter.

Chapter 4: SYSTEM ANALYSIS AND DESIGN

4.1 Introduction

The concept of this project is to design an adaptive algorithm that will ensure the communication between devices even though they do not receive sufficient power from the base station.

There are different scenarios that were considered. The first scenario is to analyze the probability of how data can be transferred using 3G and 4G technologies. The second scenario is to analyze the probability of how that will be transferred in both technologies using Grid. In the second scenario where we use the grid, the probability is only measured by assuming that the device was not able to communicate without assistance. This infers that only devices with low receiver sensitivity are considered.

4.2 System Model

As described that our system has different scenarios, in the first scenario, there are a numerous number of mobile devices and a base station. Each device receives specific power allocated to it. It was found that those different devices were receiving different signals although they were in the same place. In this scenario, 3G and 4G were considered.

In 3G, the probability of transmitting data varies with the receivers signal strength. So, the receivers with high receiver sensitivity have a high probability to transmit data.

In the figure below, is showing different devices, D1, D2, D3, and D4. It shows that if one of the devices wants to communicate with D4, will have to pass through the base station.

So, if the base station fails to allocate enough resources to enable the devices to communicate, will result in communication failure.

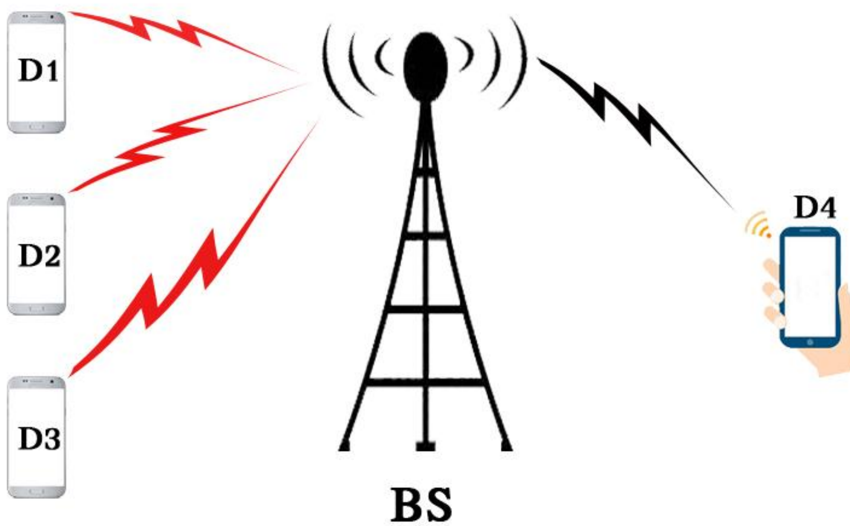

Figure 6: A scenario where there is no Grid

The probability for transmitting data according to a certain signal strength range is considered according to the table below.

Table 8: Signal strength in 3 G

Signal Strength (dbm) between	-50 and -75	-76 and -90	-91 and -100	-101 and -109	-110 and -113
Probability (%)	80-100	60-80	40-60	20-40	0

In 3G, the maximum signal power is -50, and that's when we have a maximum probability to transmit data. The probability to transmit data in the range -50 and -75 is the highest one compared to other ranges.

In 4G LTE, there are different values if compared with 3G.

The probability for transmitting data according to a certain signal strength range is considered according to the table below.

Table 9: Signal Strength versus Probability in 4G

Signal Strength (dbm) between	-70 and -90	-91 and -105	-113 and -125	-126 and -136	-136 and -140
Probability (%)	90-100	80-100	60-80	40-60	0

According to the table above, the maximum signal strength considered was -70dBm. So, in the range of -70dBm to-90dBm, is where it has the highest probability compared to other ranges.

By using communication without the grid shows the existing system. If the signal is not that enough to transmit data, it means that the information will never be transmitted.

In the second scenario, we consider using the mobile cellular. Through this, the data that were not transmitted in scenario 1 will be able to be transmitted.

From the diagram below, there are different devices D1 up to D5. If we assume that D1 wants to communicate with D5 and becomes not possible, there will be a chance to connect to one of the devices D2 to D4 using any wireless technology available and that device will transmit the data to the specified destination.

