A Comprehensive Study of M2M Area Networks and Challenges

S.Shiva Prakash,
Dept. of CSSE,
Sree Vidyanikethan Engg. College, Tirupati.
shivasthaneekam@gmail.com

Prof.C.Madhusudhana Rao,
Dept.of CSSE,
Sree Vidyanikethan Engg. College, Tirupati.
hod_csse@vidyanikethan.edu

Abstract---Machine-to-Machine (M2M) communication technologies has emerged as finest technology for next generation communication, and is moving beyond its decades of use in utilities, transport, and heavy industry in the mainstream, empowering companies to deliver a real value. This paper presents an investigation of M2M Area Network technologies such as Wi-Fi, Bluetooth, and ZigBee etc for each of major M2M applications. The major M2M applications include smart grid, home automation, remote health monitoring and industrial applications such as agriculture, mining, environment monitoring etc. For each application, there is only one specific networking technology that industry is promoting, though many available. Therefore, there is a need of Standard M2M Area Network which supports every M2M application with optimal performance. We also mentioned challenges of implementing the standardized network technology and certain important characteristics of an optimal M2M Area Network.

Key Words: M2M, Wi-Fi, Bluetooth, Ultra-Wide Band, ZigBee.

I. INTRODUCTION

M2M communication is on the rise. There will be more machines connected to the Internet than human beings in the next decade. M2M technologies transfer data on the condition of physical assets and devices to a remote central location for effective monitoring and control. While M2M concepts and technologies have been in use for quite some time, the changing business scenarios and newer use cases are acting as growth stimulants.

While M2M growth projections are high [6], the related ecosystem has been unable to keep pace with the complex requirements. In addition, the current M2M market is highly fragmented and standardization levels are low. There are a number of diverse players that need to collaborate to arrive at a specific solution. Whether it's the end equipment, the connectivity piece, the middle-ware, or the back-end systems – there are multitude of options available for any M2M use case.

The rest of the paper is organized as follows. First an overview of M2M communications is given. Then we discuss different possible M2M Area Networks for different applications. We also compare popular networking technologies by assigning priority for popular application. And then, we discussed challenges and guidelines for standard M2M Area Network. Finally, concluded this paper.

II. OVERVIEW OF M2M COMMUNICATION

M2M uses a device (sensor, meter, etc.) to capture an 'event' (temperature, inventory level, etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates

the captured event into meaningful information (e.g., items need to be restocked). M2M communication is about flow of data from a device capable of sensing data (sensors) to a remote server where data undergo processing and assessment. From server, applications will access data based policies between user and provider. M2M allows a wide variety of machines to become nodes of personal wireless networks, and provides to develop monitoring and remote control applications. This will decrease costs for involved human resources and will make machines more intelligent and autonomous.

Many standards [1] are moving quickly to support M2M communications and architectural requirements. To mention a few standards, ETSI, 3GPP, GSMA are popular. We discuss M2M communication by referring ETSI standards.

A. ETSI M2M Elements and Network Architecture:

European Telecommunication Standards Institute (ETSI) defines M2M system [2] as a combination of M2M Elements. The following are M2M Elements:

- *M2M Device:* a device capable capturing data and sending data.
- *M2M Gateway:* equipments capable of internetworking several M2M Devices.
- *M2M Area Network***:** provides connectivity between M2M device and M2M Gateway.
- *M2M Application:* software resides on devices and gateways capable of providing services.
- *M2M Core Network:* network which carries information processed, from M2M gateway to M2M Network Domain. Network like 3G, 4G, Internet etc are consider for core networks.

M2M Network Architecture shows collection of above elements in a structured manner. The following diagram shows the simple M2M network architecture.

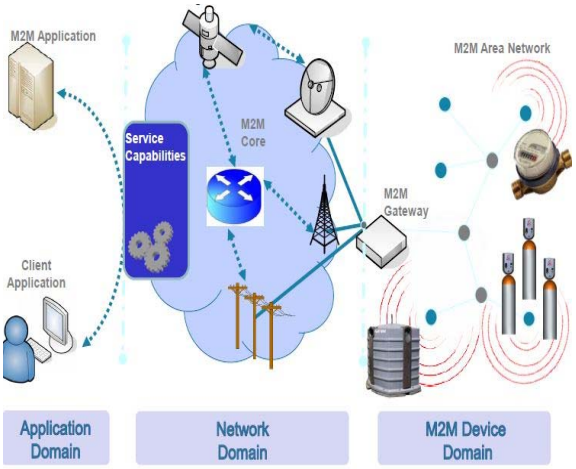

FIGURE I. *A SIMPLE M2M ARCHITECTURE*

Advances in wireless communication technologies are the key enabler for M2M communication. Network technologies like Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4), Ultra Wideband (IEEE 802.15.3a), Wi-Fi (IEEE 802.11) etc are used for connecting nodes have lower resources such as sensors, mobile phones, PDAs etc. The above mentioned Personal Area Networks and Wireless Networks are best suited as M2M Area Networks.

