CHAPTER ONE

INTRODUTION

1.1 Preface

Human-to-Human (H2H) communication has been the main driving force for the development of wireless and wired communications technologies. For instance, the Global System for Mobile Communications (GSM), which is presently the most widely deployed cellular technology in the world, was engineered for transmission of voice. For the past few years, we have witnessed an increasing number of networked machines, changing the conventional perception of human-centric communication towards networks that are independent of human interaction, which is known as Machine-to-Machine (M2M) communications [1].

M2M is a form of data communication between entities that do not necessarily need human interaction. The population of M2M machines is expected to be several orders of magnitude greater than that of the H2H population. Potential and emerging use cases of M2M communications are smart power grid, healthcare monitoring, remote security surveillance, tracking and tracing, intelligent transportation system, and many more.

Beyond Fourth-Generation (4G) wireless technologies, in particular, LTE-Advanced, is envisaged to play a central role in interconnecting machines. M2M communications desire a very different set of requirements than H2H communications because they are mainly characterized by a high device density in a cell, small amounts of payload, machine-originated communications and low traffic volumes per machine [2].The Third Generation Partnership Project (3GPP) has already started working on evolving LTE-Advanced to accommodate the characteristics of M2M communications. To date, it has specified a reference architectural model and identified a set of requirements for M2M communications over LTE-Advanced [2].

1.2 Problem Statement

Large number of M2M devices try to access the network simultaneously leads to low RA success rate, high network congestion in the PRACH, unexpected delays, packet loss, waste of radio resources, extra energy consumption, and even service interruption. The channel can be further overloaded when the MTC devices repeat their access attempts after collisions.

1.3 Proposed Solution

In this thesis the propose solution of overload control of MTC in LTE-A network is p-method. In p-method Each MTC device is assigned a predefined value p and when attempts to start the random access procedure, it will randomly generate a random number between 0 and 1 If the generated number is smaller than the value of device P-persistent, then it can start the RACH procedure and transmit RACH preamble. Otherwise, the device needs to back off and waits until another interval to try again.

1.4 Aim &Objectives

This thesis is aims to resolve the radio access network (RAN) overload problem from MTC in LTE-A network and the objectives are:

- To evaluate the performance between different overload control methods.
- To design and simulate an algorithm for overloaded MTC problem.

1.5 Methodology

In this thesis will review the random access procedure in LTE-A network and then review evaluate the existing methods of so as to reach the proposed improved method. The modeling of proposed method includes; physical and mathematical models the mathematical model results use as the base of the MATLAB environment as a simulation tool and the results provide in graphical forms.

1.6 Thesis outline

This thesis will contain of five chapters:

Chapter One:

Talk about introduction which includes preface, problem statement, Proposed Solution, Aim &Objectives and methodology. Finally, the outline of the thesis is introduced**.**

Chapter two:

Overview of LTE-Advance network, M2Mcommunications and the literature review will be discussed.

Chapter three:

Discusses the methodology and algorithms used in implementing a simulation of P scheme. The proposed algorithm; modeling and simulation by using MATLAB.

Chapter four:

Represent the basic chapter that takes the overall practical in individual steps, so MATLAB will be used to shows the simulation results and its analysis presents the results and discussion.

Chapter five:

The main ideas presented in the thesis are collected and summarized in this chapter and recommendation for future work. Provides the conclusion, which summarizes the outcome of the thesis. It also provides some recommendations for future work.

2.1 Overview of Machine to Machine communications

2.1.1 Machine-to-Machine Communication Definition

M2M is a term used to describe the technologies enabling computers, embedded processors, smart sensors, actuators and mobile devices to communicate with a remote server or device in order to monitor some physical phenomena, to take measurements and to make decisions without or with limited human intervention [3]. M2M are also called Machine Type Communication name given first by the 3GPP.

2.1.2 Machine-to-Machine Architecture

A generic and simple architecture of a M2M application is illustrated in Figure 2.1. The architecture is composed of mainly three parts, M2M Device Domain containing the M2M devices, Network Domain which relays the messages to servers located in the Application Domain, giving data to business applications the devices are deployed to [4].

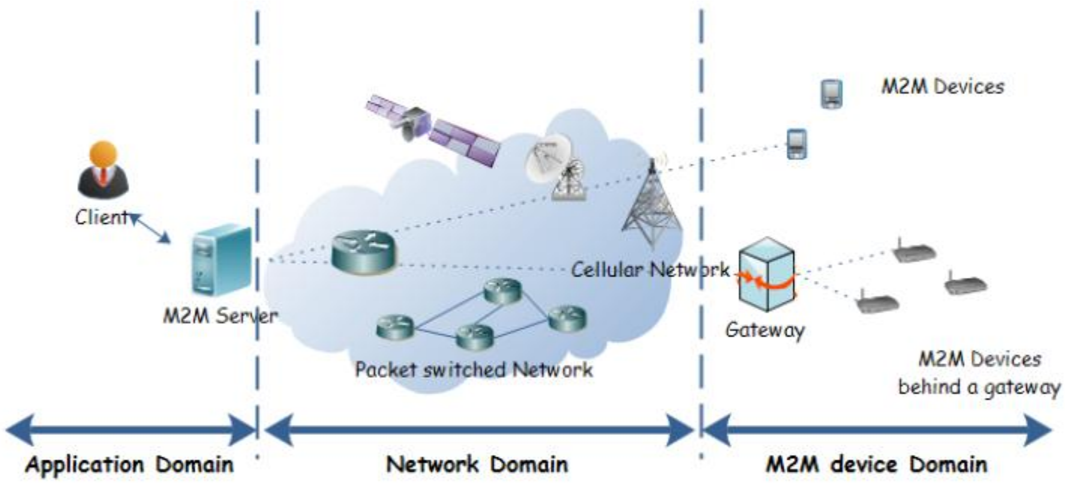


Figure 2.1: General Architecture of a M2M Application [4]

2.2 MTC Device Interworking Architecture

To enable M2M communications, two new network elements the MTCD and MTC gateway (MTCG), appear in LTE-Advanced cellular networks. A MTCD is a user equipment (UE) designed for machine-type communications, which communicates through a cellular network with an MTC server and/or other MTCDs. The network requires an MTCG gateway to facilitate communications among a great many MTCDs and to provide a connection to a backhaul that reaches the Internet. The MTCG will be able to intelligently manage power consumptions of the network, and provide an efficient path for communications between MTCDs [5]. There are different M2M communications methods:

2.2.1 Direct Transmission

Direct transmission between MTCD and eNB illustrate in figure 2.2 Similar to a normal UE, an MTCD has the ability to establish a direct link with its donor eNB. Therefore, there exist strong similarities between the eNB to UE and eNB to MTCD links. On the other hand, MTCDs normally appear in large quantities in the M2M networks and thus exhibit the service feature of group-based communications. In certain time instants, intense competition for radio resources may occur. For instance, one or more MTC groups send communication requests to an eNB simultaneously, which may cause network congestion, resulting in performance degradation for both M2M and H2H services [5].

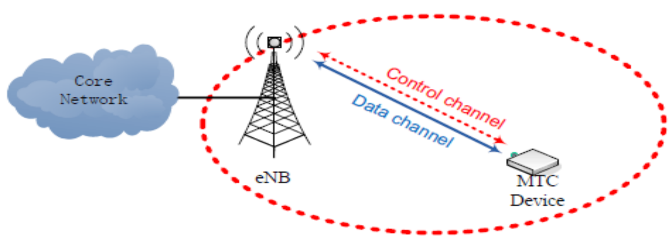


Figure 2.2: Direct transmission [5]

2.2.2 Multi-hop transmission

Multi-hop transmission as shown in figure 2.3 with the aid of an MTC gateway in order to mitigate or eliminate negative effects of M2M communications on H2H communications, an MTC gateway can be deployed in cellular networks, where all MTCDs are connected to the eNB indirectly through the relaying of the MTCG. In other words, the end-to-end communication between the eNB and MTCDs may occur via more than one hop, e.g., the eNB-to-MTCG and MTCG-to-MTCD links. Besides, MTCDs may establish peer-to-peer communications with each other with the aid of the MTCG or eNB. The eNB-to-MTCG wireless link is based on 3G LTE specifications, whereas the MTCG-to-MTCD and MTCD-to-MTCD communications can either be via 3G LTE specifications or other wireless communications protocols such as IEEE 802.15.x.The resulting multi-level network management problem can be handled with the aid of the MTCG. Each MTCD is controlled by its donor MTCG, which is managed by the eNB. The introduction of the MTCG makes the network topology more complex, leading to challenges as well as opportunities. MTCDs are usually grouped for control, management or charging facilities. The MTCDs within the same group can be in the same area and/or possess the same MTC features. Each MTCG can serve one or more groups [5].

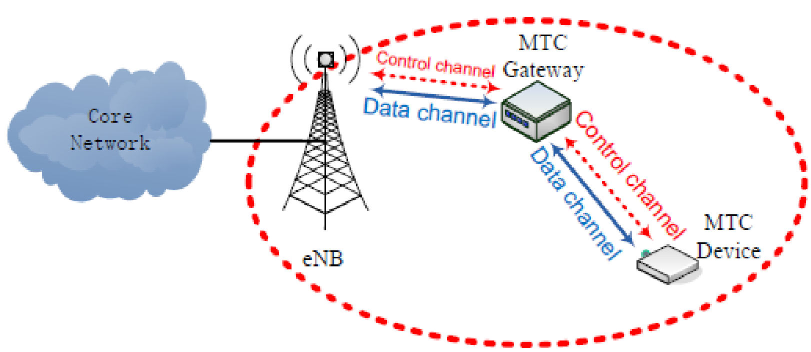


Figure 2.3: Multi-hop Transmission [5]

2.2.3 Peer to Peer Transmission

Is the transmission between MTCDs as illustrate in figure 2.4, MTCD may communicate locally with other entities, which provide the MTCD with raw data for processing and communicating to the MTC server and/or other MTCDs. Compared to other local connectivity solutions, such as IEEE 802.11a or IEEE 802.15.x, peer-to-peer transmission between MTCDs supported by a cellular network offers appealing advantages [5].

