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Article

LTE Technologies and Challenges for development of M2M Communication

Savitha AC[1], MN Jayaram[2], Aravind HS[3]

[1]Assistant Professor, [3]Professor, Electronics & Communication, JSSATE Bangalore, India.
[2]Professor & HOD, Electronics & Communication, JSS S&T, Mysuru, India.

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Corresponding Author:
Savitha AC, Electronics & Communication, JSSATE Bangalore, India.
E-mail Id:
savithalm@gmail.com

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ABSTRACT

LTE cellular network and M2M technology are predictable to perceive extensive deployment in the wide applications. M2M is the autonomous communication between associated devises without the involvement of human. Presently, LTE is considered as one of the important cellular network for an implementation of M2M communication. Hence LTE networks necessity to incorporate special features of M2M communication. In this paper we provide growth of massive type of communication with respect to the LTE releases. We briefly discussed about LTE different physical channels and features. Finally we recognized some of the challenges associated to the implementation of M2M technologies.

Keywords: LTE, LTE-CAT-M, M2M, MTC, NB-IoT

Introduction

The Long-Term Evolution is the highly developed services for the billions of mobile users which have lower delay, higher spectral efficiency. The wireless standard developed by the 3rd Generation Partnership Project (3GPP) on the technologies basis of GSM,EGSM,UMTS/HSPA.[1] The potential of LTE a includes- OFDM, OFDMA, SC-FDMA and MIMO. OFDM is one of the key enabling technologies compared with one of the existing cellular network. This core technology is used in WiMAX and Wi-Fi system. OFDM has an advantages are (i) Elegant way of multipath inference where high data stream are divided into number of parallel bit streams and each bit streams are modulated separately which is called as subcarriers. Splitting of large data streams into smaller data avoids ISI which is caused due to multipath propagation. (ii) Low computational complexity is done by using FFT and IFFT. $BlogBT_m$ gives the computational complexity in OFDM. Where B gives Bandwidth and T_m gives delay spread. This component particularly helps to reduce power consumption and cost. (iii) Frequency diversity utilization: In the subcarrier domain of OFDM has coding and interleaving which provides robust transmission against burst error and deep fading. It helps deployment to LTE in various channel bandwidths and various spectral allocation. (iv) Strong demodulation (v) Proper coherent demodulation and (vi) Facilitation of broadcast services. Disadvantages of OFDM includes - Only single user can transmit the data of the subcarrier frequency and less robust against fading.[2] OFDMA has capacity of flexible multiple accesses for wide mobile applications. The main aim of the OFDMA is to transfer user data in the proper frame and best usage of channel. From this real and non-real time services gets good quality of services along with low bit rate.[3] It is employed in the LTE downlink channel. Advantages of OFDMA includes-efficient use of frequency allocation, support multi user diversity, simple receiver and provides better BER performance. Similarly disadvantages OFDMA includes-permutation for allocation and depermutation for de allocation of the subcarrier is complex, high PAPR due to non-linearity in the amplitude, stiff synchronization of time, frequency and complex co channel interference. To solve PAPR problem in the LTE system the SCFDMA is used and it is employed in the uplink channel. More power consumption of the User Equipment (UE) is reduced in the

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SC-FDMA and hence enhances the power efficiency.SC-FDMA provides different sets of sub carriers by using IDFT at the transmitter side and DFT at the receiver side. It has two types of mapping (1) Localized mapping (2) Distributed mapping. In the localized mapping the successive set of subcarrier outputs are mapped to a fraction of bandwidth where as in the distributed mapping complete bandwidth subcarrier is mapped.[4] SC-FDMA advantages include-PAPR reduced ISI and higher throughput. Disadvantages are more spectral leakage and complex transmitter and receiver. LTE support advanced implementing in the multiple antennas which makes the system robust by providing link stability, spectral efficiency and system capability. Based on the deployment scenario the techniques used are: Transmit Diversity: The technique incorporates the contest to multipath fading in the wireless communication. It sends the same copies of signal coded with differently to a multiple transmitting antenna. It is based on the techniques SFBC where four transmitting and receiving antennas are used. It is mainly used in the downlink channel and applicable user transmission like low data rate in the VoIP. Transmit diversity enhances the system efficiency and also cell range. Beam forming: From the multiple antenna of the LTE system transmitted signal of same copies are taken for weighted and each element is focused on a particular beam area towards receiver. It provides improvement in the reliability, capacity, coverage range, battery life, and SNR. It also provides angular information required for a user. Spatial Multiplexing: It uses multiple transmitter sand multiple receiver antennas for transmitting multiple streams of data by employing appropriate processor. It is suitable for light load conditions, good SNR and hence the peak data rate. It supports multiplexing up to four transmitting and receiving antenna. Multi User MIMO: It allows the multiple users with single antenna in the uplink channel. Signal coming from the MU-MIMO are separated at the receiver using CQI.

