Performance Analysis of IEEE 802.15.6 Standard for WBSN using Castalia Simulation Tool

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Abstract: Due to the advances in Wireless Body Sensor Networks (WBSNs), IEEE standards association formed IEEE 802.15.6 task group for WBSNs. The purpose of this standard was to design new PHY and MAC layer for WBSN. In this work we have analyzed the performance of IEEE 802.15.6 standard for WBSN, using Baseline BAN MAC protocol. The results are analyzed considering different radios with different transmission powers and data rates, the effects of varying these parameters is observed on the latency and energy consumed per node. The results are validated using Castalia as a simulating tool.

Keywords: *Sensor, IEEE 80215.6, Physical layer, BAN MAC protocol, Radio signals*

1. Introduction

Wireless Body Sensor Network (WBSN) allows inexpensive and continuous health monitoring with real-time updates of medical records for a better healthcare system. WBSN is designed to operate autonomously, connecting several sensors that are located on or implanted inside the human body [1]. Introduction of WBSN for medical and healthcare has offered flexibilities and cost saving options for both medical professionals and patients. A WBSN can offer advantage of providing mobility to patients due to usage of portable monitoring devices [2], this helps in better life quality of patients. Such networks comprises various sensors that continuously monitor the signs of life i.e. temperature, blood pressure, pulse rate etc. of patients and further transmit data to the hospital for prescription and diagnosis. Recently, WBSN has gained a lot of attention in health care and medical sciences due to advances in sensing, continuous monitoring and quick warnings.

These networks aim to provide attractive alternative for medical health system than traditional medical health system because of their reduced cost and active monitoring of the patients. Generally, when people get sick they need assistance and different kind of healthcare services, patient needs 24/7 active monitoring and active medical care so WBSN might work well for patients because of its flexibility, reduced cost and more freedom as compared to the traditional health system. In WBSN, along with numerous advantages there are several issues also such as interference, eavesdropping in Body Area Network (BAN) and energy efficiency [3].

In this work, the performance of IEEE 802.15.6 standard for WBSN is analyzed using Baseline BAN MAC protocol in the Castalia Simulation tool. The results are analyzed considering different radios with different transmission powers and data rates, the effects of varying these parameters is observed on the latency [4] and energy consumed per node.

2. Related Work

A lot of research has been done to study IEEE 802.15.6 standard. In [5], the authors have evaluated the performance of WBAN by changing the distribution of slot and the data rates among various MAC access mechanisms used in IEEE 802.15.6 and the performance of WBAN was evaluated through the obtained results of latency, energy consumption and data packet breakdown using Castalia simulation tool. The performance of IEEE 802.15.6 MAC protocol is evaluated and compared with the TMAC and IEEE 802.15.4.6 [6]. The authors have evaluated the latency and throughput using Castalia as simulating tool and concluded that these MAC protocols perform better with GTS ON and temporal variation. In [7], the authors have presented analytical model that computes the QoS parameters i.e. throughput, delay and the amount of consumed energy of IEEE 802.15.6 CSMA/CA protocol used in the beacon enabled mode, assuming a limited number of nodes in saturated and lossy channel. The authors in [8] have analyzed the performance of TMAC, IEEE 802.15.6 and IEEE 802.15.4 MAC protocols under the mobility constraint considering throughput, consumed energy and latency using Castalia as a simulating tool. The authors concluded that the analysis shows IEEE 802.15.4 outperforms IEEE 802.15.6 and TMAC with temporal variation and GTS ON.

3. An Overview of IEEE 802.15.6

Due to increasing interest in the necessity of improving health care application, WBAN found its importance and IEEE association formed the IEEE 802.15.6 task group 6 in November 2007 [9]. The purpose of IEEE 802.15.6 was to define new Physical (PHY) and Medium Access Control (MAC) layers for WBSN [10]. The physical layer of IEEE 802.15.6 is responsible for the data transmission and reception, activation and deactivation of the radio transceiver and also for clear channel assessment. IEEE 802.15.6 standard supports three different PHY layers i.e.

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Narrowband (NB), Ultra Wide-band (UWB) and Human Body Communication (HBC). The selection of each layer depends on the requirements of the application. NB is responsible for activation and deactivation of radio transceiver, clear channel assessment and either data transmission or reception. UWB operates in two frequency bands, low band and high band; these bands are divided into channels. HBC covers whole protocol for WBSN [10].

