

Cognitive M2M: An Emerging Technique towards Internet of Things

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Abstract

Internet of Things (IoT) is growing day by day and becoming the part of human daily life. Internet of things is a global network of different connected machines or devices which uses intelligent interfaces for smart communications. Machines are communicating each other in order to exchange information to achieve smartness which in turn called IoT (Internet of Things). Machine to machine communications (M2M) act as a enabling technique towards IoT. Cognitive radio technology is introduced into M2M for the improved performance. This paper investigate the use of cognitive M2M in the area of smart technologies. Performance results show that cognitive M2M achieves greater throughput and energy efficiency when compared with noncognitive M2M.

Keyword : Machine to Machine, Internet of Things, Cognitive Internet of Things

difficult task to design interfaces for these large number of machines for effective communications. M2M communications is not a new scenario. It is an already existing mechanism. Long years before, machines equipped with sensors have to be manually controlled. This had occurred before the persistence of modern network techniques. M2M communications [10] are what with less or no human interventions. In other words, M2M communications can be called as internet of things or web of things or web of objects etc. Autonomous ubiquitous seamless communications are the basic requirements. M2M communications can be either direct or indirect depending on the specific application requirements. Thus M2M plays a significant role in intelligent services like IoT for an improved performance. The figure below depicts the normal scenario of M2M communications.



Fig. 1: Basic M2M Communications

1. Introduction

In the coming era, M2M communications is going to be an indispensable part of daily life which makes life easy and comfortable. M2M allows both wired and wireless devices to connect with other devices of same type. M2M communication is the communication between devices through internet, wifi, zigbee etc. Different benefits and technical advantages of M2M paves a new way into IoT. The research work in this area is still continuing in its infancy.

According to current estimations, within 10 years billions of devices will get connected to internet. It is a

- Node domain: Each of nodes are equipped with sensors for monitoring purposes and transmit packets to network domain through gateway.
- Network domain: It provides reliable channels for communication between node and application domains.
- Application domain: It act as storing domain for all sensed data from node domain.

Cognitive M2M is a technique that integrates two technologies: M2M and cognitive radio. Normal M2M suffers from different problems such as spectrum scarcity, spectrum availability etc. These challenges are well

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addressed and solved using this cognitive M2M technique. Cognitive M2M can be utilised for smart applications like smart city etc for improved performance and throughput.

2. Related Works

Cognitive Internet of things (CIoT) [11] is a new network paradigm where things or objects are interconnected and behave as agents for exchange of data with less human interventions. It follows the principles of artificial intelligence. CIoT mainly aims to achieve two goals: integration of physical and social environments and building of intelligent system for enabling smart communications. Cognition into IoT improves performance and solves issue like spectrum scarcity etc. Its merits includes saving of time and effort, improved resource utilisation etc. The cognitive process includes involvement of four layers:

- Sensing control layer - senses the environment through perceptrors and actions are taken via actuators.
- Data semantic knowledge layer- analyses the sensed data to form useful knowledge
- Decision making layer - captures information from the lower layer and makes decision regarding suitable actions
- Service evaluation layer - evaluate the services provided and send back the evaluation result to the cognition process.

M2M communications are deployed in e-health and smart grid applications. Based on the estimations, it is clear that there is an increase in number of heart patients as well as diabetes patients. Many of them are requiring active implantable devices for remote monitoring purposes. M2M communications are required for enabling e-health applications. Sensors are deployed around the patient to estimate heart rate, weight, blood pressure etc. Remote monitoring can be done, alarms can be triggered when critical conditions are met and remote controlling can also be done whenever required. Sensed information from patients are communicated to remote server through short range technologies.

There are several reasons behind the introduction of cognitive internet of things into the smart environment. It is clear that billions of devices get connected each other by near future. This results in different challenges like

interference issues, spectrum scarcity etc. Cognitive radio technology is provided with dynamic spectrum access capability which in turn avoids spectrum congestion. Operations in unlicensed bands results in significant interference issues causing performance degradation. Thus there is a requirement to explore spectrums like TV white spaces which of significant bandwidth availability (50-150 MHZ) and is available based on geographical factors. Cognitive radio usage is defined as green as they can adjust their transmissions based on operating environments. For M2M communications different protocols are used and PRMA protocols sounds more attractive due to suitable handling of traffic and efficient resource utilisation. Energy utility factor must be taken into consideration in these scenario since battery replacement is not feasible in certain areas. With PRMA [10] based protocol , once reservation is done , there will be no collisions or interference which are the causes of poor performance. PRMA based protocols can be well deployed in large scale M2M networks economically. The term M2M and IoT is rather confusing and is used interchangeably. M2M is considered as subset of IoT as shown below.

