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Design and Development of Hardware to Interconnect Heterogeneous Wireless Networks

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Abstract: Interconnection of different wireless standards to achieve wide range of connectivity and easy access to information has been at forefront in terms of modern technologies. Designing such a system is a challenging task and in this paper, we have designed a hardware based wireless heterogeneous network to enable different wireless technologies to interconnect with each other. Our experimental results show that our designed heterogeneous network performs well if the size of data is kept small and if the wireless devices connecting to heterogeneous router are kept at optimal distance. Moreover, our test results show that there is minimum bit error as well as delay if the transmission is between Bluetooth and RF module.

Keywords: Heterogeneous Wireless Networks, Heterogeneous Router,

1. INTRODUCTION

Today wireless technology is at forefront with respect to modern technologies and has become the essential means of connecting business and households to different media services. It is a means of instantaneous wire-free reliable high data rate communication, where wiring is costly or infeasible (Yang, *et al.,* 2012). Moreover, the development and advancement of portable/mobile devices capable of advanced wireless technologies hasbrought the emergence of novel era in wireless connectivity as well as easy access to information.

Integration of wireless networks may include various mixed radio access technologies (RAT) such as universal mobile telephone system (UMTS), global system for mobile communication (GSM), worldwide interoperability over microwave access (WiMAX), wireless local area network (WLAN). The idea is to interconnect such heterogeneous networks to support real time applications (Fettouh, *et al.,* 2013). To design such a hardware as well as protocol to integrate services by various wireless standards is a challenging task. For example, there is connectivity issue if someone wants to communicate or share information via Bluetooth to RF (Radio Frequency) supported device. The reason for this behavior is due to the fact that these different wireless standards operate at different frequency band and/or data rate. Motivation of this work is to build compatibility between these various wireless standards so as a particular wireless moduleis able to send and receive the data from the different wireless standards. However, designing a heterogeneous wireless network can be a challenging task as different wireless networks in close proximity might interfere with each other. Hence, the idea is to design a Heterogeneous Router (HR)to enable wireless devices on different wireless networks to interconnect with each other.

The paper is organized as follows. The literature review and related work is discussed in Section2. Section 3describesthe proposed model and the description about the prototype system. Performance analysis and results are highlighted in Section4. Finally, we conclude the work in Section5.

2. RELATED WORK

A lot of work has been done in designing protocols to combine different wireless networks and theoretically analyzing their performance. The development of hardware to support heterogeneous network has been reported by a few. In (Wu, 2016), an efficient and encrypted communication protocol for heterogeneous network was designed and developed to integrate signals from devices using different communication protocols in such a way the devices can communicate with each other. A hardware based environment is reported in(Bernardo, *et al.,* 2007). The research work mainly focused on, beyond 3rd Generation (B3G) real time testbed for mixed networks. Whereas, work presented in (Singh & Singh, 2012)is based on Zigbee wireless standard for medical application. A smart sensor platform using various sensors for the car parking is developedand interfaced using Arduino board (Urdiain, *et al.,* 2012). However, the communication between these various modules was carried out with the development of non-standard protocol. The work in (Georgitzikis, *et al.,* 2012) developed a hardware based

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platform to work over the IEEE 802.15.4 wireless standard. The work utilized various types of wireless sensor hardware platforms such as Suspot, isense Telos B, Arduino along with the mksense software library to make the inter-communication between different hardware modules to create a heterogeneous wireless sensor network.

A simulation based performance comparison between "reservation'' protocols have been report in (Suzuki and Tasaka, 1992). The authors in (Fettouh, *et al.,* 2012) have also focused on simulation (OPNET) based performance analysis and optimization of handover mechanism on heterogeneous network. The authors in (Bouckaert, *et al.,* 2009) have interconnected Wireless Mesh Network (WMN) and Wireless Sensor Network (WSN). The study suggests that the comprehensive sensing capability of sensor networks may be improved with amplified throughput, trustworthiness and vigor necessities in the form of interconnected (Mesh) networks. The authors in (Cordeiro, et al., 2004) have proposed a scenario in which the consolidation of different wireless networks standards (WPAN and WLAN) canbe achieved using their newly developed architecture named BlueStar.