On the top of PHY layer, the standard has defined a MAC layer. MAC layer is responsible for controlling access to the channel. According to IEEE 802.15.6 standard, the nodes are organized into one or two-hop star WBSNs. The entire operation of WBSN is controlled by a central unit i.e. hub. The standard divides the channels into beacon periods or super frames of same size. In each super frame, there are a number of allocation slots that are being used for data transmission. The central unit i.e. hub is responsible for transmitting beacons in order to define the super frame boundaries and allocating the slots [11]. Beacon is a signal that is sent along the first slot of any super frame, it holds the responsibility of initializing the super frame. The beacon identifies the coordinator, manages the network and the power of the transmitting systems and also does the time synchronization of the data [10].

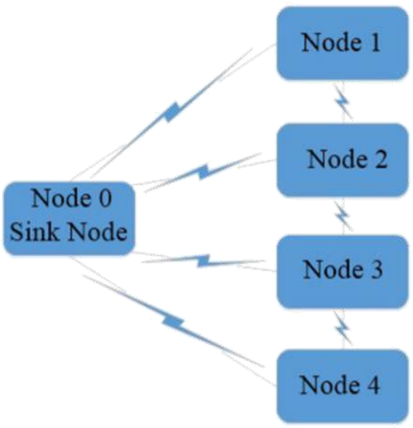


Figure.1. Node Connectivity in BAN

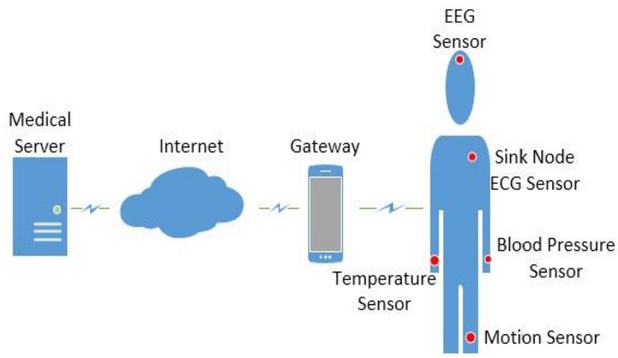
4. Proposed Architecture

Fig. 1 shows the node connectivity in BAN whereas Fig.2 shows the general architecture design of WBSN. In the proposed architecture design, five sensor nodes are attached on the body i.e. temperature, blood pressure, ECG, EEG and motion sensor as shown in figure 2. The number of nodes taken is five because the network is body sensor network so the patients won't wear a lot of sensors on their body. Network is designed in a way that all the sensor nodes are being monitored, each of which sends the data to the sink node that can be further sent to the medical server located at hospital. The packets transmitted contain the source address and the destination address, all the nodes transmit their packets to each other and the ones whose destination address matches, keeps the packet. Node 0 is considered as the sink node and rest of the nodes are the normal nodes. The communication technology used among these sensor nodes is IEEE 802.15.6 using different radios i.e. CC2420, CC1000 and BAN Radio.

In the proposed architecture the MAC used for BAN is Baseline BAN which is IEEE 802.15.6 MAC designed for BAN. The data from the sink node could be further sent to the mobile node, which acts as a gateway to the internet, for analyzing the vital signs at the hospital so that immediate action could be taken for prescription or diagnosis.

Figure.2. General Architecture Design of WBSN

5. Simulation Tool



WBSN is simulated in Castalia Simulator. Castalia is an OMNET++ based simulation tool for Wireless Sensor Networks (WSNs), Body Area Networks (BANs) and for low-power embedded devices networks [12]. Basic module structure of Castalia is shown in Fig. 3. In Castalia, the nodes are connected through the wireless channel module instead of connecting directly to each other. When a node has a packet to send, it goes directly to the wireless channel which is responsible for deciding which node should receive the packet. The physical processes links the nodes, for every physical process there is a module which holds the true value for the quantity that is represented by the physical process. The node module comprises several sub-modules such as application module which is changed by the user to implement a new algorithm. The communication module in the node module contains the Radio, MAC and routing blocks. The mobility manager module present in the node module can also be changed by the user to implement a new protocol or mobility pattern.