Motivation

In provisions of M2M communications features, a new standard of networks has to give respect for the machine in terms of cost and power.[5] For example smart meters take more battery power and device should operate in the ultra low power region. However future communication of the network will allow low complexity and small data rate which automatically supply low cost device and hence encourages M2M communication in larger quantity. Hence network architecture should be flexible to incorporate all these features and more. LTE standards support numerous technologies like CAT-0 and the CAT-M.[6] LTE-CAT-0 is fully marketable in the M2M communication. LTE-CAT-M is the LPWA technology which provides extensive area through cell sectoring, reuse cell. Comparing with the EGPRS modem cost, LTE-CAT-M modem cost reduces up to 25%. It supports all kinds of existing mobiles like 2G, 2.5G, 3G and the 4G mobile with the benefit of security. In contrast with the LTE-CAT-M, the NB-IoT adopted guard band features which reduce the bandwidth up to 180 KHz. In reality NB-IoT is considered has future gate for the M2M communication. Hence with the preamble of CAT-M and the CAT-N LTE standards, it is necessary to provide comprehensive background of the novel features and the solution. For realistic implementation of the machine it is very crucial and hence for this reasons our paper provides brief review on architecture, network technologies, design requirements and the challenges. Along with this the paper also reveals with evolutionary trail for the LTE-CAT-M and NB-IoT network for innovative research. In order to make the M2M communication efficiently we also discussed on LTE synchronization, channel evaluation and the cell search.

Contributions

The main contribution of this paper is:

1. LTE standard development cycle is discussed and shows the incentive for the M2M categories. The main features requirements for the M2M communication are compared along with the analysis.
2. Familiarize the basic concepts features of physical channels are discussed. The operation and functionalities of uplink and downlink physical channels are discussed.
3. Challenges and implementation are discussed with respect to the M2M communication.

Organization

The structure of the paper is organized as follows. Section II introduces the development cycle of the LTE standard for M2M communication. Section III provides summary on LTE architecture, highlight the importance channel structure, random access procedure and cell search. The challenges and implementation for the M2M communications are demonstrated in the section IV. Finally, conclusions are presented in Section V. The overall paper structure is shown in figure (1) and table (1) lists the notations used in the paper.

LTE Development For Machine To Machine Commuincation

The data transmission is mainly raised in the human adopted applications like M2M and cellular networks likes H2H communication. Some of the differences listed between M2M and H2H are [7]: Uplink data transfer will be more in the M2M communication as compared with the H2H communication. M2M communication has lower mobility than H2H communication. Human traffic will be more in day and evening where as M2M traffic is equally distributed all over the day. In general M2M device sends and receives a data through a packet, for a larger data the M2M devices might cause problems for accessing data like congestions in the network. Hence for this reasons, the 3GPP community provide suitable network for M2M connectivity. LTE network supports low cost, low complexity, afford extended coverage area for M2M devices, extended battery life for UE and optimize data transmission to serve large M2M devices. Enhancement of 3GPP for the requirement of M2M communication is discussed in the next.