Active forums are still developing above technologies to support M2M architecture.

B. Popular M2M Applications:

- *Asset Tracking:* Asset tracking is an important application in large industries, retails shops, super markets etc. Asset

tracking involves finding location of an entity.

- *Remote Health Monitoring:* A patient health is monitored with help of medical devices from a hospital or an expert's place.
- *Smart Metering:* An electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes.
- *Smart civic services:* Remote monitoring of trash cans by M2M enabled devices and sending SMS to civic authorities when clearing and replacement is needed.
- *Home Automation and Appliances:* Remote monitoring of house premises and communicating with a AC, Refrigerator etc.
- *Smart traffic control:* A set of devices that monitor traffic in a city and communicate the information to the city's traffic lights in order to regulate the flow of traffic (Los Angeles traffic center uses M2M for monitor traffic in real time).
- *Water Treatment:* Sensors placed in strategic locations near or around the raw water supply and also placed on various stages of the treatment process, these sensors will send real-time data to monitor the water levels.

III. STUDY ON M2M AREA NETWORKS

The Goal of the M2M hardware is to bridge the intelligence in the machine with the communication network. An Intelligent wireless data module is physically integrated with the monitored machine and programmed to understand the machine's protocol.M2M Area Networks carry data collected by M2M devices to a M2M gateway for further processing of raw data. Device manufacturers are allowing devices to support only one network technology which perform optimally constrained to that application only. The following study presents a how different M2M Area Networks support different applications.

A. Wi-Fi (IEEE802.11)

Wi-Fi is a popular technology that allows an electronic device to transfer data wirelessly over network. In Home automation, Smart grid applications, Wi-Fi is considered with low priority. Though it provides with greater data rates over large area, because of its high power consumption of devices prioritized to less.

In Remote Health Monitoring applications 802.11b/g and 802.11a (2.4GHz) standards [3], are considered more priority. These standards provide reliable high speed implementation and provide security mechanisms such as Authentication and Encryption of messages. These Security measures play big role in sensitive medical data. Wi-Fi also provides too many configuration choices for devices which cause more power consumption. Wi-Fi Direct can also be considered because of its reduced set up costs and enhanced security measures.

In Industrial applications such as forest monitoring, agriculture, retail checkouts etc, Wi-Fi is not considered as ideal technologies. Though it supports Ipv6 addressing, power consumption is main factor that puts Wi-Fi back in the race.

B. Bluetooth (IEEE802.15.1)

Bluetooth is wireless technology standard for exchanging data over short distances from fixed or mobile devices, creating Personal Area Networks (PANs) with high levels of security.

In Home automation, Smart grid applications, Bluetooth is considered with low priority because of its low data rate. Though it consumes low power, due to its limited number of devices per network (8 devices allowed) is less preferred. As number of devices, multiple networks has to be formed which causes high communication latency.

In M2M Medical Devices, Bluetooth is most preferred technology for many reasons. Though it provides low data rates, because of its robust radio design and frequency radio hopping provides very strong immunity to RF noise sources. New version of Bluetooth, Bluetooth Low Energy (BTLE) 4.0 provides very strong power management mechanisms *Health Device Profile (HDP***)** is a profile developed by Bluetooth, which is specifically for manufacturing health care devices [4].

In other M2M applications, Bluetooth is less preferred for its low range and low data rates.

C. Ultra-Wide Band (IEEE802.15.3a)

Ultra-Wide Band (UWB) is radio technology which may be at very low energy level for short range, high bandwidth communications using large portion of the radio spectrum.

In M2M applications, UWB is preferred very less preferred. Though it provides high data rate communication (1Mb/sec), due to its high power requirements it stayed in backseat. Another important reason for not using UWB is that there are no further improvements on IEEE802.15.3a, because Task Group (TG) is dissolved.

D. ZigBee (IEEE802.15.4)

ZigBee is a specification for a suite of high level communication protocol using small low power digital radios based on IEEE 802 standard for personal area networks.

In Home appliances and smart metering applications, ZigBee is highly preferred for its low power consumption and long life time of devices. Cluster based tree, self healing mesh network characteristics of ZigBee provides flexible configuration of M2M devices. Using ZigBee, M2M devices need less configuration efforts because of CSMA/CA.

In M2M Health Care applications, ZigBee is moderately preferred because of its low power consumption and ZigBee Health Care (ZHC) standard. ZHC is standard for Health Care Medical device manufacturing.

ZigBee is more robust for Industrial applications. ZigBee power consumption is lower compared to classical Bluetooth. The following diagram show comparison of power consumption in case of different communication technologies.

The below diagram show comparison of different networking technologies [5] against power consumption parameter.

