www.revistageintec.net
ISSN: 2237-0722
revista GEINTEC
Gestão, Inovação e Tecnologias

Energy Efficiency Analysis of LoRa and ZigBee Protocols in Wireless Sensor Networks

K. Raghava Rao[1*]; D. Sateesh Kumar[2]; Mohiddin Shaw[3]; V. Sitamahalakshmi[4]

[1*]Department of ECM, Koneru Lakshmaiah Education Foundation, Guntur, AP, India.

[1*]krraocse@gmail.com

[2]Department of Mathematics, Koneru Lakshmaiah Education Foundation, Guntur, AP, India.

[3]Department of ECM, Koneru Lakshmaiah Education Foundation, Guntur, AP, India.

Department of BS&H (Mathematics), Narasaraopeta Engineering College, Guntur, AP, India.

[4]Department of Freshman Engineering, Prasad V Potluri Siddhartha Institute of Technology, Kanuru, Krishna, AP, India.

Abstract

Now a days IoT technologies are emerging technology with wide range of applications. Wireless sensor networks (WSNs) are plays vital role in IoT technologies. Construction of wireless sensor node with low-power radio link and high-speed processors is an interesting contribution for wireless sensor networks and IoT applications. Most of WSNs are furnished with battery source that has limited lifetime. The maximum operations of these networks require more power utility. Nevertheless, improving network efficiency and lifetime is a curtail issue in WSNs. Designing a low powered wireless sensor networks is a major challenges in recent years, it is essential to model its efficiency and power consumption for different applications. This paper describes power consumption model based on LoRa and Zigbee protocols, allows wireless sensor nodes to monitor and measure power consumption in a cyclic sleeping scenario. Experiential results reveals that the designed LoRa wireless sensor nodes have the potential for real-world IoT application with due consideration of communicating distance, data packets, transmitting speed, and consumes low power as compared with Zigbee sensor nodes. The measured sleep intervals achieved lower power consumption in LoRa as compared with Zigbee. The uniqueness of this research work lies in the review of wireless sensor node optimization and power consumption of these two wireless sensor networks for IoT applications.

Key-words: Zigbee, LoRa, IoT, Wireless Sensor Network, Protocols, Wireless Communication.

1. Introduction

WSNs have been applying in many applications such as industrial automation processes, environmental, agricultural, medical, and many others. It is a known fact that wireless sensor network is a resource embarrassed network in which power consumption and efficiency is always the important argument since the operation of wireless sensor network depends laboriously on the life span of the sensor node's battery. The sensor nodes are always deployed in extreme environmental conditions so, it is almost impossible or difficult to recharge or replace their batteries. To achieve superior performance of the sensor node, many research works have been performed to find the optimal processing, networking, and energy efficiency for each network node. To increase the wireless sensor network efficiency and low power consumption, one of the useful methods in wireless sensor nodes that they are operated in (cyclic) slicks up sleep mode. There are three stages of operation modes: sleep, idle, and active modes. The correlation between active and sleep time is called the duty cycle and active state, wireless sensor nodes consume more power. In recent years microcontrollers provide better power options for power management such as active mode, sleep mode, and deep sleep mode. In deep sleep modes, Microcontrollers (MC) can able to consume less current in terms of micro-amps. There are disparate approaches to assess and analyze the energy consumption of WSNs such as simulation, mathematical, miniature, and experimental. An effectual management avenue is to let the sensor nodes go to sleep and wake up only when it is required and selecting the right communication protocols. We have different communication protocols used in WSNs like Zigbee, Bluetooth, Wi-Fi, and LoRa communication protocols, these are widely used protocols depending on the application requirement. In this paper we focus on Zigbee and LoRa communication modules for comparing power consumption, communication range, and data packets transmitting in different sleep time intervals in WSNs.

