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Research Article

Machine-to-Machine Communication for Wireless Mobile Health Monitoring

Varsha Wahane† and P V Ingole‡

†Department of Electronics Engineering, Sant Gadge Baba Amravti University, Amravati, Maharashtra, India
‡G.H. Raisoni College of Engineering and Management, Anjangaon Bari Road, Badnera, Amravati, Maharashtra, India

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Abstract

Machine-to-Machine communication (M2M) refers to automated applications executing on smart devices or machines that communicate through a network with little or no human intervention at all. By enabling smart devices to communicate directly with one another, M2M communications technology has the potential to radically change the world around us and the way that we interact with objects. Many applications can benefit from M2M communications, such as transportation, health care, smart energy production, transmission, and distribution, logistics, city automation and manufacturing, security and safety, and others. Thus M2M communications have emerged as a cutting edge technology for next generation communication, are developing rapidly and inspiring numerous applications. This article presents an investigation of the applications of M2M communications. First, an overview of M2M communication is given. The enabling technologies and open research issues of M2M communication are also discussed. Then we have the network design architecture/issues of M2M for wireless health monitoring. The proposed prototype implementation of "Wireless Health Monitoring System" including the M2M service platform and M2M area network

Keywords: *M2M communication, wireless health monitoring, biometric sensors*

Introduction

A car's microchip tells the engine how to operate under various conditions so that the car can achieve the best fuel economy. Computers link production plants together to monitor and maximize production. When machines "talk" they do so in a language known as "telemetry." The concept of telemetry -- remote machines and sensors collecting and sending data to a central point for analysis, either by humans or computers -- certainly isn't new. But an emerging concept is taking that idea to a whole new level by applying modern-networking technology. Three very common technologies -- wireless sensors, the Internet and personal computers -- are coming together to create machine-to-machine communications, or M2M. The concept holds great promise in promoting telemetry's use by business, government and private individuals.

M2M communications, for instance, can be used to more efficiently monitor the condition of critical public infrastructure, such as water treatment facilities or bridges, with less human intervention. It can help businesses maintain inventory or make it easier for scientists to conduct research. Because it relies on common technology, it also could help a homeowner maintain the perfect lawn or create a shopping list at a button's touch. Many advances and the transformations that have occurred in the field of mobile and telecommunications have led to the development of mobile data services over cellular mobile systems, giving support and making it easy for the development of new application.

Technology has found its way through healthcare and this brought easy accessibility in the healthcare Wireless Health Monitoring concept has been introduced and implemented in public health and medicine. This concept has made it possible for patients' to receive services such as prevention, diagnosis, therapy prognosis management with the help of information and communication technology. Wireless Health Monitoring System requires a biomedical digital assistant, which can monitor patients' health condition at any time and in any place, with wired or wireless equipment.

The rest of this article is organized as follows- We present an overview of M2M communications

This article presents an investigation of the applications of M2M communications in wireless mobile health monitoring. First, an overview of M2M communication is given. The enabling technologies and open research issues of M2M communication are also

*Corresponding author **Varsha Wahane** is a Research Scholar

discussed. Then proposed prototype implementation of "Wireless Mobile Health Monitoring System" including the M2M service platform and M2M area network.

Overview of Machine to Machine Communication

Making a machine-to-machine communication system (J.W. Mayo and S. Wallsten *et al*,2010) work is a step-by-step process. The main elements involved are sensors (usually the kind that can send telemetry wirelessly), a wireless network and a computer connected to the internet. In recent years, the topic of M2M communications has attracted much attention from industry and research community, mainly driven by the following factors:

• The emergence of wireless communication systems (e.g., GSM/GPRS, IMAX, and wideband code-division multiple access [WCDMA]) in the Internet has become the premise for the advance of M2M communications. The network infrastructures of these communication systems are already in place, and can be adopted in M2M communications.

• Advanced software component enables devices to operate intelligently and autonomously. As a result, a number of devices can communicate and perform a variety of functions to achieve the objective of the system. One example is the software defined radio (SDR), which can improve the flexibility of wireless communications.