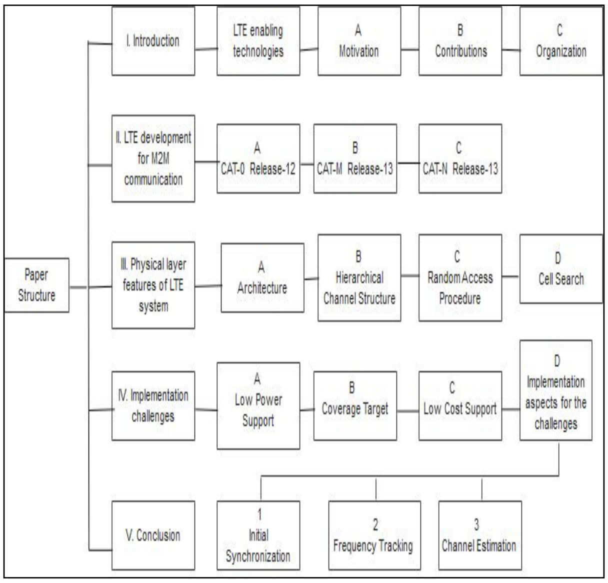

Figure 1.Chart for the paper structure

Table 1.Definitions of Acronyms

3GPP	3rd Generation Partnership Project
CQI	Channel Quality Indicator
DL	Downlink
EGPRS	Enhanced General Packet Radio Service
ISI	Inter Symbol Inference
LTE	Long Term Evolution
LPWA	Low Power Wide Area
M2M	Machine to Machine Communication
MIMO	Multiple Input Multiple Output
NB-IoT	Narrow Band Internet of Thing
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PAPR	Peak to Average Power Ratio
SC-FDMA	Single Carrier Frequency Division Multiple Access
SSS	Secondary Synchronization Signal
SFBC	Space Frequency Block Coding
UL	Uplink

CAT-0 in Release-12

CAT-0 is the new standard category in Release-12. It has decreased data transmission rate up to 1 Mbps for both UL and DL. Features includes one receiving antenna with a bandwidth of 20 MHz, and also supports half duplex communication with a relaxing time which further removes filters. Hence modem cost is reduced.

CAT-M in Release-13

It mainly addresses on LPWA and put up a strong industry attach for M2M communication. It maximizes the channel bandwidth up to 1.4 MHz, decreased complexity, prolongs battery life and supports high data rates.

CAT-N in Release-13

The design features includes enhanced network coverage area, supports QPSK modulation with a single receiving antenna, employ deep sleep modes for power consumption and the signal repetition is considered to get more gain.

Physical Layer Features of Lte System

The main objectives of the LTE standard are to create an efficient and streamlined protocol stack and architecture. In this section we provide brief summary on LTE Architecture, Hierarchical Channel Structure, Random Access Procedure and Cell Search.

Architecture

Along with the air interference, the LTE has flat and core network architecture. Here Flat indicates smaller nodes with least hierarchical structure. This system design makes the less cost and low latency. The low infrastructure of the LTE makes less interface, less protocol processing, few interoperability testing, optimized radio interface, easy to start the session and easy to merge some of the control plane protocol [8]. Figure (2) shows the overall architecture of an LTE system. The main component of LTE architecture is divided into two parts-(1) E-UTRAN (radio access network) and (2) Evolved Packet Core (core network) [9]. UE is the mobile terminal. eNode –B is the base station and it is first contact of User Equipment (UE). It provides the services between Physical and MAC layer for the function of mobility management, packet data scheduling, resources allocation for uplink and downlink, radio bearer management. Mobility management entity (MME) is responsible for the selection of gateway and tracking of the area management. It has similar function of GPRS. The function of the gateway is to termination of an interface and routes the packet into destination. It works as anchor for the MME. Also it has responsibility of charging and policy enforcement. S1 is the interface which separates E-UTRAN and EPC. It carries data in between eNode –B and S-GW. X2 is the high speed interface and support for all handover functionalities. Recently LTE-A (Advanced Long

Term Evolution) is developed which has high data rate and efficient spectral efficiency.[10] Carrier Aggregation (CA) and relay node are introduced in the LTE-A.[11,12] Relay node uses low power base station and hence increases the cell area which is in turn increases the cell capacity. Relay node supports heterogeneous networking.[13]

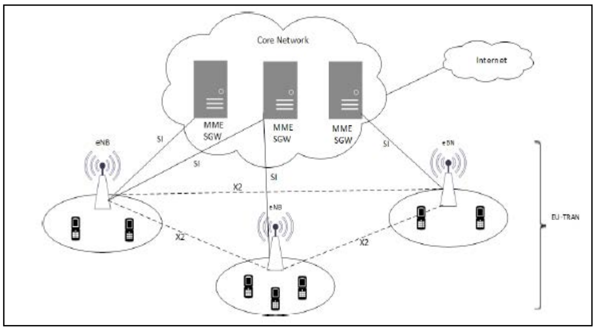

Figure 2.Overall architecture of an LTE system

Hierarchical Channel Structure

In order to provide sufficient support for a Quality of Service (QoS), LTE system it follows hierarchical frame structure.[14] Figure (3) shows the radio inference protocol architecture of the LTE system. It has three types of channel (1) Logical Channel, (2) Transport Channel and (3) Physical Channel. All the three channels are used to provide services between lower layers to upper layer. Logical channel gives type of data transmission and provide service between MAC and RLC. Transport channel offers services between PHY to the MAC. It is basically used to transfer the data above the radio interface like channel coding, antenna mapping and modulation system. Physical channel provides actual data transmission corresponding to resources blocks in time and frequency grid and carry the information to higher layers. Resource block is made up of resource element which is a smallest unit in the frequency domain. Some of the important channels used in the LTE systems are listed below.