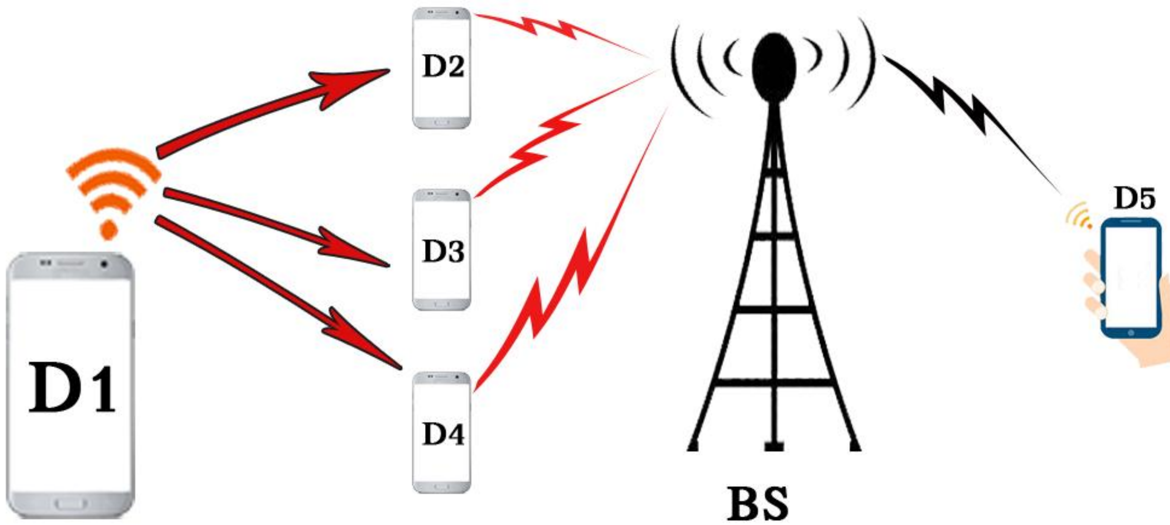

Figure 7: A scenario where there is a grid

This includes also other overlay communication technologies like Bluetooth and Wi-Fi. These technologies help to transmit data between devices.

If the device has failed to transmit data via base station due to limited signal power, it will use one of these technologies to get connected to another device in the same grid. That device will be able to play the role that was to be played by the device 1.

The table below shows the probability of how data can be transmitted in Wi-Fi.

Signal Strength (dbm) between	-30 and -67	-68 and -69	-70 and -79	-80 and -90	-90 and below
Probability (%)	90-100	80-100	60-80	20-60	0

The table below shows the probability of how data can be transmitted in Bluetooth.

Signal Strength (dbm) between	-50 and -60	-60 and -70	-70 and -79	-80 and -90	-90 and below
Probability (%)	80-100	60-80	40-60	20-60	0

In developing an algorithm, there were variations in probability whereby one device will connect to another device.

So, this infers that there will be a probability of how data will be transferred from the device to another and that probability of how the second device will transmit data to the destination through the base station.

There comes conditional probability. So, in this case, the probability to transmit data will be

P(T)=P(A)*P(B)………………….Equation 2

Where

P(T) is the probability of transmitting data to the destination.

P(A) is the probability to transmit data from the device of insufficient signal strength to Another device in Grid.

P (B) is the probability to transmit data to the base station.

The range of signal strength of the first device to be considered is those where we have the probability of zero.

4.3 Algorithm

Step 1: The device initiates the communication

Define{

S_i as signal strength;

t1 as 3G Technology;

t2 as 4G LTE technology;

w1 as the possibility to communicate via Wi-Fi;

b1 as the possibility to communicate via Bluetooth;

}

Step 2: Device checks the technology being used.

Step 3: Device checks its signal strength

Switch (technology){

Case t1:

If (Si> …..){

Send data to the Base Station;

} else {

Go to step 4.

End the activity

}

Break;

Case t2:

If (Si> …..){

Make direct communication.

End the activity

} else {

Go to step 4

}

Break;

}

Step 4: Is there a mobile grid that device can join?

If(Yes){

Go to Step 5

} else{

Print 'sending data failed!!!'

Go to Step 10

}

Step 5: Choose the mode of communication to deliver data

If (w1||b1) {

Go to step 6

}

Step 6: device gets the list of all devices in grid.

Step 7: Devices selects the devices (d2) with the highest signal strength

Step 8: Device (D1) sends data to the selected device

Step 9: Device (d2) shares information to the base station.

Step 10: End

Activity Diagram

The activity diagram below shows how activities flow during the communication of the device in the grid