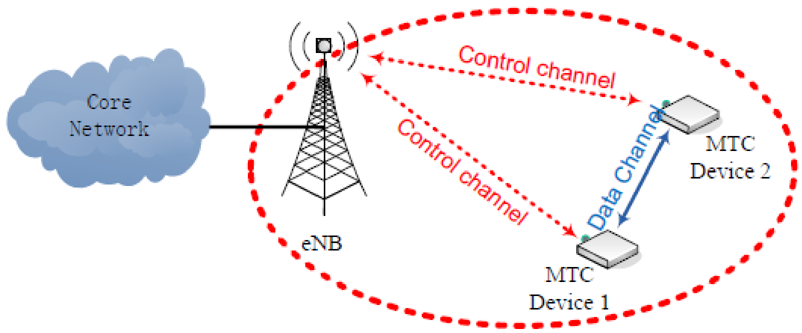


Figure 2.4: Peer –to-Peer Transmission [5]

The cellular network can broadcast local services available within a much wider coverage area. Thus, for automated service discovery, the MTCDs do not have to constantly scan for available local access points (APs) as in case of IEEE 802.11a. This is advantageous since leading to significantly reduced power consumption for scanning. With the knowledge of encryption keys at both MTCDs involved in peer-to-peer communications, a secure connection can be established without manual pairing of devices or entering encryption keys. Moreover, through the control of the eNB via peer-to-peer communications, the interference to other cellular receivers can be limited or mitigated [5].

In order to support M2M communications, the RAN architecture needs to be enhanced to enable coexisting communications between MTCD related and H2H communications in LTE-Advanced cellular networks. A part from direct transmission, MTCDs can also establish communications with their donor eNBs through multi-hop transmission. To avoid self interference and reduce implementation complexity, half duplex MTCGs are preferred for deployment in the networks [5]. Furthermore, when local services are available between nearby MTCDs, peer-to-peer communications provided by cellular networks may appear to be a local connectivity solution.

2.3 M2M applications

M2M communication can be used to create a rich set of applications like Smart Grid, Healthcare and Intelligent Transportation System [2].

2.3.1 Smart Grid

Smart grid is the next-generation electrical power system, which embraces M2M communications in order to control and optimize power generation, distribution and consumption. Smart machines also known as smart meters, gather utility usage information from electrical appliances and send the information to the M2M server at the utility provider for analysis by communicating directly through LTE-Advanced [2].

2.3.2 Healthcare

M2M communications facilitate remote patient monitoring and healthcare services. Thus, elderly or chronically ill patients can stay at home. One or more machines are used to send the patient’s health information (e.g., blood pressure and body temperature) to the M2M server in the hospital at regularly intervals or on-demand via LTE-Advanced [2,4].

2.3.3 Intelligent Transportation System

M2M communications can be applied to enhance transport efficiency, security and safety. Machines onboard vehicle's navigation systems communicate status information (e.g., location and velocity) to the M2M server via LTE-Advanced. The M2M server in turn analyzes the collected information and sends up-to-date traffic information to the vehicle's navigation system through LTE-Advanced [2].

2.4 Comparison between M2M and H2H Communication

M2M communications differ from H2H communications since a service in M2M is based on data communications which can be part of different business scenarios. They are, in general, characterized by some properties making them very different from H2H applications [4]. The main properties are:

- Large number of devices: Typical applications require a lot of devices deployed in the same area leading to high density or distant leading to a large spread.
- Devices can send and/or receive frequently or infrequently small amounts of data.
- Low mobility for devices meaning that they don't move, move infrequently or move in a predefined region.
- Reduced costs as these applications are used in everyday life and may involve a large number of devices.
- Devices may be grouped into Groups. This is interesting for charging, policing and multicast (toward a group).
- Devices should require ultra low power consumption.

- Time tolerant (generally), since data can be usually delayed. However, real-time transmission should also be considered for some applications.
- Time controlled as the devices may send and receive data only at certain periods of time.
- Security of exchanges between the devices and the server.

To summarize, M2M communications involve a huge number of cheap and low-power devices which generate small amount of traffic. These properties make M2M applications different and quite challenging in terms of deployment and management [4].

2.5 LTE-Advanced Networks

LTE-Advanced are proposed to meet or exceed the requirements of International Telecommunication Union (ITU) for 4G cellular systems known as International Mobil Telecommunications-Advanced (IMT-A). LTE-A adopts orthogonal frequency-division multiple access (OFDMA) in the downlink (DL) and single-carrier FDMA (SC-FDMA)in the uplink (UL), along with spatial multiplexing using multi-layer multiple-input multiple output (MIMO) [6] .

In LTE-A, carrier aggregation is employed to support flexible spectrum aggregation and maximum deployment bandwidths of 100 MHz. Via advanced MIMO techniques, LTE-A enable speak data rates of 1 Gbps in DL and 500 Mbps in UL, and performance gain of 1.4 to 1.6 from LTE in both capacity and cell-edge user throughput to be achieved. Other features include coordinated multipoint (CoMP) transmission in DL and CoMP reception in UL, enhanced inter cell interference coordination (eICIC), self-Optimizing networks (SON), and multimedia broadcast/multicast service (MBMS) [7] .

2. 5.1 LTE-Advance Network Architecture

The LTE-A network comprises two parts Core Network (CN) responsible for overall control of mobile devices and establishment of an IP packet flow. Radio Access Network (RAN) is responsible for wireless communication and radio access which provides necessary user and control plane protocols for communicating with mobile devices in LTE-A, consists of base stations referred to as evolved Node-Bs (eNBs) and mobile device is referred to as user equipment (UE) can be either an H2H or MTC device. eNBs are interconnected through the X2 interface. Besides, in RAN eNB is connected to the CN through the S1 interface. A high-level architecture of LTE-A networks with M2M communication is shown in Fig 2.5, where the MTC devices are connected to the eNBs either directly or via the MTC gateway (MTCG) [8].

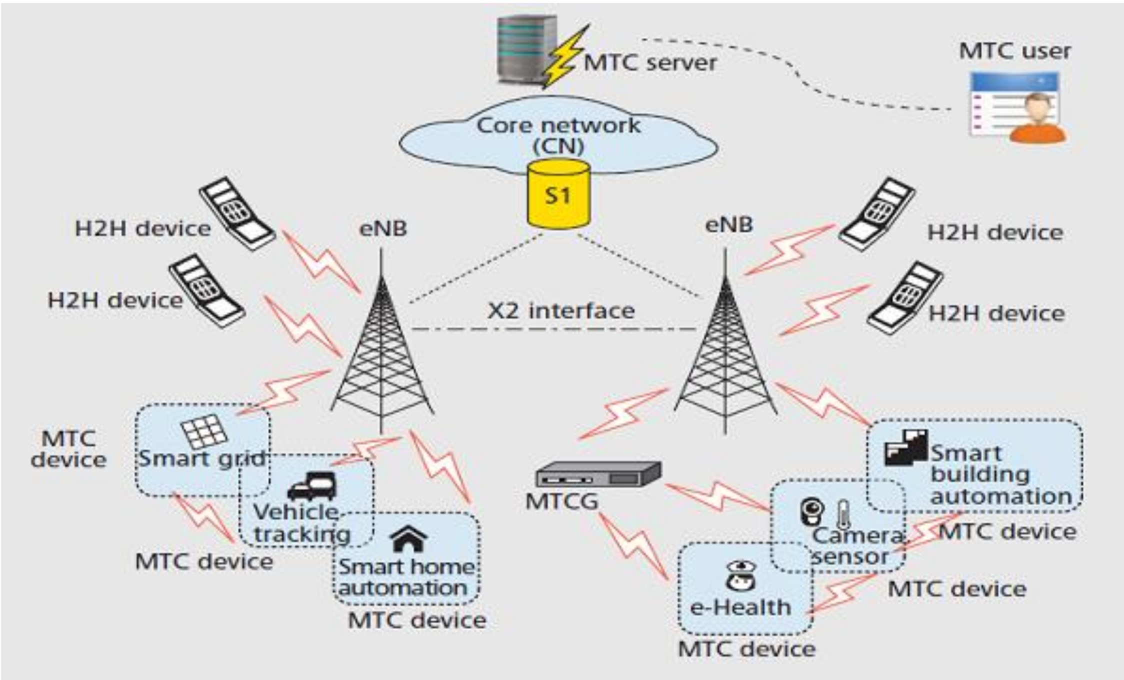


Figure2.5: Machine-to-Machine Communication in LTE-A Networks [8]

2.6 Random Access Procedures in LTE Networks

In LTE networks, user data is transmitted through Physical Uplink Shared Channel (PUSCH) via scheduled transmissions. Asynchronous devices acquire synchronization with eNodeB and reserve uplink channel using RACH. RACHs are repeated in the system with a certain period. Each node requiring an uplink channel transmits a preamble in a RACH.

There are two types of access in a RACH. The first type is contention-based, which is used for regular users. The second type is contention-free, which provides low latency service for users with high priority (e.g., handover).

Only focus on the contention-based random access, which consists of the following steps [9].

In Step 1; each user equipment (UE) randomly selects a sequence called a preamble from a pool known both to UEs and the eNodeB. The transmission of this sequence serves as a request for a dedicated time-frequency resource block in the upcoming scheduling transmission in Step 3. As UEs only transmit the sequence without incorporating their own IDs in the request, when two UEs select the same preamble, the eNodeB will receive the same sequence.