Broadcast Channel (BCH): This channel is mainly used to broadcast information like bandwidth, antenna configuration, reference signal to the entire cell area and it is associated with downlink (DL).

Multicast Channel (MCH): It is a point to multi point channel associates with MCCH, MTCH and support to the Multicast/ Broadcast Single Frequency Network (MBSFN). It uses the number of synchronized data of the Base Station (BS) and send the same information to multiple users.

Paging: It is a downlink channel used to transform paging message to the registered User Equipment's in the cell area.

Dedicated Channel (DCCH): It is a bidirectional channel and dedicated only to a transmission of information to the UE and network.

Random Access Channel (RACH): It is only specific to the transport channel and transform tiny of amount data to the RRC states.

Downlink Control Information (DCI): This channel carries the information like scheduling, coding, TPC (Transmit Power Control) and modulation which are associated both UP/DL. It supports different 10 formats.

Control Format Indicator (CFI): It gives the symbols used in the sub frame. The valves takes from CFI=1or 2 or 3 and send to the physical channel.

H-ARQ Indicator (HI): It gives acknowledgement with respect to the link transmission send through physical hybrid indicator. HI=1 indicates (ACK) positive acknowledgement and HI-o indicates (NAK) negative acknowledgement.

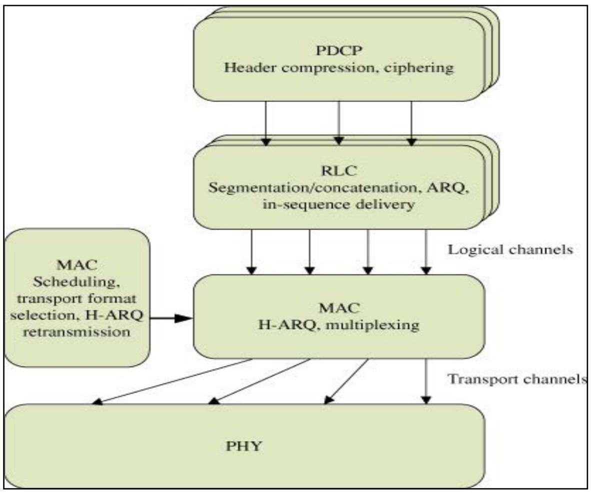

Figure 3.Radio interface protocol stack of LTE architecture

Random Access Procedure

When the UE starts communicating with eNode –B proper synchronization has to be done for suitable network condition.[15] Once the synchronization is completed the UE is undergo for random access procedure for the connection. Random access procedure is required to [16]:

- Get an initial access
- Reestablishment of connection if radio link fails
- Hand over between one eNodeB to other eNodeB
- Updating of UE location and for scheduling process

LTE supports two types of Mechanisms for Random Access

Non-synchronized random access: If the UE uplink is failed in the time synchronization this non-synchronized random mechanisms is used to notify the packet data to the user equipment.

Synchronized random access: It is used when the time synchronization is present in the uplink and its function is to data transmission for the scheduler from eNode-B.

Non synchronized random access procedure of an LTE system has four steps which is shown in figure (4).

Step 1: Random Access Preamble Transmission

When the multiple UEs transmit access call to the eNodeB randomly it selects orthogonal preamble for the next access slot. It utilizes the correlation-based mechanism and particular time slot for the successful guaranteed data transmission.

Step 2: Random Access Response

After receiving preamble the eNodeB starts sending messages includes back off indicator, timing instruction, uplink resource and scheduling is required for user equipment.

Step 3: Scheduled Transmission

This step is used to assist conflict resolution. It can be used to transmit additional data messages for the UL-SCH scheduling. It uses the device identity to avoid preamble collision. H-ARQ protocol gives support for the improvement of transmissions reliability.