• Sensors that can be used to collect information for M2M systems are being widely used and increasingly adopted. The decreasing cost and increasing capability of sensors and their convenience in deployment make widespread adoption practical.

Different from human-to-human communications, which mainly involve voice calls, messaging, and web browsing, the objective of M2M communications is to increase the level of system automation in which the devices and systems can exchange and share data. Therefore, the protocol and data format are the major issues in M2M

Communications to ensure seamless data and control flows. Recently, a lot of efforts have been put into the standardization. For example,

ETSI Standardizes M2M Communications

ETSI, the European Telecommunications Standards Institute, setting globally-applicable standards in all areas of information and communication technologies (ICT) such as telecommunications, radio communications, broadcasting, and related fields. There are currently 36 technical committees within ETSI working in the following areas:

- Wireless Access Networks
- Future of Wired Networks
- @Home
- Transportation
- Content Delivery / Broadcasting
- Living with Things
- People & Social Responsibility
- Security
- Public Safety
- Efficient Interoperability

ETSI has launched the M2M Technical Committee with the purpose to develop an end-to-end architecture for M2M communications. Also, to accelerate the adoption of wireless interconnectivity of different M2M components, mobile operators around the world have been active in constructing platforms to integrate M2M services with infrastructure networks and launching M2M projects (e.g., GSM Association's Embedded Mobile Initiative).

M2M Architecture

The general architecture of a M2M application (Huai-Lei Fu, Hou-Chun Chen, Phone Lin, and Yuguang Fang *et al*, 2012) can thus be represented with the schematic shown in Figure 1. The architecture consists of three parts: the Device Domain which contains the M2M devices, the Network Domain which transports the messages between the M2M devices and the servers located in the Application Domain, which runs business applications that process collected data from devices and issue commands when and where needed. The major components of the architecture are described here

M2M Device: These devices are capable of sending data to the appropriate application servers and, if necessary, can respond to commands from the applications running on those servers.

M2M Area Network: A network providing connectivity between m2m Devices and m2m Gateways. Examples of m2m Area Networks include: Personal Area Network technologies such as IEEE 802.15, SRD, UWB, Sigsbee, Bluetooth; and local networks such as PLC, M-BUS, and Wireless M-BUS.

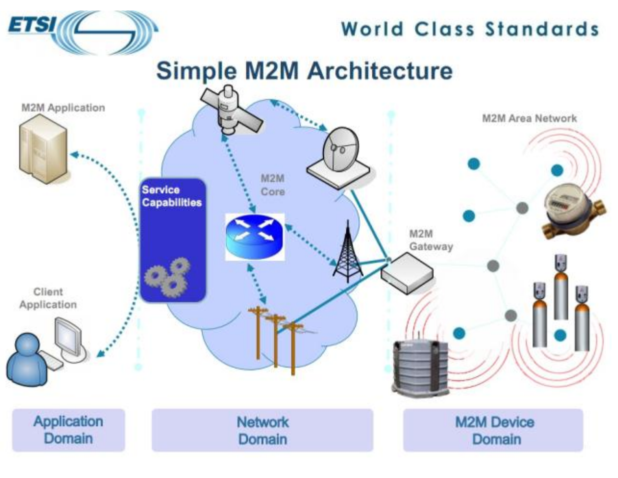

Fig.1 M2M Architecture

M2M Gateway: The use of m2m capabilities to ensure that m2m Devices interwork and interconnect to the communications networks.

M2M Communications Networks: These are the communications networks between m2m Gateways and m2m Applications (servers). They can be further broken down into Access, Transport and Core Networks. Examples include (but are not limited to): ds, PLC, satellite, LTE, GERAN, UTRAN, outran, W-LAN, and IMAX

M2M Applications Server: Contains the middleware layer where data travels through various application services and is used by the specific business-processing engines. Typically, M2M servers are operated by the service provider e.g., a utility company.

Wireless M2M Communications And Its Applications

The advances in wireless technologies (J.W. Mayo and S. Wallsten *et al*,2010) that enable mobility and eliminate the need for cable installation .For M2M components have pushed the development of wireless M2M communications. Since different M2M components vary in types and sizes, and may be located in remote areas with limited accessibility, wireless access is more cost effective and flexible for deployment. With wireless communications technologies, M2M communications are transforming from traditional wired Ethernet toward wireless environments.