In Step 2; the eNodeB acknowledges all the preambles it has successfully received, conveying a timing alignment instruction so that subsequent transmissions can be synchronized.

In Step 3; UEs begin using PUSCH to transmit their IDs upon receiving the acknowledgement. If two UEs have selected the same preamble in Step 1, both will be instructed to transmit their IDs within the same time-frequency resource block in Step 3, and then a collision will happen.

In Step 4; contention resolution message will be broadcast with the ID of UEs successfully decoded by the eNodeB. If a collision happens while the eNodeB still manages to decode the message in Step 3, it will inform the UE whose Step 3 message is decoded and this successfull UE will send an ACK. Unacknowledged UEs will remain silent until the next RACH.

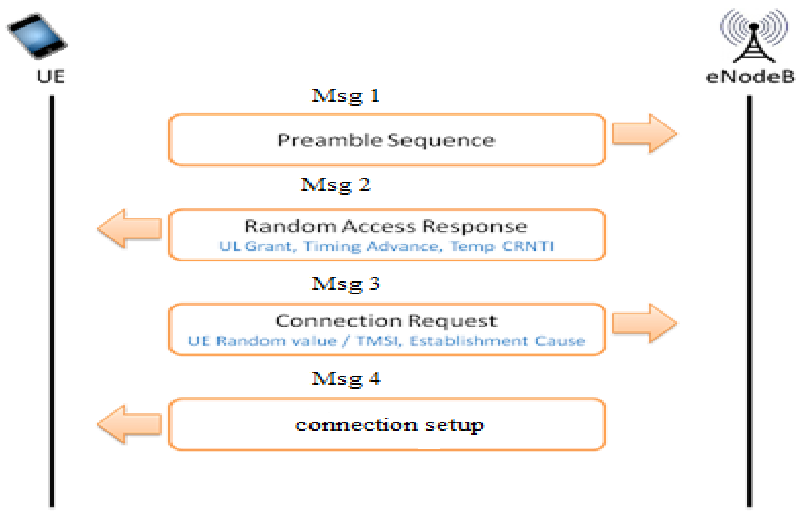


Figure 2.6: RA procedure signaling

2.7 Overload of M2M over LTE-A

Overload of the network can be caused by many mobile payment terminals that become active on a national holiday or by high numbers of metering devices becoming active almost simultaneously after a period of power outage. Also some MTC applications generate recurring data transmissions at precisely synchronous time intervals precisely every hour or half hour [10].

RAN overload happen in the radio part which called E-UTRAN When a device wants to connect to RAN then it has to perform RACH procedure. If a large number of devices try to access the network at the same time then RACH congestion can occur because there are only 64 preambles in a PRACH slot and if many devices try to access the network they may end up choosing the same preamble as another device and this will lead to collision which can result in failure of that preamble attempt. Such devices will then backoff and try to access the network at a later time. This leads to delays and more congestion at a later stage [11].

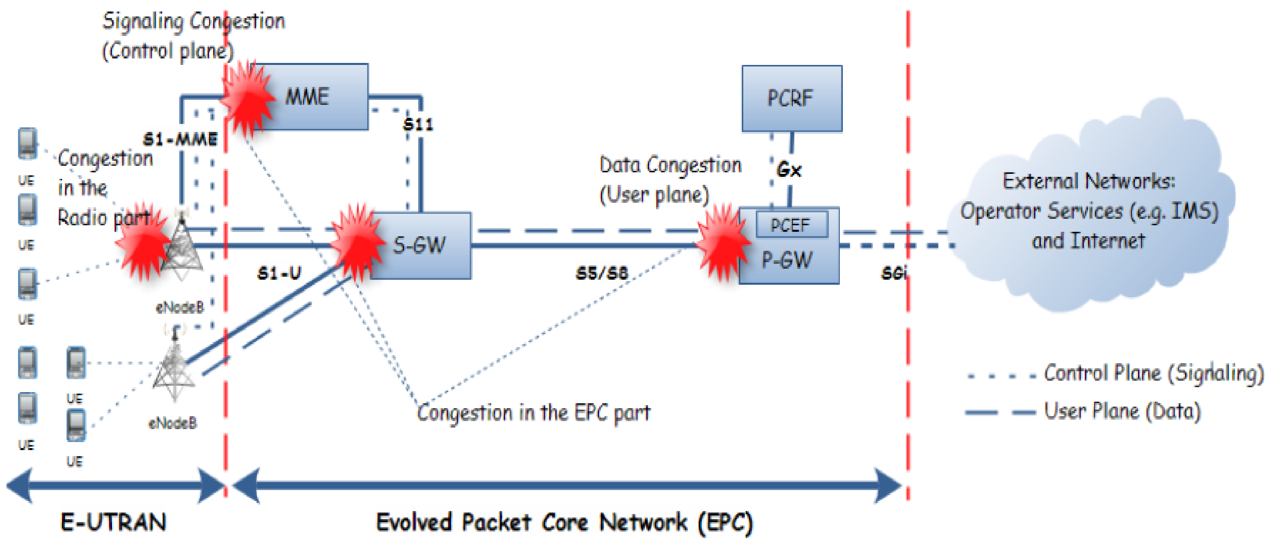


Figure 2.7: Types of Congestion in the LTE-A Network [4]

2.8 RAN Overloads Control Methods

The purpose of RAN overload control is to avoid RAN overload when mass MTC devices simultaneously contend for the RACH. From the perspective of the way that M2M traffic is generated, the RAN overload control schemes can be categorized as follow.

2.8.1 Push based approach

The MTC traffic is pushed from M2M devices to the network without any restriction until RAN overload is detected [12].

Examples of push based RAN overload control schemes are

2.8.1.1 Dedicated Resource Allocation

Allocating dedicated resource to the M2M devices can reduce the severe impact on the random access of UE which consist of two schemes [14]:

2.8.1.1.1 Slotted access scheme

In this scheme, each M2M device is allowed to perform Random Access only in its dedicated access slot. The M2M device can calculate the allowable access slots through its ID and RA-cycle. The RA-cycle is an integer number multiple of a radio frame that is broadcast by the eNB. If the total number of unique access slots is smaller than the number of M2M devices in a particular cell, several M2M devices share the same access slot, and collision can occur. Increasing the RA-cycle can reduce collision but creates unacceptable delay of an RA request [8].

2.8.1.1.2 Separating RACH Resources

In this scheme, preambles and time-frequency resources of the RACH for UEs and M2M devices are separated to prevent a large number of UEs and M2M devices from utilizing a common preamble at common time frequency resources. The separating RACH resources scheme facilitates to reduce the impact on UEs However; the performance improvement in extremely high congestion level of M2M devices is still limited [13].

2.8.1.2 Dynamic Allocation of RACH Resources

In this scheme, the eNB dynamically allocates additional resources for the RACH based on congestion levels and overall traffic load. Although the dynamic allocation of RACH resources can be effective in most cases, the performance improvement is limited by the availability of additional resources [13].

2.8.1.3 Backoff Based Scheme

In this scheme, the backoff time of UEs is set to a fixed small value (e.g., 20ms), while the backoff time of M2M devices is set to a large value (e.g., 960ms). It is expected that the extended backoff time can alleviate collisions and thus facilitating the collision resolution. However, although the backoff based scheme can provide performance improvements under a low congestion level in the RACH and not solve a high congestion level when the RACH is overload [18].

2.8.1.4 Maximum Number of Preamble Transmission Adjustment

In this approach the maximum number of preamble transmission is aim to investigate whether M2M devices can increase the success rate of RACH procedure by configuring larger maximum number of preamble transmission [18].

2.8.1.5 Wait Timer Adjustment

Wait timer here means the additional period M2M devices have to wait after they fail to receive RAR, Msg3 and Msg4. In this period, UE cannot send anything to eNB [18].

2.8.1.6 Access Class Barring (ACB)

This approach classifies M2M devices based on their access classes (AC 0 _ 9). To be specific, M2M devices in different access class apply different Backoff Indicators, persistent value, or wait timer. Note that since currently no approaches to differentiate M2M devices are standardized, all M2M devices are homogeneous and always apply the same parameters [18].

2.8.2 Pull based methods

Pull based is centralized scheme where eNBs can control the number of devices depending on the PRACH load and resource availability.

2.8.2.1 Contention free approach

Contention free approach is one of the pull based methods which is generally used at the time of handover. In this approach, the eNB will assign a contention free preamble to UE. UE will send the RA Req with this congestion free preamble. These methods can only be used in special cases like handover and not during normal RACH procedure [11].

2.8.2.2 Paging Method

In paging method, all M2M devices in idle mode listen to the paging message. Only when IDs of M2M devices are included in the paging message can they initialize random access procedure. In spite of the elimination of preamble collision, resource efficiency of RACH is limited by the maximal number of device ID that can be included in a paging message. Besides, paging method will cost of extra paging resource as tradeoff [11].

2.8.3 Self Optimizing Overload Control (SOOC) scheme

A self optimizing algorithm continuously adapts network resources and/or network parameters in order to meet specified high-level goals. Current LTE-advanced RA procedure only includes a simple algorithm for adjusting the PRACH transmit power for each unsuccessful RA attempt. The other resources are not adapted according to the PRACH channel load condition. In this section, we describe a self optimizing overload control (SOOC) mechanism for M2M communications, which enables the base station to automatically add or reduce PRACH resources when it detects an increase or decrease in PRACH load, respectively. In order to completely prevent PRACH from overloading, SOOC also includes the RACH resource separation scheme, the access class barring scheme and the slotted-access scheme [2].