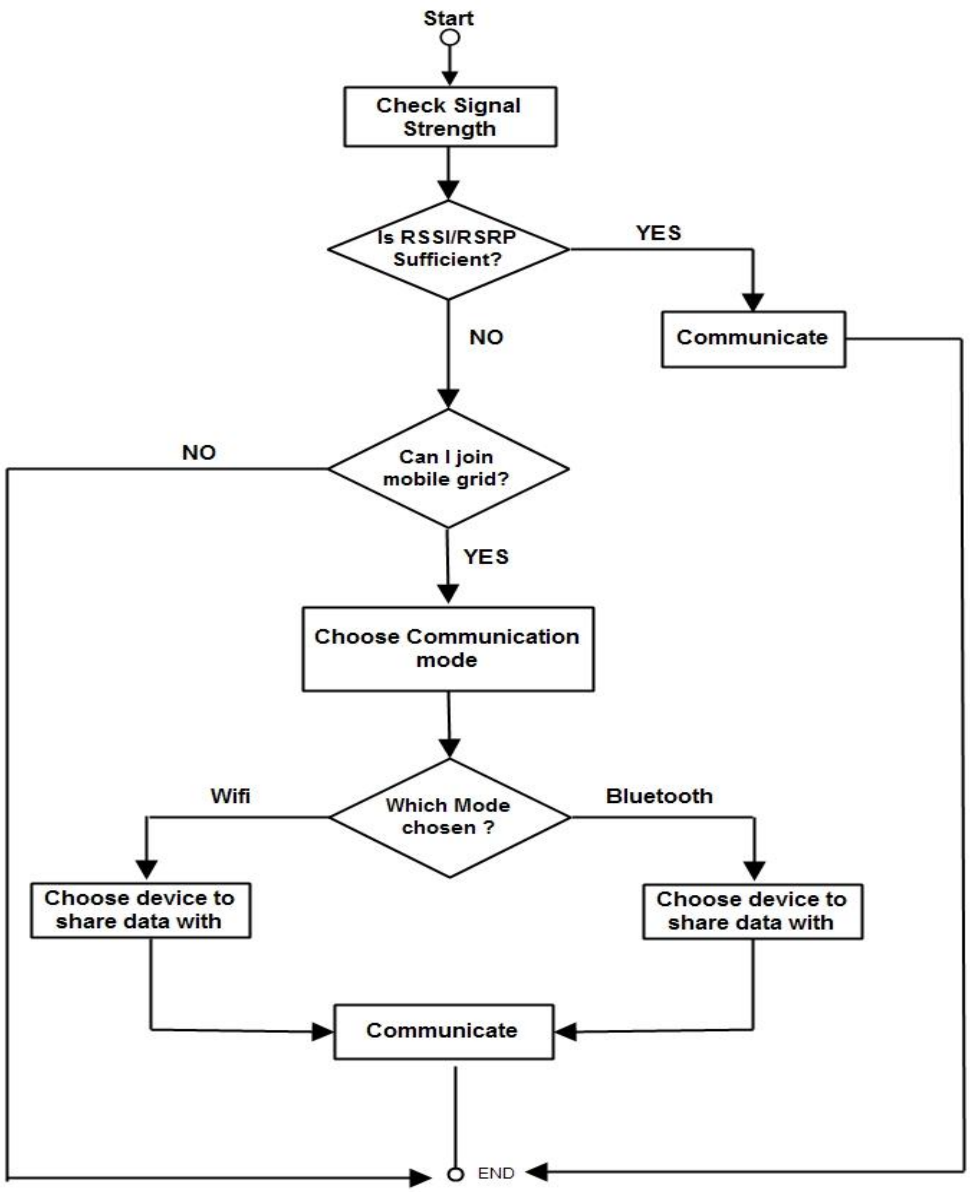

Figure 8: Activity Diagram

4.4 Multiple Devices initiating Communication at the same time.

From the figure below, it is representing the way communication will be done when we have more than one device that wants to communicate using the grid.

In Region 1, there are big numbers of devices that need to communicate with other devices in Region 2. Devices in Region 1 are being served by Base Station T1, and Devices in Region 2 are being served by Base Station T2. Both Region 1 and Region 2 have grid Systems names Grid System 1 and Grid System 2 respectively. TN is any base station that may be used to in communication between device from Region 1 and device from Region 2.

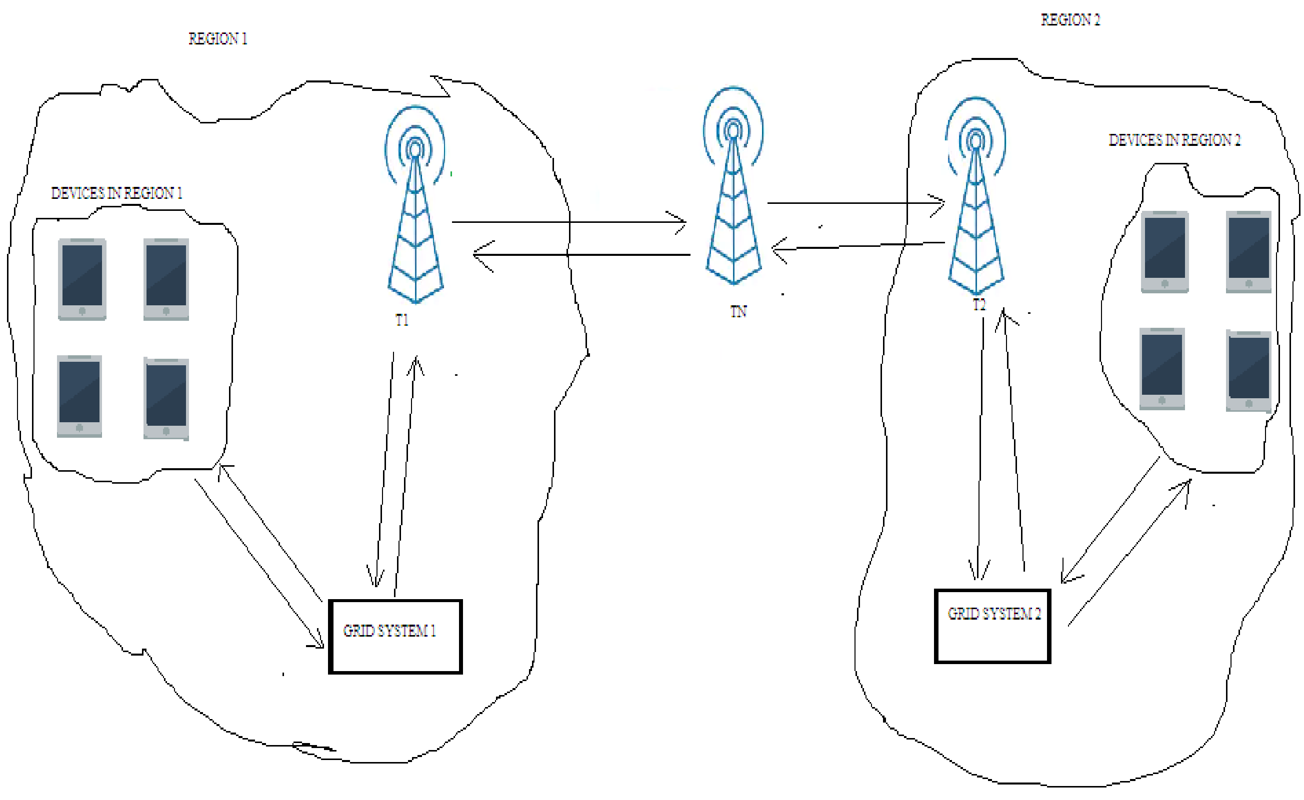

Figure 9: Cellular Grid with multiple users

The Figure below, describes in details the devices in Region 1, Devices with N are nodes of the Grid. Those devices without N are not registered in the Grid System.