Enabling Wireless Technologies for M2M Communications

Advanced wireless communication technologies are the key enablers for M2M communications.
To realize a unified architecture of M2M communications, M2M networks are required to bridge seamlessly with various communication systems by supporting multiple communication technologies: mobile broadband communications (e.g. WiMax and

Long Term Evolution [LTE]) and local area networking (e.g., WiFi).

In home networks, ubiquitous smart electronic devices other than traditional telephones and computers, embedded with wireless communication technologies, are outfitting. Communications among the smart electronic devices generally feature low data rate, low mobility, and low power consumption. Short-range communication technologies like IEEE 802.15.1 Bluetooth, ultra wideband (UWB), and Infrared Data Association (IrDA) can be employed for connection between smart electronic devices (i.e. M2M components) and an M2M gateway in the home environment. An ad hoc network provides the connectivity among multiple decentralized nodes without a pre-existing infrastructure, which is the case for most M2M components in the real world. Fast and low cost interconnection of dispersive M2M components can be achieved by ad hoc networking. For M2M components in an ad hoc environment, medium-range communication Technologies like IEEE 802.15.4 (ZigBee) and IEEE 802.11 (Wi-Fi) (Zubair Md. Fadlullah, Mostafa M. Fouda, Nei Kato, Akira Takeuchi, Noboru Iwasaki, and Yousuke Nozak *et al*, 2011) can be adopted to cover the transmission range. The cellular network is presently one of the most widely deployed wireless networks around the world, and offers a great advantage to developing M2M communications. It provides radio coverage over a wide geographic area, which enables a large number of distributed remote M2M components (e.g. sensors) to communicate with each other via base stations. Also, since the cellular network supports mobility, more flexible M2M applications (e.g. intelligent transportation system) can be accommodated.

Applications of M2M Communications

M2M applications enable independent devices such as industrial meters to communicate with mobile applications. Application that are capable of producing alerts like fire detector and personal security/anti-theft, wake up upon detecting the event that should be reported to the appropriate server or human operator, and send their alerts and notifications to appropriate response centres. During the rest of the time, the devices remain in idle state and they are effectively detached from the network. Examples of M2M applications are Home Heating control, Lighting control, Remote media control ,Transportation Emission control, Toll payment, Navigation, Road safety, Traffic control, Telemetry Measurement of utility consumption ,Parking meters , Vending machines, Tracking Asset tracking, Cargo tracking, Fleet Rental Vehicle monitoring, Truck monitoring, eHealth, Remote patient monitoring, Mobile health, Remote diagnostics, Security Surveillance applications, human/object tracking, etc. Finance Point of sale terminals

Open Research Issues

Despite the increasing M2M solutions and deployment based on current communication systems, there are many technical challenges. In the following, we discuss several important research issues to be addressed in this field.

Standardization — M2M communications will require an integration and convergence among various different communications systems (e.g., local and wide area networks). However, there is very little standardization for it. Standardization of a seamless and unified M2M architecture is highly demanded to promote rapid development and application of M2M communications. Also, complete standardization of the enabling technologies of M2M communications (e.g., RFID, ZigBee, and UWB) needs to be specified.

Traffic Characterization — Characteristics of traffic exchanged among M2M components have not been well studied so far. M2M traffic will be different from that of human-based networks due to the special functions (e.g., data collection and monitoring) and requirements (e.g. hard real-time traffic). Traffic characterization is the fundamental to the design and optimization of network infrastructures. M2M traffic characterization is also required to provide quality of service (QoS) support for M2M applications.

Protocol Re-design — The current leading transmission protocols of the Internet, TCP/IP, are known to be inefficient for M2M traffic due to the redundant and energy-wasting overhead compared to the low data volume needing to be transmitted.

Thus, transmission protocols specially designed for M2M communications need to be explored.

