International Journal of Membrane Science and Technology, 2023, Vol. 10, No. 2, pp 3164-3173

# Design Framework, Analysis, and Modeling for WSN Health Monitoring Systems

Vijay P. Singh[1], Geeta D. Salunke[2], Mamta Koban[3]

[1] *Professor, Department of E & C Engineering, School of Engineering, SSSUTMS, Sehore, Madhya Pradesh, India.* [vijaybhabha12@gmail.com](mailto:vijaybhabha12@gmail.com)

[2] *Research Scholar, Department of E & C Engineering, School of Engineering, SSSUTMS, Sehore, Madhya Pradesh, India.*
*Assistant Professor, AISSMS College of Engineering, Pune, Maharashtra, India.*
[geetasalunke@gmail.com](mailto:geetasalunke@gmail.com)

[3] *Research Scholar, Department of E & C Engineering, School of Engineering, SSSUTMS, Sehore, Madhya Pradesh, India.*
*Assistant Professor, AISSMS Inst. of Information Technology, Pune, Maharashtra, India.*
[mamta.wanjre@gmail.com](mailto:mamta.wanjre@gmail.com)

**Abstract:** Wireless Sensor Networks (WSNs) have emerged as a promising technology for health monitoring in various domains, including medical, environmental, and industrial applications. This paper presents a comprehensive study on the design framework, analysis, and modeling of WSNs for health monitoring systems. The primary objective of this research is to develop a robust and efficient framework for the real-time monitoring and management of health-related data.

The paper first provides a thorough background on WSNs, highlighting their significance in modern monitoring systems. It discusses the limitations of existing health monitoring solutions and presents the rationale for proposing a novel framework.

The design framework outlined in this paper encompasses both hardware and software components, emphasizing the selection of appropriate sensors, communication protocols, data aggregation techniques, and power management strategies. The paper also addresses the specific requirements of health monitoring in diverse applications, considering factors like sensor placement and data management.

To evaluate the proposed framework's performance, the paper introduces mathematical models and simulations, which assess the system's energy consumption, latency, and reliability. Additionally, it presents the outcomes of real-world case studies and experiments that validate the effectiveness of the framework.

Results and discussions within the paper emphasize the comparative advantages of the proposed framework over existing systems and highlight the potential implications for health monitoring applications. The paper concludes with a summary of its key findings, contributions to the field, and suggestions for future research directions.

This research provides a valuable reference for researchers, practitioners, and engineers working in the field of health monitoring and WSNs, offering insights into the design and analysis of efficient systems that can enhance health-related data collection and management.

## 1. INTRODUCTION

The Wireless Sensor Network (WSN) is rapidly emerging as a key enabling technology for many different kinds of uses. The implementation of ubiquitous health monitoring in both homecare and hospital settings has been made easier by recent developments in WSN. Modern developments in wireless communication, power-efficient integrated circuits, and sensors have made it possible to create small, light, inexpensive, intelligent physiological sensor nodes. One or more vital indicators can be sensed, processed, and sent by these nodes. They can also be utilized for health monitoring in wireless body sensor networks (WBSNs) and wireless personal area networks (WPANs). In order to provide adaptable, dependable, secure, real-time, and power-efficient WBSNs appropriate for healthcare applications, numerous studies have been conducted or are now underway. As a new effective technology in health monitoring systems, IEEE 802.15.4/ZigBee, a communication standard for low-power wireless communication, is designed to effectively regulate and monitor a patient's state as well as to lower the cost of power and maintenance.

## 2. LITERATURE SURVEY

Gouse Baig Mohammad, S. Shitharth [1] presented the IoT remote healthcare monitoring system that provides the patient's conditions through Web browser. For simulation purposes, they used Contiki OS with 6LoWPAN protocol stack, and Cooja, the built-in Contiki simulator. CoAP was selected as application level protocol for remote data access and representation. Security techniques for intelligent healthcare monitoring systems were introduced by S. Anitha, P. Jayanthi, and V. Chandrasekaran [2]. These techniques effectively detect replication attacks and safeguard the system. The possible real-time implementation of the suggested techniques, which include Fingerprint-based Zero Knowledge Authentication (FZKA), Secured Ant Colony Optimization (SACOP), and Exponential Moving Average based Replica Detection (EMABRD). When comparing the three algorithms, SACOP outperforms EMABRD and FZKA in terms of malicious node detection probability, but at the cost of higher storage and communication overheads. In terms of detection probability, FZKA outperforms EMABRD, but at the expense of higher overheads. Therefore, EMABRD performed better in terms of overheads than SACOP did in terms of detection probability among the three algorithms. In addition to the attacks previously mentioned, Zeeshan Ali a, Anwar Ghani et al. [3] pointed out that Liu-Chung's scheme was vulnerable to user impersonation attacks and leaks of users' private keys towards sensors. Challa et al.'s scheme is also beset by errors, broadcasting issues, a lack of authentication between sensor nodes and the Trusted Authority (TA), replay attacks, Denial of Service (DoS) attacks, forgery attacks, and communication delays brought on by the TA's involvement. In this paper, an improved scheme was proposed to mitigate the weaknesses of the Liu-Chang and Challah et al. schemes using elliptic curve cryptography and bilinear paring. The proposed scheme's security was proven by the formal security analysis conducted using BAN logic and the simulation tool AVISPA. Additionally, the thorough informal security analysis confirms that our scheme was secure from known attacks. Wireless Body Area Network was utilized in healthcare applications by Mozhgan Mohammadi Nezhad [4] to gather data from patients who were being monitored remotely. These networks need to be resilient to sensor failures because they are used in medical applications. This implies that it needs to distinguish between false alarms from misbehaving sensors and emergency alarms from patients. To more accurately alert people to emergency situations, they put forth a method for detecting faulty measurements. The suggested method was predicated on linear regression, threshold biasing, and decision trees. Their goal was to identify both single and multiple flaws to minimize needless medical intervention. A real healthcare dataset was used to test the suggested methodology. The suggested strategy is effective in obtaining a high Detection Rate and a low False Positive Rate, as shown by the experimental results. This algorithm is more trustworthy for use in medical emergencies because it can identify both single and multiple anomalies. A novel method was put forth by N. Saleh et al. [5] to address the issues brought on by finite energy sources. employing a quaternary transceiver (instead of a binary one) in the sensor node's architecture, which will use the modulator/demodulator and amplitude/phase units to increase the amount of bits transmitted per symbol. Because there are more bits transmitted per symbol, the system will use less energy during the transmission phase. Additionally, it was suggested to use a neural network static random access memory (NN-SRAM) in a clustering-based system for wireless sensor networks with energy constraints. Throughout the data distribution process, the plan lowers the overall energy consumption for transmission and storage. It was demonstrated through simulation results using the Matlab and Spice software tools that the implementation of a neural network static random access memory in a clustering based system reduces the system's overall energy consumption by approximately 76.99%.

