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RESEARCH ARTICLE

Machine-to-Machine Communications for Smart Homes

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Abstract – Machine to Machine (M2M) can be described as technologies which allow both wired and wireless systems to communicate with other devices of the same ability.M2M brings several benefits to industry and business, since it can be used in a wide range of applications for monitoring and control purposes. It is expected that M2M technologies when combined with smart phones will become integral elements in smart homes. Accordingly, in this study, a sample application of M2M technologies is presented. In the presented application, using temperature data provided by sensors, the smart air conditioner automatically adjusts itself. Although the presented application is just a simple example of how M2M can be used, it has the potential of affecting all areas improving our day to day life.

Index Terms – Machine-to-machine communications, M2M, smart homes, SIP.

1. INTRODUCTION

Machine to machine (M2M) communications enable the exchange of data between any kinds of machines and devices. Although M2M communication is typically used for remote monitoring and control, it enables innovative advances in technology and can be used for many other purposes in a large number of applications including manufacturing and inventory control, environmental monitoring and animal tracking, smart energy, connected homes, smart signage, and in-vehicle systems. Basically, in M2M communications, remote sensors gather data and send it wirelessly to a network, where it is next routed, often through the Internet, to a server [1-3]. The software running on the server analyzes the data and acts upon.

An M2M system consists of radio frequency identification (RFID), sensors, wireless or cellular communications links and software application programmed to help a networked device interpret data and make appropriate decisions. M2M currently does not have a standardized connected device platform and many M2M systems are built to be either task-specific or device-specific. However, it is expected that vendors will need to agree on a set of standards for device-to-device communications, as M2M becomes more pervasive.

In recent years, M2M has been selected for many demanding applications such as telemetry and Supervisory, Control and Data Acquisition (SCADA). Different from telemetry, which can be described as automatic remote transmission of measured data, and SCADA, most of M2M applications are based on well-established existing standards in terms of communication protocols and transmission methods. However, telemetry applications are generally based on proprietary solutions developed to address specific customer or application requirements. On the other hand, M2M use open protocols also found on the Internet and local networks. In addition, the data formats are similar in appearance.

The communication network in M2M applications is the central connection component between the data integration point and data end points, and can be established using a local area network, wireless network, public telephone network/ Integrated Services Digital Network (ISDN), the Global System for Mobile Communications (GSM) mobile network, or similar technologies. Wireless M2M connections can be established over larger distances by means of GSM mobile connections. As shown in Figure 1, in this case, a cell phone network provided by a GSM company forms the physical network and the provider offers and ensures access to its cell phone network based on a contractual agreement. From a very wide range of M2M applications, tracking, telemedicine, and infrastructure monitoring are the most common ones which have been implemented via GSM technologies. It is foreseen that M2M applications based on GSM technologies have great potential in terms of growth and cost saving. Currently, the lack of standardization in interfaces and data formats between data end points and the data integration point is still the main problem in GSM based M2M applications.

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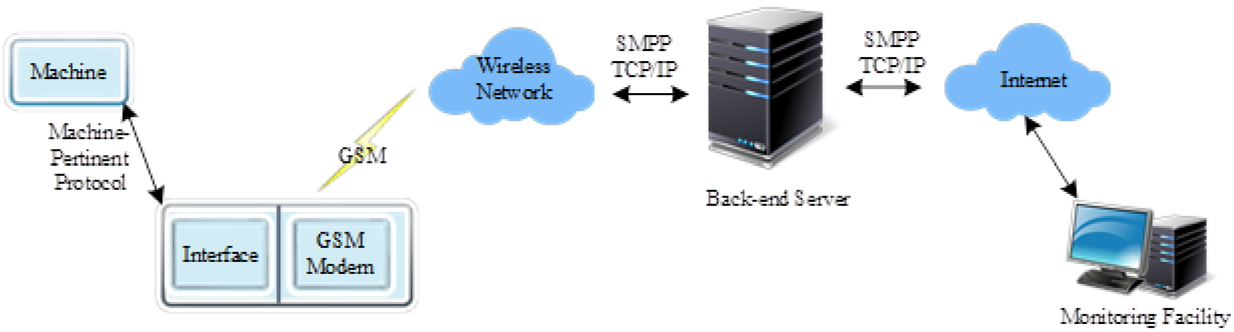

Figure 1 Implementing an M2M application over a GSM network

It is widely expected that M2M technologies combined with smart phones will play a crucial role in smart homes [2, 4, 5]. Therefore, major device vendors and telecommunications service providers have started to focus on these technologies and put smart phone applications in their offerings and strategies. In this study, we focus on developing an example M2M application to show how M2M technologies can improve our lives. Although the developed application requires the use of smart air conditioners, it can be configured to work with standard air conditioners with a remote control.