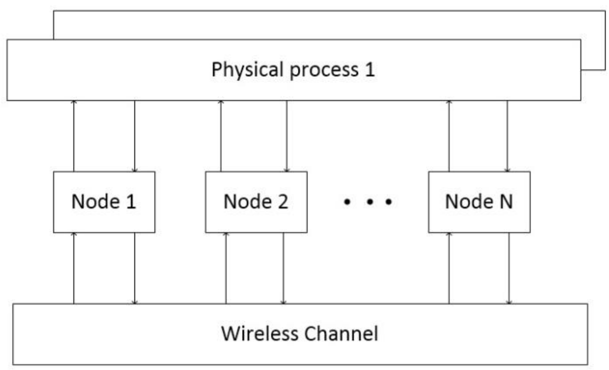


Figure.3. Basic Structure of Castalia [12]

6. Results and Discussions

For the performance analysis, certain parameters are varied such as radios, transmission powers and physical data rates of Baseline BAN MAC. Radios used are CC2420, CC1000 and BAN Radio, first the radio used is CC2420 with the data rates of 32kbps, 250kbps, 650kbps and 1024kbps then CC1000 is considered using same data rates and at last the results are analyzed using BAN Radio. Maximum and minimum transmission power taken for CC2420 is 0dBm and -25dBm respectively, 10dBm and -20dBm for CC1000 whereas -10dBm and - 25dBm for BAN Radio. These changings are done in order to see the effect on latency, and energy consumed per node.

6.1 Latency

Latency is defined as the time taken by a packet of data to reach from one destination to the other. Following figures are the latency results obtained for different data rates i.e. 32, 250, 650 and 1024kbps. In the graphs of latency, x-axis represents latency in ms from 20ms up to infinity whereas y-axis shows the number of packets received.

Fig. 4 and Fig. 5 show the latency of CC2420 Radio with maximum and minimum transmission power of 0dBm and -25dBm respectively. As shown from the figures, at 20ms with higher data rate there are more packets received with 0dBm than with -25dBm transmission power whereas at 600ms there are almost zero packets received with 0dBm but with -25dBm, the number of packets received is being decreased by increasing the data rate.

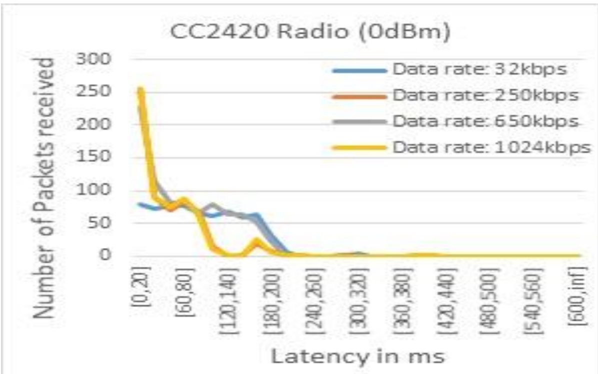


Figure.4. Latency with CC2420 Radio and 0dBm Tx Power.

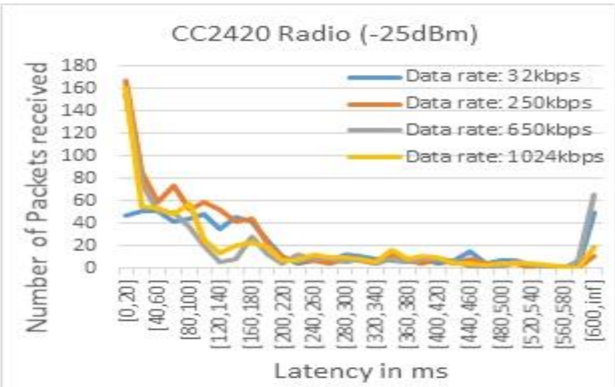


Figure.5. Latency with CC2420 Radio and -25dBm Tx Power

Fig. 6 and Fig.7 show the latency of CC1000 Radio with maximum transmission power of 10dBm and minimum of -20dBm. As shown from the figures, the number of packets received is very low approximately 10 packets at delay of 20ms till 580ms with both the transmission powers. Whereas at 600ms, the number of packets received is greater in higher data rate with -20dBm transmission power than that of 10dBm and with the lower data rate the number of packets received is same with both the transmission powers.