Mangharam, et al. [6] from Carnegie Mellon University created a sensor network-based coal mine rescue equipment. This system makes use of voice streaming over WSN. The investigation focuses on a TDMA-based network scheduling to fulfill audio timing specifications. For data transfer and hardware-based global time synchronization, the designed hardware features a dual radio architecture. This system has a minimal network size and is intended for coal mine rescue. To transmit sound, it makes use of an SD card and a codec chip for extra memory. It is large, expensive for a sensor node, and consumes a lot of power. Malan, et al. [7] investigated WSN for various medical uses. WSN is used as an emergency message delivery system in hospitals, emergency medical care, and disaster areas. Using MICA motes, CodeBlue monitors and records blood oxygen levels and cardiac data from a large number of patients using pulse oximetry and electrocardiogram (ECG) sensors. A vital sign monitoring system with life emergency event detection using WSN was introduced by Lee et al. [8]. Patients' vital signs, such as their ECG and body temperature, are wirelessly sent to a base station that is linked to a PDA or server. A ZigBee-based wireless health monitoring system for smart homes was introduced by Dagtas et al. [9]. They created a rudimentary processing platform that enables the detection of fatal failure and heart rate. Currently, they are utilizing ZigBee radio modules and in-home ECG probes to construct a prototype of the suggested system. A device access control mechanism was described by Juyng and Lee [10]. They suggested a ZigBee-based health monitoring system that would transmit physiological health data in a dependable manner. Physiological signal devices of the wrist, chest belt, shoulder, and necklace types were developed by them. They use a ribbon-type temperature sensor, a SpO2 sensor, two PDMS (polydimethylsiloxane) electrodes for ECG, and a CC2430 microcontroller as the central component. Their W-PSD wrist-type physiological signal device measures 60 x 65 x 15 mm, and its total system weight, including a single lithium-polymer battery, is 160 g. Retransmissions also offer a dependable means of data transmission. They identify the network device's power issue. Its power source is a small battery. It can work for 6 hours without replacement or recharging. It is small, light weight, and easy to bring, but its life time from small battery should be improved. A prototype portable system for measuring body temperature, ECG, and phonocardiography (PCG) was proposed by Chien and Tai [11]. They create a three-wired lead ECG and insert a capacitor-style microphone into the stethoscope's tube for PCG. A microcontroller, PDA, and Bluetooth transceiver and receiver modules are used to create a wireless connection between a sensing module and PDA. As a system for monitoring health, this one has certain shortcomings. Firstly, anytime a user wishes to measure health conditions, they should turn on the PDA. As a result, this system is not automated, event-driven, or programmable. Secondly, this system has a memory unit, numerous large external circuits, and wired leads for the ECG. Due to its large size and weight, it is not suited for use as a wearable device and is therefore challenging to transport. Third, they consume a lot of power due to their complexity and abundance of external devices. Therefore, from the perspective of wireless health monitoring, it has limitations. Microsoft unveiled HealthGear, a wearable system for tracking health in real time by Oliver and Msngas [12]. Its multiple physiological sensors are used to track and evaluate the plethysmographic signal, heart rate, and blood oxygen level (SpO2). A cardiac monitoring system called Human++ was created by Gyselinckx et al. [13] for multi-parameter ambulatory health monitoring, including electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG). Three body area network-connected sensor nodes and a base station make up this system. They use an MSP430F149 microcontroller with a 12-bit ADC to sample the biosignal at 1024 Hz. Data is gathered from each sensor node by the base station and sent to a PC or PDA via a USB interface. This system uses two AA batteries to operate on its own for three months. Brown, et al. [14] enhanced the system which is compact, light-weight, and low-power WPMS platform is designed for continuous, ambulatory autonomic response monitoring in practical applications. An MSP 430 MCU, a Nordic nRF24L01 2.4 GHz radio, a 50 Ohm antenna, and a 165 mAh lithium-ion battery power the Human++ UniNode. A node's dimensions, including the battery, are 20X29X9 mm3. They use a static TDMA protocol and have a star network topology. They have developed wristbands and chest belts as wearable medical sensors. One Human++ UniNode is linked to the ECG and respiration sensors (20X22X4 mm3), which are integrated into a chest belt. On the other hand, a second Human++ UniNode is linked to the skin conductance and skin temperature sensors (20X25X5 mm3), which are integrated into a wrist band. With full active operation, the wrist node draws 4 mA and the chest node draws 2.6 mA, for a battery life of approximately 41 hours and 63 hours, respectively. A wearable ECG device for continuous monitoring was presented by Fensli et al. [15]. The common PDA, which is a hand-held device, receives the amplified ECG signal from a wearable gadget. The 500 Hz sampling frequency used by the sensor to detect ECG signals is converted to digital data with a resolution of 10 bits. Following digitization, the signal uses a modulated RF link operating at 869.700 MHz to transmit continuously to a handheld device. The application of this system has been concentrated on emergency scenarios. We presented WPMS-based patient monitoring in Monton et al. [16]. This BSN is made up of two different kinds of modules and uses star network technology. To detect health signals, a tiny device (34x48mm2) known as a sensor communication module (SCM) is connected to one or more sensors. SCMs use ZigBee to send signals to a personal data processing unit (PDPU), a central processing unit measuring 73x110x25 mm3. The PDPU is intended to establish connections with local external systems via either 1) UWB for individual devices, like PDAs or PCs, 2) Wi-Fi for LAN connections, or 3) GPRS for WAN connections. Milankovic et al. [17] proposed a single-hop WSN topology. Each sensor for health monitoring is directly connected to an individual PDA, which provides the connectivity to a central server. They mainly focus on the synchronization and energy efficiency issues on the single-hop communication network between network devices and PDA.

