M2M Home Network Using 3 Selected Wireless Technologies

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Abstract— **Homes today are becoming more high-tech so that they are being automated, networked and wired. The reason behind this is so that they can be better managed and monitored more efficiently just like any office or any secure place. The advent of the internet has made it possible for the home to be networked so they can be monitored and managed remotely. This is very much possible now with the different technologies that are available currently. The target for this project is to develop and implement a machine-to-machine (M2M) home networking using wireless technologies, where the electronic devices of the home will be interconnected wirelessly and communication will be between the devices. Triggers and switches will be by the machines themselves which means there would be lesser human intervention in the process. Three networking technologies were used in this project, namely, Bluetooth, ZigBee and Wi-Fi. The M2M home network system is an interconnection of home devices which are grouped into sub-networks represented by each of the three wireless technologies. These three sub-networks are linked through LAN via a PC interface that would alternate utility between them. The software will act as bridge between these three different technologies. Bluetooth is connected with other Bluetooth-enabled electronic devices through a Personal Area Network (PAN), Zigbee is connected to electronic devices such as light fixtures, television, stereo, or any other home electronic devices, and Wi-Fi is connected to remote monitored IP cameras.**

Index Terms— **Bluetooth, home network, Wi-Fi, M2M, wireless technologies, ZigBee.**

I. Introduction

Gone were the days when home communications are stand-alone. Today, almost all home electronic devices can be hooked up in a network, not just the telephones and computers, but also extending to all other devices. The quest for, what we call smart homes, are getting more and more popular.

Remote home systems are being extended more from telephones to incorporate other kinds of electronic gadgets from TVs and stereos to more sophisticated machines used [1].

From home entertainment to kitchen appliances, from air conditioners to heaters, more and more machines are being used in the home. This would call for more efficient management and monitioring not just inside the home itself but also remotely. Technology now would make it possible for integrated homes to be inteconnected via networking technologies which would enable the communications for humans to machines and vice versa. This paper however, is concerned with the ability of these ordinary household machines to be connected together, communicate to each other and trigger action with lesser human intervention. This method of communication is called machine to machine (M2M) communication through networking. The M2M gadget class is normally described by low power utilization and next to zero human intercession. By and large, these machines communicate with each other through a central controller. With this idea in mind, the home has now a limitless possibility for automation.

Some examples of applications for M2M home networking are: home security sensing, lighting control, HVAC (heating, ventilation and air condition) frameworks, apparatuses that run keen matrix applications, medicinal gadgets, and stimulation frameworks. These can be integrated and be controlled from inside the home [2].

As the development of the electronic technology and communications technology, people have the high requirements for daily life and work, using home networks for a smart home is more and more widely applied [3]. Because of globalization, people travel a lot and are always away from home. Naturally they would want to know the family and home's condition at any place. What's more, when their homes have problems, they will soon receive relevant information, so that remote monitoring becomes a very important function for smart home system. But the use of wire transmission way can't satisfy people's need for remote monitoring. However, wireless communication is able to overcome the disadvantages of wire transmission, which can get rid of geographical constraints.

II. M2M Home Networking

Castillo [4] has stated in his article that the future of communications are not just between human anymore or even human to machine and vice-versa but now machine to machine communications are getting more popular. So one of the applications of machine to machine communication is through home networking. According to Mitchell [5] increasingly more homes are being automated for several reasons, such as, file sharing where sharing between computers gives more flexibility than using mediavdrives for sharing photos, music files, and documents, and also use a home network to save copies of all of important data on a different computer. Backups are one of the most critical yet overlooked tasks in home networking; printer peripheral sharing - once a home network is in place, it's easy to then set up all of the computers to share a single printer or a network scanner, Web cams, and CD or DVD players/burners; internet connection sharing - using a home network, multiple family members can access the Internet simultaneously without having to pay an ISP for multiple accounts; multi-player games - many popular home computer games support LAN mode where friends and family can play together, if they have their computers networked; internet telephone service - So-called Voice over IP (VoIP) services allow people to make and receive phone calls through the home network across the Internet, saving call costs; home entertainment - newer home entertainment products such as digital video recorders (DVRs) and video game consoles now support either wired or wireless home networking. When these products are integrated into the home network, it would enable online Internet gaming, video sharing and other advanced features that can be enjoyed by the whole family in the home [5].