Step 4: Contention Resolution

It sends the contention resolution of the messages to the DL-SCH for the response of user equipment and matches the messages between identity transmitted and identity also it checks the message is not received. If the message is not received it understands that collision has occurred and makes an arrangement for the next user equipment. H-ARQ will give successful acknowledgment.

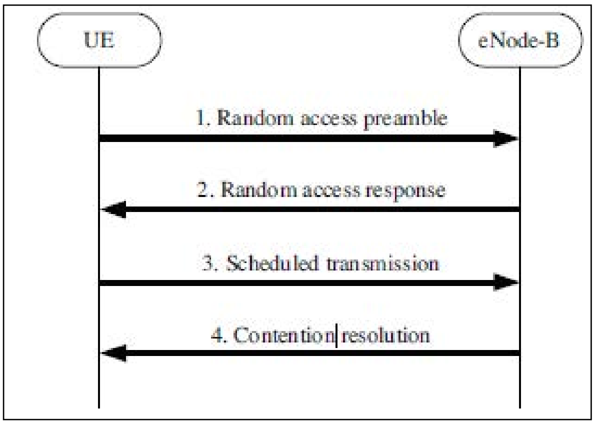

Figure 4.Non Synchronized Random Access Procedure

Cell Search

When the User Equipment's powers ups, it requires frequency and time synchronization for a cell and finds cell ID via cell search or synchronization method. This synchronization is important due to both orthogonality in the uplink and downlink intra-cell transmission. Cell search includes timing synchronization, frequency synchronization, and identification of cell bandwidth, configuration of an antenna and length of the cyclic prefix. It has hierarchical cell search which is shown in figure (5). The primary step carriers the physical ID group [$N_{ID}^{(2)}$=0,1,2] and the secondary synchronization carries the physical signal ID group [$N_{ID}^{(1)}$=0,1,.......167]. In the initial step the user equipment identified the symbol timing, frequency and cell ID$N_{ID}^{(2)}$ and it is achieved by using filtering of the received data signal and proper synchronization processes. Sequences. Timing of the OFDM symbol is detected but not frames timing. In the second step cell ID group $N_{ID}^{(1)}$ and the frame timing is detected. Miss pair of sequence in the synchronization signals like (d1, d2) as mentioned as (d2, d1) is prohibited. Resolving this property takes 5minutes. In the last step broadcasting of the channel information like bandwidth, frame of the system, antenna number etc from the PBCH.

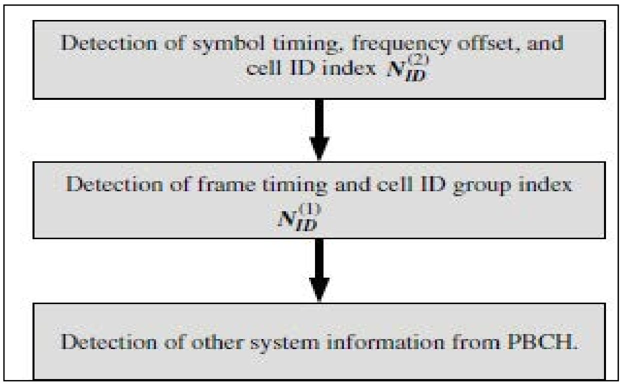

Figure 5.Cell search process

Implementation Challenges

Various implementation challenges faced by the M2M communication are summarized in this section.

Low Power Support

Longevity of device battery depends on the utilization of the device on various statuses like idle, sleep mode and connected mode. In 3GPP Release-12, the Discontinuous Reception (DRX) negotiates the network power up to 2.56 sec and Release-13 extended up to 10.24 sec. Still, further extension leads to the effect on RAN functionality like accuracy and mobility.

Coverage Target

The link budget of 3GPP is 142.7 dB whereas link budget of NB-IoT is 164dB. Improvement of 20dB margin leads to low data rate, seven time increase in the coverage area or loss due to the signal penetration of the outer wall of a tower. Simultaneously it also meets the latency, battery life and data rate.

Low Cost Support

Low cost design leads to the less features with less performance. For instance, facilitate convolution codes for decoding, spatial diversity for transmitting and receiving antenna, advanced signal processing for synchronization, simple switch for filter, adopting HARQ, channel estimation for the entire sub frames will need to be updated. Reducing the cost also depends on the hardware module and also achievement of optimized algorithms will not be unique for various modules of the system.