## 3. PROPOSED METHODOLOGY

Figure 1 shows a PAN coordinator starting a non-beacon-enabled network. A coordinator with one PAN ID connects network devices desiring access to the PAN through broadcasting. An association process starts with an active or passive scan. This scan process allows a device to locate those coordinators transmitting a beacon frame within a PAN area. Note that the beacon request command is not required for a passive scan process. The end device issues an active scan. The active scan selects one channel and transmits a *BeaconRequest* command to the broadcast address (0xFFFF) and broadcast PAN ID (0xFFFF). Then an end device listens to that channel for beacon from any coordinator. Once the defined time expires on that channel, the end device scans another channel and transmits the *BeaconRequest* command again. This active scan process continues until all channels have been scanned. After the scan is complete, the MAC sends a MAC_MLME_SCAN_CNF with the PAN information received during the scan.

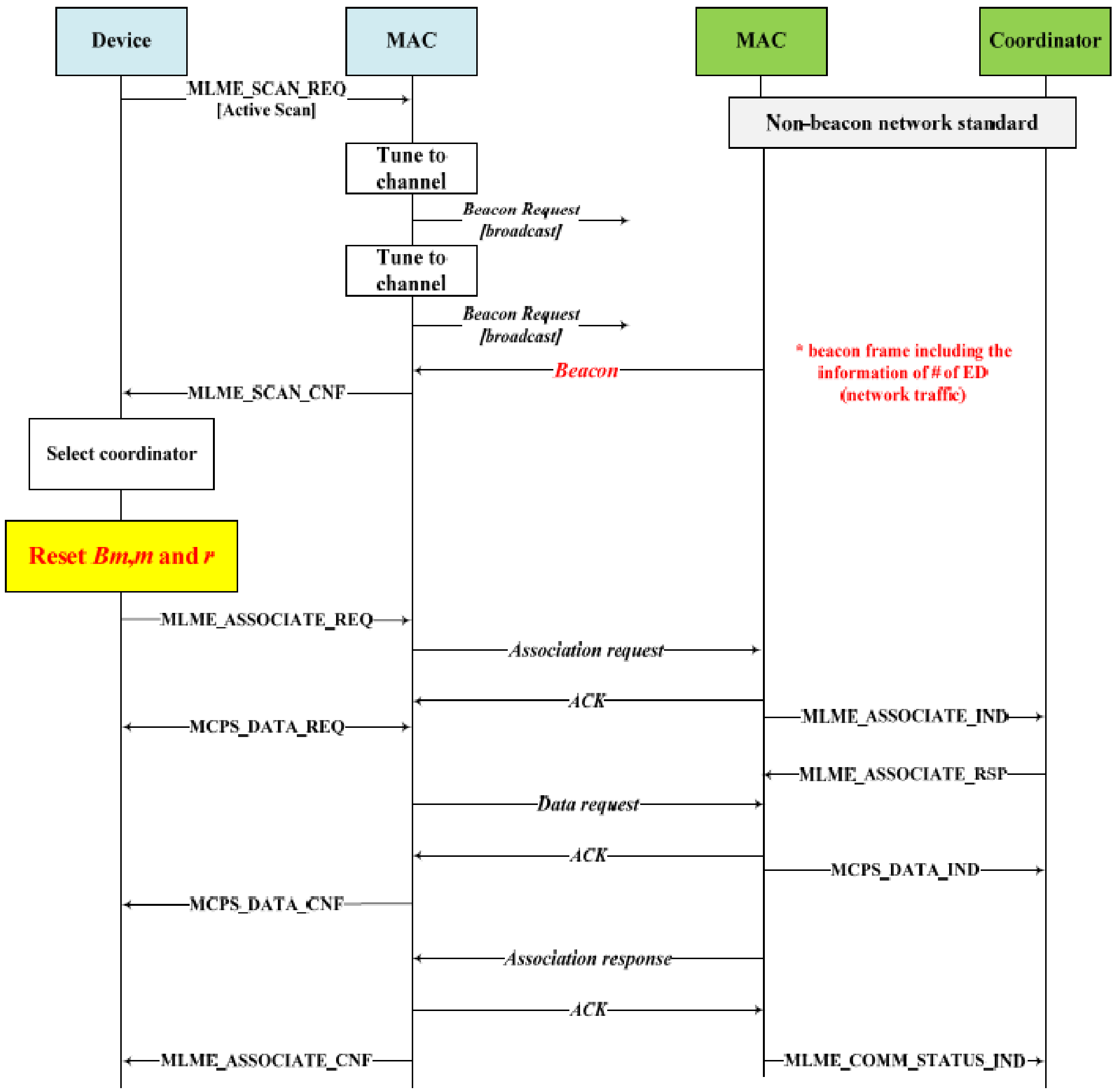


**Figure 1.** Modified association network flow for priority data transmission.

The higher layer of a device checks the PAN descriptors and selects a coordinator. After choosing the coordinator, a node sends an *Association request* frame to the coordinator. Then the coordinator sends to the currently connected node the information that depends on the network address generated by the network protocol. At this step, the coordinator arranges and gives the short address to the currently connected node. From these processes, the PAN coordinator can recognize how many devices are associated with it.

