Towards a Wearable Embedded System for Real Time Feedback in Health and Sports Applications Based on Bluetooth Wireless Sensor

Mohammad Tarik Mohammad[1], Rabee M. Hagem[2], Omar Kanaan Taha[3], Hamed A. Mahmood[4]

[1,2,4] Computer Engineering Department, University of Mosul, Mosul, Iraq
[3] Dams and Water Resources Engineering Department, University of Mosul, Iraq
[1] ORCID No: https://orcid.org/0000-0002-4938-4477
[2] ORCID No: https://orcid.org/0009-0008-3564-0776
[3] ORCID No: https://orcid.org/0009-0001-0119-2302
[4] ORCID No: https://orcid.org/0000-0001-6143-330X

Keywords

IoT
Embeded system
Real time,
Wireless sensor

Abstract

Real-time feedback plays a vital role in sports and health applications, allowing athletes to improve their performance and people with medical issues to keep track of their health. This Paper suggests an embedded wearable device that uses Bluetooth technology to deliver real-time feedback. The system was designed as an example of Internet of Things (IoT) technology since it combines wireless connectivity, sensors, and microcontrollers. The wearable embedded system is supported by Bluetooth wireless making it possible for athletes to get rapid feedback on their vital signs and performance parameters, enabling real-time modifications and training schedule optimization. To evaluate the system's performance, experiments were conducted in both air and water environments. The objective is to examine how signal intensity and distance varied across these various media. The results showed that this system is feasible in the air for long distances and in water with and without turbidity for short distances.

Research Article
Submission Date : 06.04.2023
Accepted Date : 12.08.2023

1. INTRODUCTION

The Internet of Things (IoT) is an interesting topic in the IT revolution of the most recent decade. This new model is hoped to be the following stage of the Internet that connects objects of the physical world with each other and links them with the virtual world (Khan et al., 2012; Zheng et al., 2011). Connecting devices has some challenges, such as power consumption, range, and security (Khan et al., 2012). These challenges are also crucial in a Wireless Sensor Area Network (WSAN), which is a network that comprises different kinds of sensors and actuators that are connected. These gadgets would then be able to gather, offer, and follow up on information gathered from the physical world. The Internet of Things has been used in different applications including health and sport (Khan et al., 2022; Abbasi-Kesbi et al., 2020; Memon et al., 2020). The Internet of Things has been used in different applications including health and sport (Khan et al., 2022; Abbasi-Kesbi et al., 2020; Memon et al., 2020).

* Resp author; e-mail: mohammad.t.mohammad@uomosul.edu.iq.

Most of the time, WSAN gadgets don't require electrical outlets and are relied upon to work proficiently with batteries as their source of energy. These limitations revoke Wi-Fi communication as a reasonable choice because of its high-power utilization. In order to reduce the power consumption of Wi-Fi, sleep mode must be activated on the device, a solution that creates additional restrictions of a sensor or actuator connecting through the Wi-Fi. These constraints prevent collecting data from a sensor and or actions from an actuator because of the device's sleep mode.

To use these devices at their full capability and to enhance a wireless environment, different methods of communication could be used. One of the options is to use Bluetooth Low Energy (BLE) as the wireless communication technology. BLE allows for more power consumption, which permits sensors and actuators to keep them turned on and connected to the local gateway. In addition, it has many other features, including compatibility, cost efficiency, reliability, robustness, ease of use, and integration with different applications (Gupta & Mohammed, 2022). Low-cost and low-power consumption wearable devices have been designed to be used in different sports (Hagem et al., 2013; Hagem et al.,2015). A considerable number of studies have been done about using different types of wireless technologies in designing wireless sensor systems to be used for different applications, including health and sports. One of the researchers performed a comparative study between multiple kinds of wireless protocols to design a short-range wireless communication about transmission time, complexity, and power consumption (Lee et al., 2007). Important research used Bluetooth Low Energy BLE as the communication standard to implement a home pool automation system using the WSN and compare the results with the Particle Photon Wi-Fi development board (Nilsson & Lindman, 2017). Another research developed a mobile electrocardiogram monitoring system by using a single chip electrocardiogram ECG signal acquisition module, a Bluetooth module, and a smartphone. The monitoring system can get the ECG signals, send the data through Bluetooth to the smartphone, and process and display the final data on the smartphone screen (Yu et al., 2012).