The authors (Piyare and Lee, 2013) have proposed an architecture that is expendable and adjustable to interconnect WSN and Cloud. However, the paper has limitation for specific networks such as Xbee and RF.The authors in (Cao, *et al.,* 2009) presented the prototype of heterogeneous advance wireless network (HAWK).The work stated in this paper provided an awareness of implementation and design of wireless networks in different facets of hardware and software to the readers. Hence, it is possible to make a realistic deployment of heterogeneous wireless networks (HWN). The authors in (Mohanty, 2007) have shown to cope with research challenges such as addressing and routing to interconnect different networks. The proposed scheme communicates between different WSNs and Internet Protocol version 4 (IPv4) based networks.

A comprehensive performance analysis of wired/wireless heterogeneous networks has been reported in (Li, *et al.,* 2009). The main idea presented by the authors was overall network performance interpretation approach. The proposed approach was purely based on fuzzy analytic hierarchy process (FAHP). The experimental work was carried out using simulation model. (Yuan, 2011) has introduced the scheme to interconnect heterogeneous wireless networks, that is based primarily on IP switching.

(Saini, *et al.,* 2015)has presented work of designing a wireless standard transceiver based on Zigbee standard. The simulations of the transceiver were carried out over the MATLAB. Another work in (Rahman, *et al., 2013)* showed simulation of different wireless standard receivers. Three different types of protocols WiFi, Bluetooth and Zigbee were focused in this paper. The optimization of energy utilization in WSN has been studied in (Ouni & Ayoub, 2013) using NS2 simulation tool. Whereas, performance analysis of Zigbee wireless standard using real testbed has been demonstrated in (Mraz, *et al.,* 2013).

3. PROPOSED MODEL

The idea behind the development of the project is develop a system or hardware to work as a router, in such a way that different types of wireless hardware devices such as Bluetooth, Zigbee, can communicate with each other to form a heterogeneous network. We name this device a heterogeneous router (HR) to work as a translator.

3.1 Structural Design

The proposed model basically consists of a heterogeneous router (HR) and end devices that operate on different platforms such as Zigbee, and Bluetooth. These end devices form a full duplex communication with HR. The proposed model is shown in **(Fig. 1)**.

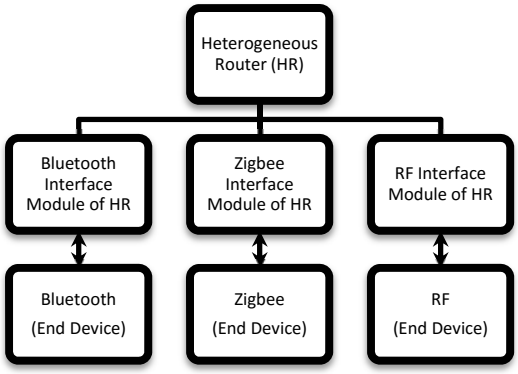

Fig. 1 : Proposed Communication Model

The design of heterogeneous router has been the challenging task and its design scheme is shown in **(Fig. 2)** and the description of the block diagram is as follows.

The heterogeneous router (HR), which basically consists of different hardware modules is connected together with the help of power and data lines using Arduino board. The power and data lines are used to power each device and carry information. To ensure integrity of data and proper connectivity, we have checked the output of each hardware module through the help of different software's supported by each hardware module. We also did number of test to ensure the HR stays in stable and reliable working state and behave in a proper manner using software application. For example, it is also ensured that the hardware

modules communicate with HR bi-directionally. The data testing utility software used for RF module is Arduino Serial IDE Monitor, and for Zigbee module is XCTU software. Microcontroller is programmed using Arduino Serial IDE Monitor software. The developed heterogeneous router's hardware design is shown in **(Fig.3).** and the model containing HR, RF end point, Zigbee end point, as well as Bluetooth end point is shown in **(Fig.4).**