The remainder of the paper is organized as follows. M2M communications, Constrained Application Protocol (COAP) and Session Initiation Protocol (SIP) are reviewed Section 2. Section 3 presents the use M2M for smart home applications. Section 4 explains the design of a sample M2M application and presents the obtained results. Finally, the paper is concluded in Section 5.

2. M2M COMMUNICATIONS AND PROTOCOLS

M2M can be viewed as the set of systems, networks, processes and data which connects machines with machines for different purposes. Different from most of the other technologies, many M2M systems are designed to support multiple applications. For instance, a connected home environment can support multiple applications such as energy management, security, video on demand and control of appliances. Similarly, in a telematics application, vehicle event data is accessed by different applications such as navigation, condition monitoring and insurance. Although M2M has many benefits, M2M communications present a unique set of technical challenges that must be addressed by any connected application [3, 5-10]. M2M applications must be able to connect over networks that may be unreliable, and that often have limited bandwidth, especially when connecting over cellular networks. M2M devices themselves also often have limited processing power and a need to minimize power consumption. In addition, due to non-standardization, developers often choose specific M2M modules which come with their own software development kits (SDKs) with vendor-specific mechanisms for device and application management. Therefore, developers and OEMs become locked into the chosen hardware, server preferred by the vendor and management framework. This limits both flexibility and interoperability.

Generally M2M designs can be divided into two broad categories, namely hybrid and all- Internet Protocol (IP), since there is no one-size-fits-all architecture for M2M technology. Different from the past, now TCP/IP is available in modest hardware, thanks to low-cost all-in-one networking chips and migration to an increasing interoperability with IP communication within industrial networking standards. On the other hand, hybrid M2M designs involve M2M nodes which cannot accommodate standard networking interfaces. Hybrid designs typically accommodate legacy telemetry-type systems and low-end M2M device nodes, which include passive sensors, low-frequency devices, and one-time use devices like sensors for weapons testing and seismic events. Since the main objective of M2M communications is to increase the level of automation in which the systems and devices are able to exchange and share data, in M2M communications, the protocol and data format are the key issues to ensure the seamless data and control flows [4]. Hence, in recent years, there have been a lot of standardization efforts to develop an end-to-end architecture for M2M communications and speed up the adoption of wireless interconnectivity of different M2M components.

2.1 Protocols used in M2M applications

The protocols used in M2M and Internet of Things (IoT) applications were designed to address the requirements of highly resource-constrained devices and M2M and IoT scenarios. For instance, since HyperText Transfer Protocol (HTTP) over TCP is not feasible in M2M and IoT applications, to close the gap between microcontroller-based low-power devices and the Web of Things, COAP was developed and in this way RESTful applications can talk end-to-end to tiny devices using Request-uniform resource identifiers (URIs) for addressing and uniform interfaces for interaction. Similarly, the adoption of SIP for session control ensured interoperability of networks, services, and devices from different providers. Later on, SIP has been adopted as the standard for session control of M2M video applications. In the following subsections, COAP and SIP protocols are briefly explained.

2.1.1 COAP

COAP is an application layer protocol designed to be used in simple resource-constrained electronics devices such as low power sensors, switches, valves and similar components, and allows them to communicate over the Internet for control and remote supervision purposes. In addition to being easily integrated with the web technologies, it also meets specific requirements such as simplicity, very low overhead and multicast support, which are important for deeply embedded devices with limited computing power, memory and power supply such as M2M and IoT devices [11]. The Internet Engineering Task Force (IETF) Constrained RESTful environments Working Group [11] has done the major standardization work for this protocol in order to make the COAP protocol suite be suitable for M2M and IoT applications by adding a set of new functionalities. Since COAP is built on top of the User Datagram Protocol (UDP), it has significantly low overhead and supports multicast. It is organized into two layers, namely, the transaction layer and the request/response layer. While the former is responsible for handling the single message exchange between end points, the latter is responsible for the transmission of requests and responses for the resource manipulation and transmission [12].

2.1.2 SIP

SIP is an application-layer control protocol for signaling and controlling multimedia communication sessions [13]. While it is mostly used in Internet telephony applications, it is also used for instant messaging all over IP networks. It is a text based protocol with syntax similar to that of HTTP and defines the messages sent between endpoints to govern establishment, termination and other elements of a call. Since it is an application layer protocol, it is independent of the underlying layers [13]. Like COAP, the standardization of SIP has been carried out by the IETF [14]. There are two different types of SIP messages namely requests and responses. While the first line of a response message has a response code, the first line of a request message has a method to define the nature of the request and a URI, a string of characters used to identify a name of a resource, to indicate where the request should be sent.