Spectrum Management —Due to the limited spectrum resource, wireless M2M technologies need to efficiently transmit signals over frequency channels. However, traditional static spectrum allocation may not be able to achieve optimal spectrum management, due to the inevitable shift of spectrum requirements in the supply and demand for wireless M2M services. Thus, secondary spectrum markets, which provide use of the spectrum to entities other than the original license holders, should be well functioning to ensure that available spectrum will migrate to more efficient usage. Challenges lie in how to build up a well behaved secondary market. Discussion with respect to M2M spectrum licenses can be found in (J.W. Mayo and S. Wallsten *et al*,2010), which studies the underlying principles of secondary markets and the evolving policies toward well-functioning secondary spectrum markets.

Optimal Network Design — As M2M communications will connect a number of devices and systems together, the optimal network design is an important issue. The network design has to minimize cost of M2M communications (e.g., hardware, maintenance, and radio resource usage) while meeting QoS requirements of the traffic and applications.

Proposed System

Health monitoring is repeatedly mentioned as an area which can explore for application areas of Pervasive computing. Wireless Mobile Health Care is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers. As mobile devices have become an inseparable part of our life it can integrate health care more seamlessly to our everyday life. It enables the delivery of accurate medical information anytime anywhere by means of mobile devices. Recent technological advances in machine–to-machine communication which includes sensors, low-power integrated circuits, and wireless communications have enabled the design of low-cost, miniature, lightweight and intelligent bio-sensor nodes. These nodes, capable of sensing, processing, and communicating one or more vital signs, can be seamlessly integrated into wireless personal or body area networks for wireless mobile health monitoring. Here we propose a model "Wireless Mobile Health Monitoring System", which can provide medical feedback to the patients through mobile devices based on the biomedical and environmental data collected by deployed sensors.

The goal of Wireless Mobile Health Care is to provide health care services to anyone at any time, overcoming the constraints of place, time and character. The use of this technology in the field of health and wellness is known as pervasive health care. The potential for pervasive computing [17] is evident in almost every aspect of our lives including the hospital, emergency and critical situations, industry, education, or the hostile battlefield. Mobile computing describes a new class of mobile computing devices which are becoming omnipresent in everyday life. Handhelds, phones and manifold embedded systems make information access easily available for everyone from anywhere at any time. Mobile health care takes steps to design, develop and evaluate mobile technologies that help citizens participate more closely in their own health care. In many situations people have medical issues which are known to them but are unwilling or unable to reliably go to a physician. Obesity, high blood pressure, irregular heartbeat, or diabetes is examples of such common health problems. In these cases, people are usually advised to periodically visit their doctors for routine medical check-ups. But if we can provide them with a smarter and more personalized means through which they can get medical feedback, it will save their valuable time, satisfy their desire for personal control over their own health, and lower the cost of long term medical care.

Proposed System Architecture

Wireless Mobile Health Monitoring System, (U. Varshney *et al*,2007) we propose to collects patient's physiological data (temperature, ECG, oxygen saturation and heart beats) through the bio-sensors. The data is aggregated in the sensor network and a summary of the collected data is transmitted to a patient's personal computer or cell phone/PDA. These devices then forward data to the medical server for analysis. After the data is analysed, the medical server provides feedback to the patient's personal computer or cell phone/PDA. The patients can take necessary actions depending on the feedback from medical server. The system contains three components. They are

Fig.2: Wearable Body Sensor Network

1. Wearable Body Sensor Network [WBSN]
2. Patients Personal Home Server [PPHS]
3. Medical Server [IMS].

They are described below.

Wearable Body Sensor Network [WBSN]

