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AGRICULTURAL MONITORING REMOTE SENSOR USING MACHINE TO MACHINE COMMUNICATION

[1]M.GOWTHAMI | [2]N.R.SIVARAJ

[1]PG Student, Jayalakshmi Institute Of Technology,Thoppur,

[2]Asst professor, Jayalakshmi Institute Of Technology,Thoppur.

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ABSTRACT

Machine-to-Machine (M2M) communications enables networked devices to exchange information among each other as well as with business application servers and therefore creates what is known as the Internet-of-Things . The research community has a consensus for the need of a standardized protocol stack for M2M communications. On the other hand cognitive radio technology is very promising for M2M communications due to a number of factors. It is expected that cognitive Machine-to-Machine communications will be indispensable in order to realize the vision of IOT. However cognitive M2M communications requires a cognitive radio enabled protocol stack in addition to the fundamental requirements of energy efficiency, reliability, and Internet connectivity. The main objective of this paper is to provide the state of the art in cognitive M2M communications from a protocol stack perspective. The paper covers the emerging standardization efforts and the latest developments on protocols for cognitive M2M networks. Besides, the paper also presents the authors' recent work in this area, which includes a centralized cognitive Medium Access Control (MAC) protocol, a distributed cognitive MAC protocol, and a specially designed routing protocol for cognitive M2M networks. These protocols explicitly account for the peculiarities of cognitive radio environments. Performance evaluation demonstrates that the proposed protocols not only ensure protection to the primary users (PUs) but also fulfill the utility requirements of the secondary M2M networks.

1. INTRODUCTION

The communication industry has seen a tremendous growth over the last two decades. A plethora of technologies exist today with a single objective of providing ubiquitous connectivity between people on the planet. The next big thing in communications would be a truly connected world of not only the people but also the everyday objects.

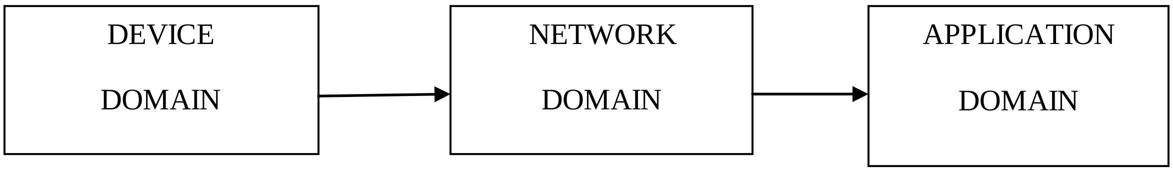

Fig.1. Protocol structure for M2M communications

Therefore, this decade is widely predicted to see the rise of connected devices that are not mobile phones and do not require human control. Machine-to-Machine (M2M) communications is an emerging communication paradigm that provides ubiquitous connectivity between devices along with an ability to communicate autonomously requiring no human intervention. M2M communications acts as an enabling technology for the practical realization of Internet-of-Things (IoT). Market size projections show a large potential for M2M market that is expected to grow rapidly in the next few years. This is due to a number of factors including the widespread availability of wireless technologies, declining prices of M2M modules, and economic incentives. Some of the most prominent M2M application areas include security and public safety (surveillance systems, object/human tracking, alarms etc.), smart grids (grid control, industrial metering, demand response), vehicular telematics healthcare (telemedicine, remote diagnosis, etc.), manufacturing, and remote maintenance, vending machine control etc.) M2M communications will be realized through a range of technologies and networks. Wide area connectivity is provided through a gateway. Capillary M2M networks are generally characterized by huge number of low cost and low complexity devices, requirements of high energy efficiency and reliability, unplanned deployments, high packet loss ratios, use of low power link layer technologies, etc. Despite active research on M2M communication, especially over the last couple of years, cognitive M2M communications is still a vastly unexplored field with only a handful of studies. The main objective of this paper is to provide the state of the art in cognitive M2M communications from a protocol stack perspective. To the best of our knowledge, this is the first study on protocol aspects of cognitive M2M communications.

2. M2M COMMUNICATIONS

Cognitive radio technology provides as a novel approach to address the spectrum scarcity and spectrum inefficiency issue in wireless networks. In cognitive radio networks, unlicensed users dynamically access the frequency band/channel whenever the licensed user (primary user) is absent and need to vacate the band/channel whenever the latter is detected. There are several motivations for using cognitive radio technology in M2M communications (and hence the term cognitive M2M) . Spectrum Scarcity: A fundamental challenge in M2M is the ever increasing number of M2M devices.

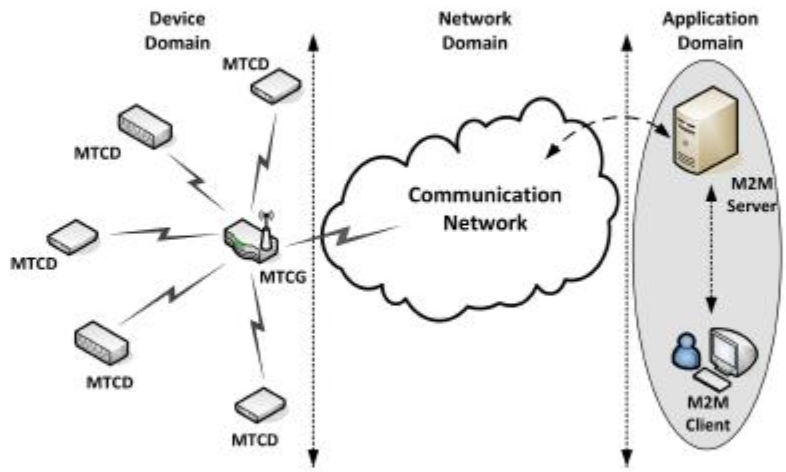

Fig.2. Network topology and frame structure for PRMA-based cognitive MAC protocol