2. SYSTEM SPECIFICATION

The Red Bear Duo was designed to simplify the building process of Internet-of-Things (IoT) with dimensions of (40×20×13) mm. The board includes STMicroelectronics STM32F205 ARM Cortex-M3 @120MHz, 128 KB SRAM, and 1MB Flash Broadcom BCM43438 Wi-Fi 802.11n (2.4GHz only) + Bluetooth 4.1 (Dual Mode) combo chip On-board 16 Mbit (2 MB) SPI Flash Integrated chip antenna with the option to connect external antenna 18 I/O pins RGB status LED. The Bluetooth specifications chip on this board is: a small antenna of a 2 dBi peak gain with a frequency band (2402-2480) MHz is used. The output power is (class 1.5) with 9 dBm and sensitivity of -86 dBm with BER of 0.01% for the π/4-dqpsk (2Mbps). Figure 1 shows the Red Bear Duo board (Thumb-size website, 2016).

Figure 1. The redbear Due wifi & BLE module (Thumb-size website, 2016)

3. METHODOLOGY

The methodology is based on checking the BLE signal strength in air and water with distance. Some letters, such as the Hello word are sent every second, and the BLE firmware controller receives the data. The distance is calculated for successful communication, which means receiving the data exactly the same as at the transmitter side. The Duo is fixed on an athlete's arm, and the measurements are done with and without arm movement, which is the case for most sports. This is applied to air and water. In water, the methodology was based on using two different types of water, which are pure and turbid, and checking the signal strength in the two cases. A water tank with (50× 100) cm is used to check the signal strength in water.

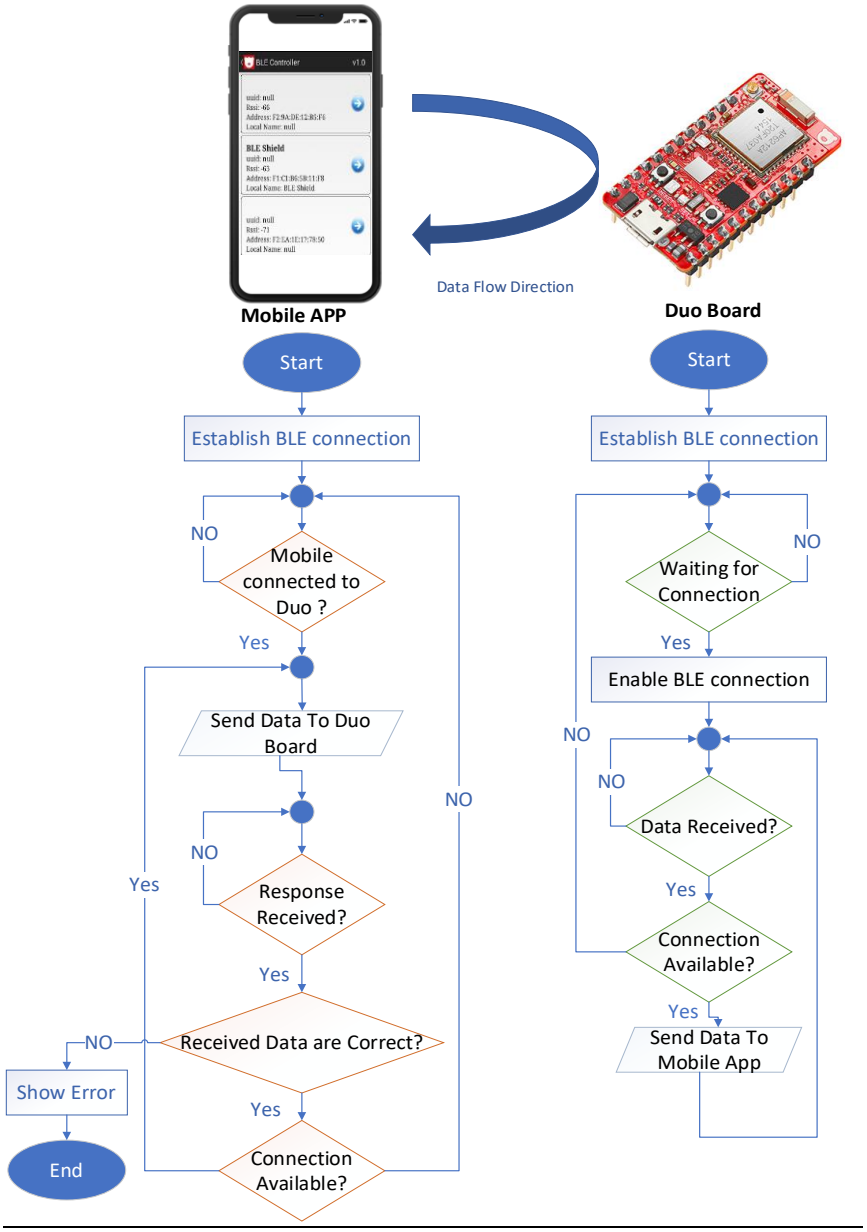

Figure 2. Proposed system algorithm.