Dx is the device which does not have network coverage.

Mi is message being transferred.

Dx has the possibility to communicate using D1 or Dn depending on the criteria that they have much signal strength using either Bluetooth or Wi-Fi

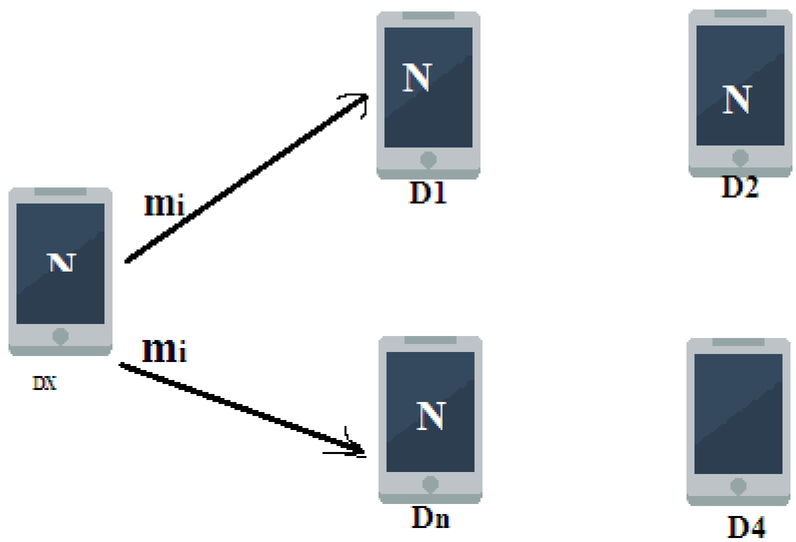

Figure 10: Devices in Grid Region 1

The figure below describes in details the grid system.

It has the following

1. **Scheduler:**
   It is used to schedule how messages should arrive to the Job Manager
2. **Job Manager:** Manages all jobs that enter into the grid system.
3. **Time Keeper (Tk):** Keeps the time when every message arrives into the Grid System.

4. **Gate Keeper:** Manages all security concern of the grid. It verifies whether the message is coming from the valid user. It authorizes the users to use the Grid System.
5. **Resource Manager:** This is used to manage how the resources are being utilized in the system.
6. **Queue:** This is used to handle all messages in the Queue and manages load balancing and optimization.
7. **Grid Manager:** This is used to manage all activities in the Grid System.
8. **Raid0**: This is used to keep data such that in case one database server fails, it automatically uses another one. That is to say, it helps to avail data in the grid system.