It is expected that a multitude of connected devices will exist in near future. Interference: With a multitude of connected devices operating in unlicensed bands, significant interference issues will arise between self-existing and co-existing M2M networks. This will not only deteriorate the performance of M2M network, but also adversely affect the conventional Human-to-Human (H2H) services operating in the unlicensed bands. Device Heterogeneity: M2M networks are diverse in terms of applications and services which may cause diversity in network protocols and data formats. The cognitive ability is particularly suitable for M2M communication in order to deal with device and protocol heterogeneity as M2M networks will be more efficient and flexible if devices are smart enough to communicate with others freely.

From networking perspective, IETF WPAN protocol will be instrumental in connecting M2M devices to the Internet. 6LoWPAN bridges the gap between Internet and low power M2M devices by providing IPv6 networking capabilities through special encapsulation and header compression techniques that allow IPv6 packets to be sent over low power link layer technologies. Given the low power and lossy nature of M2M networks, routing issues can be very challenging. IETF has recently standardized an effective routing protocol known as RPL (Routing for Low Power and Lossy Networks), which is capable of quickly building routes, distributing routing knowledge among nodes with little over head, and adapting topology in an efficient way. RPL is expected to be the standard routing protocol for majority of M2M applications including smart grid.

3. PHY LAYER FOR M2M NETWORKS

The resource constrained nature of M2M devices creates various challenges for the PHY layer design of cognitive M2M networks. Some of the main challenges include low complexity Software Defined Radio (SDR) based transceivers for energy efficient reconfigurability operations, lightweight spectrum sensing algorithms with high detection probability, and low cost dynamic spectrum access solutions that require minimum overhead. While a lot of research exists on conventional cognitive radio architectures, spectrum sensing algorithms, and spectrum access solutions, the aforementioned challenges have been rarely addressed in literature. The IEEE 802.15.4m TG provides the PHY layer specifications for cognitive M2M networks working in TVWS. Till date, seven different PHY layer designs in seven different regulatory domain specific frequency bands. However these designs are mainly from modulation and coding perspectives only. Moreover, there is little investigation on the complexity of these designs for cognitive M2M networks.

4. RESULTS AND DISCUSSION

In order to implement this protocol stack in cognitive M2M networks, M2M devices must be equipped with cognitive functionalities. From feasibility perspective, an important concern is that such functionalities are considered to be complex and expensive for low cost M2M devices.

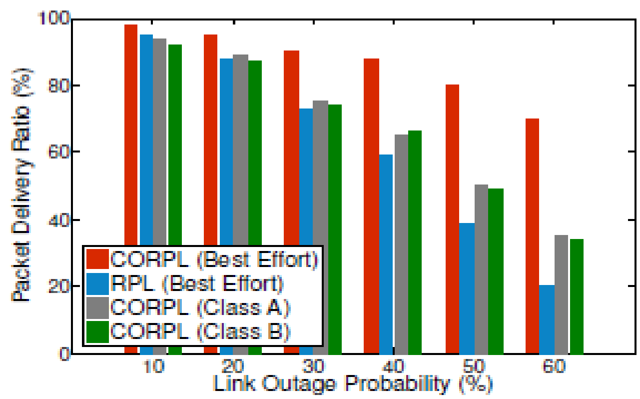

Fig.3. Packet Delivery Ratio

However, with recent advances in microelectronics and signal processing communities, M2M devices are becoming increasingly sophisticated to perform spectrum oriented operations. From practical perspective, not all M2M devices in a network need to be fully equipped with cognitive functionalities. For example,

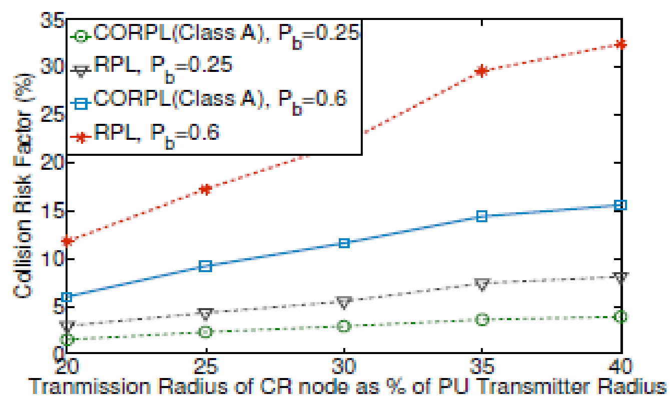

Fig.4. Collision Risk Factor

in a centralized architecture, as proposed in the PRMA-based cognitive MAC , a master-slave operation can be provided such that another node provides cognitive functionalities for M2M devices.

CONCLUSION

M2M communications is an enabling technology for the practical realization of the IoT. M2M communications will revolutionize every aspect of present day life by creating smart homes, smart grids, smart transportation, smart buildings, and smart cities. Cognitive radio technology will play a crucial role in realizing the vision of IoT. In this paper, for the first time, the use of cognitive radio technology in capillary M2M networks has been investigated from a protocol stack perspective. Successful operation of cognitive M2M requires an energy efficient, reliable, and Internet-enabled protocol stack with cognitive radio aware protocols from PHY to transport layer. Apart from highlighting the key challenges at different layers and the emerging standardization efforts, the paper covers the latest developments on protocols for cognitive M2M networks.

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