The Duo is placed inside a plastic bag that is waterproof to protect the electronic components from damage by water. For displaying the data sent to the RedBear DUE and monitoring the signal strength, the BLE Controller app which is available for Android and iOS smartphones is used. The app is

designed by the RedBear Lab to work with most of the BLE boards. We modified the internal firmware code for the DUE to send the data, for instance, the "Hello" word every second and tested receiving the same data and displaying it on the BLE Controller app. The proposed algorithm is shown in Figure 2.

4. RESULTS AND DISCUSSION

Experiments are conducted in air and water to test the signal strength with distance for successful communication. In the air, the received signal is tested from the Due board when it is in a fixed location, on a person's arm with moving and without moving. The maximum distance that Due can handle receiving the complete data was 93 meters, as shown in Figure 3 which is considered a good distance for giving and receiving feedback between a coach and players in some sports such as running, volleyball, and basketball.

On the other hand, the Due module is tested in two cans of water containing pure water and turbid water respectively. The two water cans, the turbidity meter, and the ReadBear DUE are shown in Figure 4.

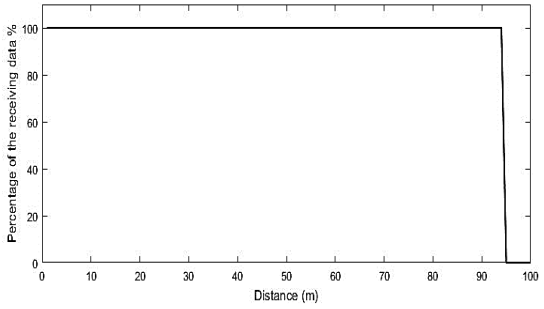

Figure 3. The percentage of received data with distance from the DUE board on a fixed location, on an arm with movement, and on an arm without movement.

The water turbidity does not mainly affect the DUE's board signal as shown in Table 1. Notice that the Aluminium Silicate Hydroxide (Al2Si2O5(OH)4), called also Kaolinite is added to get water with high turbidity with 430 NT compared with 1.5NTU for pure water.

Figure 4. The turbidity meter, two water cans containing pure water and turbid water respectively, and the redbear due board.

Table 1. The due's signal strength difference between the pure and turbid water.

DUE's signal strength inside water can containing pure water	-77 dB

DUE's signal strength inside water can contain highly turbid water	-71 dB

Then, the Due board is inserted inside a water tub with a dimension of (50×100) cm as shown in Figure 5. The signal strength is monitored at different depths and directions. Figure 6 shows the signal strength in pure water concerning the width W, the depth D, and length L of the water tub edges. When the distance exceeded 6 cm under the water, the signal is dropped.

The results based on the graph above for the signal strength showed that Bluetooth technology cannot be used for long-distance communication in water. This is because of the high attenuation that the high frequency signals face in water [9-10]. However, for some water sports applications, such as swimming, some arrangements could be made by connecting the sensor on the swimmer's wrist, and communication could be established with the coach when the wrist was outside of the water. In this case, the communication will be air-to-air, which is proven to be successful over long distances in this paper.

Figure 5. Testing the Due board in a plastic bag running and stepping inside a water tub at 11°C and turbidity of 1.5 NTU.

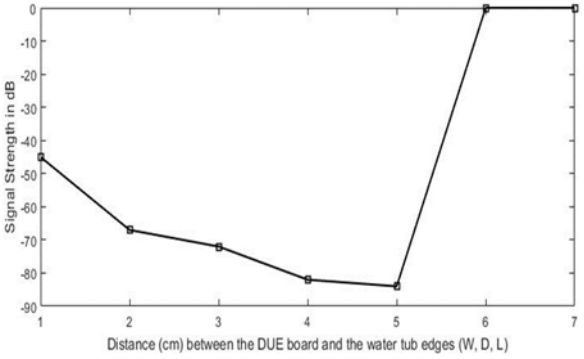

Figure 6. The signal strength of the due board inside the water tub.