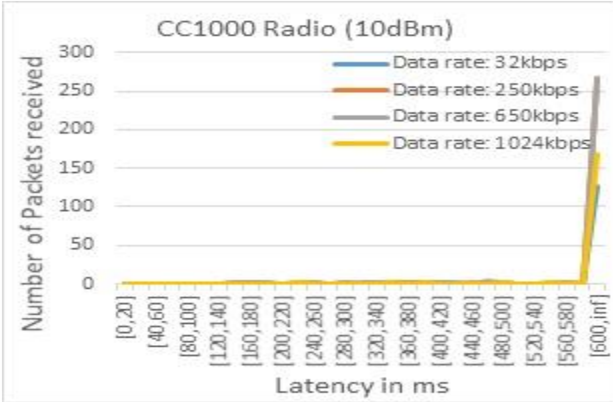


Figure.6. Latency with CC1000 Radio and 10dBm Tx Power

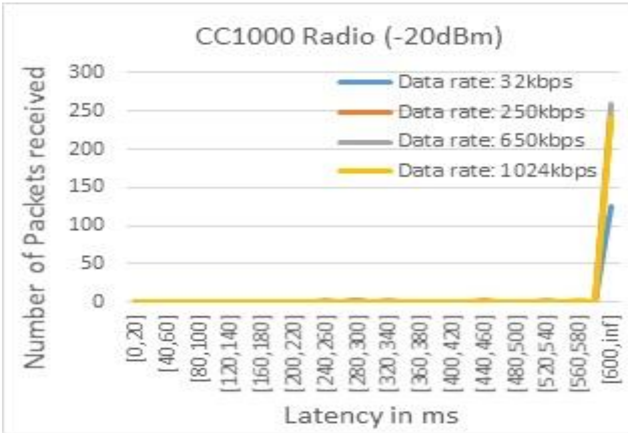


Figure.7. Latency with CC1000 Radio and -20dBm Tx Power

Fig. 8 and Fig. 9 show the latency of BANRadio with maximum transmission power of -10dBm and minimum transmission power of -25dBm. For -10dBm, the curve is getting smoother as we increase the data rate and at the start there are more packets received i.e. 310 packets as compared to BANRadio with -25dBm transmission power. Whereas with -25dBm transmission power, the number of received packets keep increasing at the start (at delay of 20ms) as we increase the data rate. At the start, the number of packets received is lower with low data rate whereas at the end (at delay of 600ms), the number of packets received is more with the low data rate, for -25dBm power.

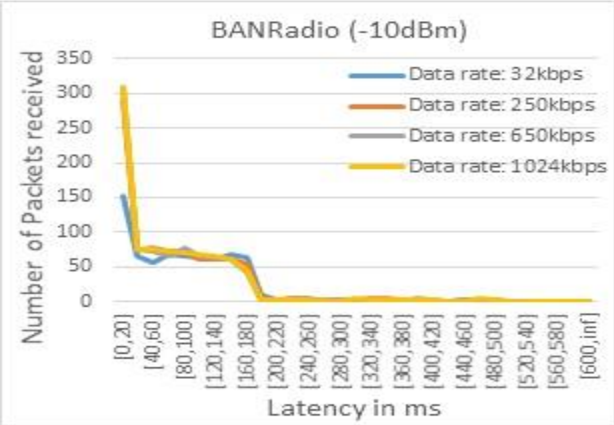


Figure.8. Latency with BANRadio and -10dBm Tx Power

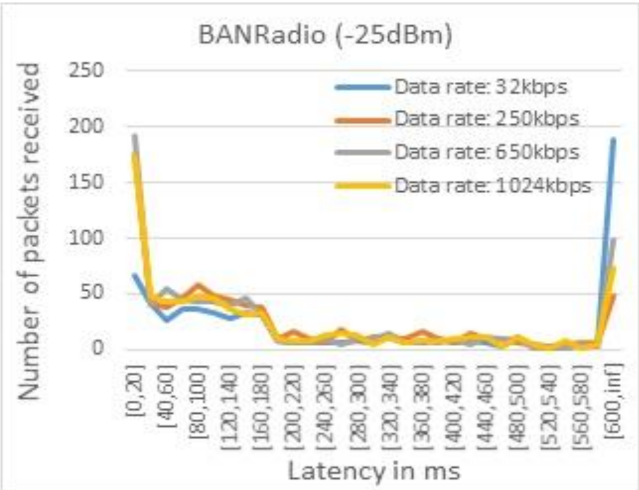


Figure.9. Latency with BANRadio and -25dBm Tx Power

6.2 Energy Consumption

Figure 10 and figure 11 are the energy graphs of CC2420 radio with maximum transmission power of 0dBm and minimum transmission power of -25dBm. As shown from the figures, energy consumption is more in the high data rate i.e. 1024kbps with 0dBm transmission power whereas with - 25dBm transmission power, the consumed energy is more for the low data rate i.e. 32kbps.