3. M2M FOR SMART HOMES

Nowadays, the newest devices and applications are simplifying our tasks and making better use of available resources, and transforming the way we live. Various home automation solutions for energy management, security, remote monitoring and control, and e-health offer various advantages and improve the way we live. As shown in Figure 2, smart home solutions with the offered solutions can be seen as the next stage of existing home automation solutions. Although the list of smart home applications is open-ended, home care for the elderly & disabled, energy efficiency, comfort & entertainment, and safety & security are the major application areas of smart home services [15].

Smart homes are complex heterogeneous environments comprising three main components, namely a home automation system, a control system, and a home automation network [16, 17]. The home automation system contains a set of home appliances which fulfill several functions in the house for the well-being of the home owners [15]. The function of the home appliances can be roughly divided into sensors, actuators or both. The control system combines human with software based control by using the information provided by the sensors and the instructions sent to actuators and this way it achieves one or more high-level goals or functions of the smart home, as required by the home owners. Finally, the home automation network assures that all the smart home components can exchange status and control information. Typical to all computing systems, the architecture of a smart home is influenced by the computational capabilities of the components which build the smart home. While both centralized and distributed type of smart home architectures can be found, with the advances in pervasive and ubiquitous computing, distributed smart home applications nowadays are more common.

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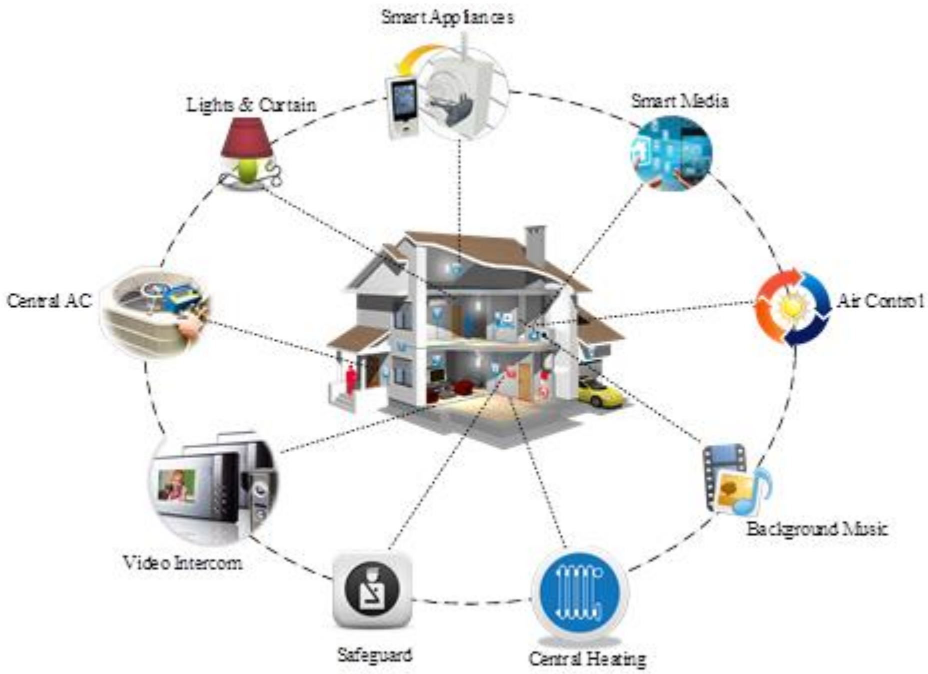

Figure 2 A smart home example

4. PROPOSED APPLICATION

To show the use and advantages of smart home applications, we designed a smart air conditioning application for smart home services. In the proposed application, the smart air conditioner periodically receives the value of current temperature and displays it. To do this, the software application running on the smart air conditioner checks every 3 seconds to learn whether a new value has been received or not. The logging facility of the software application logs all the received values and adjusts the air conditioner depending on the received value.

As shown in Figure 3, the proposed application consists of three main components: a SIP server, a Raspberry Pi 2 board with temperature and humidity sensors [18] and a smart air conditioner. As shown in Figure 4, the SIP server is responsible for providing the connection between the smart air conditioner and the Raspberry Pi 2 board. It is not busy all the time since it does not manage the connection continuously.