5. CONCLUSION

The Bluetooth Low Energy BLE board's (RedBear DUE) performance is tested in the air and underwater. The air test is conducted in a fixed location, on a person's arm with and without moving in different directions with a 93 m successful communication range. Experiments are conducted in pure water and in turbid water to discover if turbidity is an effective factor in the RedBear Bluetooth signal strength. The results showed that the DUE board can be used in water with limited distances and depths because of the high water attenuation for the 2.4 GHz frequencies. One of the best features of the RedBear board or any other BLE board is the low power consumption that enables any project to operate for a long time. Therefore, using the BLE board is very useful in sports and health

applications, especially with the high need for using portable and small sensors to monitor the elderly and athletes in these two fields.

Conflict of Interest

There was no conflict of interest between the authors during the creation of this study. No financial support has been received and there are no conditions that provide financial or personal benefit.

Contribution of Authors

The authors involved in this study contributed to all aspects of the study. All authors contributed to the idea, design, inspection, resources, data collection, literature review, critical review and analysis, and interpretation sections of the study.

REFERENCES

Abbasi-Kesbi R., Nikfarjam A., Nemati M.,(2020).Developed wireless sensor network to supervise the essential parameters in greenhouses for internet of things applications. IET Circuits Devices Syst.,vol. 14 Iss. 8, pp. 1258-1264. doi: https://doi.org/10.1049/iet-cds.2020.0085.

Gupta, A., and Mohammed, I., (2016). Bluetooth low energy (BLE) fundamentals, Cypress Semiconductor. [Online]. [Accessed: Sep - 2023] https://www.embedded.com/design/connectivity/4442870/Bluetooth-low-energy--BLE--fundamentals.

Hagem R. M., Sabti H. A., Thiel D. V.(2015).Coach-Swimmer Communications Based on Wrist Mounted 2.4GHz Accelerometer Sensor. Procedia Engineering, vol. 112, pp. 512-516. doi: https://doi.org/10.1016/j.proeng.2015.07.234.

Hagem R. M., O'Keefe S. G., Fickenscher T., Thiel D. V. (2013). Self Contained Adaptable Optical Wireless Communications System for Stroke Rate During Swimming. in IEEE Sensors Journal, vol. 13, no. 8, pp. 3144-3151, doi: https://doi: 10.1109/JSEN.2013.2262933.

Khan, R., Khan, S. U., Zaheer, R., and Khan, S. (2012). Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges, *10th International Conference on Frontiers of Information Technology*, pp. 257–260. doi: https://doi.org/10.1109/FIT.2012.53

Khan A. N, Cha Y., Giddens H., Hao Y. (2022).Recent Advances in Organ Specific Wireless Bioelectronic Devices: Perspective on Biotelemetry and Power Transfer Using Antenna Systems. Engineering, vol. 11,pp. 27-41, doi: https://doi.org/10.1016/j.eng.2021.10.019.

Lee, J., Su, Y., and Shen, C., (2007). A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi. *33rd Annual Conference of the IEEE Industrial Electronics Society (IECON)*, pp. 46-51, Nov. 5-8, Taipei, Taiwan. doi: https://doi.org/10.1109/IECON.2007.4460126

Memon S. F., Memon M., Bhatti S.(2020).Wearable technology for infant health monitoring: A surve . IET Circuits Devices Syst. , vol. 14 Iss. 2, pp. 115-129. doi: https://doi.org/10.1049/iet-cds.2018.5447 .

Nilsson E. Lindman T.(2017).Implementation and evaluation of Bluetooth Low Energy as a communication technology for wireless sensor networks ,*Bachelor thesis* [Innovative programming], pp.10. https://www.diva-portal.org/smash/get/diva2:1112860/FULLTEXT01.pdf

Thumb-size Cloud-ready Internet-of-Things (IoT) board with co-existing WiFi and BLE capability, (2016). [Online]. [Accessed: Sep - 2023] , https://github.com/redbear/Duo.

Yu, B., Xu, L., and Li, Y., (2012). Bluetooth Low Energy (BLE) Based Mobile Electrocardiogram Monitoring System. *Proceeding of the IEEE International Conference on Information and Automation*, pp. 763-767, Shenyang, China. doi: https://doi.org/10.1109/ICInfA.2012.6246921

Zheng, J., Simplot-Ryl, D., Bisdikian, C. and Mouftah, H. T. (2011) The internet of things [Guest Editorial]. *IEEE Communications Magazine*, vol. 49, no. 11, pp. 30–31. doi: https://doi.org/10.1109/MCOM.2011.6069706