2.8.4 Heuristic Algorithm to update p

A heuristic algorithm is aim to adaptively update the ACB factor p. In a real system, the eNodeB cannot acquire the number of backlogged users in the system. The information it has limited to the number of successful transmissions and the number of collisions during each time slot, as well as the total number of M2M devices that have registered in the system. There is an inherent trade-off in choosing the ACB factor p. When p is too large, there will be a lot of preambles transmitted in the air, and there will be collisions on most of the preambles. On the other hand, when p is too small, very few users will be able to pass ACB check and transmit their preambles, resulting in fewer collisions but under-utilization of network resources [15].

2.8.5 Numbering Scheme (NS)

When a M2M device does successful RACH procedure, the eNB assigns a number between 0 to n. If a device is assigned a number k then on its next network access, it will send the RA Req on kth PRACH slot from the time of activation of the device. In general in M2M communications, devices do not access the network continuously like in the case of periodic weather monitoring and reporting to the remote server. So each time when M2M devices access the network, RACH procedure is needed for uplink synchronization of them with eNB. If the device fails in kth PRACH slot, then it will backoff and will send the RA Req on 2kth PRACH slot. If the device fails even after, then it will no longer wait for the next kth PRACH slot. It will follow the normal backoff scheme. Here, the value of n is chosen by eNB in such a way that simultaneous access of a number of devices is spreaded across some PRACH slots to reduce contention. At the same time average access delay should also be controlled [11].

2.8.6 Prioritized Random Access (PRA) scheme combined with dynamic access barring (DAB)

In [16] the PRA scheme solves the RAN overload problem and provides QoS for different classes of M2M devices. This is achieved by pre-allocating RACH resources for different M2M classes while preventing a large number of simultaneous RACH attempts. The proposed PRA architecture is composed of two main components: virtual resource allocation with class dependent backoff procedures and dynamic access barring.

2.8.6.1 Virtual Resource Allocation

M2M devices are classified into five categories: H2H, low priority, high priority, scheduled, and emergency as shown in Table 2.1.Virtual resources are assigned to M2M devices according to the following designs:

1- H2H can use all the available RACH opportunities.

2- The emergency and the scheduled traffics share the same virtual resource allocation.

3- Low/high priority traffic and emergency/scheduled traffics are assigned different virtual slots [16].

Table 2.1: Classification of MTC Traffic [16]

Class name	Application exemplar	QoS requirement
H2H	Voice call	Hardly effected by MTC
Low priority	Consumer electronics/ fleet management	Strict delay
High priority	E-care	Strict delay
Scheduled Smart	Smart meters	Delay tolerant
Emergency	Seismic alarms	Extremely short delay

A dedicated resource allocation to emergency will result in extremely low utilization since emergency tasks are very rare. Therefore, we let emergency and scheduled traffics share the same virtual slots and then use back-off schemes to resolve collisions. In contrast, we separate resources of scheduled traffics and low/high priority traffics for the benefit of providing different techniques to delay-tolerant and delay constrained MTC devices [16].

Where eNB decides the virtual resource allocation according to the knowledge of the statistics of the M2M devices. This information may be stored in certain system information blocks (SIB) of the eNB, and a MTC device reads the SIB to acquire the updated realization of the virtual resource allocation. The SIB also allows emergency enhancement. After successful receiving an emergency alarm, eNB marks an emergency flag to 1 (the default is 0), which can easily be implemented by inserting one bit into the SIB, and resets the flag when sufficient information has been acquired. If the flag has value 1, an M2M device belonging to the scheduled class trying to transmit Msg1 for the first time should delay its access attempt for time T1. Such mechanism prevents emergency traffic from being submerged by other M2M attempts of different classes and provides emergency traffic higher reliability and shorter delay [16].

2.8.6.2Dynamic Access Barring for Collisions Avoidance

Although have allocated different resources for different classes to reduce the chance of collision, the number of M2M devices can be too large for eNB to grant enough number of channel accesses in a short time. Thus dynamic access barring is worked for collision avoidance. The DAB operates as follows. eNB continuously monitors the expected number of successfully decoded Msg1 during the i-th RACH opportunity to determine the state of the current loading by using loading indicator [16].

2.8.7 Scheduling Based Scheme

The concept of scheduling-based scheme is based on the pull-based scheme. As the M2M Server is aware that M2M devices have data to send (according to the periodicity of data transmissions) or the M2M Server needs information from the M2M devices, the CN would page the M2M devices for data transmissions. With pull-based scheme, the M2M device will perform an RRC connection establishment upon receiving a paging message. In scheduling-based scheme, the M2M devices are paged to contend on a specific contention area. The contention area appears on the Physical Uplink Shared Channel (PUSCH) and is dedicated to M2M devices. If an M2M device fails in contention, it would wait for the next dedicated contention area before reaching the RACH limitation. The period between consecutive M2M dedicated contention areas is scheduled by eNB and CN. This message would be conveyed through paging message. In this scheme, eNB schedules the dedicated contention area for M2M devices of the same type to contend on it. In this way, M2M devices won't contend with H2H devices and the collision problem won't happen [17].

2.8.8 Event-Triggered Based Scheme

Separate RACH resources for MTC are one of the envisioned RAN improvements for machine type communications. With the increasing of various applications there would be incredible large number of M2M devices in a cell. If RACH resources are shared between M2M devices and H2H devices, the huge amount of M2M devices would cause the effects on the performance of H2H devices. Although H2H devices wouldn't be affected by M2M devices by means of separated RACH resources, periodically allocating dedicated RACH resources would waste UL resources due to the occasional transmissions from M2M devices. Therefore, dynamically allocate and release separate RACH resources for M2M at the time instance that any M2M device desires to transmit data and at the time instance that all the M2M devices finish their data transmissions respectively [17]. The Event-triggered based scheme combines the advantages of Separate RACH resources for M2M approach by using different RACH resources between M2M and H2H devices and Dynamic allocation of RACH resources approach dynamically allocate additional RACH resources for devices to use [17].

2.9 Summary

The following table summary up the different work in the different method

Table 2.2: Summary of literature review

Paper	Characteristics	Weakness
Ming-Yuan Cheng,Guan-Yu Lin, Hung-Yu Wei and Chia-Chun Hsu [18]	The paging message sends to all M2M devices. M2M devices' IDs are included in the paging message only they can initialize random access procedure.	Long delay and high consumption of downlink resource because limited paging list.
Hsien Hao Lai [17]	The M2M devices are paged to contend on a specific contention area which appears on the Physical Uplink Shared Channel (PUSCH). If an M2M device fails in contention, it would wait for the next dedicated contention area before reaching the RACH limitation.	Access delay is large
Anthony Lo,Yee Wei Law, Martin Jacobsson and M.Kucharzak[2]	Mechanism for M2M device, enables the base station to automatically add or reduce PRACH resources when it detects an increase or decrease in PRACH load, respectively.	Total performance is still limited at high congestion level.

Paper	Characteristics	Weakness
Shao-Yu Lien, Kwang-Cheng Chen and Yong hua Lin [13]	Network dynamically allocates additional RACH resources for the M2M devices based on the predicted access load of M2M devices.	Total performance is high at reserves available resources.
Mukesh K. Giluka,Aiswarya Prasannakumar, Nitish Rajoria and Bheemarjuna R. Tamma [11]	eNodeB assigns a number to M2M device when it connects to. At each connection RACH procedure is needed for uplink synchronization.	Lower success rate at high congestion with large delay.

3.1 Introduction

The RAN overload issue in 3GPP LTE-A is caused by many MTC devices trying to transmit data to a base station, called Enhanced Node B (eNB) in LTE-A, within a very short period of time. It is one of the key issues in MTC since the air interface is the first and the last miles of M2M communications [16].

M2M applications characterize a massive deployment, which generates a huge amount of data/signaling traffic, congesting the available radio resource, and thereby overloading the communication networks [18].

3.2 Proposed Method

All M2M devices assigned a predefined value **P** each time when a M2M device attempts to start the random access procedure; it first randomly generates a random number between 0 and 1. If the generated number is smaller than the device's P value, it can transmit RACH preamble Otherwise, the device needs to backoff and waits for the next interval to try again with another new arrival M2M devices.

3.2.1 System Descriptive Analysis

Consider that LTE-A network consists of one base station (eNB) with many M2M devices. The coverage area is about 5000 m^2 simplicity, we assume that the macro cell has a BS in the middle of the cell; so the cell radius is about 2500 m. shown in Figure 3.1 is the diagrammatic representation of the simulation mode.

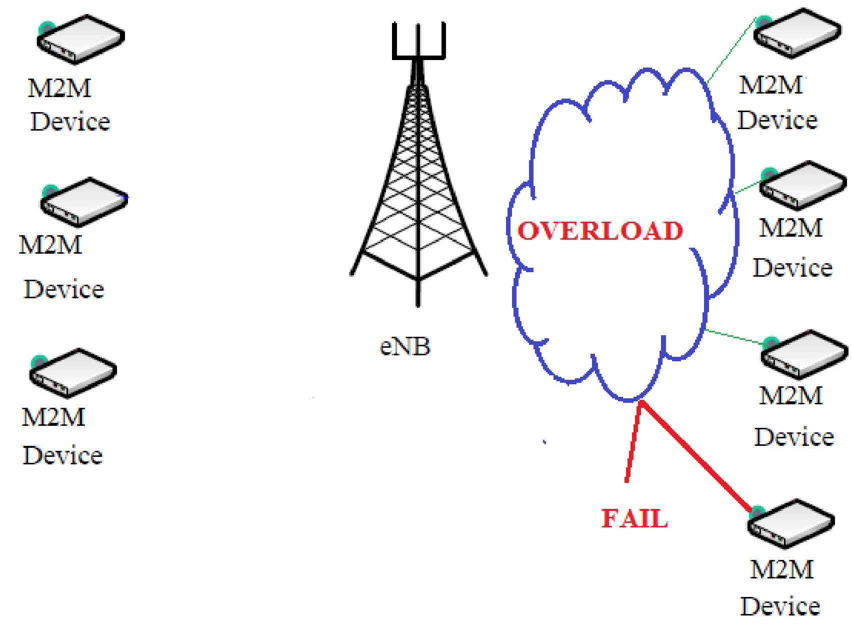


Figure 3.1: System Model

3.2.2 Mathematical Model

Consider *N* M2M device which have previously registered with an eNodeB. These devices have just recovered from an emergency, e.g., a power blackout and all of them try to re establish synchronization with the eNodeB. As these devices are not synchronized, they will not be activated all at once, but with in a limited timeT_A, denoted as the activation time. Each MTC device is activated at time $0 \leq t \leq T_A$ with probability f (t) in which f (t) follows a beta distribution with parameters α and β as [15].

$$f(t) = \frac{t^{\alpha-1}(T-t)^{\beta-1}}{T^{\alpha+\beta-1}\,\beta_{(\alpha,\beta)}} \tag{3.1}$$

Which $\beta_{(\alpha,\beta)}$ is the Beta distribution function.