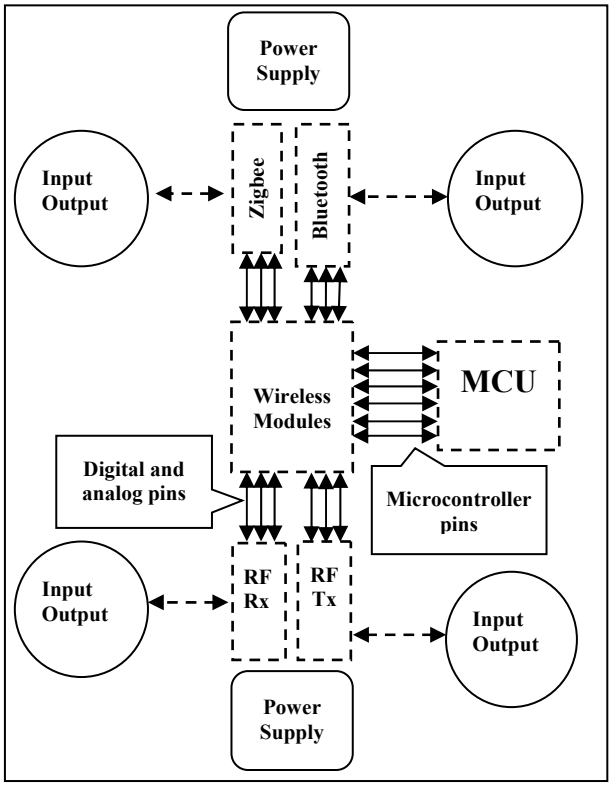

Fig. 2 : Block diagram of complete developed scenario

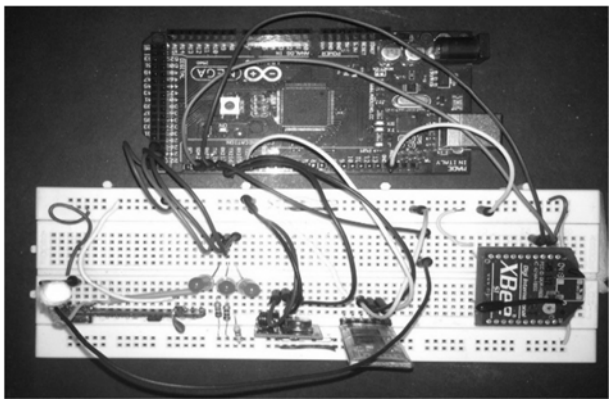

Fig. 3 : The snapshot of HR's hardware design

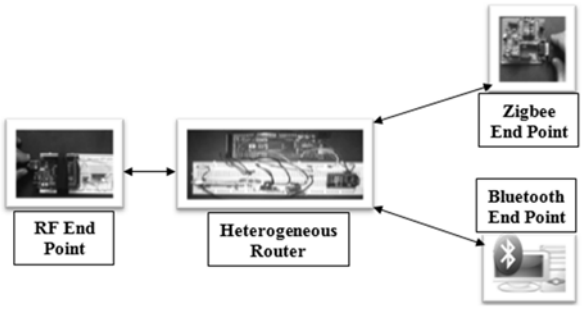

Fig. 4 : The test-bed model for HR

3.2 Program Formulation

The open source Arduino board possess software environment to write code to make communication possible between wireless modules. The structure, physical data, and translation has been carried out with the help of different libraries. For example, we have used virtual wire library, which has the compatibility with RF wireless hardware module. Whereas, serial library is utilized to support zigbee, xbee, and Bluetooth modules.

Based on the utilized hardware, the write-up of coding process can be categorized into two main sections. The first section involves initialization process and the other section includes execution and loops. For instance, we need addressing techniques to select the particular device to either receive or send the data. Each hardware module has its own assigned unique address and it is used to identify and communicate with the device.

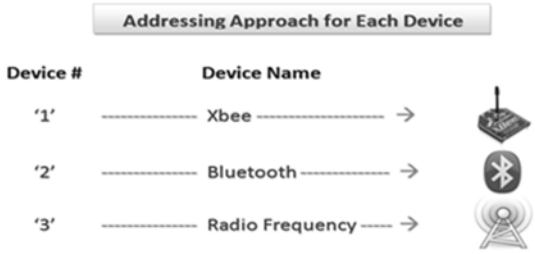

Fig. 5: Addressing approach for each hardware module

The **(Fig. 5).** illustrate the overall addressing approach for each hardware module. Whereas, the snapshot of successful communication between hardware modules is shown in **(Fig. 6).** The Fig. 6 illustrates that the test messages are successfully transmitted between different hardware modules.

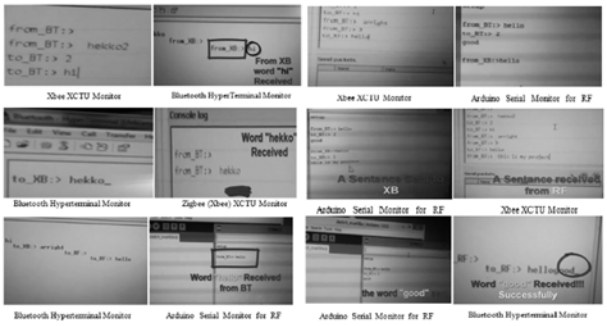

Fig. 6: The snapshot of successful transmission and reception of messages using the designed system