Fig. 12 and Fig. 13 shows the energy graphs of CC1000 radio with maximum and minimum transmission powers of 10dBm and -20dBm respectively. As shown from the figures, energy consumption is lower for lower data rate i.e. 32kbps with 10dBm transmission power whereas in -20dBm transmission power, the consumption is more for low data rate i.e. 32kbps. And the maximum energy consumption in CC2420 radio is 3.159J that is more than the energy consumed by other two radios. Hence it can be concluded that this radio consumes large amount of energy than the other two radios.

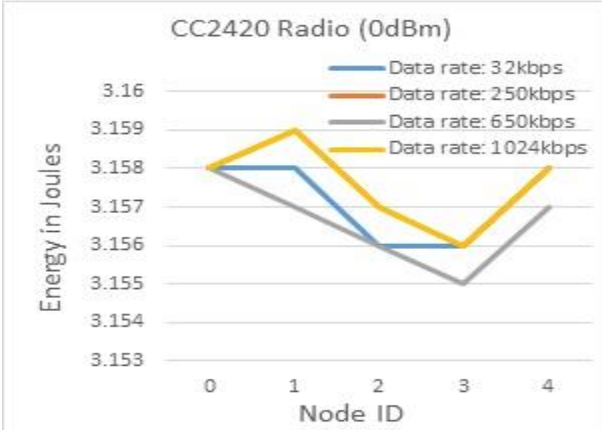


Figure.10. Energy Consumption with CC2420 Radio and 0dBm Tx Power

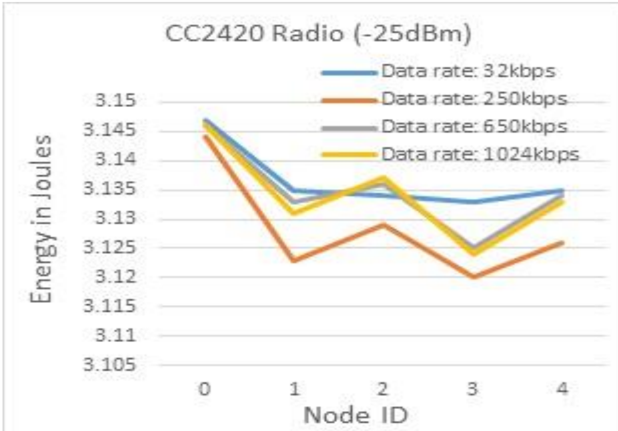


Figure.11. Energy Consumption with CC2420 Radio and -25dBm Tx Power

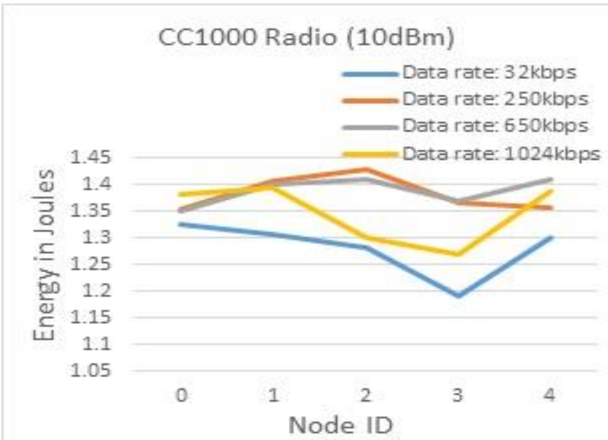


Figure.12. Energy Consumption with CC1000 Radio and 10dBm Tx Power

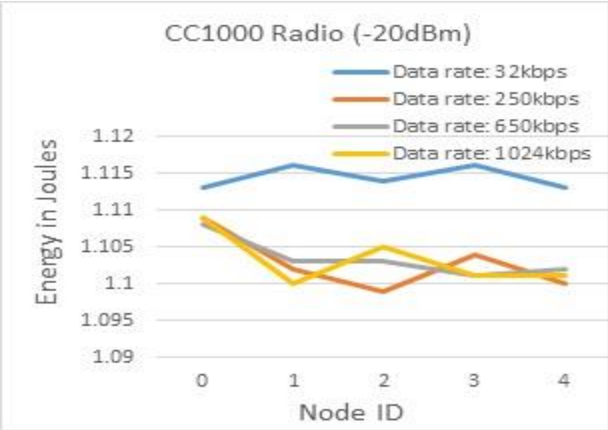


Figure.13. Energy Consumption with CC1000 Radio and -20dBm Tx Power

Fig. 14 and Fig. 15 are the energy graphs of BANRadio with maximum of -10dBm and minimum of -25dBm transmission powers. As it can be seen from the figures that the energy consumption remains same with the change in data rate i.e. 0.158J. Hence it can be concluded that there is no effect of changing the physical data rate and transmission power on energy in BAN Radio. And the energy consumption in BAN Radio is the lowest as compared to the other two radios. This analysis shows that the BAN Radio is good for lower energy consumption applications than CC2420 and CC1000 radios.