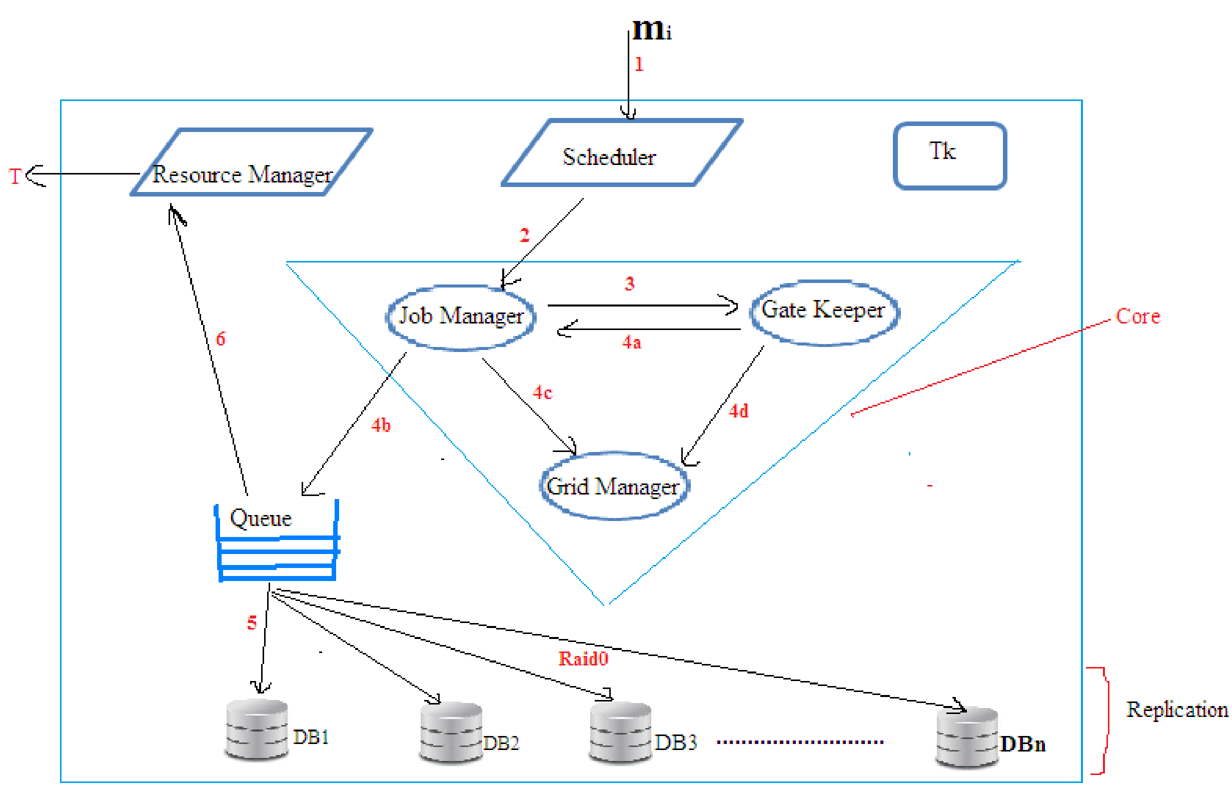

Figure 11: Grid System

4.4.1 RESOURCE MAMAGER

The figure below describes in details how grid manager works

As described from the diagram of the grid system, it helps to manage how the resources are being utilized.

It has the table

TN is Transaction number of the message, Dx is the device id (IMEI) of the user that need to communicate having the problem of network coverage. DH (Helper) is the id of the device that will help to transmit information on behalf of Dx.

It keeps records of messages that were transferred, transaction fee, and the status shows whether the message was transferred or not. Time shows the timestamp when the message was transferred, Refund status shows whether the message initiator (Dx) has refunded the fee to the helper (DH).

The rows in yellow color are messages which were delivered but not yet refunded.

The rows in red color show the message that was completed failed to be delivered.

Grid manager also checks whether the maximum number of message the user have to transfer has exceeded.

In case the Dx has handed over to another base station, the Resource manager sends the message to refund in case he has not refunded.

Resource Manager

TN	Dx (Sender id)	DH (Helper Id)	Message	Fee	Status	Time	Refund Status
1	IMEIDX1	IMEIDH1	Massage Content 1	Cost 1	Delivered	t1	1
2	IMEIDX2	IMEIDH2	Massage Content 2	Cost 2	Delivered	t2	1
3	IMEIDX3	IMEIDH3	Massage Content 3	Cost 3	Delivered	t3	1
4	IMEIDX4	IMEIDH4	Massage Content 4	Cost 4	Delivered	t4	1
5	IMEIDX5	IMEIDH5	Massage Content 5	Cost 5	Delivered	t5	1
6	IMEIDX6	IMEIDH6	Massage Content 6	Cost 6	Delivered	t6	1
7	IMEIDX7	IMEIDH7	Massage Content 7	Cost 7	Delivered	t7	0
8	IMEIDX8	IMEIDH8	Massage Content 8	Cost 8	Delivered	t8	1
9	IMEIDX9	IMEIDH9	Massage Content 9	Cost 9	Delivered	t9	1
10	IMEIDX10	IMEIDH10	Massage Content 10	Cost 10	Delivered	t10	0
11	IMEIDX11	IMEIDH11	Massage Content 11	Cost 11	Failed	t11	1
12	IMEIDX12	IMEIDH12	Massage Content 12	Cost 12	Delivered	t12	1
n	IMEIDXn	IMEDHn	Massage Content n	Cost n	Delivered	tn	1

Not Refunded

Message not delivered

Figure 12: Resource Manager

4.4.2 Queuing Model

Queuing model as per Kendall [1953], General format is A/B/C/N/K

A represents inter-arrival time distribution

B-Represents service time distribution

C-Represents number of parallel servers

N-Represents System Capacity

K-Represents Size of Calling Population

So in our case

A, B are exponential or Markov Distribution=M

C is 1 as 1 message is passing at a time.

So the queue notation is N,K is infinite.

M/M/1/∞/∞

Also, As Pn = at the steady state probability of having n customers in the system

λ is the arrival rate

μ is the service rate of one server

ρ is the server utilization

Sn is service time of nth customer

LQ (t) is the number of customers in the queue at time t

w is the Long run average time spent in the system by the customer

WQ is Long-run average time spent in queue per customers

So mean is the number of customers per service=1/ **μ**

So mathematically expectation E(x) of a message from the client on the server is

$$E(x)= \sum_{i=1}^{\infty} \mathrm{Xi} * \mathrm{Pi}$$

Where x is the number of customers sending message pi is its probability of arrival

I is the counter to maximum () number of customers expected as they are exponential or Markov according to model M/M/1/∞/∞

Or in an absolutely continuous case

$E[X]=\int_R x.f(x)dx$

Where f(x) is the density of random variable x.