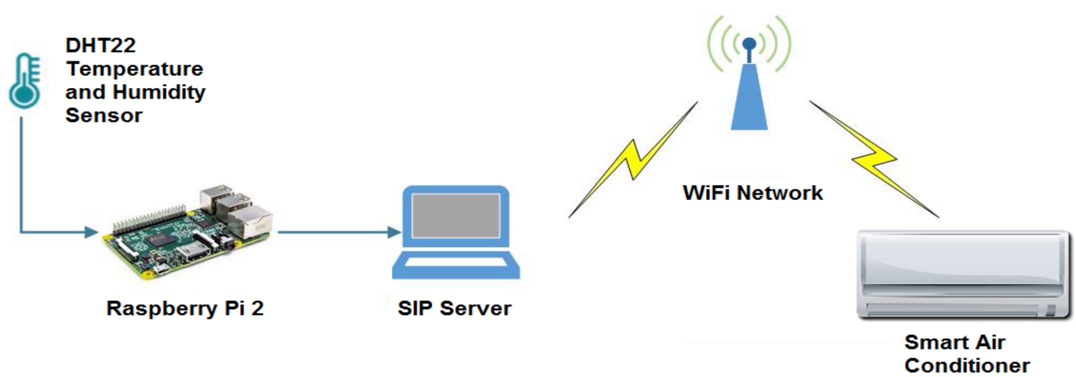

Figure 3 Proposed M2M application

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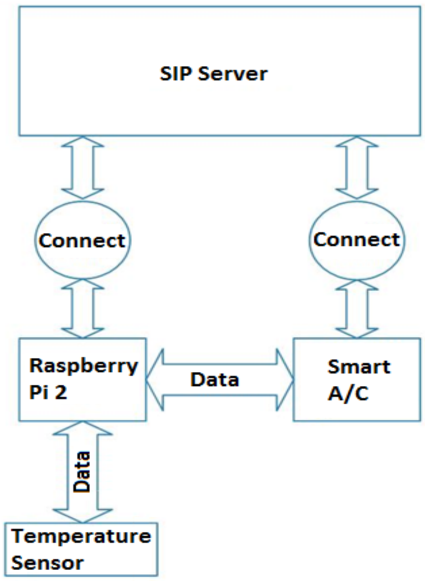

Figure 4 System data diagram

The user can switch on/off and can see the current temperature value displayed by the smart air conditioner. The user can also enable the Raspberry Pi 2 board and this way the board can receive the temperature values from the temperature sensor as shown in Figure 5 and send them to the SIP server. The SIP server acts as a gateway between the other devices and can start the connection between them, as shown in Figure 6. The user can also check all the logs created by the system online or offline. Although the designed application is not a comprehensive one, it is a perfect example to show one of the many benefits of smart home applications. Since the designed application is not computationally intensive, it can be implemented in low-cost systems.