4. PERFORMANCE ANALYSIS

The designed wireless heterogeneous network is tested for its performance in terms of data transmission and reception. A random dummy data is transmitted between different hardware modules using heterogeneous router. The result of data transmission and reception from Bluetooth to RF hardware module is shown in **(Fig. 7).**

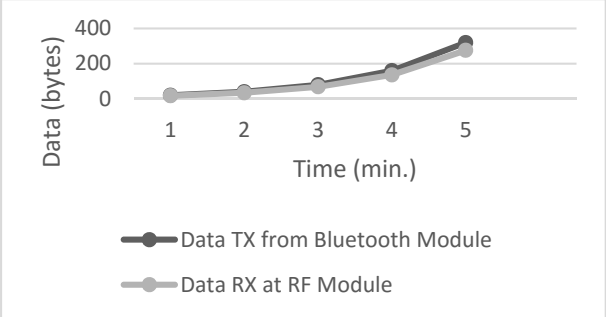

Fig. 7: Data transmission and reception between Bluetooth and RF hardware module

To understand the working mechanism, the data from Bluetooth end device is transmitted to Heterogeneous Router (HR), which in turn forwards it to destined RF enabled end device. The successful transmission mechanism of data at different intervals of time is shown in **(Fig. 7).** Whereas, the data transmission between Xbee and Bluetooth hardware module is shown in **(Fig. 8).**

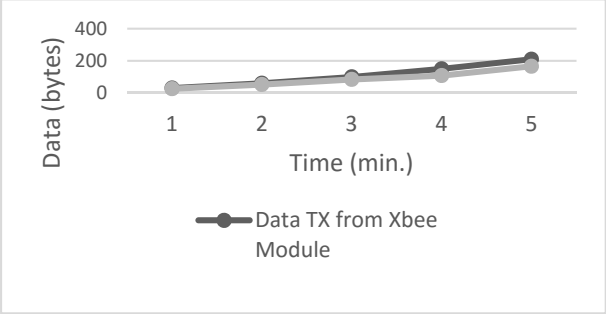

Fig. 8: Data transmission and reception between Xbee and Bluetooth hardware module

The horizontal axis of the graph shows the time in minutes for the reception and transmission of data. Whereas, the vertical axis represents the data transmitted and received at the end device or end point. It is observed as the chuck size of data is increased, the probably of successful reception of data decreases. The graphical analysis shows that the performance of data transmission between Bluetooth and RF hardware module is good. Similar experiments were conducted to test the proper functionality of data transfer between different hardware modules. The results of such experiments showed similar behavior and are not shown for the sake of limited space.

Moreover, the communication between hardware module is tested and analyzed through oscilloscope (DS1M12). The results generated with the help of Easy Logger for DS1M12 electronic oscilloscope are shown in **(Fig. 9).**

The first two graphs on top show the magnitude response and the other two on bottom show the phase response of the hardware modules. The colored lines represent each hardware modules data reception and transmission. The horizontal axis of magnitude plot represents the frequency in hertz and vertical axisof magnitude plot represents voltage in mill volts. Whereas, the horizontal axis of phase plot represents the frequency in hertz and vertical axis of phase plot represents angle in radians. The phase response shows that there is minute or little delay of data reception between RF and Zigbee hardware module.

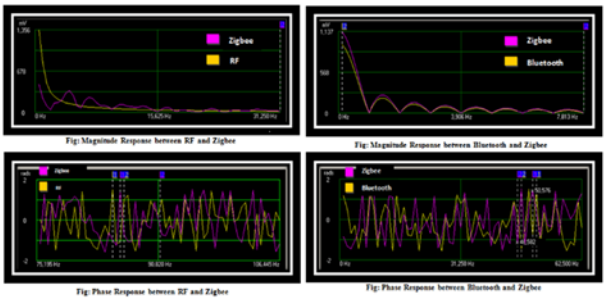

Fig. 9: Magnitude and Phase response of communication held between hardware modules

The communication between Bluetooth and Zigbee module show identical curves, representing minimal delay and exact same data transfer. The results demonstrate that the designed system is very sturdy and its performance depends upon factors such as data size, range, and power supported by each wireless hardware module.

5. CONCLUSION

In this contemporary era, the connectivity between different or various types of network standards has become a pre-requisite in one way or another. With the

help of our designed heterogeneous network (HN), it is possible to make the communication between different wireless standards and hence share the information through heterogeneous router (HR) on finger tips.

Presently, the HN module contains no any security characteristics. In future, we plan to incorporate security features by adding the additional software program to the .proposed HN module

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