Also, during the communication process between a coordinator and nodes, the former can recognize the latter by several communication packet parameters. It can detect the address parameter of each device by MLME_ASSOCIATE and MCPS_DATA process parameter values. Because a coordinator can know how many nodes join itself, it can estimate the network status. In our proposed scenario, if some nodes request the beacon to join the PAN, the coordinator sends the beacon frame with network status on the frame using the Frame Control Field (FCF) as shown in Figure 2.

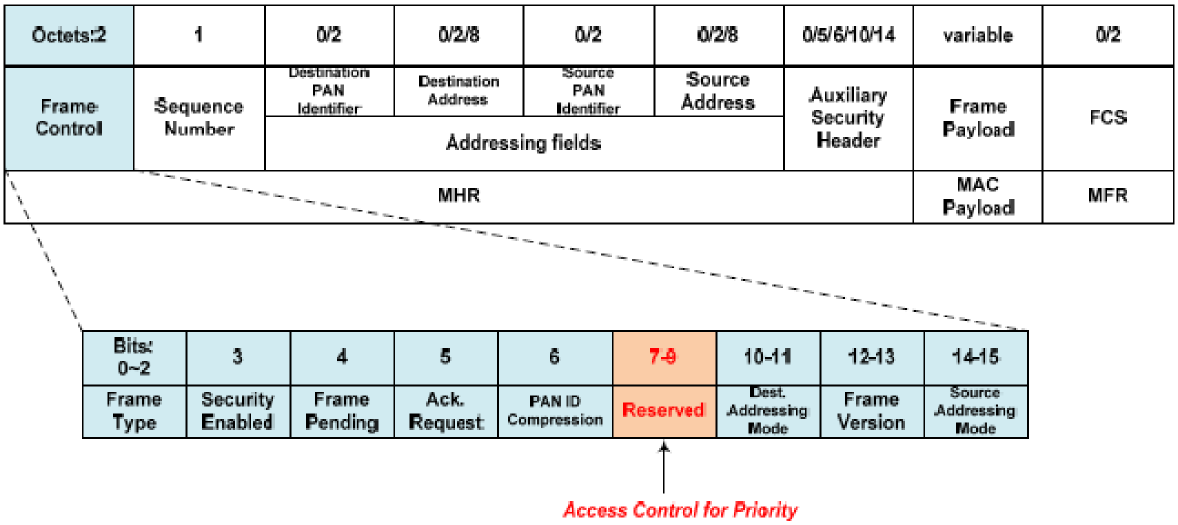


**Figure 2.** Frame Control Field (FCF).

MAC header's (MHR) Frame Control is 2 bytes long and contains information defining the frame type, addressing field, and other control flags. The reserved field has 3 bits, i.e., bits 7 to 9. The algorithm proposed in this work uses the reserved field to show variable network status. After a node receives a beacon frame from a coordinator about network status, it can decide to reset its *BE* value to avoid collision; or to associate to that coordinator or scan other available coordinators.

To decide the status of a coordinator, a device checks the reserved field in FCF. These bits predefined by a coordinator indicate the current status. A device sets *Bm* accordingly. By setting it differently for network traffic, it can reduce the transmission delay and data packet collision. Note that the IEEE 802.15.4 standard does not consider different network status and set *Bm* to be 3 for all network devices. Figure 3. shows the proposed algorithm for priority packet transmission. It presents two parts of the algorithm. The first part is about realignment parameters (*Bm, BM,* and *m)* based on the network status.

Before a device is associated with a coordinator, it can recognize the network status, i.e., the number of devices in a same PAN, by checking the 3-bit reserved field at FCF in a beacon frame from the coordinator. From Table 1, the network status information to the 3-bit reserved field at FCF in beacon, i.e., 0x001 as $N < 5$, 0x010 as $5 \le N < 10$, and 0x011 as $10 \le N$ is applied.