However, in most home networking, the linkages are still machine to human (M2H). Users are now vying for machine to machine (M2M) networking because more people would want convenience through lesser human intervention. With the dramatic penetration of embedded devices, machine-to-machine (M2M) communications will become a dominant communication paradigm in home networks, which currently concentrate on machine-to-human or human-to-human information production, exchange, and processing [6].

From Alheraish study [8], M2M (short for machine-to-machine, man-to-machine or mobile-to-machine) is estimated to get an exponential growth in the coming years.

M2M enables the flow of data between machines and machines and ultimately machines and people. Regardless of the type of machine or data, information usually flows from a machine over a network, and then through a gateway to a system where it can be processed and analyzed. On other words, M2M allows a machine or device to transmit or receive its data remotely over a network. This makes M2M a very good solution for many problems such as reducing the cost (e.g. the cost of the labors that control or check the machine will be reduced by controlling and checking the machine remotely), and reducing the time of monitoring and controlling the machine (especially when the machine is very far, the time to get to the machine is very long compared to a single click or sending a simple text message). Yue [7] corroborate this, as they state in their paper that home M2M networks are characterized by low power, low cost, and low human intervention, which has huge potentials to improve service quality and reduce cost.

For Chen [9], the term M2M communications is widely employed to refer to data communications without or with limited human intervention among various terminal devices such as computers, embedded processors, smart sensors/actuators and mobile devices, etc. M2M solutions fulfill very specific requirements that existing technologies are unable to adequately support [10]. The rationale behind M2M communications is based on three observations: (1) a networked machine is more valuable than an isolated one, (2) when multiple machines are interconnected, more autonomous applications can be achieved [11], and (3) smart and ubiquitous services can be enabled by machine-type devices intelligently communicating with other devices at anytime and anywhere [9]. Gligoric [12] also mentioned that M2M communication is now prevalent in mobile devices through Long Term Evolution (LTE) networks.

III. Wireless Technologies In Home Networking

Millions of households worldwide have adopted home computer networking [13]. Millions more have yet to build their first home network. Even those who've previously taken the plunge are now beginning to revamp their networks for wireless - the current wave of useful technology for home networking [14]. As wireless technologies become available to more users from divergent technical backgrounds, they have become easier to use. According to Mitchell [5], building a wireless home network has the following benefits:

Computer mobility - notebook computers and other portable devices are much affordable than they were a few years ago, therefore, with wireless home network, one can work on the couch, porch, or wherever in the house is most convenient at the moment; no unsightly wires in the home, no tripping on exposed cables and no expense for pre-wiring or in-wall or in-floor wiring; Wireless technology is clearly the future of networking [15]. In building a wireless home network, one can learn about the technology and be able to teach friends and relatives and also be better prepared for future advances in network technology coming in the future.

Mitchell [5] stated that computer networks for the home and small business can be built using either wired or wireless technology. Wired Ethernet has been the traditional choice in homes, but Wi-Fi and other wireless options are gaining ground fast. Both wired and wireless can claim advantages over each other; both represent viable options for home and other local area networks (LANs).

Mitchell [5] compared wired and wireless networking in five key areas, namely, ease of installation, total cost, reliability, performance, and security. Wired LANs use Ethernet cables and network adapters . Although two computers can be directly wired to each other using an Ethernet crossover cable , wired LANs generally also require central devices like hubs , switches , or routers to accommodate more computers.

For dial-up connections to the Internet, the computer hosting the modem must run Internet Connection Sharing or similar software to share the connection with all other computers on the LAN. Broadband routers allow easier sharing of cable modem or DSL Internet connections, plus they often include built-in firewall support.

No computer network is completely secure and homeowners should research this topic to ensure they are aware of and comfortable with the risks. Important security considerations for homeowners tend to not be related to whether the network is wired or wireless but rather ensuring: the home's Internet firewall is properly configured; the family is familiar with the danger of Internet "spoof emails" and how to recognize them; the family is familiar with the concept of "spyware" and how to avoid it; and, babysitters, housekeepers and other visitors do not have unwanted access to the network [5].