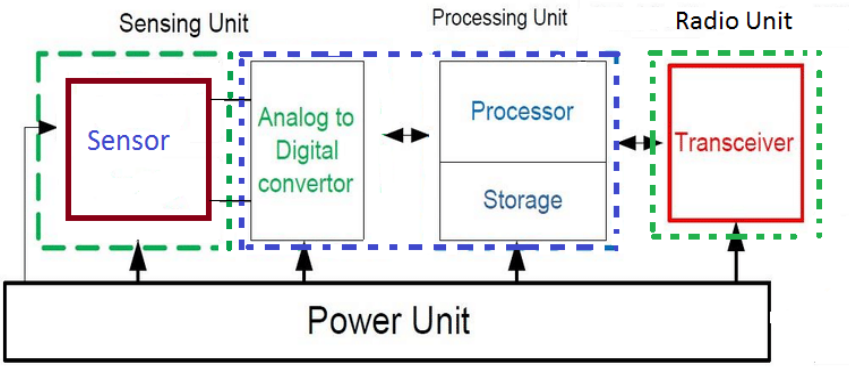
2. Literature Review

Wireless sensor networks have maximum utility when they can be worked "any-time, anywhere at any environmental conditions" [1]. When developing low power wireless sensor network for an IoT application, the major concerns are selecting desired hardware, software [2] and radio link between the sensor node and gateways, selecting right hardware shows the impact on power consumption in sensor node lifetime. Earlier research proposed power efficiency measuring in low powered WSNs in different methods. Nelson Rosa et al. [3] proposed the power consumption of WSNs by using simulation models along with a set of tools and automate the proposed approach. Antonio Moschitta et al. [4]. Sabrine Khriji et al. [5] proposed a method for estimating the energy consumption of a low power wireless node using pan stamp NRG 2.0.and calculates the consumed energy for different operation cycles. The authors described how much energy is consumed for each state and the required time for each operational cycle. Using these measurement results they improved the precision of the energy component of the pan stamp wireless platform, however, they did not compare different wireless sensor networks power consumption. Demented et al. [6] have practically analyzed the power consummation of Bluetooth, Zigbee, and ANT protocols, BLE consumes low power when compared to ANT, and ZigBee successfully done that power consumption of wireless sensor networks might change depending on different factors like packet size, distance, and output power, however, they did not test the power consumption analyzed model using LoRa modulation. Kanitkornkhanchuea et al. [7] analyzed the power consumption of wireless communication protocols namely Zigbee and Wi-Fi experimentally and concludes that the sensor node using ZigBee consumed less power and took a shorter time to connect to the gateway node than using Wi-Fi. However, they did not compare power consumption using LoRa modulation.

3. Sensor Node Design

Wireless sensor network is a compilation of sensing nodes, acts as data processing and network switching and they can sense, convert data in one form to another and communicate to another sensor node and head nodes (HN). The sensor node architecture delineated in figure 1. Sensor nodes operate with low Power consumption is a major concern.

Figure 1 - A Structure of a Wireless Sensor Network Node

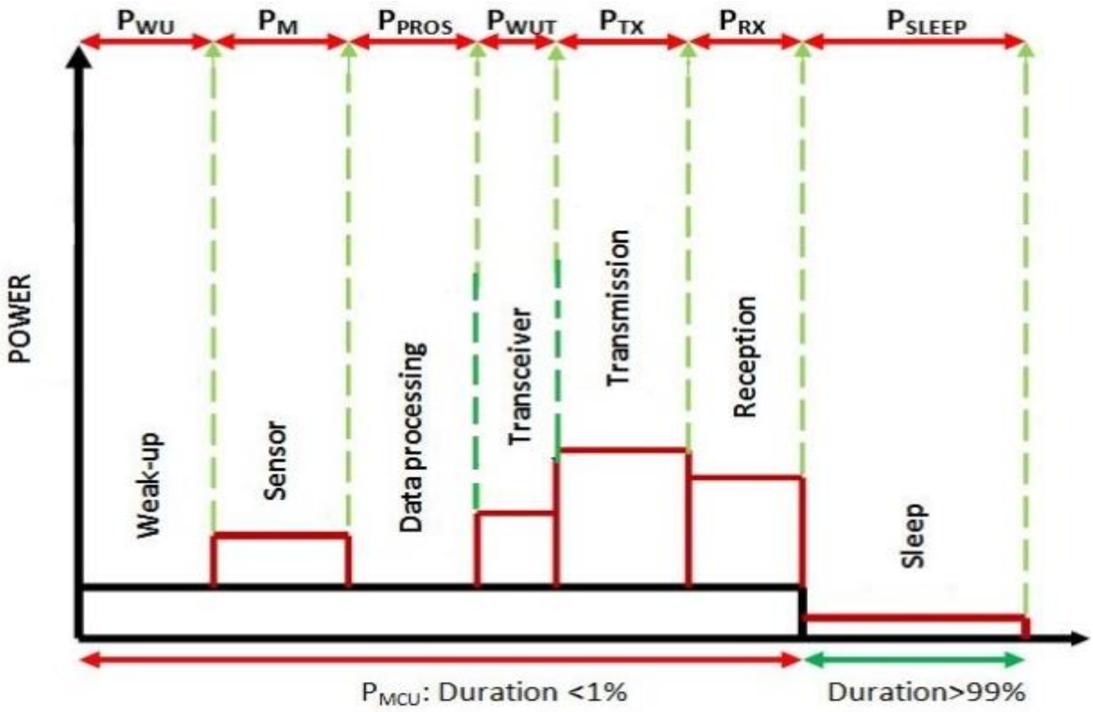


Sensing, processing, power source and transceiver unit are four major modules in wireless sensor node architecture. *Sensing unit:* Sensors and module are the electronic devices that detects and respond to some type of input from the physical environmental conditions, these parameters are in analog form and converted in to digital format. *Processing unit:* acquisition of an output signal from the sensor unit, process the data after accession and communicate data to the transceiver. *Power*

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

source unit: One of the most important unit in sensor node. Most of the sensor node equipped with one or more batteries as power source *Transceiver unit:* Once data processing is done, the data send to sink node. Several wireless communication protocols have been bounced in the recent years. Amid these, long-range, low-Power, and high data rate communication protocols are gaining a lot of fascinate in real-world applications.

Figure 2 - Power Consumption Model of Sensor Node



The working of sensor node is characterized by variable time durations. Figure 2 illustrates achievable working time duration of the sensor node in different operating modes, which are maneuver by the Central processing Unit. In this proposed model, power consumed by the sensor node A and B for one cycle is given by equation 1.

$$P_{total} = P_{active} + P_{sleep} \quad (1)$$

Where P_{Sleep} and P_{Active} are the measured power by the sensor nodes in sleep mode and the total power consumed by the microcontroller, respectively.

$$P_{active} = T_{sleep}.P_{sleep} \quad (2)$$

Where P_{Sleep} and T_{Sleep} is sleep time duration and total power consumption. Total active power consumption of the sensor node is given by equation 3.

$$P_{Active} = P_{WU} + P_{m} + P_{proc} + P_{WUT} + P_{TX} + P_{RX}, \quad (3)$$

Where P_{WU} wake up time, P_m measurement of sensor, P_{proc} data processing, P_{WUT} wake up of radio module, P_{TX} data transmission power and P_{RX} data reception respectively. The active mode is managed by the microcontroller. The consumed power P_{WU} during the wake-up time duration T_{WU} is given below.