**Table 1. Reserved Fields in FCF**

| Command Frame | Nodes in PAN |
|---|---|
| 0x001 | $N < 5$ |
| 0x010 | $5 \le N < 10$ |
| 0x011 | $10 \le N$ |

If the current network has a relatively large size, i.e., $N > 10$, or many network devices are already in the PAN, a device would stop associating itself to that coordinator but look for another. If the number of already joined devices is more than 5, but less than 10, a device sets the MAC parameters as default value. If it is less than 5, the device sets adaptive MAC parameters.

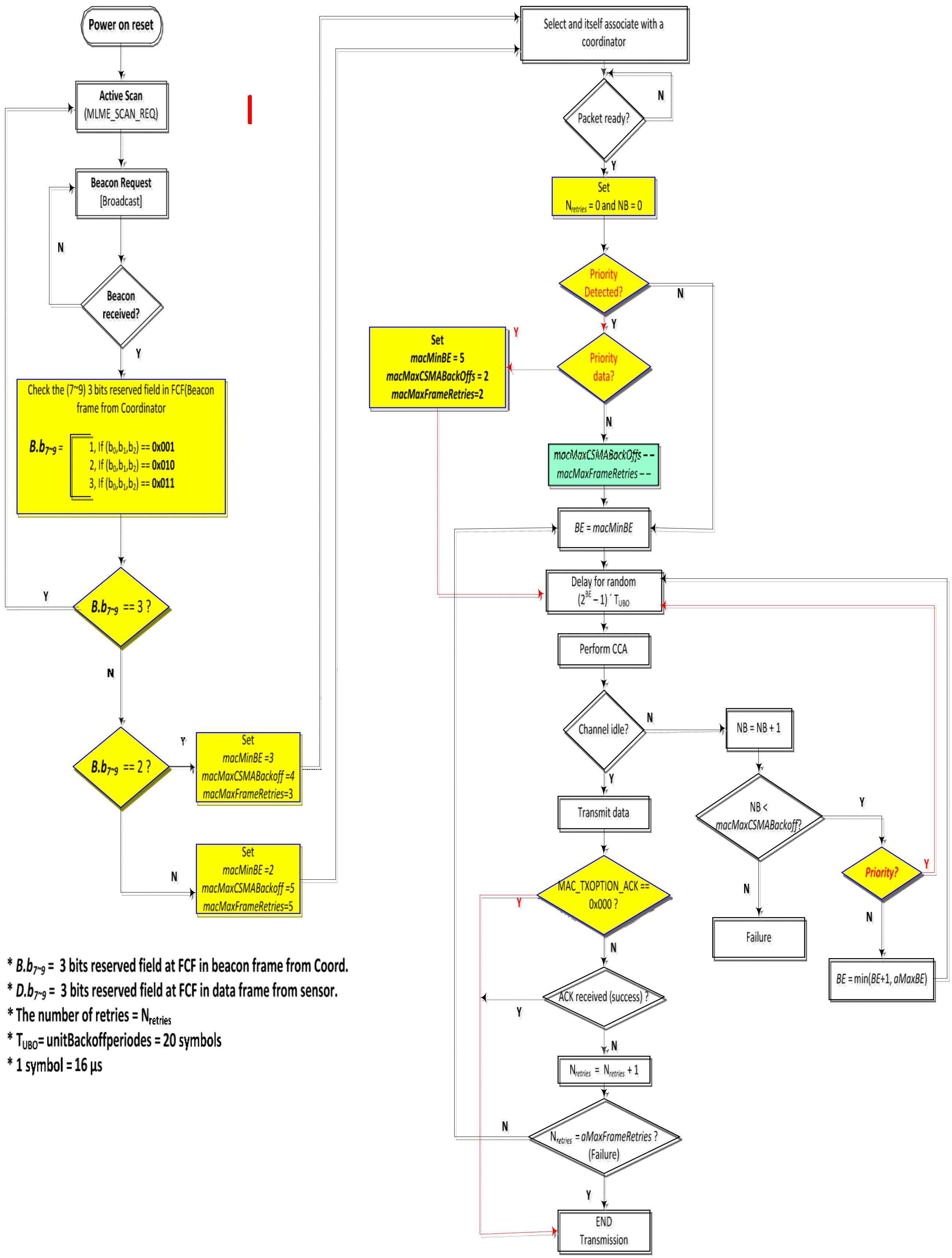


**Figure3.** Proposed algorithm for priority packet transmission.

## 4. REFERENCES


[1] Mohammad, G. B., & Shitharth, S. (2021). Wireless sensor network and IoT based systems for healthcare application. *Materials Today: Proceedings*.

[2] Anitha, S., Jayanthi, P., & Chandrasekaran, V. (2021). An intelligent based healthcare security monitoring schemes for detection of node replication attack in wireless sensor networks. *Measurement*, *167*, 108272.

[3] Ali, Z., Ghani, A., Khan, I., Chaudhry, S. A., Islam, S. H., & Giri, D. (2020). A robust authentication and access control protocol for securing wireless healthcare sensor networks. *Journal of Information Security and Applications*, *52*, 102502.

[4] Nezhad, M. M., & Eshghi, M. (2019, April). Sensor single and multiple anomaly detection in wireless sensor . In *2019 27th Iranian Conference on Electrical Engineering (ICEE)* (pp. 1751-1755). IEEE.

[5] Saleh, N., Kassem, A., & Haidar, A. M. (2018). Energy-efficient architecture for wireless sensor networks in healthcare applications. *IEEE Access*, *6*, 6478-6486.