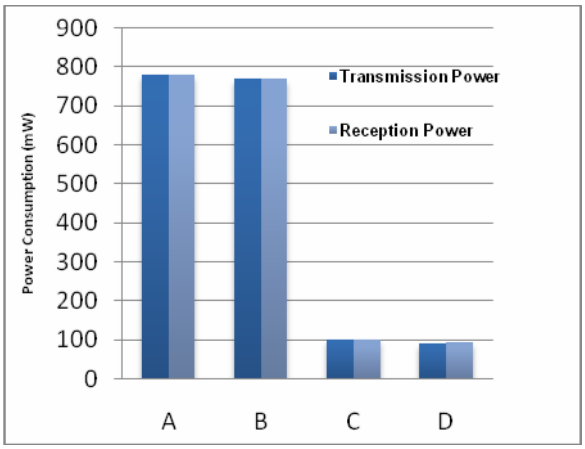

FIGURE II. *COMPARISION OF COMMUNICATION TECHNOLOGIES.*

IV. COMPARISON OF NETWORKING TECHNOLOGIES (VS.) M2M APPLICATION

This sub-section provides a summary of above investigation in M2M Area Networks and its utilization in M2M applications. We presented a summary in tabular form with ratings for networking technologies.

The priority for networking technologies given based on several technical aspects as well as based on industries usage.

As shown in the table, Wireless networks Wi-Fi, Bluetooth, Ultra Wide Band and ZigBee are considered. And M2M Applications like Smart grids, Home appliances, Health care monitoring and Industrial applications are considered. A 3 level priority values are given for each combination of Network and Application. This table helps in manufacturing M2M devices with supporting communication stacks according to applications.

The cost of device increases based on number of networking technologies it supports.

V. CHALLENGES AND SPECIFICATIONS FOR STANDARDIZED NETWORK TECHNOLOGY

As presented in previous sections, there are several technologies for several applications. It is always optimal and better to have a standardized network technology for better performance and provides large scope for involving new domains into M2M. This section presents a set of challenges and specifications for developing a standard network technology for M2M communication.

The main obstacle for developing standard network technology is data from different contrasting types of domains in M2M applications. These domains include medical, agriculture, home appliances, security etc. The IEEE 11073 data model is available to bridge the gap between unstructured and structured data. Currently ZigBee and Bluetooth only are using IEEE 11073 extensively. But IEEE 11073 supports only medical or wellness related data. One more tough challenge is trade-off between power usage and data rate. There must be a smooth trade-off between power usage and data rate such that by keeping low power usage and a optimal threshold data rate should be maintained. The other challenges include proper protocols for communication, security and infrastructure limitations. The following are important specifications for developing standard M2M Area Network.

- A standard M2M Area Network technology must possess a standard data model like IEEE 11073 for medical devices.
- In protocol stack, a M2M specific application layer protocol like Constrained Application Protocol (CoAP) must be supported by network.
- This network must provide a way to include more Data Aggregators (proxy-m2m

gateways) to reduce burden on M2M gateway.

- It must also support Ipv6 addressing because of its large address space.

TABLE I. COMPARISION OF VARIOUS TEHCNOLOGIES.

M2M Applications Vs Network Technologies	**Wi-Fi (IEEE 802.11)**	**Bluetooth (IEEE 802.15.1)**	**Ultra Wide Band (IEEE 802.15.3a)**	**ZigBee (IEEE 802.15.4)**
Smart Grids	2	3	3	3
Home Appliances	2	2	2	2
Health Care Monitoring Applications	1	1	3	2
Industrial Applications	3	2	2	1

1-High Priority ***2-Moderate Priority*** ***3-Low Priority***

VI. CONCLUSION

According to market researchers like ABI, M2M network is expected to reach more than 85 million connections globally by 2012, and more than 200 million by 2014. With such a tremendous growth in M2M network needs a standard protocols to be the next revolution after computer and internet. So much ambiguity lies only on selecting what kind of M2M Area Network. This paper presents a comprehensive study of several network technologies. Also, we have compared the technologies that helps to prioritize networks. We have presented a brief set of challenges and specifications for developing a standard networking technology specifically for M2M communication.

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Mr.S.ShivaPrakash received the B.Tech degree in Computer Science and Systems Engineering from JNTUH, Hyderabad and M.Tech Degree in Computer Science from JNTUA, Anantapur. He is currently working as Assistant Professor, in Sree Vidyanikethan Engeineering College, Tirupati, Andhrapradesh, India. He has published Several papers in National and International Conferences and Journals. His field of interest is Computer Networks.

Prof.C.Madhusudhana Rao received the B.Tech degree in Electrical Engineerning from Nagarjuna University, Guntur and M.Tech Degree in Computer Science and Engineering from VTU, Belgaum. He is currently working as Professor and Head, in Sree Vidyanikethan Engeineering College, Tirupati, Andhrapradesh, India. He has published Several papers in National and International Conferences and Journals. His area of interests are Randomized algorithms, Wireless Networks.