IV. THE 3 WIRELESS TECHNOLOGIES, BLUETOOTH, ZIGBEE AND WI-FI

Three wireless technologies were used in this system, namely, Bluetooth, ZigBee and Wi-Fi. These three were selected because of popularity and convenience.

A. Bluetooth

The Bluetooth wireless technology is set to revolutionize the way people perceive digital devices in our homes and office environment. Now they are no longer just the individual devices; instead, with the embedded Bluetooth technology, they form a network in which appliances can communicate with each other. This wireless technology is especially useful in home environment, where there exists hardly any infrastructure to interconnect intelligent appliances. It could be suitably used for home automation in a cost-effective manner [16].

Since Bluetooth has been designed as short-range radio interfacing [17], normally a range of 10 meters, and a maximum of eight active devices can be attached to a piconet. The home networks however need a much larger coverage than 10 meters and also may be required to support more than 8 active devices. Thus, a scatternet, which is d.esigned for a home network, need to overcome these restrictions of standard Bluetooth scatternets. Bluetooth provides flexibility in establishing an ad hoc network. Thus the formation of scatternet cn be quite complex. This leads to numerous problems. Firstly, in term of communication, routing protocol between piconets becomes complicated. Secondly, the number of hops and communication delay become unpredictable [18].

In Tajika's [17] system, they adopted Bluetooth as a wireless communication device. The reason why Bluetooth is selected for the system is as follows. For white appliances, it is essential to adopt a communication device with low power consumption from the regulation perspective. In addition, wireless is preferable in view of its portability. Of course low cost and small size for the implementation are essential. Another reason is Bluetooth has a capability to transfer data at a rate of more than 100 Kbps, while keeping the characteristics mentioned above. Furthermore, it is an advantage for the system just to embed a single device satisfying both the appliance control and data transfer, and to keep the system as simple as possible [17].To better control energy consumption in the Smart Home, the Home Area Network (HAN) is used to collect sensor information from a variety of devices inside the home, and optionally sends control information to these devices. ZigBee is a high technology for the Smart Home network communication. It is designed to be able to get rid of electrical cabling inside home. ZigBee, as a wireless mesh networking scheme low in cost, power, data rate, and complexity, is ideal for Smart Home applications [18].

B. ZigBee

Smart Home is a versatile technology system, small from family of intelligent control lighting, security precautions, the situation of the indoor environment monitoring, large to the realization of different places or exotic home security, monitoring, as well as medical care, distance education control, etc,and it can infiltrate to all the aspects of home. these are its main directions of future development. And ZigBee technology is a very reliable wireless data transmission network, from the standard communication distance of 75 meters to the infinite expansion, it is a network platform made by 65,000 wireless data transmission modules, as each ZigBee technology used Netcom letter in self-organizing way, every data transmit between ZigBee network can communicate with each other, as long as each other in the network communication module can find each other automatically, quickly. They can develop into a interoperability of ZigBee networks. If the relative position of network module terminal has changed, modules can through the way of research Communication Object to determine the contact of each other, then refresh the existing network. So that even though the path is interrupted, as the ZigBee technology is a combination of self-organizing dynamic routing mesh topology, it can solve this problem very well, thus ensuring reliable data transmission. Therefore at any time and status, it is very suitable for the utilization and development of intelligent home [20].

C. Wi-Fi

In Yoon and Kim's [21] study, by taking advantage of upcoming industrial standard WiFi-Direct (formally known as WiFi peer-to-peer), the wireless network connectivity is now extending to other home appliances such as digital televisions, camcorders, and printers. This new standard allows consumer electronics devices to establish direct (i.e., instant ad-hoc peer-to-peer) connectivity while sustaining the WiFi infrastructure-mode connection to the Internet as well as the backward compatibility with already deployed WiFi devices. Sooner or later, in home networks, there will be diverse WiFi-equipped digital devices producing, storing, manipulating, and sharing multimedia contents. Within this wirelessly-connected home network, downloaded IPTV video streams are recorded at the local storage space of digital TV and then instantly shared with other devices. Digital camcorders can upload the recoded video streams to either digital TV or other storage-capable devices. Also, instant media sharing between mobile phones can be made without requiring the help of WiFi access points (APs).