[6] Mangharam, R., Rowe, A., Rajkumar, R., and Suzki, R., “Voice over sensor networks,” In Proc. of the 27th IEEE Int. Real-Time Systems Symposium, Rio de Janeiro, Brazil, 2006.

[7] Malan, D., Fulford-Jones, T., Welsh, M., and Moulton, S., “Codeblue: an ad-hoc sensor network infrastructure for emergency medical care,” in Proc. of the 1st Int. Workshop on Wearable and Implantable Body Sensor Networks, London, UK, 2004.

[8] Lee D.S., Lee Y.D., Chung W.Y., and Myllyla R., "Vital Sign Monitoring System with Life Emergency Event Detection using Wireless Sensor Network," 5th IEEE Conference on Sensors, Daegu, South Korea, pp. 518-521, 2006.

[9] Dagtas S., Pekhteryev G., and Sahinoglu Z., “Multi-stage Real Time Health Monitoring via ZigBee in Smart Homes,” Proceedings of the 21st International Conference on Advanced Information Networking and Applications Workshops, Vol.2, pp. 782-786, Niagara Falls, Ont, May 2007.

[10] Juyng J., and Lee J.,“ZigBee Device Access Control and Reliable Data Transmission in ZigBee Based Health Monitoring System,” 10th International Conference on Advanced Communication Technology, Vol. 1, 17-20, pp.795 – 797, Gangwon, Korea, Feb. 2008.

[11] Chien R., and Tai C., "A New Wireless-Type Physiological Signal Measuring System Using a PDA and the Bluetooth Technology," IEEE International Conference on Industrial Technology, pp.119–120, Mumbai, Dec 2006.

[12] Oliver N., and Flores Msngas F., “HealthGear: A real-time wearable system for monitoring and analyzing physiological signals,” Microsoft Res., Tech. Rep. MSRTR- 2005-182, Apr. 2006.

[13] Gyselinckx B., Penders J., and Vullers R., “Potential and challenges of body area networks for cardiac monitoring,” J. Electrocardiology, vol. 40, pp. S165–S168, Nov, 2007.

[14] Brown L., Grundlhner B., Penders J., and Gyselinckx B., “Body Area Network for Monitoring Autonomic Nervous System Responses,” 2009 3rd International Conference on Pervasive Computing Technologies for Healthcare – Pervasive Health 2009, Article number 5173603, April 2009.

[15] Fensli R., Gunnarson E., and Gundersen T., “A wearable ECG-recording system for continuous arrhythmia monitoring in a wireless tele-homecare situation,” Proc.of the 18th IEEE Symposium on Computer-Based Medical Systems, pp. 407-412, Ireland, June 2005.

[16] Monton E., Hernandez J. F., Blasco J. M., Herve T., Micallef J., Grech I, Brincat A, and Traver V, “Body area network for wireless patient monitoring,” Telemed. EHealth Commun. Syst., vol. 2, issue 2, pp. 215–222, Feb. 2008.

[17] Milenkovic A., Otto C., and Jovanov E., “Wireless sensor networks for personal health monitoring: Issues and an implementation,” Computer Communications, vol. 29, pp. 2521-2533, 2006.

[18] Akyildiz I. F., Su W., Sankarasubramaniam Y., and Cayirci E., “Wireless Sensor Networks: a Survey,” Computer Networks, vol. 38, pp. 393-422, 2002.

[19] Bae, D. J., Lee, T. J., Choi, H. K., and Chung, M. Y., “A contention access mechanism based on a partitioned contention access period in IEEE 802.15.4 MAC,” IEICE TRANS. COMMUN., vol.E93-B, no.12, Dec 2010.

[20] Barth, A.T., Hanson, M.A., Powell Jr., H.C., and Lach, J., " TEMPO 3.1: A body area sensor network platform for continuous movement assessment," 6th International Workshop on Wearable and Implantable Body Sensor Networks, BSN 2009, Article number 5226915, Pages 71-76 , Berkeley, CA, 2009

[21] Bianchi, G., “Performance analysis of the IEEE 802.11 distributed coordination function,” IEEE Journal on Selected Areas in Communications, vol.18, no. 3, pp. 535-547, 2000.

[22] Burchfield, T. R., Venkatesan, S., and Einer, D., “Maximizing throughput in Zigbee wireless networks through analysis, simulations and implementations,” In Proc. Of the Int. Workshop on Localized Algorithms and Protocols for Wireless Sensor Networks, pp.15-29, Santa Fe, New Mexico, June 18-20, 2007.

[23] Chai J., and Yang H., “The research of the community healthcare network based on ZigBee technology,” 7th Asian-Pacific Conference on Medical and Biological Engineering, vol.19, pp. 567-570, Beijing, China,April 2008.

[24] Chen Y., and Wang X., "Design of Distributed Intelligent physiological parameter Monitor System Based on Wireless Communication Technology," International Seminar on Future BioMedical Information Engineering, pp.403-406,Wuhan, Hubei, Dec 2008.

[25] Choi S., Cha H., and Cho S., " A Soc-based Sensor Node: Evaluation of RETOSenabled CC2430," 4th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, SECON 2007, Article numbe 4292825, Pages 132-141, San Diego, CA, 2007.

[26] Choi, Jin Soo and Zhou, Mengchu, “Performance analysis of ZigBee-based body sensor networks,” IEEE International Conference on Systems Man and Cybernetics (SMC), Istanbul, Turkey, pp. 2427-2433, October 2010.