Assume there are I_A random access channels within the activation time. The duration of the random access channel is shorter than the interval between two random access channels. We divide the activation time into I_A discrete slots where slot *i* begins with i_{th} random access channel.

The length of each slot is equal to the interval between two random access channels. The i_{th} time slot starts at t_{i-1} and ends at t_i .The first time slot starts from t_0= 0. The last one ends at $t_{I_A} = T_A$. To simplify the model, we assume that new activations within time slot *i*, *i.e.*, within $[t_{i-1}, t_i]$, will only take place at the beginning of this random access channel and choose this channel for their first random access attempts [15].

The expected number of new activations (arrivals) during each time slot, n_i $i = 1, 2, \ldots, I_A$, is subject to the distribution of activation traffic $f(t)$ and the total number of devices *N* as [15].

$$n_i = \int_{t_{i-1}}^{t_i} f(t)\ dt \qquad i = 1, 2 \ldots I_A. \tag{3.2}$$

n :users (includes new arrivals and backlogged users). Suppose there are M available preambles in each RA-TS and users choose preambles with equal probability given by 1/M.

- **The Successful Transmission**

Takes place when exactly one user (device) chooses a given preamble. The success probability for M2M devices can be written as [19]:

$$p_s^{M2M} = \binom{n}{1}\left(1 - \frac{1}{M}\right)^n \tag{3.3}$$

p_s^{M2M} : is the success probability of M2M device

From equation (3.3) the success probability for M2M is equal to

$$P_s^{M2M} = \frac{n}{M}\left(1 - \frac{1}{M}\right)^{n-1} \tag{3.4}$$

- **Throughput of M2M Devices**

Can compute the throughput derivative from equation (3.4) as [19]:

$$T^{M2M} = M.P_s^{M2M} \tag{3.5}$$

Or write as:

$$T^{M2M} = n\left(1-\frac{1}{M}\right)^{n-1} \tag{3.6}$$

Where T^{M2M} : Throughput of M2M device

- **The Idle probability of M2M Devices**

This means there is no device to choose a preamble m (m∈ {1, 2...? M}), we can calculate idle probability as [19].

$$p_i^{M2M} = \binom{n}{0}\left(1-\frac{1}{M}\right)^{n} \tag{3.7}$$

So idle probability of M2M is equal

$$P_i^{M2M} = \left(1-\frac{1}{M}\right)^{n} \tag{3.8}$$

Where P_i^{M2M} : idle probability of M2M

- **The collision probability for M2M Devices**

Happen when two or more M2M devices are choosing the same preamble in the same time can be derived from equation (3.4) and equation (3.8) and written as [19].

$$P_c^{M2M} = 1 - P_s^{M2M} - P_i^{M2M} \tag{3.9}$$

So the collision probability from equation (3.9) is equal to

$$P_c^{M2M} = 1 - \frac{n}{M}\left(1-\frac{1}{M}\right)^{n-1} - \left(1-\frac{1}{M}\right)^{n} \tag{3.10}$$

Where P_c^{M2M} : collision probability of M2M device

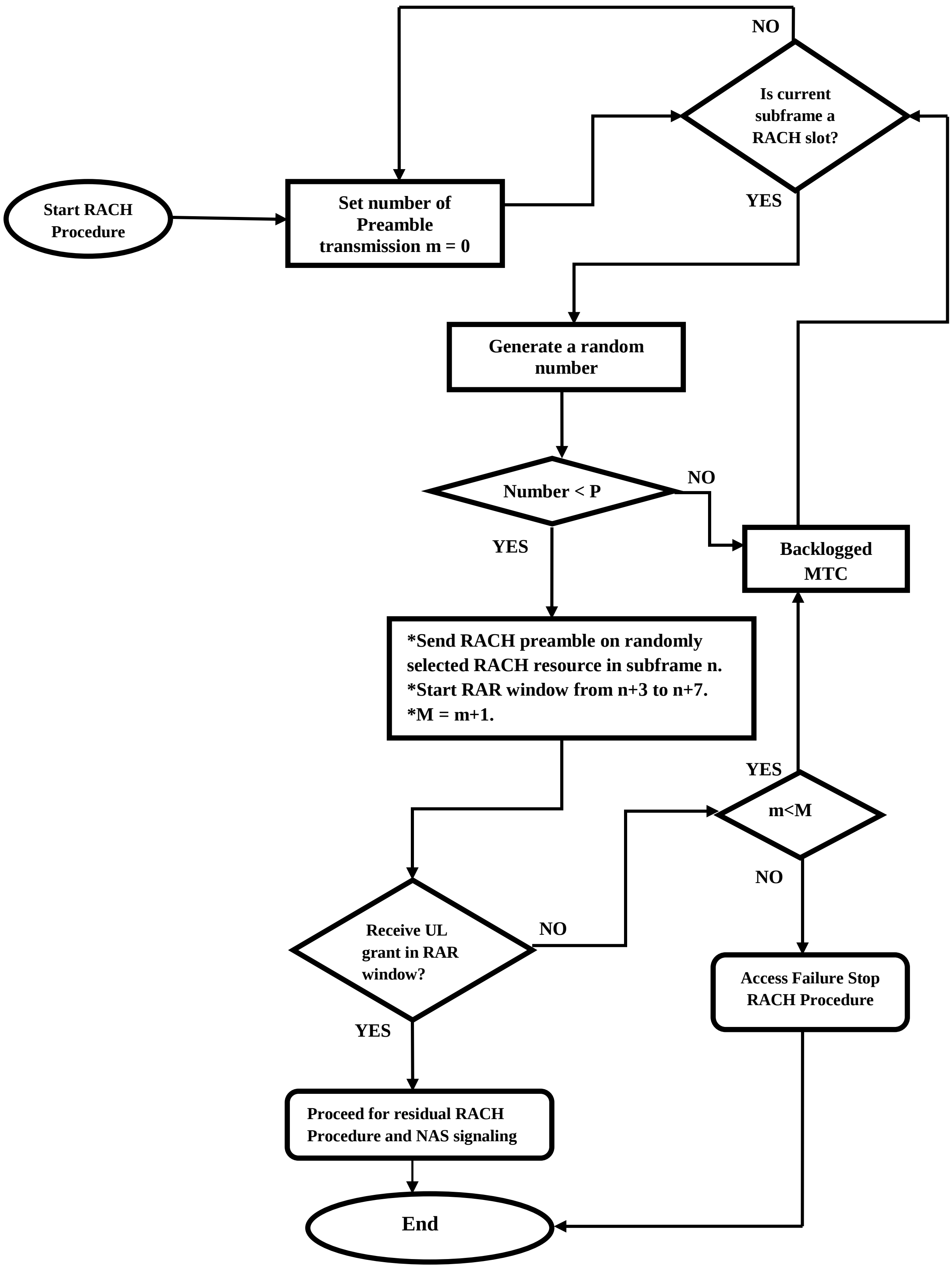
3.3 Simulation Model

3.3.1 Algorithm Description

When M2M device is ready to transmit preamble, it will check whether the current time slot is random access slot (In ten milliseconds, M2M has two opportunity to send preamble). Otherwise, M2M will wait until the next random access slot is coming. After that each M2M device is given a predefined value P. M2M device will randomly generate a random number between 0 and 1. If the generated number is smaller than the value of device P, then it can start the RACH procedure and transmit RACH preamble. Otherwise, the device needs to back off and waits until another interval to try again.

After sending the preamble, the M2M will increase the number of transmission times by one, and start the random access response (RAR) timer, and then wait for RAR. Once receiving the random access response in the RAR window, M2M will process TA (Timing Alignment) and UL grant and prepare for send RRC Connection Request. On the other hand, if M2M cannot receive random access response in RAR window (i.e., eNB fails to detect the preamble from the M2M), M2M will check whether its number of preamble transmission times is smaller than the maximum number of preamble transmission. If yes, M2M will randomly choose a time slot based on Backoff Indicator and prepare for the next preamble transmission. If not, M2M will stop performing RACH procedure and indicate a random access problem to the upper layers.

3.3.2 Flow Chart



M: maximum number of preamble transmission times

3.4 Simulation Assumption Parameters

As shown in table below:

Table 3.1: simulation parameters

Parameters	Value
System type	Single cell
Cell radius	2.5Km
Number of MTC devices	300
RA preamble sequence format	0
Number of UL grants per RAR	3
System bandwidth	5MHz
PRACH configuration index	6
Available preambles	54

4.1 Simulator Environment

MATLAB (Matrix laboratory) is an interactive software system for numerical computations and graphics. As the name suggests, MATLAB is especially designed for matrix computations: solving systems of linear equations, computing eigenvalues and eigenvectors, factoring matrices, and so forth. In addition, it has a variety of graphical capabilities, and can be extended through programs written in its own programming language.