Most WiFi devices in the home network are heterogeneous in their computational capability, networking bandwidth, power supply constraint, and mobility mode. For example, a digital printer typically has less computational power and networking bandwidth than a tablet PC. Mobile hand-held devices such as smart phones and digital camcorders may have a moderate computational power, whereas they do not hold persistent wireless connectivity due to user mobility [21].

V. RESULTS

The project is the development and implementation of a M2M home network composed of three subnetworks, each of which are wireless technologies. The three technologies were developed so that they can be interconnected with electronic devices within the home and would enable these devices to communicate with each other. A central PC interface was developed as a bridge to integrate the three subnetworks so that these can be monitored, either within the home itself or remotely from outside the home. The software for the PC interface was developed using C# and Visual Basic. The result is a working home network using the three wireless technologies, with the devices controlled from the PC interface, with lesser human intervention.

Below is pseudo code for the algorithm of the system process to perform the different tasks for the M2M Home Networking system. Each subnetwork namely, Bluetooth, Zigbee and Wi-Fi, has its own module, represented by OPTION 1, 2 and 3 in the pseudo code below, and individual tasks, as shown in the procedures below:

```
BEGIN
    SELECT TECHNOLOGY (OPTIONS)
        OPTION 1: // Bluetooth Subnetwork
            {SELECT Available Bluetooth Hardware
(Status)

                {Discover;  Pair Device;}
                PAIR WITH DEVICE;
                CONNECT WITH DEVICE;}
        BREAK; GO TO Alt 1;
        OPTION 2: // ZigBee Subnetwork
            {SELECT DEVICE;
             CONNECT DEVICE;
             OPERATE;}
          BREAK; GO TO ALT 1;
         OPTION 3: // Wi-Fi Subnetwork
          {SELECT TASKS (Settings)
            {Set Snapshot Directory;
             Add Camera Parameters;
             Edit Camera Parameters;
             Remove Camera Parameters;}
```

```
        CONNECT (IP Camera)
        {IP Camera;
         Open Snapshot Directory;
         Settings;}
      BREAK; GO TO ALT 1;
Alt 1: IF MORE TASKS
         THEN GO TO SELECT TECHNOLOGY;
         ELSE  GO TO EXIT;
      EXIT;
END;
```

Bluetooth Subnetwork

For Bluetooth, this subnetwork is a personal area network (PAN). PAN is a computer network used for data transmission between devices such as laptops, telephones and tablets for personal use. These devices are interconnected within the range of an individual person, typically within a range of 10 meters. In this project, the PAN system through Bluetooth was connected with nearby telephones for file access, music or video remote play. It was also connected with bluetooth speakers, with bluetooth enabled earpiece and with other accessories such as keypad.
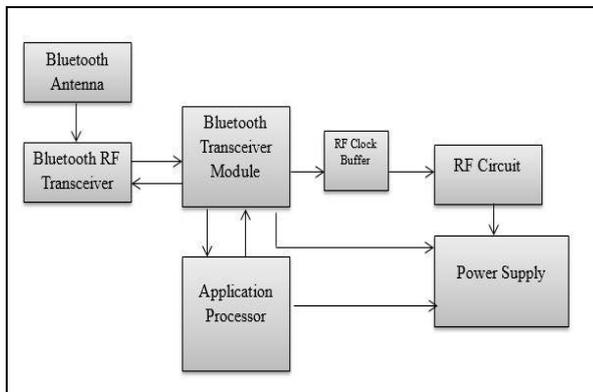

Fig. 1 Working diagram for the Bluethooth subnetwork.

ZigBee Subnetwork

The ZigBee subnetwork, a wireless mesh networking, is a low cost system. This was connected to different home devices. It is specifically developed for home automation. This fact actually made the project to necessarily include this technology in the M2M home networking system. The signal range of the ZigBee is comparatively short, 10-100 meters, but is ideal for home device connectivity. Devices that the project's individual representation connections are home electronic devices, which could be lights, television, refrigerator, speakers, A/C, and other such devices that can be connected to the ZigBee network.