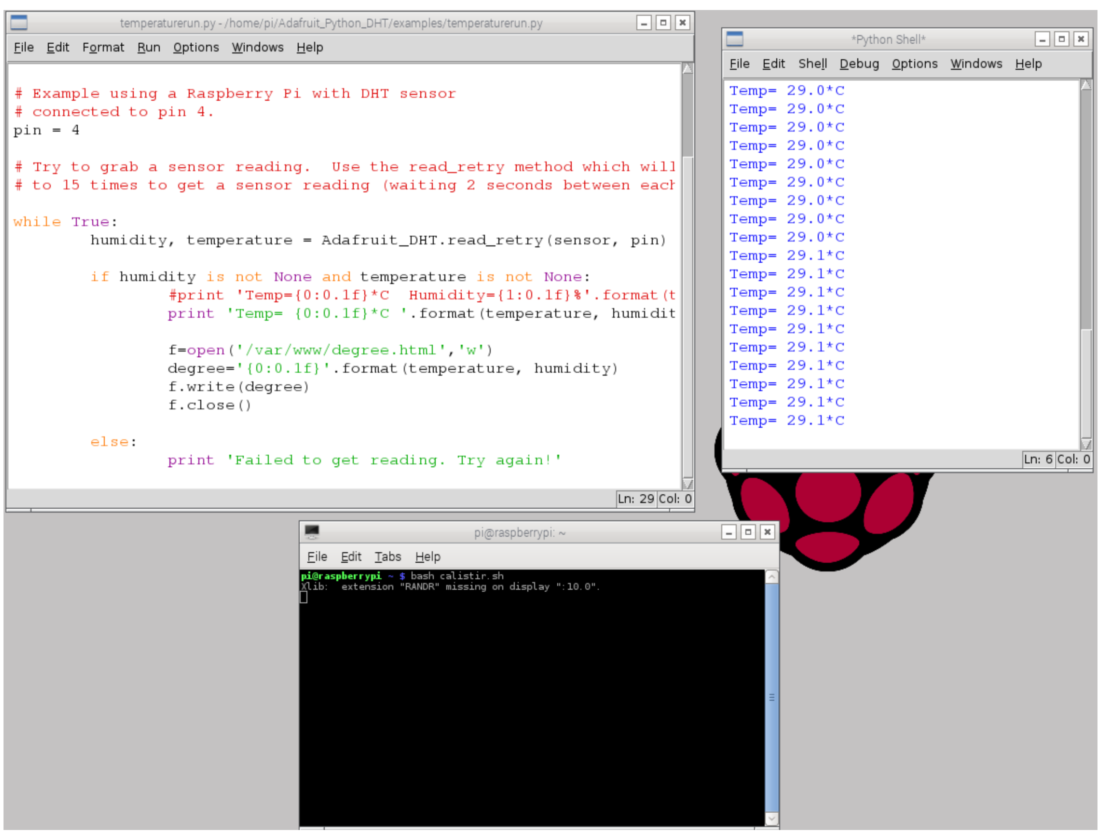

Figure 5 Obtaining temperature values through the Raspberry Pi 2 board

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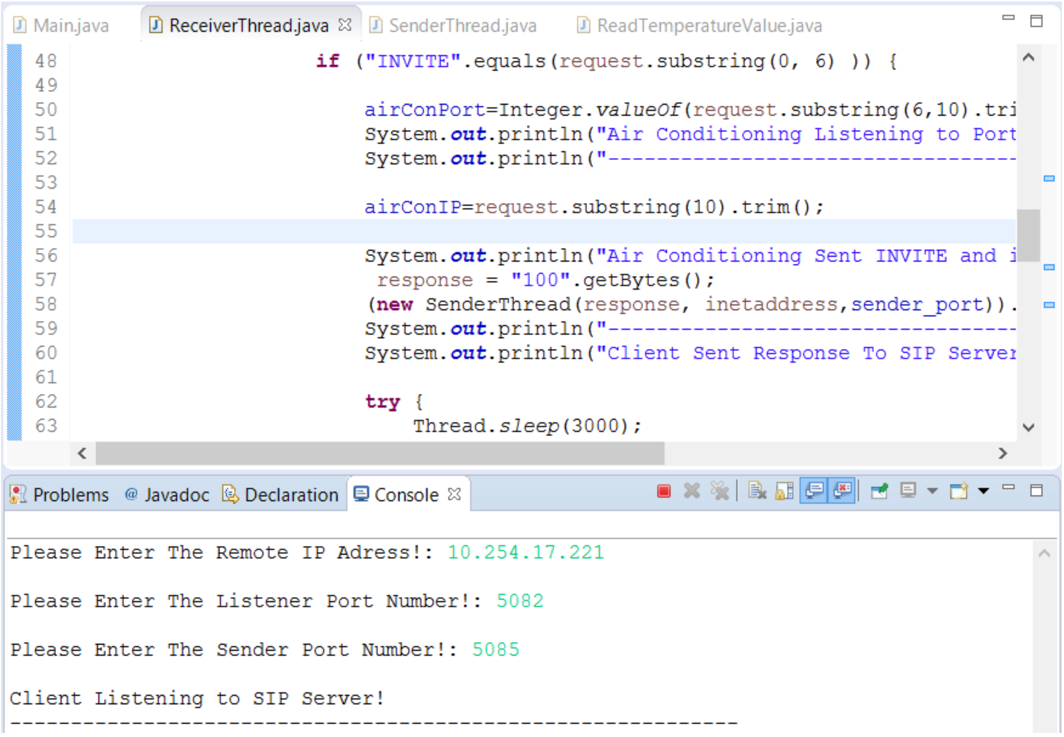

Figure 6 Activating the remote device

5. CONCLUSION

Machine to machine (M2M) communications enable networked devices and services to exchange information and perform one or more actions without the manual assistance of humans. M2M communication can be used for various purposes in a wide range of applications, and hence can bring several benefits to industry and business. They are viewed as a key enabler of the Internet of Things (IoT) and ubiquitous applications, like mobile healthcare, telemetry, or intelligent transport systems.

In this paper, we present M2M communication based control of an air conditioner to show the usability and practical implementation of M2M. Using temperature values provided by a group of sensors, the air conditioner automatically adjusts itself. This application is a simple example of how M2M technologies have started to improve our day to daylife. Source code of the application is available upon request by the readers. As a future work, we plan to integrate other functionalities and services to the proposed application, and combine it with other smart home applications.

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