[27] Choi, Jin Soo and Zhou, Mengchu, “Recent Advances in Wireless Sensor Networks for Health Monitoring,” International Journal of Intelligent Control and Systems, Vol. 15, No. 4, pp. 49-58, December 2010.

[28] Choi K., and Song J., "A Miniaturized Mote for Wireless Sensor Networks," International Conference on Advanced Communication Technology, ICACT ,Vol 1, Article number 4493814, Pages 514-516, Korea, Feb 2008.

[29] Daneshgaran F., Laddomada M., Mesiti F., and Mondin M., “Unsaturated Throughput Analysis of IEEE 802.11 in Presence of Non Ideal Transmission Channel and Capture Effects,” IEEE Transactions on Wireless Communications, vol.7, pp. 1276-1286, April. 2008.

[30] Estrin D., “Embedded Networked Sensing Research: Emerging System Challenges,” in NSF Workshop on Distributed Communications and Signal Processing for Sensor Networks, Illinois, USA, 2002.

[31] Feng W., Arumugam N., and Krishna G. H., “Impact of interference on a Bluetooth network in the 2.4 GHz ISM band,” The 8th International Conference on Communication Systems, Vol. 2, pp. 820 - 823, Singapore, Nov. 2002.

[32] Guo W. W., Healy W. M., and Zhou M., “An Experimental Study of Interference Impacts on ZigBee-based Wireless Communication Inside Buildings,” In Proceedings of 2010 IEEE International Conference on Mechatronics and Automation (ICMA 2010), pp. 1982-1987, Xi’an, China, August 4-7, 2010.

[33] Heart Attack http://www.medicinenet.com , accessed date: Jan 2010.

[34] Hande A., Polk T., Walker W., and Bhatia D., “Indoor solar energy harvesting for sensor network router nodes,” Microprocessor and Microsystems, Volume 31, Issue 6, Pages 420-432, Sept. 2007.

[35] Howitt I., "WLAN and WPAN coexistence in UL band," IEEE Transactions on Vehicular Technology, Vol. 50, No. 4, pp. 1114 - 1124, July 2001.

[36] Hauer J., Handziski V., and Wolisz A., “Experimental Study of the Impact of WLAN Interference on IEEE 802.15.4 Body Area Networks,” Proceedings of the 6th European Conference on Wireless Sensor Networks, pp, 17-32, Cork, Ireland, February 2009.

[37] Hackmann G. 2006 “802.15 Personal Area Networks,” Department of Computer Science and Engineering, Washington University. http://www.cse.wustl.edu/~jain/cse574-06/wpans.htm accessed date: Feb 2010.

[38] Hyun L. et al., “Issues in data fusion for healthcare monitoring,” Proceedings of the 1st International Conference on Pervasive Technologies Related to Assistive Environments, Vol.282, pp.1-8, Athens, Greece, July 2008.

[39] IEEE, Wireless medium access control (MAC) and physical layer (PHY) specifications for low-rate wireless personal area networks (WPANs),” IEEE Std. 802.15.4-2006, 2006.

[40] Ilyas, M., and Mahgoub, I., Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems, Boca Raton, CA: CRC, 2005.

[41] Jovanov E., Milenkovic A., Otto C., Groen P. D., Johnson B, Warren S, and Taibi G, "A WBAN System for Ambulatory Monitoring of Physical Activity and Health Status: Applications and Challenges," IEEE-EMBS 2005, 27th Annual International Conference, pp. 3810 - 3813, Shanghai, China, Jan 2005.

[42] Jo J.H., and Jayant N., "Performance Evaluation of Multiple IEEE 802.11b WLAN Stations in the Presence of Bluetooth Radio Interference," IEEE Journal on Communications, vol. 2, pp. 1163-1168, May 2003.

[43] Jung, C. Y., Hwang, H. Y., Sung, D. K., Hwang, G. U., "Enhanced Markov chain model and throughput analysis of the slotted CSMA/CA for IEEE 802.15.4 under unsaturated traffic conditions," IEEE Transactions on Vehicular Technology, 58(1):473-478, 2009.

[44] Kang M. et al., "Adaptive Interference-Aware Multi-Channel Clustering Algorithm in a ZigBee Network in the Presence of WLAN Interference," Proc. of the International Symposium on Wireless Pervasive Computing, pp.5-7, San Juan, Puerto Rico, Feb. 2007.

[45] Khemapech I., Duncan I., and Miller A., "A Survey of Wireless Sensor Networks Technology," Proceedings of the 6th Annual PostGraduate Symposium on the Convergence of Telecommunications, Networking & Broadcasting, Liverpool John Moores University, Liverpool, 2005.

[46] Kim, E. J., Shon, T., Park, J., and Jeong, Y.S., "Throughput Fairness Enhancement Using Differentiated Channel Access in Heterogeneous Sensor Networks," Sensors 2011, 11(7), 6629-6644; doi:10.3390/s110706629.

[47] Kim, T. O., Park, J. S., Chong, H. J., Kim, K. J, and Choi, B. D., "Performance Analysis of IEEE 802.15.4 Non-beacon Mode with Unslotted CSMA/CA," IEEE Communications Letters, pp.238-240, April 2008.

[48] Kim S. M., Chong J. W., Jung C. Y., Jeon T. H., Park J. H., Kang Y. J., Jeong S. H.,Kim M. J., and Sung D. K., "Experiments on Interference and Coexistence between Zigbee and WLAN Devices Operating in the 2.4 GHz ISM Band," Proc. NGPC, pp. 15 - 19, Nov 2005.