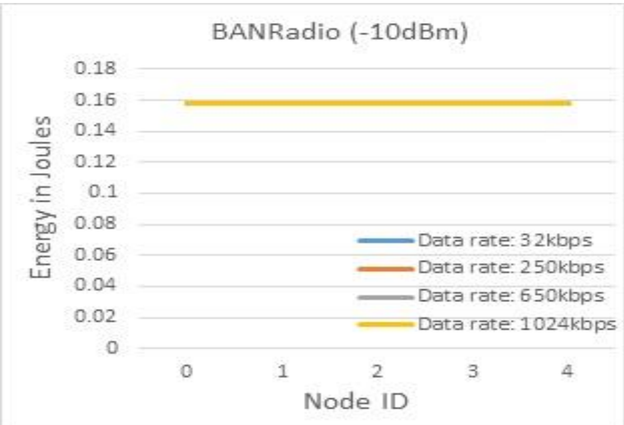


Figure.14. Energy Consumption with BANRadio and -10dBm Tx Power

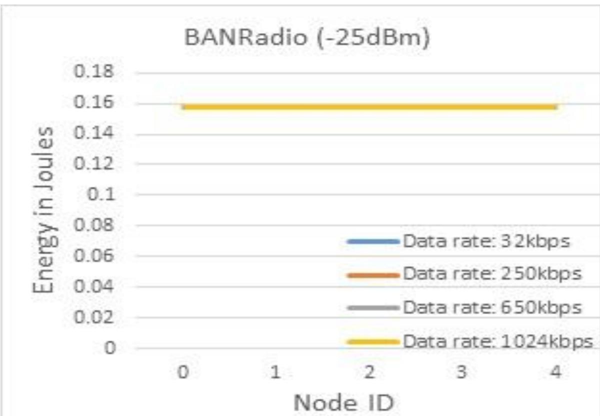


Figure.15. Energy Consumption with BANRadio and -25dBm Tx Power

7. Conclusion

Importance of WBSN in medical health system is increasing vastly due to its ease of use, reliability, reduced cost and freedom. In this work, the performance of IEEE 802.15.6 MAC (BaselineBAN) is analyzed by varying the physical data rates, transmission powers and radios. The performance is evaluated using Castalia as a simulating tool considering latency and energy consumption per node as performance metrics. From the analysis done, it is observed that BAN Radio performs better in energy consumption for IEEE 802.15.6 since BAN radio consumes lowest energy as compared to the other two radios. Whereas CC2420 radio consumes highest amount of energy in comparison to CC1000 and BAN radios. For the latency analysis, it is concluded that in BAN radio there are more number of packets received initially at the delay of 20ms whereas the packets are received after a lot of delay in CC1000 radio which means that in terms of latency CC1000 doesn't performs well than the other two radios.

The impact of increasing and decreasing the data rates using maximum and minimum transmission power is also observed on the latency and energy consumptions.

8. Acknowledgement

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Aisha Sahito graduated from Mehran University of Engineering and Technology, Jamshoro in Electronics Engineering in 2014.