4.2 Results

The simulation environment consists of 300 MTC devices, who's distributed by Beta distribution one LTE-A base station covered area about 5000*5000 m^2 , assumed that the macro cell has a BS in the middle of the cell. Shown in figure 4.1 the generation of the MTC device and eNB positions in simulation area shown by red stars and blue stars, respectively.

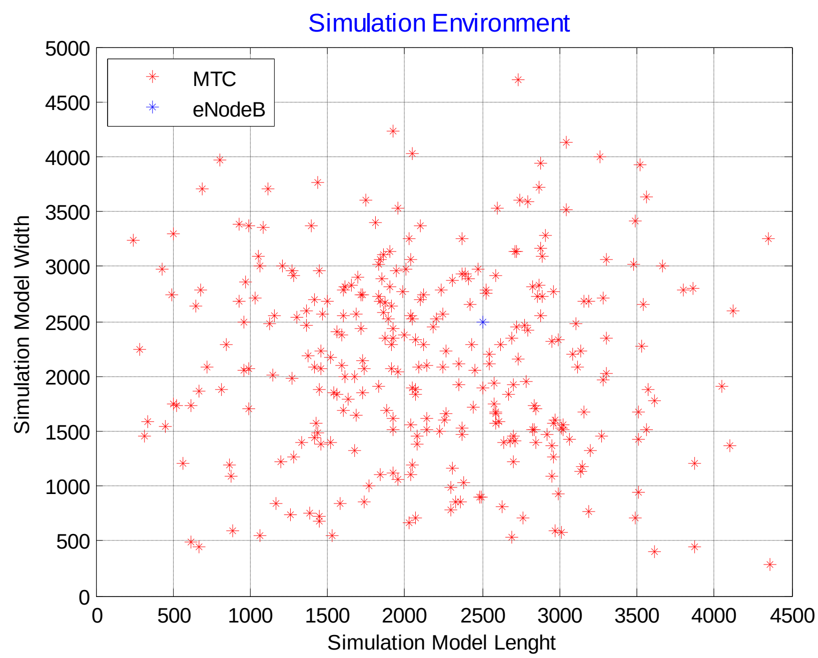


Figure 4.1: Simulation Environment

Firstly, in proposed solution assigned a predefined value number to all M2M devices called **P**. Then each M2M device will randomly generate a random number between 0 and 1. If the generated number is smaller than the value of **P**, then it can start the RACH procedure and transmit RACH preamble. Otherwise, the device needs to back off and waits until another interval to try again. Then calculate the success probability, throughput, idle probability, and collision probability in two cases at P=0.15 and P=0.04.

4.2.1 The success probability

Is defined as the number of preamble successfully received by the eNB divided by the total number of RACH preamble transmission in that time slot. In other words, the total number of request RACH preamble is the number of MTC devices sending preamble at that time slot. Success probability has two cases as show below

Case 1 at P=0.15

As shown in figure 4.2 below the rate of success to n MTC device. Noticed that the success probability increase with increasing of number of MTC device until reach to 100 devices. More than 100 devices the success probability will be decreasing rapidly. For example, the success probability is 0.7373, 0.0422, 0.0194, and 0.0093 for 100, 600, 700, and 792 MTC devices respectively.

Case 2 at P=0.04

As shown in figure 4.3 below, the success probability started at 0.0185 and increasing until 0.31 with 44 MTC devices. And then decrease rapidly until 0.0067 with 300 MTC devices. And will be zeroes for all additional MTC devices.

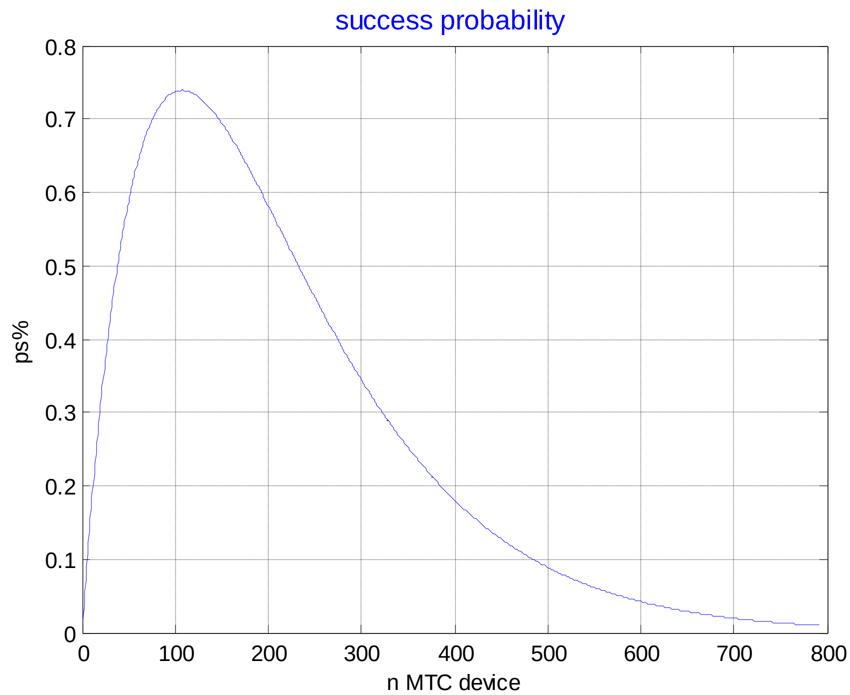


Figure 4.2: Success Probability Case 1 at P=0.15

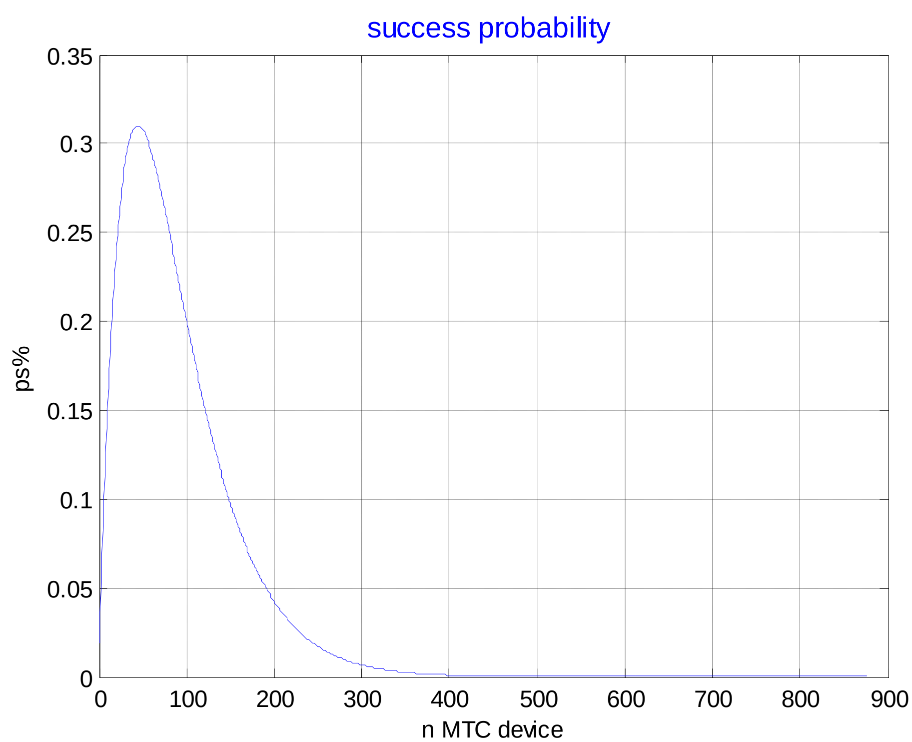


Figure 4.3: Success Probability Case 2 at P=0.04

4.2.2 Throughput

Is the product of the number of RAOs per second and the number of successful transmissions per RA-TS. Throughput has two cases

<u>Case 1 at P=0.15</u>

In figure 4.4, the amount of throughput grows linearly with the increase of desired success probability . Observe that the amount of the throughput increase with increasing of number of MTC devices until 100. More than 100 devices the throughput will be decrease rapidly. For example, the throughput amount is 39.8146, 31.4105, 9.7748, 2.2814, and 0.5048 with 100, 200, 400, 600, and 792 MTC devices respectively.

<u>Case 2 at P=0.04</u>

In figure 4.5 below, the amount of throughput started at 1 and increasing until 16.6505 with 40 MTC devices. And then decrease rapidly until 0.0067 with 500 MTC devices. And will be zeroes for all addition number of MTC devices.