[49] Kohvakka, M., Kuorilehto, M., Hannikainen, M., and Hamalainen, T.D., "Performance analysis of IEEE 802.15.4 and ZigBee for large-scale wireless sensor network applications," Proc. 3rd ACM Int. Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks, Terromolinos, Spain, Page 48- 57, 2006.

[50] Lee, B. H, Lai, R. L., Wu, H. K., and Wong, C. M., "Study on Additional Carrier Sensing for IEEE 802.15.4 Wireless Sensor Networks," Sensors 2010, 10(7), 6275- 6289; doi:10.3390/s100706275.

[51] Lee J. S., Su Y. W., and Shen C. "A comparative study of wireless protocols: bluetooth, uwb, zigbee, and wi-fi," Proceedings of The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON), pp. 46-51,Taipei, Nov. 2007.

[52] Miller M.J., and Vaidya N.H., "A MAC protocol to reduce sensor network energy consumption using a wakeup radio," IEEE Transactions on Mobile Computing, 4(3), Page(s):228 – 242, May-June 2005.

[53] Misic, J., and Misic, V. B. "Access delay for nodes with finite buffers in IEEE 802.15.4 beacon enabled PAN with uplink transmissions," Comput. Commun., vol. 28(10), pp. 1152-1166, Jun. 2005.

[54] Misic, J., Shafi, S., and Misic, V. B., "Performance of a Beacon Enabled IEEE 802.15.4 Cluster with Downlink and Uplink Traffic," IEEE Transactions on Parallel and Distributed Systems, pp. 361-376, April 2006.

[55] Ning X., Rangwala, S., Chintalapudi, K. K., Ganesan, D., Alan Broad, Govindan, R,and Estrin, D., "A wireless sensor network for structural monitoring," Proceedings of the 2nd international conference on Embedded network sensor systems SenSys 04, Vol.20, Issue:7, pp.12-24, Baltimore, MD, USA, Nov. 2004.

[56] Omeni O., Eljamaly O., and Burdett A., "Energy Efficient Medium Access Protocol for Wireless Medical Body Area Sensor Networks," Proc. IEEE-EMBS Symposium on Medical Devices and Biosensors, pp. 29-32, Cambridge, UK, Aug 2007.

[57] Pakzad, S. Z., Fenves, G. L., Kim, S., and Culler, D. E., "Design and Implementation of Scalable Wireless Sensor Network for Structural Monitoring," Journal of Infrastructure Systems, Vol. 14, Issue:1, pp. 89-101, 2008.

[58] Geeta D. Salunke, Vijay P. Singh and Chaya R. Jadhav, "A Review Approach to Modeling, Analysis, and Design Framework for Wireless Sensor Network Health Monitoring Systems". (2022). Journal of Pharmaceutical Negative Results, 165-177.

[59] Geeta D. Salunke, Vijay P. Singh and Chaya R. Jadhav, "DEVELOPMENT OF A CONTINUOUS MONITORING SYSTEM FOR HUMAN BODY TEMPERATURE AND HEART RATE SOUND. (2022). Journal of Pharmaceutical Negative Results, 3303-3313.

[60] Kashid, M. M., Karande, K. J., & Mulani, A. O. (2022, November). IoT-Based Environmental Parameter Monitoring Using Machine Learning Approach. In Proceedings of the International Conference on Cognitive and Intelligent Computing: ICCIC 2021, Volume 1 (pp. 43-51). Singapore: Springer Nature, Singapore.

[61] Dr. P. B. Mane and A. O. Mulani, "High throughput and area efficient FPGA implementation of AES algorithm", International Journal of Engineering and Advanced Technology, Vol. 8, Issue 4, April 2019

[62] A. O. Mulani and Dr. P. B. Mane, "Secure and area Efficient Implementation of Digital Image Watermarking on Reconfigurable Platform", International Journal of Innovative Technology and Exploring Engineering, Vol. 8, Issue 2,Dec. 2018 .

[63] P. B. Mane and A. O. Mulani, "High Speed Area Efficient FPGA Implementation of AES Algorithm", International Journal of Reconfigurable and Embedded Systems, Vol. 7, No. 3, pp. 157-165, November 2018.

[64] Mamta S. Koban, Vijay P. Singh, & Rajesh Bodade, *"Investigation on Efficient Deep Learning Framework for Spinal Deformities: A Review Approach"* Journal of Pharmaceutical Negative Results, Oct. 2022, pp. 153–164.

[65] Mamta S. Koban, Vijay P. Singh, Rajesh Bodade, *"INVESTIGATION OF EFFICIENT DEEP LEARNING FRAMEWORK FOR TREATMENT OF SPINAL DEFORMITIES"*, Journal of Pharmaceutical Negative Results, Dec.2022, pp. 3314–3324.

[66] Mamta S. *Koban*, A.A.Ansari, Rajesh Bodade, "*Localization and Prediction of Spinal Vertebrae Fracture in Human Body Using Deep Learning Approach: Review Paper",* 7th International Conference on "Shaastrarth-2022" on "Computational Optimization, Modeling and Simulation: Recent Trends and Challenges" on 25th – 26th March 2022, organized by Rungta College of Engineering and Technology, Bhilai, Chhattisgarh.


DOI: https://doi.org/10.15379/ijmst.v10i2.3082