R denotes real number

$Var(x)=E(x^2)-(E[x])^2$

While variance is defined by 0^2, Var(x) is the measure of spread variation of the possible values of x around the mean and standard deviation denoted by O or $\sqrt{var(x)}$

M/M/1 Queue

Suppose that its service time in the queue are exponentially distributed having a mean of $\mathbf{1}/\mu$ then variance is

$$O^2=\frac{1}{\mu^2}$$

The mean and the standard deviation are the same so $\rho = \boldsymbol{\lambda}/\mu$

So steady state parameters are

$$L \Rightarrow \boldsymbol{\lambda}/(\mu - \boldsymbol{\lambda}) = \rho/1-\rho$$

$$W \Rightarrow \mathbf{1}/(\mu - \boldsymbol{\lambda}) = 1/\mu(1-\rho)$$

$$WQ \Rightarrow \boldsymbol{\lambda}/\mu(\mu - \boldsymbol{\lambda}) = p/\mu(1-\rho)$$

$$LQ \Rightarrow \boldsymbol{\lambda}^2/\mu(\mu - \boldsymbol{\lambda}) = \rho^2/\mu(1-\rho)$$

$$P_n \Rightarrow (1-\frac{\boldsymbol{\lambda}}{\mu})(\frac{\boldsymbol{\lambda}}{\mu})^n=(1-\rho)\,\rho^n$$

Chapter 5: RESULTS AND DISCUSSION.

5.1 Probability Results for transmitting data without the grid in 3G and 4G

a. The probability for transmitting data in 3G

According to the graphs below X-axis represents the signal strength of the device from -140dBm and less and Y-axis represents the probability of the device to transmit data at certain signal strength.

From the graph below, from -140dBm and below, there is no probability for data to be sent. But the probability increases as the RSSI value increase. So this shows the devices that will receive lower values of RSSI, will not be able to communicate.

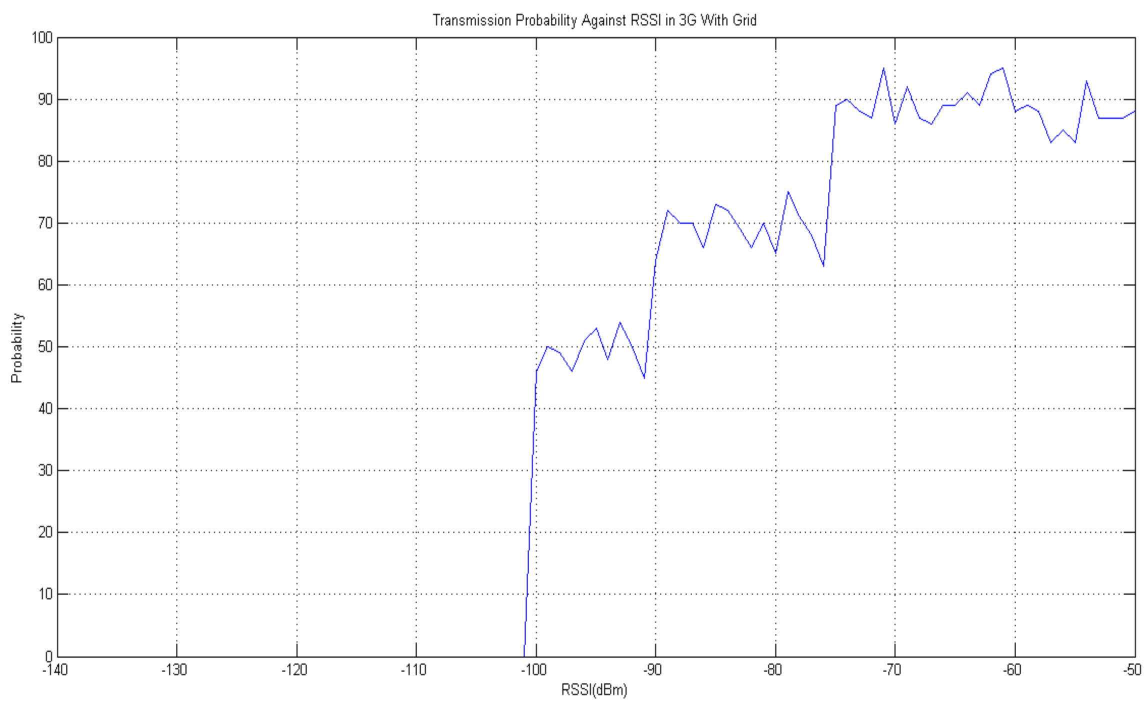

Figure 13: Transmission Probability against RSSI in 3G with Grid

b. The probability for transmitting data in 4G LTE

According to the graph below, in 4G LTE, the RSRP has a wide range where it's possible for it to transmit information. But from the RSRP value of -

136dBm, communication cannot be possible. From the graph, it shows the probability as zero.

And probability keeps increasing as RSRP value increases.