The devices connected are remotely controlled for switching on or off, operations, file access, etc. via the PC interface.
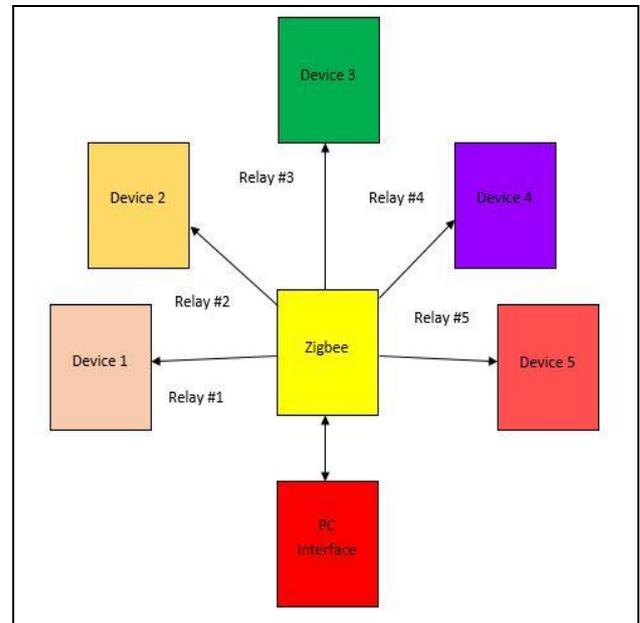

Fig. 2 Working diagram for the Wi-Fi subnetwork.

Wi-Fi Subnetwork

For the Wi-Fi subnetwork, the device connected is the IP camera. An IP camera is a networked digital video camera that transmits data over a Fast Ethernet link. IP cameras (also called "network cameras") are most often used for IP surveillance, a digitized and networked version of closed-circuit television (CCTV). The project has prepared for the connection of up to 8 cameras in the system. However, in the pilot run of the system, only one camera was used for remote monitoring and to take videos and still photographs of the area in the home under surveillance.

The IP cameras connected to the Wi-Fi was able to take photos, record videos and remotely monitor the areas covered by the cameras. Initially, the digital files were stored in the central pc server.
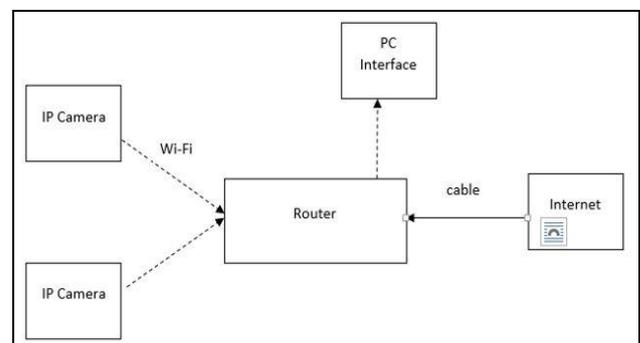

Fig. 3 Working diagram for the M2M Home Network System.

Since the system will be involving three technologies, there are three hardware groups that were built and will be linked together via PC interface. The three subnetworks representing each technology involved, namely, Bluetooth, ZigBee and Wi-Fi, have their own application software. The overall system is a M2M home network developed to monitor the home and to automate the different electronic devices that requires little human intervention to operate.
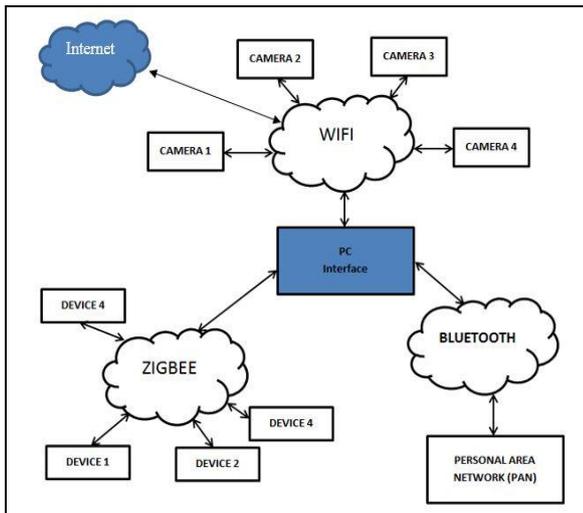

Fig 4 Working diagram for the M2M Home Network System.