$$P_{WU=}(P_{MCU}(f_{MCU})) . (T_{WU,}) \quad (4)$$

Where f_{MCU} is microcontroller clock frequency (which differs from microcontroller to microcontroller) P_{MCU} and T_{MU} are power consumed by the microcontroller and weak-up duration respectively. Measuring power consumption of the sensor node is given in equation 5.

$$P_M=(P_{MCU}(f_{MCU})) +T_M \quad (5)$$

Where $(P_{MCU}(f_{MCU}))$ and T_M are the consumed power and time duration of measurements by the microcontroller respectively. After the measurement step, the microcontroller proceeds to data processing which is given by equation 6.

$$P_{PROC}= (P_{MCU}(f_{MCU})). (N_{INST}/F_{MCU}) \quad (6)$$

Where N_{INST}/F_{MCU} (data processing depends number of instructions/clock frequency of the microcontroller) and $(P_{MCU}(f_{MCU}))$ are the consumed power during the data processing, Then consumed power during transceiver weak-up time given in equation 7 respectively.

$$P_{WUT} = (P_{MCU}(f_{MCU})). T_{WUT} \quad (7)$$

The power consumed by the data transmit mode P_{TX} is given as below.

$$P_{TX}= (P_{MCU}(f_{MCU})) + T_{TX} \quad (8)$$

Where P_{TX} and T_{TX} are time duration and power consumption while data transmission, the consumed power by the received data P_{RX} is given by the following equation.

$$P_{RX}= (P_{MCU}(f_{MCU})) + T_{RX} \quad (9)$$

The sensor node power consumption depends on overall working time in the various modes. It can be written as the following.

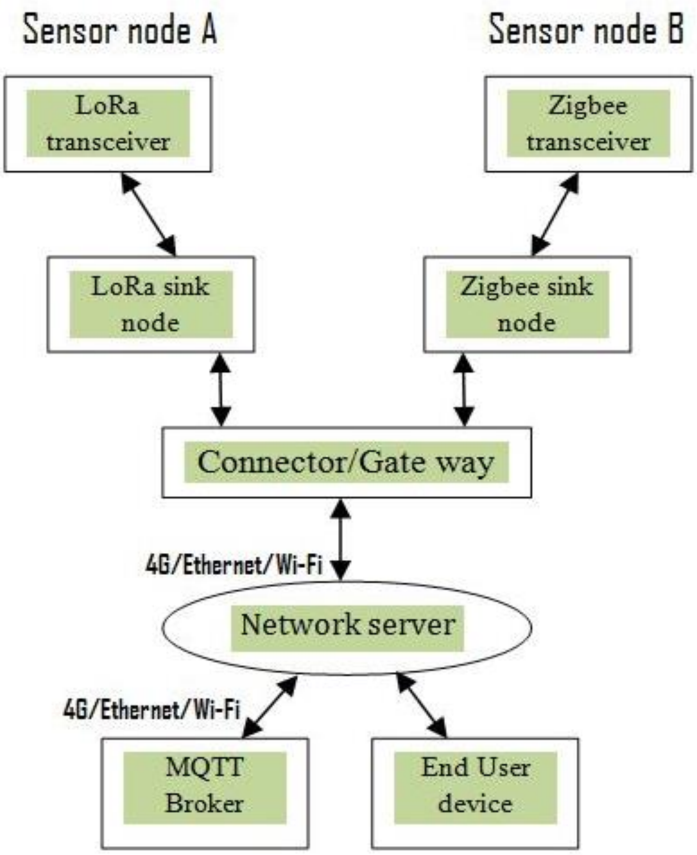
$$T_{MCU}(f_{MCU}) = T_{WU} + T_M + T_{proc}(f_{MCU}) + T_{WUT} + T_{TX} + T_{RX}, \quad (10)$$

After developing proposed sensor node model, system implementation section depicts the power consumption monitoring and analysis between LoRa and Zigtbee communication protocols.

4. Experimental Setup

The LoRa and ZigBee sensor nodes was designed, developed, and experimentally tested. Experimental system model consists sensor node A (LoRa) and sensor node B (ZigBee) transceivers, sink nodes A and B, central connector/gateway, network server, and end user (Bevy wise IoT platform) application for monitoring and characteristics analysis of both sensor nodes. Figure 5 depicts experimental system setup model.

Figure 5 - Experimental Setup for System Model

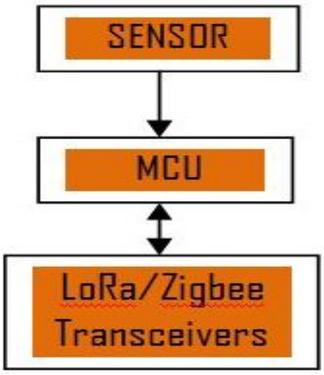


4.1. Proposed sensor node A and B

Sensor node A and B equipped with AVR architecture based ATmega328 microcontroller because of its unique features (especially data processing speed and various low power consumption options), which is suitable for wide range of WSNs and IoT applications. SHT21 digital sensor for measuring temperature and humidity which is integrated with I2C serial communication protocol makes easy to interface any microcontroller. LoRa transceiver (SX1728) [11] radio interface with sensor node A and ZigBee (Xbee S2C) transceiver interface [12] with sensor node B, and INA226 sensor [10] interfaced for measuring voltage and current level of the sensor node. Figure6 shows sensor node A and B.