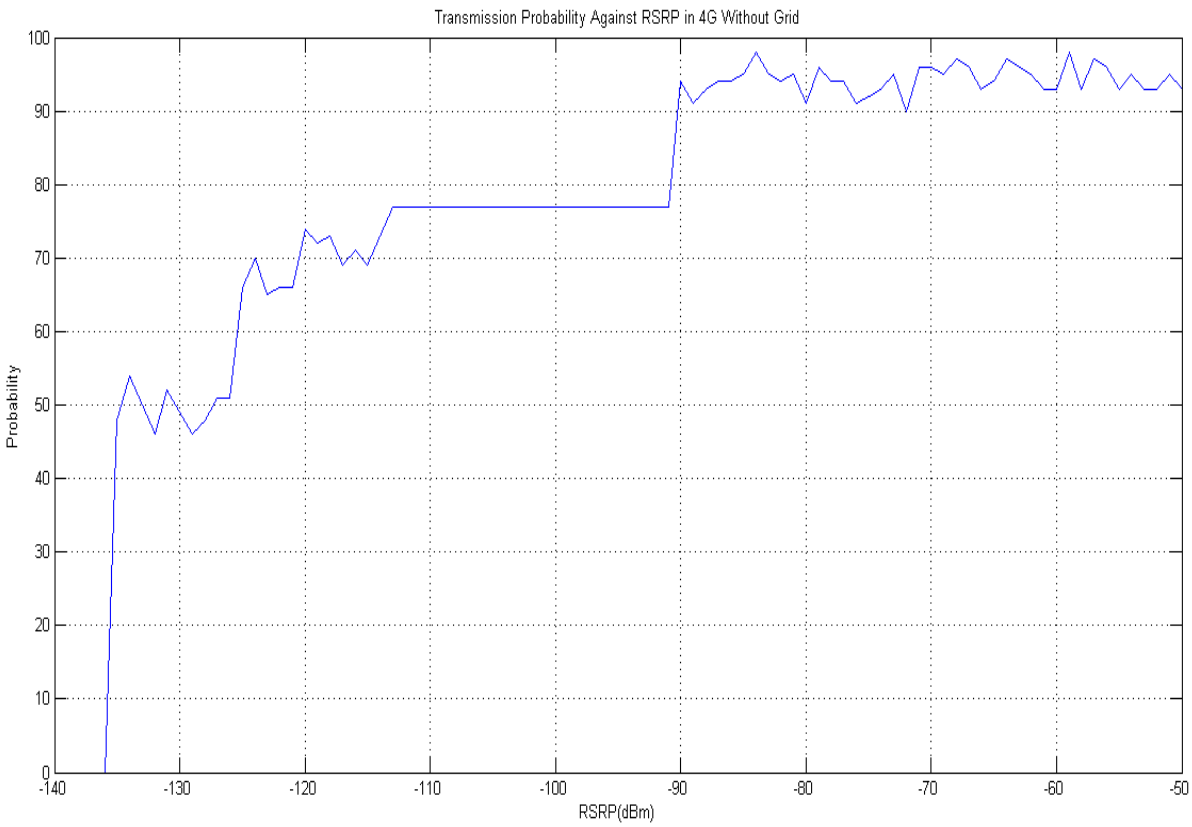

Figure 14: Transmission Probability against RSRP in 4G without Grid

5.2 Probability Results for transmitting data in Grid for both 3G and 4G

a. The probability for transmitting data in 3G with Cellular Grid

In the figure below, it shows the scenario whereby the device (D1) in the ranges where it's not possible to communicate in both 3G and 4G LTE, has got connected with the device (D2) that is using 3G technology.

So the x-axis represents the RSSP values of the device (D2)

Y-axis represents the probability for D1 to transmit data. The legend shows the probabilities used to connect D1(3G or 4G LTE) to D2 using (3G).

The probability increases as

1. RSSI for D2 increases.
2. The probability for connecting from D1 to D2 increases.

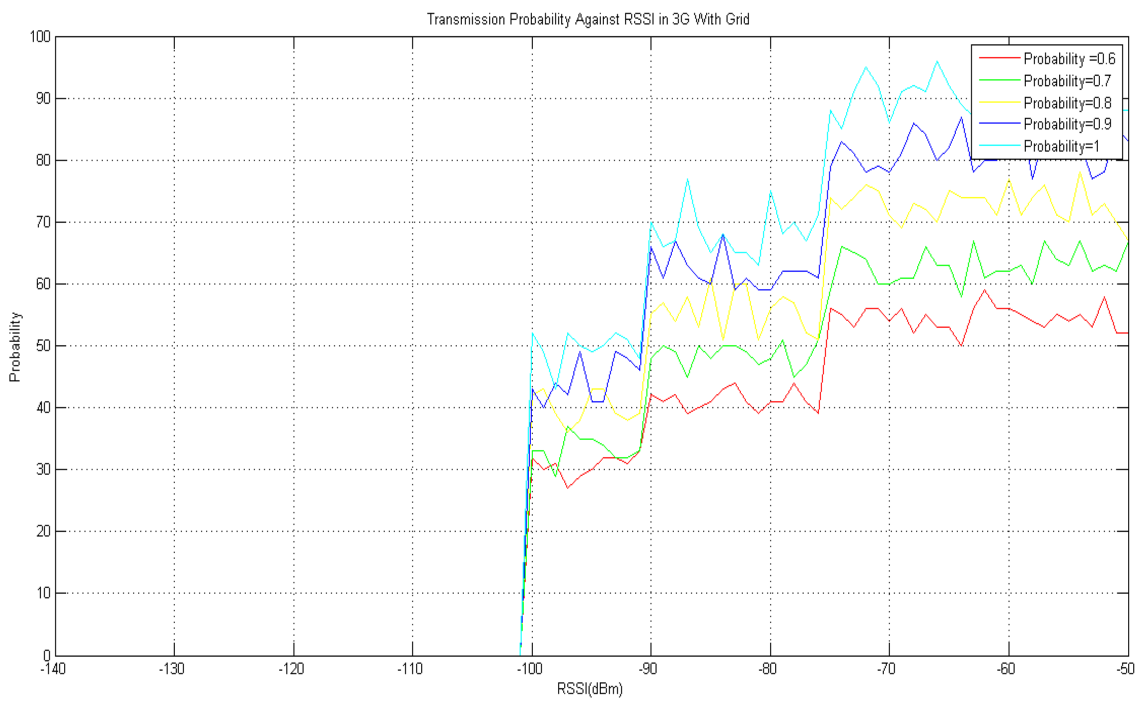

Figure 15: Transmission Probability against RSSI in 3G with Grid

b. The probability for transmitting data in 4G with Cellular Grid.