The three sub-networks, representing the technologies involved are linked together to form the M2M Home Network.. The system has been implemented and worked well with the use of substitute device for real appliances in the case of Zigbee subnetwork The following figure (Fig. 5) is the main interface that controls the whole system:
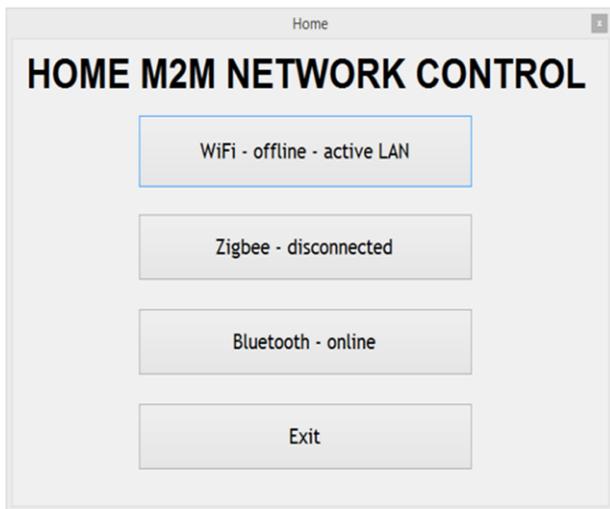

Fig. 5 Main interface for M2M Home Network.

The project has developed a machine to machine (M2M) home network using three technologies, namely, Bluetooth, Zigbee, and W-Fi. The three sub-networks will be working together to control home devices in different ways but all of them would be to make the home network to be operating with less human intervention.

VI. CONCLUSION

In the course of the project the requirements of the system were gathered and the framework was developed. The design for both hardware and software requirements was completed and implemented.

A well-functioning M2M home network using three wireless technologies which are sub-networks of the project. The three technologies are, Bluetooth, Zigbee, and Wi-Fi networks.

The project was confined to the three technologies and some specific devices connected for each of them. The connection for the home network is with local wireless network which is controlled by a PC interface. Only simple home electronic devices were connected to the wireless technologies for easier and more convenient system execution.

A software was developed for each of the sub-networks for machine to machine connection and for monitoring and control. Also a main software application interfaced the three sub-networks to enable a smooth control and communication between the three technologies.

The Bluetooth sub-network is connected to simple devices and can operate the devices by remote. The Zigbee subnetwork is connected to electronic light representing electronic home devices for electronic switching. The Wi-Fi is connected to IP camera which enables the network to operate the camera by taking videos and snapshots remotely.

The M2M home network using wireless technologies is a work in progress. There is a wide future capability which can be enhancements for the system. The following would be recommended as future work that can be added or enhanced to improve on the system: More electronic devices can be added to each of the sub-networks that would make the home fully automated and smart; More wireless technologies may be considered to be added or may replace any of the ones used in the project, such as, body sensors (body area network), Radio Frequency Identification (RFID), Z Wave, and others; To make the system more sustainable, solar cells may be used as a source of power instead of electricity; More security capability may be included in the system so that the home will be more safe and secure;

The system may also include medical sensor capability which will be able to detect the user's medical diagnosis; other capabilities like temperature sensor, humidity sensor, and other such characteristics which will enhance the home network is recommended; and, home gateway (HGW) can be integrated in the home networking system so that internet connection will be more efficient.

REFERENCES

[1] D. Kim, J. Lee, W. Kwon, and I. Yuh, (2002). Design and implementation of home network systems using UPnP middleware for networked appliances. IEEE Transactions on Consumer Electronics, 48(4), pp.963--972.J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," IEEE Trans. Electron Devices, vol. ED-11, pp. 34-39, Jan. 1959.

[2] A. Hossain, H. Van, Y. Jin, and W. Soh, (2007). Indoor localization using multiple wireless technologies. pp.1--8.A. Cichocki and R. Unbehaven, Neural Networks for Optimization and Signal Processing, 1st ed. Chichester, U.K.: Wiley, 1993, ch. 2, pp. 45-47.