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

Figure 6 - Sensor Node Design

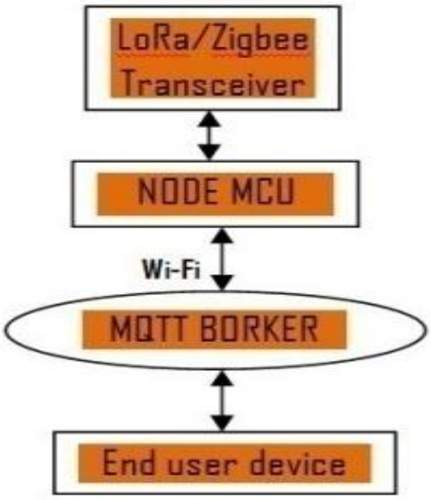


We designed and programmed our proposed energy model algorithm for sensor node A and B, such a way that measured sensor data transmitting to sink node A and B in cyclic sleep modes.

4.2. Proposed Sink Node A and B

The sink node design is depicted in Figure 7 NodeMCU chose as the main controller [8, 9] (which is based on ESP-12 Wi-Fi module) and separately interface Zigbee and LoRa radio modules to NodeMCU. Sink node configures as gateway and received data packets send to MQTT broker

Figure 7 - Sink Node Design



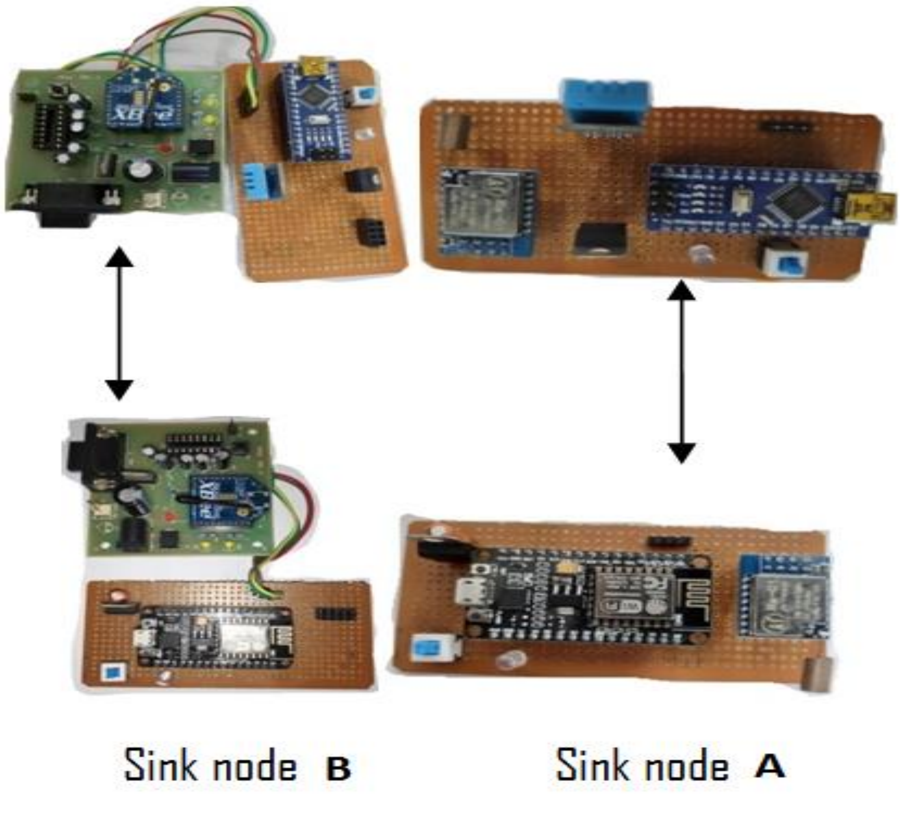
4.3. Experimental Hardware Setup

We have set up two experiments to demonstrate the implemented functionality and test sensor nodes. The objective of the experimental setup was sensor nodes active power consumption, sleep

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

power consumption and distance between sensor nodes to sink nodes. Both sensor nodes separately tested. In first experiment sensor node interfaced with Zigbee transceiver as shown in figure 8. The Zigbee sink node configured as a gateway, receives incoming data packets from Zigbee sensor node and convert into MQTT protocol based data packets and send to Bavy wise IoT platform [13] via a Wi-Fi. In second experimental setup, we disabled Zigbee and connected LoRa module, now that LoRa sink node acts as a gateway to connect and send MQTT protocol based data packets to IoT platform, so each of the sensor node measured current consumption while sensor nodes under test individually. The distance between sensor nodes to sink node was fixed to 5 and 10 meters respectively and the transmitting power fixed with default module setting for sensor nodes A and B. Size of the data packets sends from the sensor node to sink node 8 to 64(8,16,32, and 64) bytes. Sleep time varied from the ensuring steps 15, 30, 50, 80 and 100 seconds and recorded average RSSI, sleep and active current consumption of each sensor node A and B. Sensor node A and B are periodically programmed to send data packets to sink node. After each data transgression sensor node entered into the profound sleep mode until sleep time over. After receiving data packets from sensor node, the sink node converts data into MQTT protocol-based data format and send to Bevy wise IoT platform.