Implementation Aspects for the challenges

Initial Synchronization

There are many techniques are adopted for initial synchronization like cell search. Probability detection with processing time is shown in figure (6) under Secondary Synchronization Signal (SSS) condition for an SNR=-6dB and -15dBs.[17] Many algorithms are approached for channel estimation, about limited antenna ports and use of SNR. One of the important approaches is the time averaging with SSS detection rate. Here detection rate can be increased by enhancing the average period. But high Doppler Effects are not considered for harsh environment.

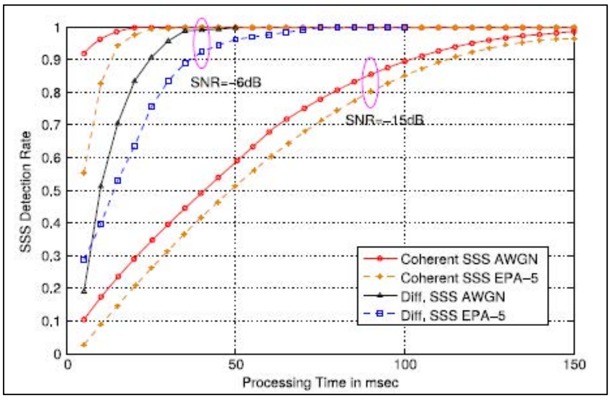

Figure 6.Probability detection versus SSS processing time

Frequency Tracking

Tracking of frequency is required due to the uncompensated errors and Doppler Effect. With the introduction of LTE in M2M communication there are two issues are arises (1) Frequency tracking becomes is deactivated for a period of EDRX cycles and also it requires re-synchronization for DRX. (2) Frequency tracking error due to enhanced area with low SNR. In [18] have proposed repetitive approach for broadcast channel mapping especially for the support of enhanced coverage area but it cannot be employed for a cell area of 1.4MHz.

Channel Estimation

Channel estimation is the biggest challenges for M2M communication when it will to the different chain processing. In[19] have presented Minimum Mean Squared Error (MMSE) in which channel estimation is done based on the knowledge, statistics and SNR. Further robust channel estimation is done through MMSE where filter coefficients designed for worst case of the channel conditions and it is used in the cost of minor performance degradation [20]. Conversely, LTE M2M communication needs special treatment to maintain low complexity, deep coverage conditions and high speed channels. In order to reduce the effect of channel differential cross-correlation is adopted. Significant degradation of the Channel State Information (CSI) is shown in the figure (7) along with the decision statistic for M windows. Simulation results of the Cell detection for M2M communication indicate the averaging windows of the statistics. Comparison of differential cross correlation with direct correlation is done by keeping known valves of CSI.

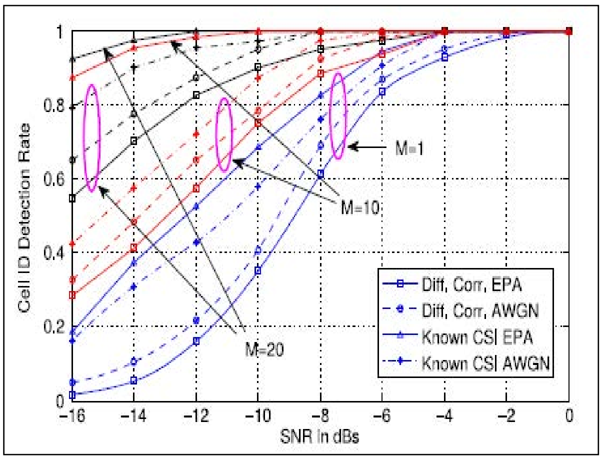

Figure 7.Simulation of the cell detection for M2M communication

Conclusion

Rapid development of M2M technology leads to use in many platforms and also it forms the basic foundation for Internet of Things in which billions of the devices is going to be connected in upcoming future. Long term evolution is one of the gifted technologies for the M2M communication, which has high spectral -efficiency network, very low latency and extensive coverage area. Still numerous deployments are included in LTE network for the new M2M technologies. In this paper we presented the development of LTE for M2M communication with respect to the specifications and the limitations. It is argued that traditional coverage enhancements techniques are not relevant for the new categories. New alternatives are discussed to remove diversity gain and also we present some of the challenges and its implementation towards low power and low cost.

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