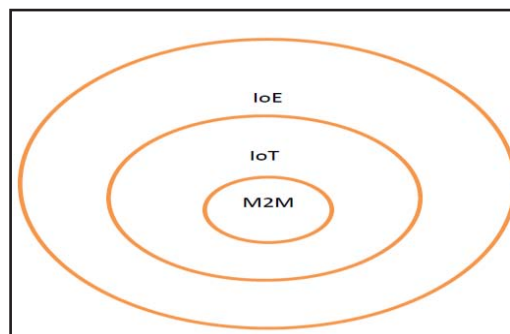


Fig. 2 :Relationship between IoT and M2M

Table 1: Comparison between IoT And M2M

Features	M2M	IoT
User interface	no	no
Environment	closed	open
Connectivity	Non-IP to device	IP to device
Marketing ben-efits	Less significance	More significance
Security issues	less	more
Applications	Telecom only	Telecom, cloud etc
No of connected devices	less	more

3. Proposed System

M2M communication is not a newer technique. It is a closed approach enabling communication between devices thus achieving telecom applications. It faces different problems and is listed below

- Spectrum scarcity - This happens due to the increasing number of M2M devices.
- Interference - Operations in unlicensed bands results in interference issues which results in performance degradation.
- Coverage issues - Some devices will be located in the areas where wireless connectivity is not feasible.
- Energy consumption - Some devices may consume huge power and will be located in areas where battery replacement is not always possible.
- Device heterogeneity - M2M communications involves wireless and wired connectivity between other devices of same type.

Due to these limitations, cognitive radio technology is incorporated into M2M to achieve better throughput and hence the performance. The proposed cognitive M2M system is shown below

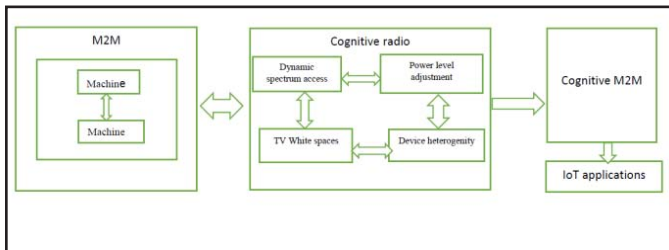


Fig. 3: Cognitive M2M

M2M communications is limited to telecom applications and connect devices to devices. QoS requirements in M2M communications are specific to the applications. It poses significant constraint in resource utilisation. Cognitive radio module includes following parts:

1) Dynamic Spectrum Access

Cognitive radio is provided with dynamic spectrum access capability so that existing spectrum can be effectively utilised in order to avoid the shortage of spectrum. Spectrum will not be always available at all geographic areas since applications to be considered are mobile.

2) TV Whitespaces

Operation in unlicensed bands results in interference issues causing performance degradation. Thus there is a need to explore spectrum opportunities such as TV whitespaces. TV Whitespaces refers to a large portion of UHF/VHF band that is becoming available based on geographic conditions. Significant bandwidth are available (50-150MHz).

3) Power level Alteration

Use of cognitive radio technique is considered to be green or efficient as it can adjust transmission level depending on operating environments. Energy efficiency can be well achieved with PRMA protocols. High energy efficiency leads to prolonged life time.

4) Device Heterogeneity

Cognitive M2M communications are heterogeneous in terms of protocol and data formats. M2M communications are usually with devices of same type. Different protocol stack have to be used for cognitive M2M communications. Table II shows different protocols at different network layers. Table III shows a comparative study between two techniques based on certain metrics.

The protocol stack of Cognitive M2M should fulfil the following requirements:

- **Energy efficient protocol stack** - Protocol stack should exhibit lower power consumption. Many of M2M devices are battery operated and has no ability to draw power from mains.
- **Internet enabled protocol stack** - M2M communications are internet enabled/IP enabled ie connecting IP to the devices
- **Highly reliable protocol stack** - Reliability must be addressed at protocol stack layers since lossage of data occurs due to link failure.

Table 2: Cognition Enabled Protocol Stack

Layers	Protocols
Application	CoAP
Transport	CRAHN
Network	CORPL
MAC	CRB MAC
Phy	802.15.4m

Besides the improvement in protocol stack lots of other enhancement can be integrated with this cognitive radio technology:

- Cooperative spectrum sensing techniques can be incorporated for improved channel detection performance
- Cross layer design leads to significant performance improvement through the optimisation of parameters at different layers.
- Joint design of CORPL with PRMA protocol can also be explored.
- Cognitive protocols must be also context aware to meet diverse QoS requirements.

Different protocols to be integrated with M2M communications includes:

1) IEEE 802.15.4

It provides PHY layer specifications for M2M networks. It is designed to operate in unlicensed band (2.4-2.485GHZ). M2M networks introduces significant challenges at PHY layer due to resource constrained nature.

2) CRB MAC

It is a receiver based MAC protocol. It exploits the broadcast nature of wireless technology. It mainly aims to meet energy efficiency and reliability requirements of M2M networks and follows preamble sampling approach.

3) CORPL

Routing in cognitive environments are worth challenging since routing protocols had to account for temporal and spatial protection, optimisation of operation of primary and secondary networks. The main objective of cognitive and opportunistic protocol is to retain directed acyclic graph and it follows a opportunistic forwarding approach.