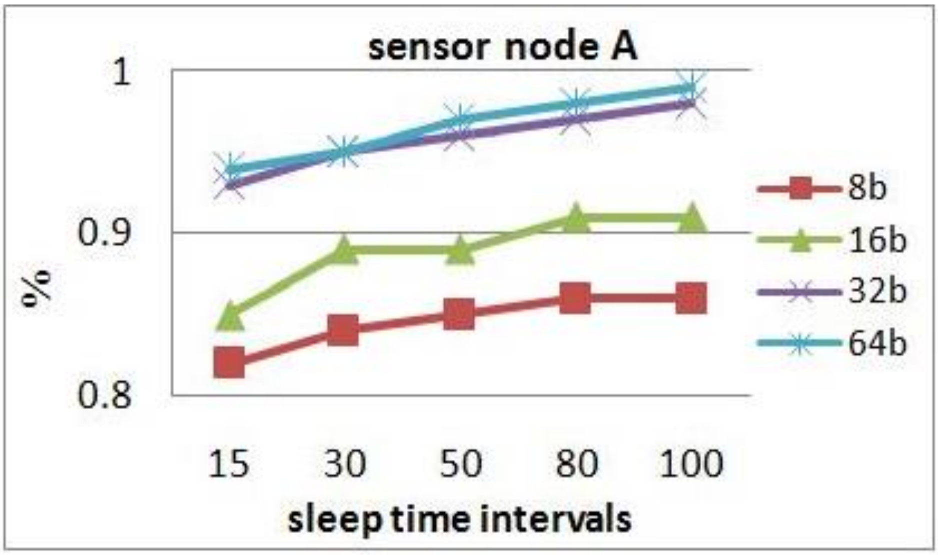
Figure 8 - System Hardware Setup

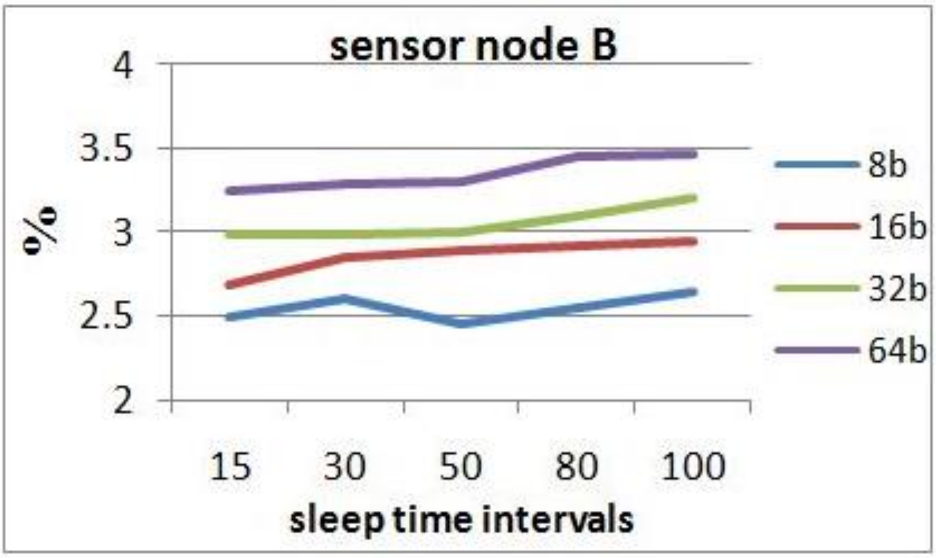


5. Experimental Results

The experimental setup tested in indoor condition, overall results shows that LoRa consumes less power and better communication distance than Zigbee (IEEE 802.11.4). Compared to sensor node A, sensor node B had evolved duty cycle. The payload size did not effect on duty cycle. Figure9 shows duty cycle of sensor node A and B.

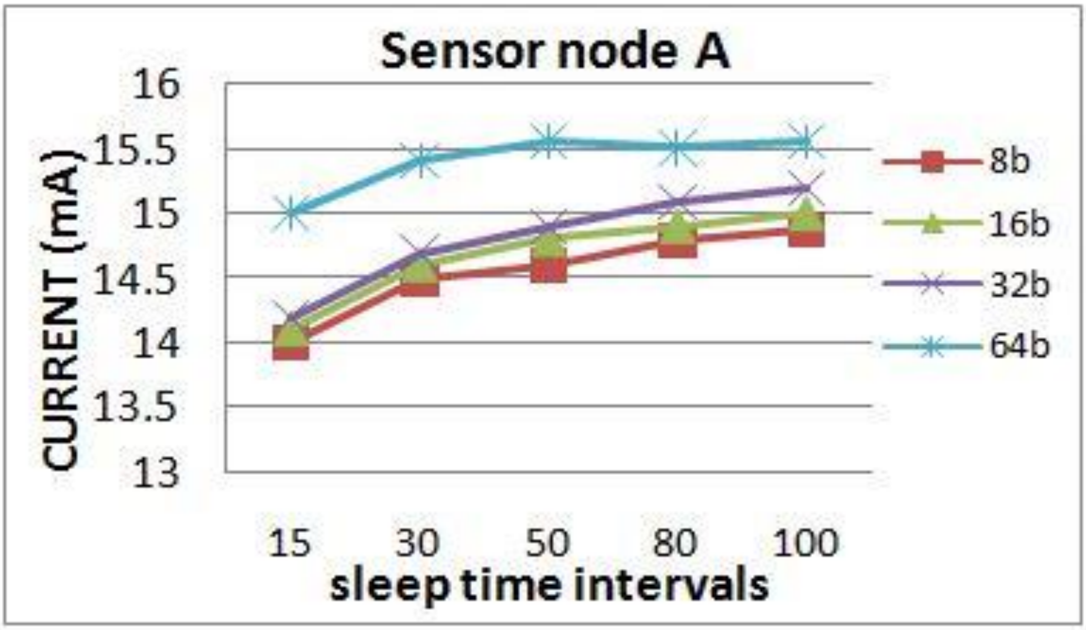
Figure 9 - Sleep Timevs. Duty Cycle of Sensor Node A and B