Wearable Body Sensor Network (WBSN) (Boulmalf M,Belgana A,Sadiki T,Hussein S,Aouam T,Harroud H *et al*,2012) is formed with the wearable or implantable bio-sensors in patient's body. These sensors collect necessary readings from patient's body. For each organ there will be a group of sensors which will send their readings to the group leader. The group leaders can communicate with each other's. They send the aggregated information to the central controller. The central controller is responsible for transmitting patient's data to the personal computer or cell phone/PDA. It is suggested (A. van Halteren, D. Konstantas, R. Bults, K. Wac, N. Dokovsky, G. Koprinkov, V. Jones, and I.Widya. *et al*,2004) that for wireless communication inside the human body, the tissue medium acts as a channel through which the information is sent as electromagnetic (EM) radio frequency (RF). So in WBSN, information is transmitted as electromagnetic (EM) radio frequency (RF) waves. The central controller of the WBSN communicates with the Patients Personal Home Server [PPHS] using any of the three wireless protocols: Bluetooth, WLAN (802.11) or ZigBee. Bluetooth can be used for short range distances between the central controller and PPHS. WLAN can be used to support more distance between them. Nowadays ZigBee introduces itself as a specialized wireless protocol suitable for pervasive and ubiquitous applications. So ZigBee can be used for the communication too. We proposed a Bluetooth for WBSN.

Patient's Personal Home Server [PPHS]

The Patient's Personal Home Server (PPHS) can be a personal computer or mobile devices such as cell phone/PDA. We suggest mobile devices because it will be more suitable for the users to use their mobile devices for this purpose. PPHS collects information from the central controller of the WBSN. PPHS sends information to the Medical Server [MS]. PPHS contains logics in order to determine whether to send the information to the MS or not. Personal Computer based PPHS communicates with the MS using Internet. Mobile devices based PPHS communicates with the MS using GPRS / Edge / SMS. The best way to implement MS is by Web Service or Servlet based architecture. The MS will act as the service provider and the PPHS will act as the service requester.

Medical Server [MS]

Medical Server [MS] receives data from the PPHS. It is the backbone of this entire architecture. It is capable of learning patient specific thresholds. It can learn from previous treatment records of a patient. Whenever a doctor or specialist examines a patient, the examination and treatment results are stored in the central database. MS mines these data by using state-of-the-art data mining techniques such as neural nets, association rules, decision trees depending on the nature and distribution of the data. After processing the information it provides feedback to the PPHS or informs medical authority in critical situations. PPHS displays the feedback to the patients. Medical authority can take necessary measures.

Proposed System Architecture

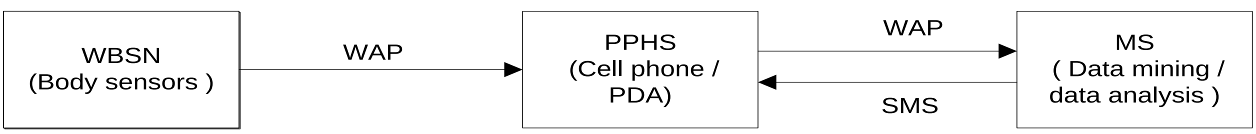

Fig.3 Block Diagram of Wireless mobile health monitoring

The heart of this proposal is the Medical Server (MS). So here describing it in more details with possible scenarios below. In the proposed, Wireless Mobile Health Monitoring System, we will monitor the temperature, oxygen saturation, heart beats and ECG .Why these need to be monitored is describe in more details with possible scenarios below.

In intensive care units, there are provisions for continuously monitoring patients. Their heart rates, temperatures etc. are continuously monitored. But in many cases, patients get well and come back to home from hospital but it may be required some attention may not be directly in hospital. But the disease may return, he may get infected with a new disease, there may be a sudden attack that may cause his death. So in many cases, patients are released from hospital but still they are strongly advised to be under rest and observation for some period of time (from several days to several months). In these cases, wireless mobile health monitoring system can be quite handy.

Conclusion

M2M communication plays an important role in data exchange of a pervasive computing regime, and can be adopted in many applications (e.g. public safety, energy management, and transportation) with objectives to improve efficiency and reduce cost. In this article, an overview of M2M communication has been given, including the motivation, network architecture and adopted communication technologies. The open research issues have also been discussed. M2M communication for “Wireless Mobile Health Monitoring System” has been introduced. Thus the proposed wireless mobile health monitoring system helps the individual by monitoring his or her health and cautions him to take necessary action against any upcoming health deteriorating conditions.

This paper presents a M2M communication for Wireless Health Monitoring System. As a young technology, we do foresee tremendous potential for M2M systems and M2M communication plays a central role to benefit modern and future human life.

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