In the figure below, it shows the scenario whereby the device (D1) in the ranges where it's not possible to communicate in both 3G and 4G LTE, has got connected with the device (D2) that is using 4G LTE technology.

So the x-axis represents the RSRP values of the device (D2)

Y-axis represents the probability for D1 to transmit data. The legend shows the probabilities used to connect D1(3G or 4G LTE) to D2 using (4G).

The probability increases as

3. RSRP for D2 increases.
4. The probability for connecting from D1 to D2 increases.

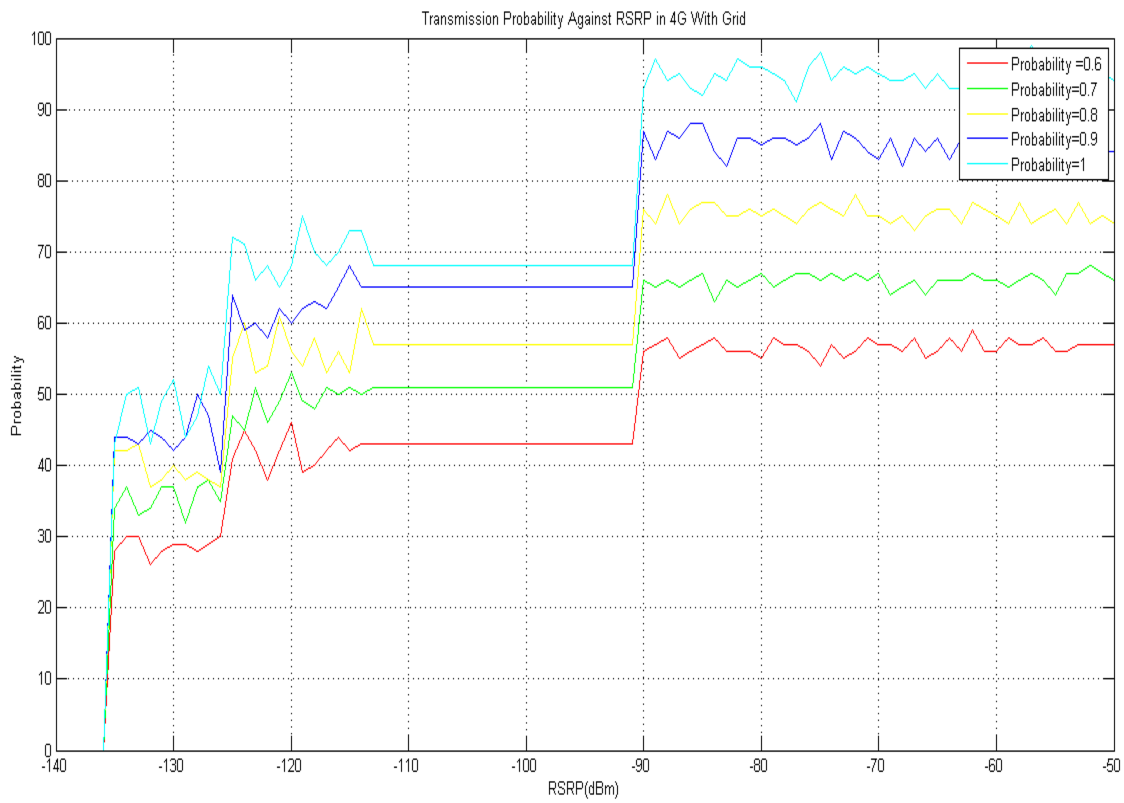

Figure 16: Transmission Probability against RSRP in 4G with Grid

5.3 Conclusion Chapter Five

Under this chapter, the detailed information on the simulated results is given. It shows that by using the grid, the probability of sending information increases. And it shows that the option of using the grid is appropriate to be used in cases where we have very low receivers signal because as the number of paths used to deliver information increases, decreases the chance for the information to be delivered. The probability also increases with the technology used, as in 4G LTE; the probability is higher than that of 3G. In Brief, the proposed idea is better than the existing one.

Chapter 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion of Chapter Six

In this thesis, Adaptive Algorithm for Resource allocation in cellular Grid was to find the way of how devices in the cellular system can be given a chance to communicate with other devices using the cellular tower. The proposed algorithm we referred to the probability theories to help in demonstrating how it is valid. The proposed system models show that the probability to initiate communication in areas with very low signal strengths increases when Mobile Cellular Grid is introduced in the area. This technique has value only in the area with low signal coverage.

6.2 Recommendation

As the number of mobile equipment increasing at a tremendous rate, this possibility can be implemented in all devices by manufacturers, and telecom companies, to increase the number of users who can be served by the base station.

We also recommend that researchers to work on security issues that can be brought by this technology.

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