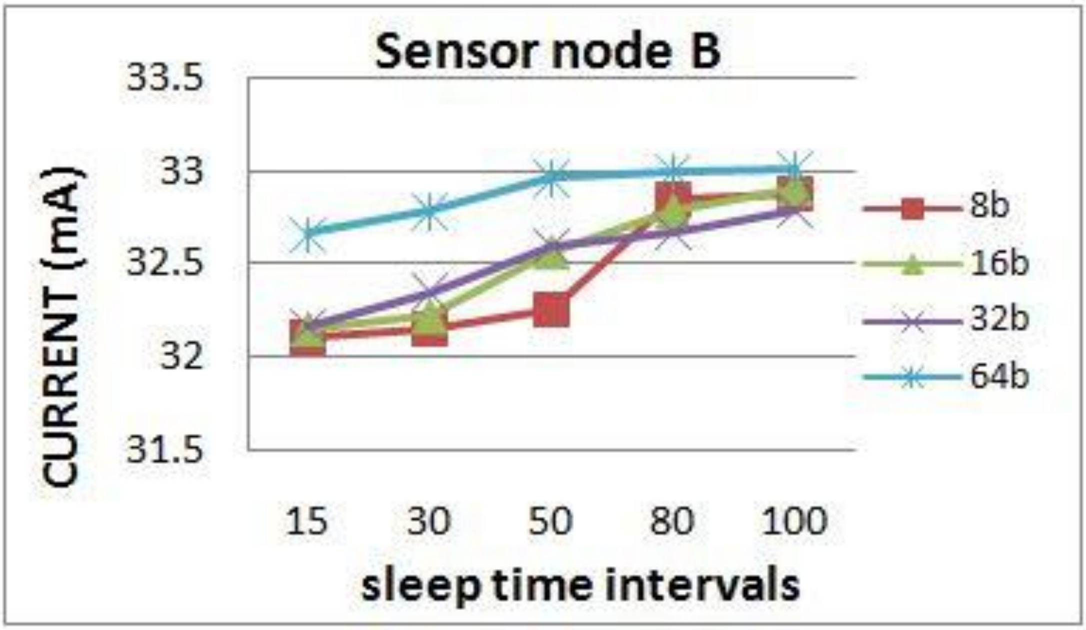




From experimental result figure 10 shows sensor node A had low current consumption in sleep mode in different time intervals and figure 11 shows average active time of sensor node A and node B. Sensor node A has high active current consumption when transmitting payload to gateway when compared to sensor node B. Sleep time current consumption in sensor node B have much high when compared to sensor node A. Sensor node A configured in cyclic data transmission to sink node with +17dbm RF output and RSSI -100db sensitivity settings. The current consumption of sensor node A is 15mA and receive current consumption is 10.3mA. Sensor node B configured same as sensor node A and observed sleep mode current consumption of sensor node B was 33mA.

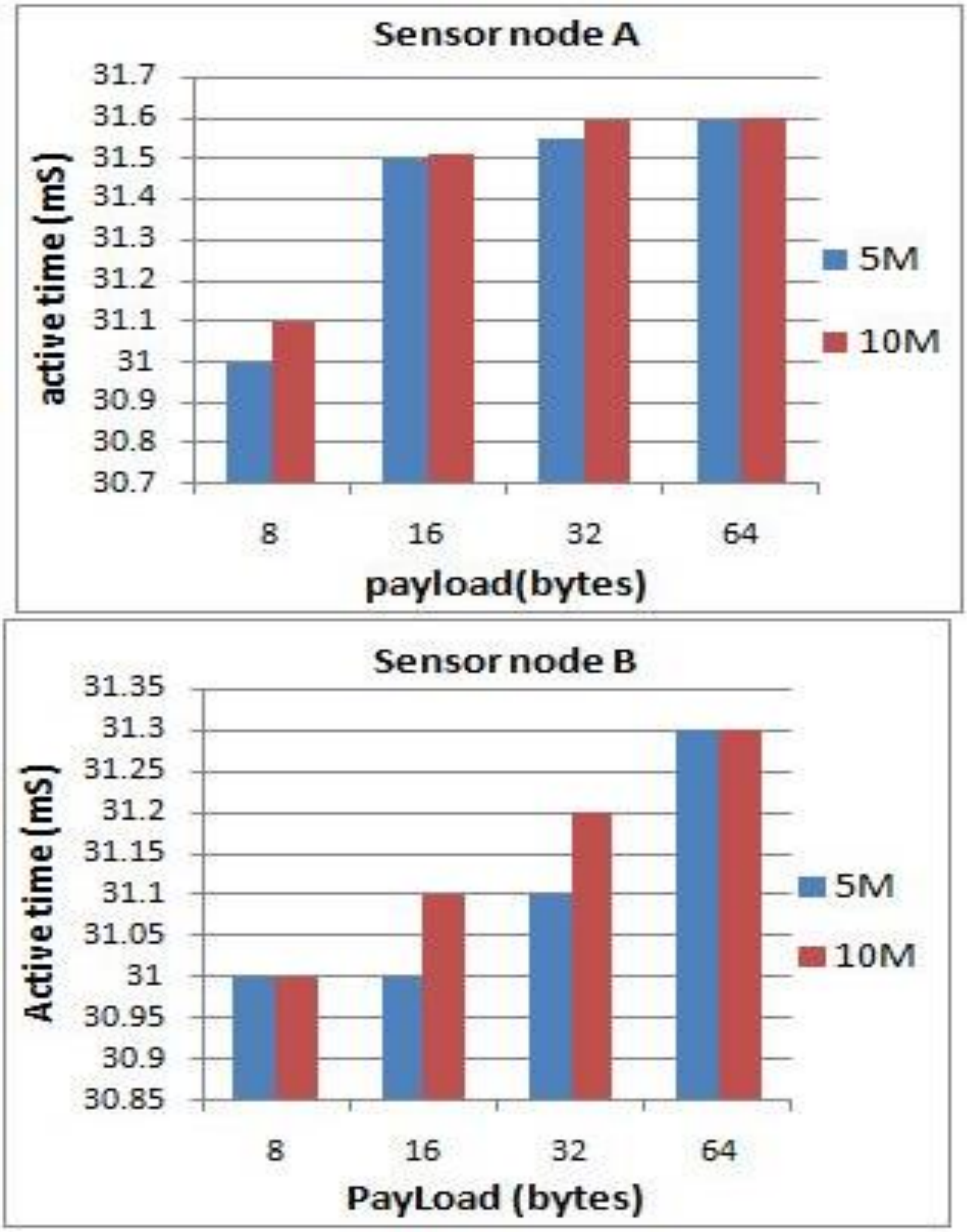
Figure 10 - Sleep Time Interval (sec) vs. Current Consumption of Sensor Node A and B





ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

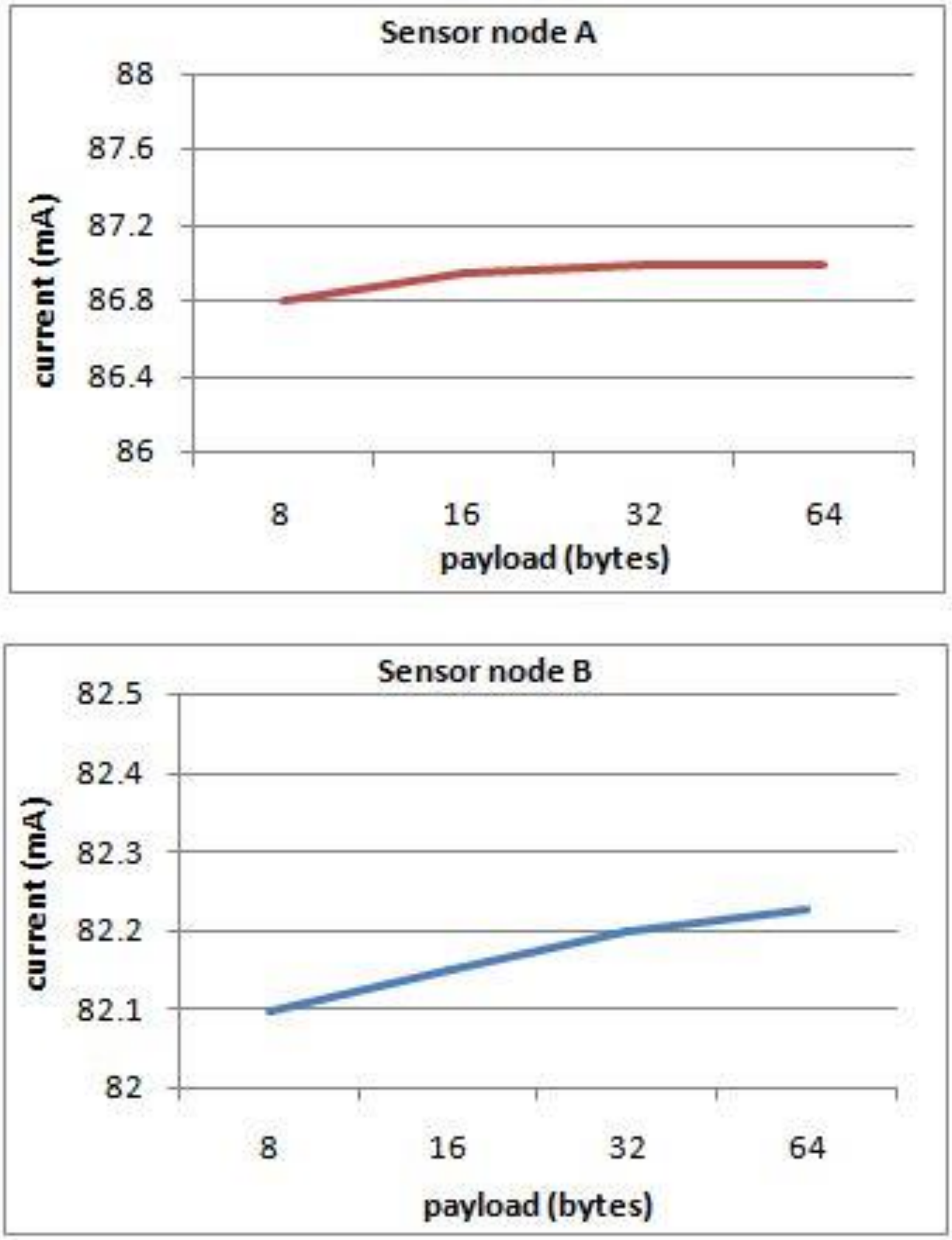
Figure 11 - Payload vs. Mean Active Times (ms)



Compared to sensor node A sensor node B consumed more current in sleep mode. Impact of the average active time and payload per cycle shows in figure 12 for both sensor nodes A and B both sensor nodes had almost recorded same active time reading in 5 and 10meters but when compared to sensor node A sensor node B active time per bytes slightly increased.