[3] W. Xiang, F. Hu, W. Wang, and M. Dohler, (2012). Design and Implementation of Smart Home System, Proceedings of the 2013 Fourth International Conference on Intelligent Systems Design and Engineering Applications Radio resource allocation in LTE-advanced cellular networks with M2M communications. Communications Magazine, IEEE, 50(7), pp.184--192.

[4] J. Castillo, (2009). The survival of communications in ad hoc and M2M networks: Study of the applications of hybrid intelligent nodes that process simultaneous signals IEEE802. 11h/Bluetooth in comparison with IEEE 802.11 h/802.15. 3.

[5] B. Mitchell, (2014), What Are the Benefits of Networking. Retrieved: 30 September 2014. http://compnetworking.about.com/cs/wireless/f/whywirelesslan.htm.

[6] Yan, et. al., (2011) Home M2M Networks: Architectures,Standards, and QoS Improvement, IEEE Communications Magazine , April 2011.

[7] L. Yue, K. Jiawen, and Y. Rong, (2013), Efficient and Secure Resource Management in Home M2M Networks, International Journal of Distributed Sensor Networks, October 2013.

[8] A. Alheraish, (2004) Design and Implementation of Home Automation System. IEEE Transactions on Consumer Electronics, 1092 Vol. 50, No. 4, NOVEMBER 2004.

[9] M. Chen, V. Leung, R. Hjelsvold, X. Huang, "Smart and interactive ubiquitous multimedia services," Computer Communications, vol. 35, no. 15, pp.1769–1771, Sep. 2012.

[10] Service requirements for machine-type communications (MTC); stage 1, release 11. Technical Report TR 22.368 V11.0.1, 3GPP, Sophia Antipolis, France, Feb. 2011.

[11] J. Wan, M. Chen, F. Xia, D. Li, and K. Zhou, "From machine-to-machine communications towards cyber-physical systems", Computer Science and Information Systems, vol. 10, no. 3, pp. 1105–1128, Jun 2013.

[12] N. Gligoric, S. Krco, D. Drajic, S. Jokic, and B. Jakovljevic, (2011). M2M device management in LTE networks. pp.414--417.

[13] M. Nakamura, A. Tanaka, H. Igaki, H. Tamada, and K. Matsumoto, (2008). Constructing home network systems and integrated services using legacy home appliances and web services. International Journal of Web Services Research (IJWSR), 5(1), pp.82--98.

[14] M. Inoue, T. Higuma, Y. Ito, N. Kushiro, and H. Kubota, (2003). Network architecture for home energy management system. Consumer Electronics, IEEE Transactions on, 49(3), pp.606--613.

[15] P. Parikh, M. Kanabar, and T. Sidhu, (2010). Opportunities and challenges of wireless communication technologies for smart grid applications. pp.1--7.

[16] N. Sriskanthan, F. Tan, A. Karande, (2002), Bluetooth based home automation system. Microprocessor and Microsystems, Elsevier Science, 2002.

[17] Y. Tajika, T. Saito, K. Teramoto, N. Oosaka, M. Isshiki, "Networked home appliance system using Bluetooth technology integrating appliance control/monitoring with Internet service," Consumer Electronics, IEEE Transactions on , vol.49, no.4, pp.1043,1048, Nov. 2003

[18] W. Lilakiatsakun, A. Seneviratne, "Wireless home networks based on a hierarchical Bluetooth scatternet architecture," Networks, 2001. Proceedings. Ninth IEEE International Conference on , vol., no., pp.481,485, 10-12 Oct. 2001.

[19] M. Idoudi, H. Elkhorchani, K. Grayaa, "Performance evaluation of Wireless Sensor Networks based on ZigBee technology in smart home," Electrical Engineering and Software Applications (ICEESA), 2013 International Conference on , vol., no., pp.1,4, 21-23 March 2013.

[20] F. Anan, X. Xiaoling, Y. Wenling, Z. Li, "The Realization of Intelligent Home by ZigBee Wireless Network Technology," Circuits, Communications and Systems, 2009. PACCS '09. Pacific-Asia Conference on , vol., no., pp.81,84, 16-17 May 2009.

[21] H. Yoon, J. Kim, (2010) "Collaborative streaming-based media content sharing in WiFi-enabled home networks," Consumer Electronics, IEEE Transactions on , vol.56, no.4, pp.2193,2200, November 2010.