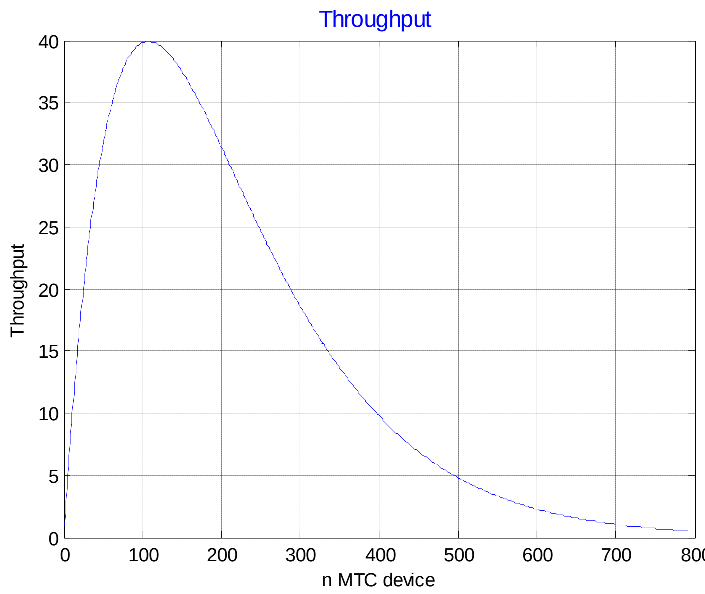


Figure 4.4: Throughput Case 1 at P=0.15

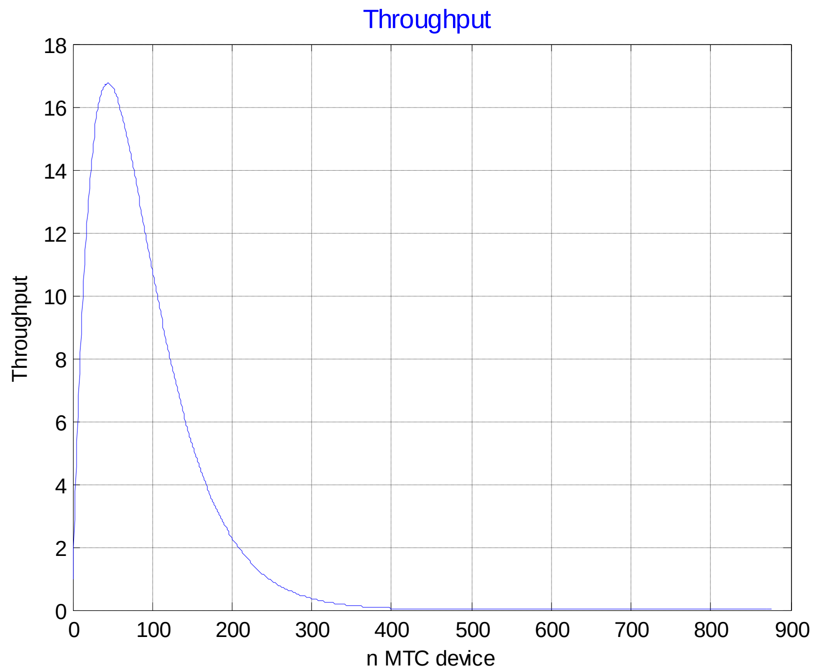


Figure 4.5: Throughput Case 2 at P=0.04

4.2.3The Idle Probability

Is defined as the number of “idle” MTC device divided by the total number of n device. There are two cases of idle probability

Case 1 at P=0.15

As shown in figure 4.6 below, the idle probability started at 100% and decrease rapidly with increasing of number of devices. For example, 0.9815, 0.1542, 0.0238, and 0.0037 with 1, 100, 200, and 300 respectively.

Case 2 at P=0.04

As shown in figure 4.7 below, the idle probability started at 100% and decrease rapidly with increasing of number of devices. For example, 0.9815, 0.1542, 0.0238, and 0.0037 with 1, 100, 200, and 300 respectively.

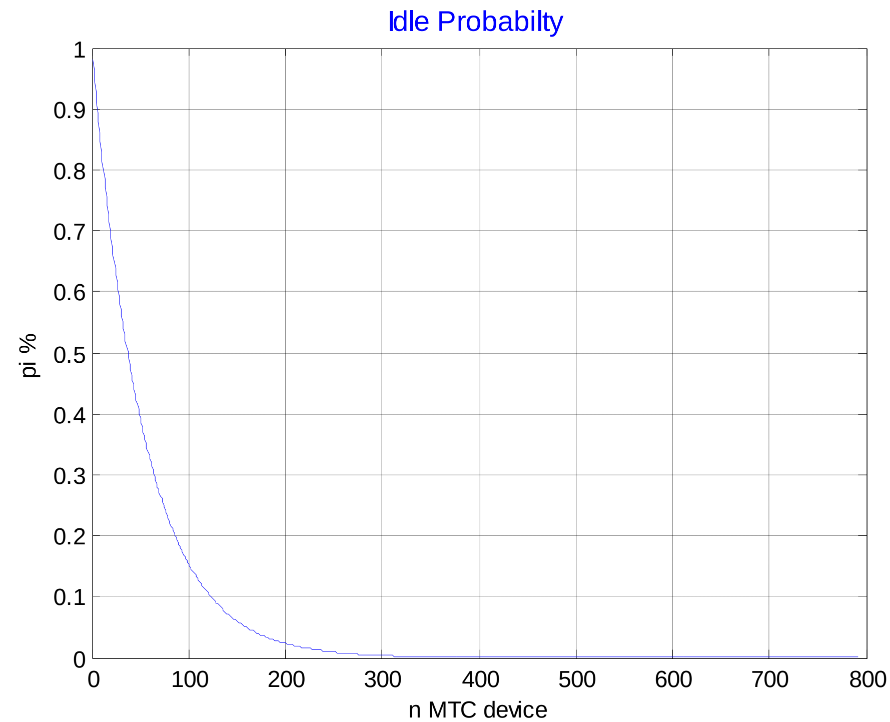


Figure 4.6: Idle Probability Case 1 at P=0.15

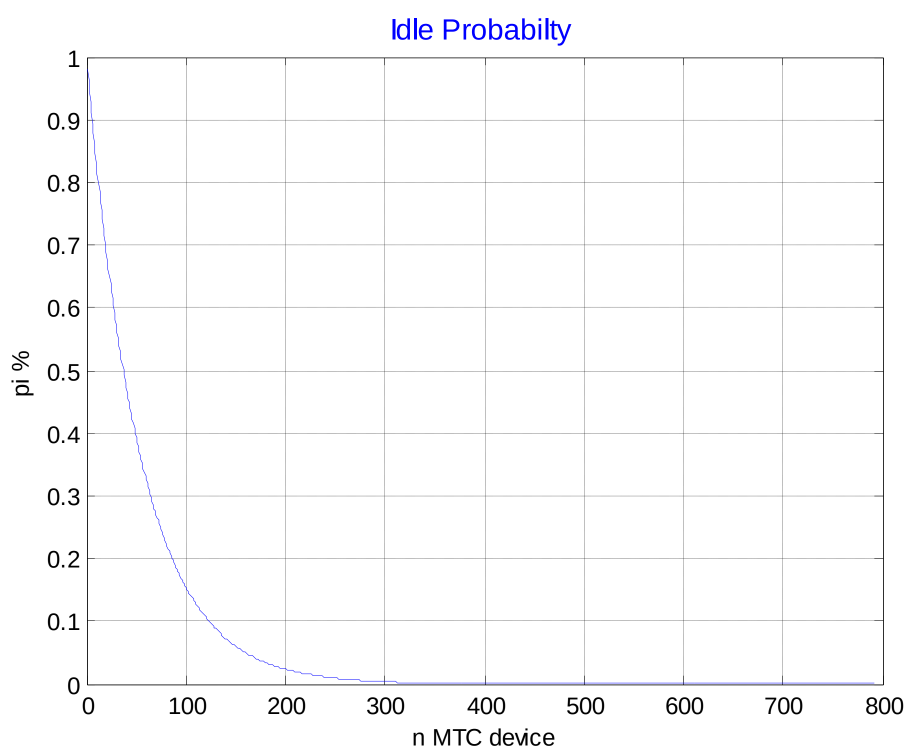


Figure 4.7: Idle Probability Case 2 at P=0.04

4.2.4The Collided Probability

Is defined as the number of “collided” preamble divided by the total number of preambles. There are two cases of collided probability

<u>Case 1 at P=0.15</u>

The figure 4.8 show the collision probability that increase rapidly with increasing of number of MTC devices. For example, 0.0203, 0.1084, 0.6522, 0.8184, and 0.9907 with 50, 100, 300, 400, and 792 MTC devices respectively.

<u>Case 2 at P=0.04</u>

Figure 4.9 show the collision probability started at 0 and increasing rapidly 0.6456 with 100 MTC devices until 100% with 600 MTC devices and for all addition number of MTC devices.