4) Transport Layer and Above

TCP protocols is adopted for cognitive environments. It mainly accounts for periodic spectrum sensing, PU activity etc. TP-CRAHN protocol integrates additional

functionalities like spectrum sensing and switching functionalities apart from congestion control, flow control etc. Since cognitive M2M introduces variety of new applications, CoAP is considered as standard application protocol.

Table 3: Comparison between Cognitive M2M and M2M

Metrics	Cognitive M2M	M2M
Throughput	high	low
Energy consumption	low	high
Spectrum availability	high	low
Interference	low	high
Coverage	high	low
Reliability	yes	no
IP enabled	yes	no
Device heterogeneity	yes	no

4. Analysis

1. Throughput

Detailed performance evaluation of cognitive M2M over normal M2M communications has been carried out through analytic modelling and simulation studies. Cognitive M2M provides better throughput than the former one since it is provided with dynamic spectrum access capabilities and energy efficient approach. Cognitive M2M explore the usage of TV whitespaces which meets significant bandwidth requirements. Throughput is measured in terms of signal to noise ratio and threshold probability of detection while keeping energy consumption and interference to minimum. Channels are considered to be noisy. Throughput T is calculated using the following equation:

$$T = (\text{transmission rate/success rate}) * P \quad (1)$$

Where P = probability which is the function of SNR and SNR is defined as signal to noise ratio based on Shannon theorem

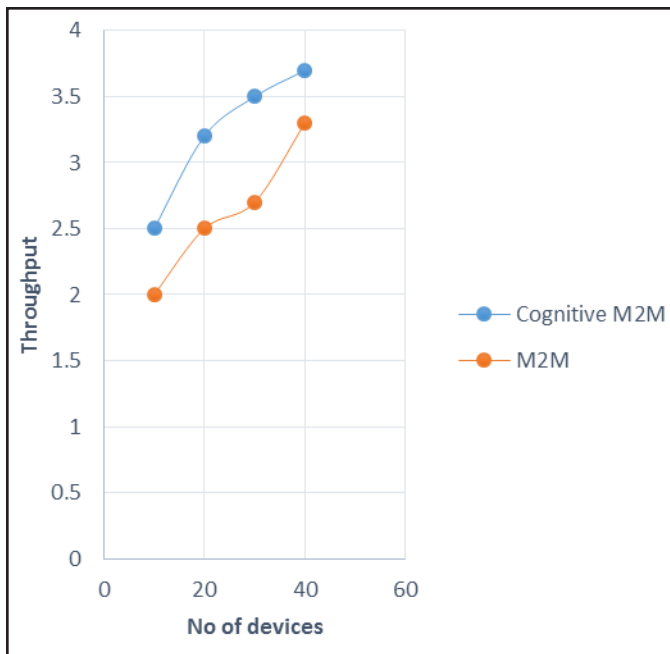


Fig. 4: Analysis of Throughput

2. Energy Consumption

Usage of cognitive technology is considered to be green since it adjust its transmission levels based on operating environment conditions. Energy utilisation contributes a lot to network lifetime. Energy efficient technology only leads to prolonged lifetime of the network. Normal M2M technique may operate in unlicensed band resulting in interference issues and causing performance degradation. Its energy consumption is more when compared to cognitive technique. Machines may be deployed in areas where battery replacement is not always possible. This also results in poor performance of M2M when compared with M2M technique.

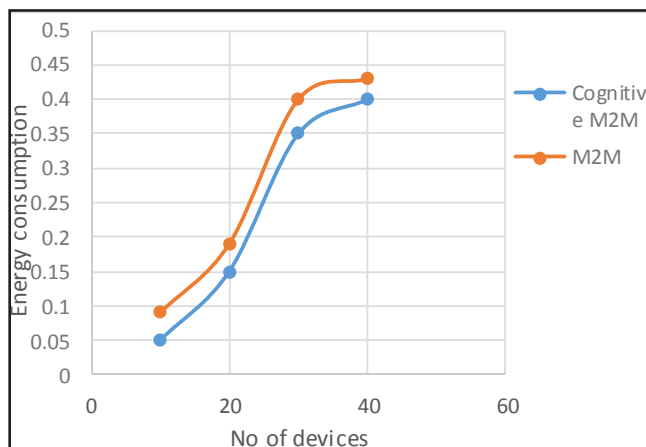


Fig. 5: Energy Consumption

5. Conclusion

M2M communications act as enabling platform for Internet of Things. M2M communications are suited for different applications such as smart city, smart home etc. But it faces different challenges like spectrum scarcity problem, energy consumption and interference issues etc. This all results in performance degradation. Cognitive radio technology can be integrated with this M2M communications for wide range of spectrum availability through its dynamic spectrum access capability. TV whitespaces can also be explored to reduce interference issues as well. Thus cognitive M2M can be utilised for different IoT applications with improved throughput and performance.

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