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

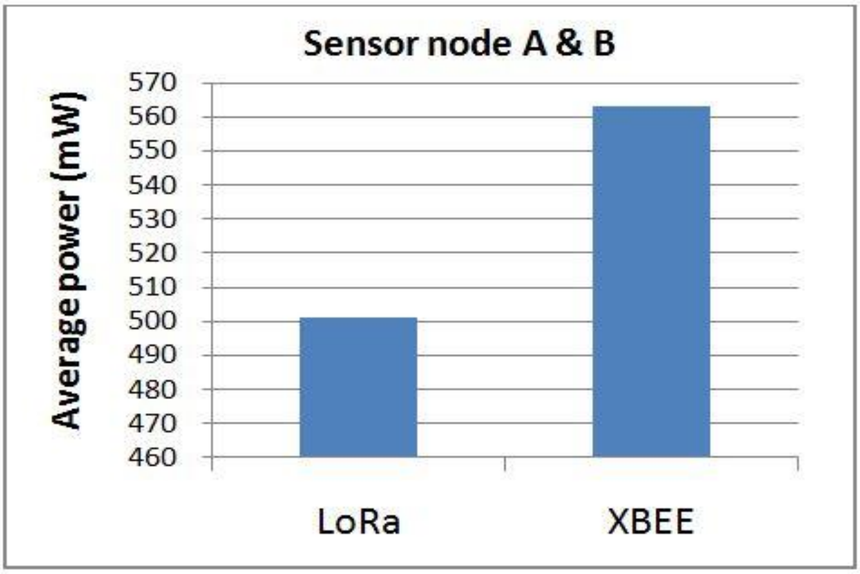
Figure 12 - Active Current Consumption vs. Payload



The spreading factor (SF), bandwidth (BW), carrier frequency and coding rate are the different parameters, configure these parameters will give batter transmission range and low power consumption Figure 13 shows total mean power consumption from sensor nodes to sink node in different distances i.e. 5 meters and 10 meters observed for 100 samples with sleep time intervals of 8 seconds

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

Figure 13 - Average Power Consumption of Sensor Node A & B



When compared to mean power consumption of both sensors node A and B, sensor node A consumed less energy.

6. Conclusion and Future Work

This proposed work is analyzed the power consumption of ZigBee and LoRa communication protocols in a cyclic sleep scenario. It is not possible to identify the exact power consumption in cyclic sleep intervals of both sensor nodes (sensor node A and B) from the data sheet alone. The actual power consumption is determined by combination of interacting factors, not just the averages receive, transmit, and sleep currents and data rate typically given in the data sheet. It is practically tested for different pay loads, sleep time intervals and at different distances to identify energy efficiency of sensor nodes. The current consumption in LoRa node is slightly high than Zigbee node while transmitting the payload but in average power consumption (including sleep mode) LoRa consumed less power than Zigbee. Sleep time current consumption is high in Zigbee when compared to LoRa. The Impact of the average active time and payload per cycle for LoRa is less than Zigbee sensor node. The life time of the sensor nodes are increases using this sleeping scenario. The LoRa modulation is more efficiency in long range data transmission compared to Zigbee sensor node

Recommendations: LoRa/ LoRa WAN gives better transmission range and with possible combination of transmission parameters, can achieve less power consumption LoRa technology may suitable for most of IoT applications.

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 06.06.2021 – Accepted: 06.07.2021

Acknowledgement

This project is utilized the resources and lab equipment under the FIST grant Govt. of India Ref. No. SR/FST/ETI-410/2016.Also this paper work is carried out as part of the sponsored project grant by DST-ICPS Govt. of India division Ref. No. DST/ICPS/CPS/2018/910(G)

References

A. Forster, *"Introduction to wireless sensor networks",* Wiley-IEEE press, 2016.

Chunliang Zhou et.al. "A Wireless Sensor Network Model considering Energy Consumption Balance" *Hindawi Mathematical Problems in Engineering*, 2018, Article ID 8592821, 1-8

Jones, C.E., Siva lingam, K.M., Agrawal, P. et al. "A Survey of Energy Efficient Network Protocols for Wireless Networks". *Wireless Networks* **7**, 343–358 (2001)

Nelson Rosa Bruno Silva and Paulo Maciel et al. "Evaluating the Power Consumption of Wireless Sensor Network Applications Using Models".

Antonio Moschitta and Lgorneri "Power consumption assessment in wireless sensor networks" feb-12-2014 doi:10.5772/57201

Khriji, S., Cheour, R., Goetz, M., El Houssaini, D., Kammoun, I., &Kanoun, O. (2018). "Measuring Energy Consumption of a Wireless Sensor Node During Transmission: pan Stamp". *IEEE 32nd International Conference on Advanced Information Networking and Applications (AINA).* doi:10.1109/aina.2018.00050

Artem Dementyev, Steve Hodges, Stuart Taylor and Joshua Smith "Power Consumption Analysis of Bluetooth Low Energy, ZigBee and ANT Sensor Nodes in a Cyclic Sleep Scenario" 2013

NodeMCU, NodeMCUDevKit V.1.0, https://goo.gl/Dbsqow. (Access: Mar. 15, 2018.)

Espressif., ESP8266. https://goo.gl/qQftMF. (Access: Mar. 15, 2018)

Adafruit, "INA226 Module," https://goo.gl/TyiHUP. (Access: Mar. 15, 2018.)

"LoRa" https://www.lora-alliance.org

Digi. https://www.digi.com/resources/documentation/digidocs/pdfs/90002002.pdf

Bevywise IoT plat form https://www.b evywise.c om/iotplatform