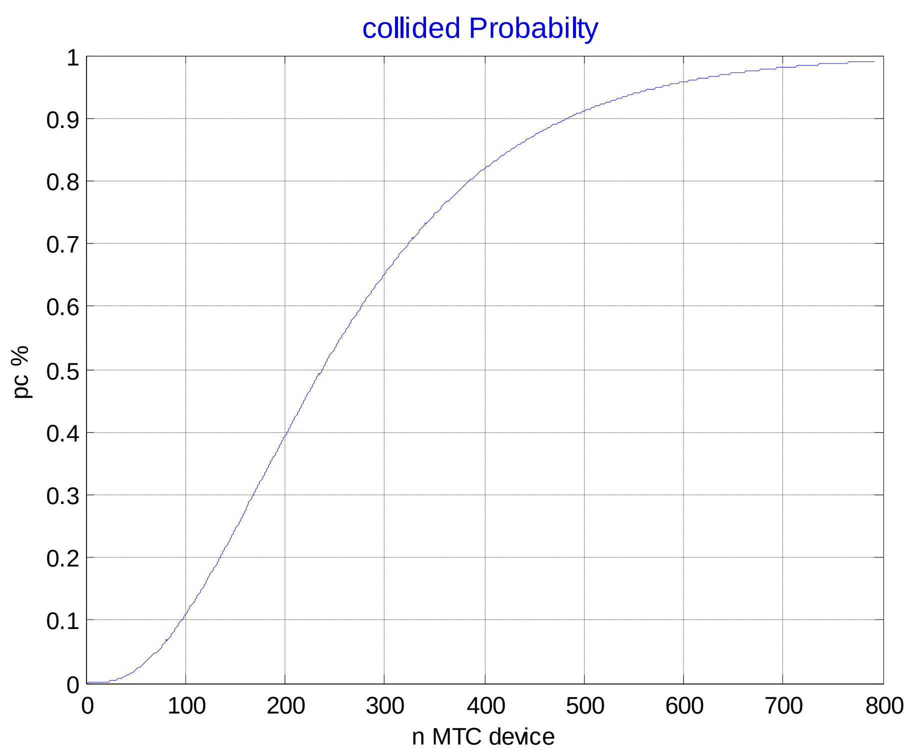


Figure 4.8: Collided Probability Case 1 at P=0.15

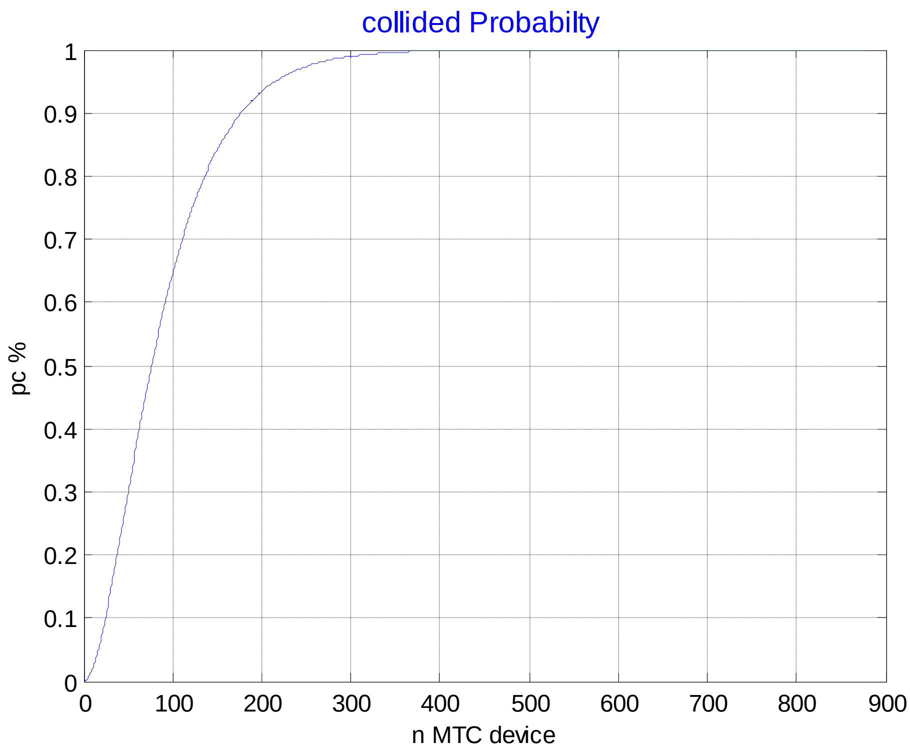


Figure 4.9: Collided probability Case 2 at P=0.04

4.3 Discussion

The simulation results using MATLAB 7.8.0 show performance of hybrid mechanism of **P** persistent method and backlogged MTC device in metrics such as success probability, Throughput, idle probability and collided probability, which help in solving the problem of RAN overload.

Observe that from figure 4.2 the success probability is increasing rapidly until the number of device reach to 100 devices where the success probability is about 73% that is better than case 2 where highest success is about 32% as in figure 4.3.

Notice that in case1 the large numbers of success MTC devices increase the amount of throughput as shown in figure 4.4 and decrease it in case 2 as in figure 4.5. As shown in figures 4.6 and 4.7 idle probabilities rate are same in the two cases.

From figure 4.8 in case1 the collided probability rate is low compare to the collided probability rate in case2 as shown in figure 4.9.

Increasing of success MTC devices reach by proposed method to reduce the average of the overload rate to 67% in case 1. In another case, high number of collided MTC device caused large amount of overload than in case1as shown in figure 4.10.

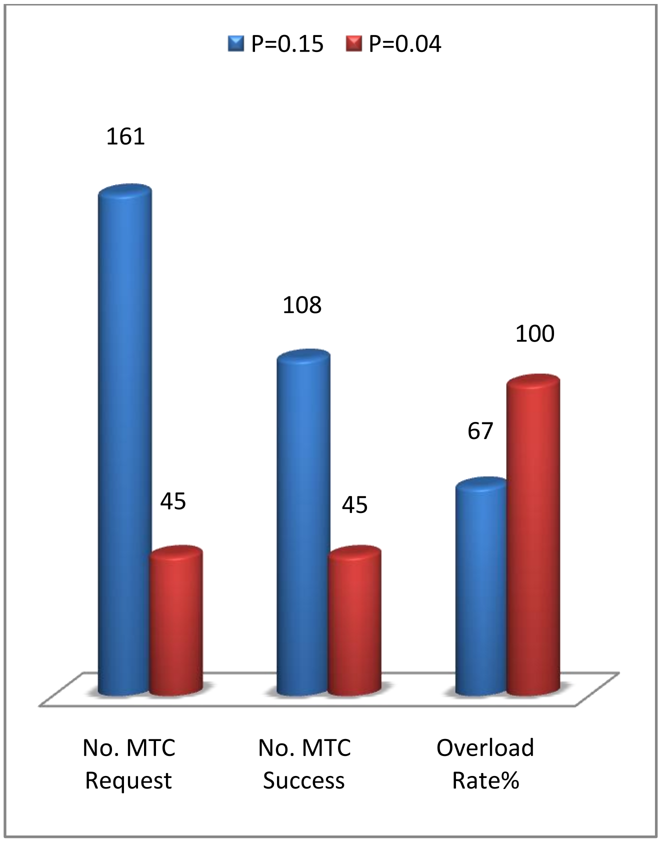


Figure 4.10: Overload Rate

Finally, observe that the proposed overload method solved the RAN Overload problem within limit number of MTC devices and give a suitable resolution when the value of P is large.

5.1 Conclusion

Modern communication is evolving towards M2M communications that require little or no human intervention. Unlike H2H, M2M communications are characterized by high machine density per cell, small amounts of payload, machine-originated communications, time-tolerant and low traffic volume per machine. These characteristics pose new challenges to LTE-Advanced which is designed for human centric communication. One of the key challenges facing LTE-Advanced is the large number of machines initiating random access to LTE-Advance's base station all at once. This could lead to severe overload on LTE-Advanced RACH and we have used theoretical results to show the full scale of the overload problem as the number of machines increases. As a result, the proposed hybrid mechanism of **P** method and backlogged resolved the RAN Overload Problem within limit number of MTC devices and give a suitable resolution.

5.2 Recommendations and Future Works

Note that there are many types of RAN Overload Control Methods. However, it is difficult to consider all methods during designing the proposed mechanism due to complexity of methods and conflicting issues (Backoff indicator, Access Class Baring, Paging method, Slot Access, etc…) of multiple methods. But if consider more issues to the proposed mechanism the outcome of the RAN Overload Method would definitely improve.

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MATLAB Code

```
%This Program for RAN Overload Performance and Evaluation in MTC of
LTE-A Network
%----------------------------------------------------
close all;
clear all;
clc;
  %The inputs variables
%----------------------------------------------------
n=300; % n is numbers of User Equipment
sww=5000; %Simulation Width
swl=5000; %Simulation Length
sim_time=7200; % Simulation time in seconds about (2 hour )
LTEA=5120;   % LTEA Bandwidth in KHz about (5 MHz)
M=54;
p=0.15000;
%p=0.04000;
%p=0.50000;
preamble=54; % total number of preamble in  LTEA
status=zeros(1,n);
xpos_eNodeB=2500;
ypos_eNodeB=2500;
success=0;
reject=0;
s=zeros(1,n);
req=0;
n_req=0;
%Generate Mobile and BS positions in simulation area
%-------------------------------------------------------
figure %1
xpos_MTC=round(swl*betarnd(3,4,1,n));
ypos_MTC=round(sww*betarnd(3,4,1,n));
plot(xpos_MTC, ypos_MTC,'*r');
grid
hold on;
plot(xpos_eNodeB,ypos_eNodeB,'*b');
title('Simulation Environment ','FontSize',12,'color','b');
xlabel('Simulation Model Lenght');
ylabel('Simulation Model Width');
%b=betarnd(3,4,n,1);
h = legend('MTC','eNodeB',2);
set(h,'Interpreter','none');

%calculation of p method
%-----------------------------------------------------------
for k=1:n

    s=rand(1,k);

    if s(k)<=p

  req=req+1;

     if M>0

        M=M-1;

        success=success+1;
```

```
        else
       reject=reject+1;
        end
    else
        reject=reject+1;
        n_req=n_req+1;
    end

end

%Add the Backlogged MTC Device
%--------------------------------------------------------------------

n=n+reject+n_req;

M=54;

for k=1:n
     s=rand(1,k);
    if s(k)<=p
    req=req+1;
        if M>0
        M=M-1;
        success=success+1;
        else
       reject=reject+1;
        end
    else
        reject=reject+1;
        n_req=n_req+1;
    end

end

% Calculation of success probability,Throughput,Idle probability and
% collided probability
%--------------------------------------------------------------------

  for k=1:n
ps(k)=((k/54)*((1-1/success)^(k-1)));
T(k)=preamble*ps(k);
pi(k)=((1-1/preamble)^(k));
pc(k)=1- pi(k)-ps(k);


  end

figure %2
plot(ps)
grid
title('success probability ','FontSize',12,'color','b');
xlabel('n MTC device');
```

```
ylabel('ps%');

figure %3
plot(T)
grid
title('Throughput ','FontSize',12,'color','b');
xlabel('n MTC device');
ylabel('Throughput');

figure %4
plot(pi)
grid
title('Idle Probabilty ','FontSize',12,'color','b');
xlabel('n MTC device');
ylabel('pi %');

figure %5
plot(pc)
grid
title('collided Probabilty ','FontSize',12,'color','b');
xlabel('n MTC device');
ylabel('pc %');
```