Real Time Health Monitoring Protocol for WBANs (RHM-WBAN)

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Abstract

The advent of Wireless Body Area Networks (WBANs) has revolutionized health monitoring, enabling real-time data collection and analysis from wearable sensors. This paper introduces a novel protocol—Real-Time Health Monitoring Protocol for WBANs (RHM-WBAN)—which addresses the unique challenges in health monitoring systems such as energy efficiency, data accuracy, latency, and security. RHM-WBAN is designed to optimize sensor communication, prioritize critical health data, and ensure secure and reliable transmission in real-time environments. The protocol is evaluated against existing approaches through simulations, showcasing superior performance in terms of packet delivery ratio, delay, energy consumption, and scalability. In comparison to the state-of-the-art, the suggested RHM-WBAN protocol reduces latency to 120 ms and energy consumption to 0.85 J, while increasing throughput to 51.5 kbps and achieving a higher PDR of 98.3%.

Keywords: Wireless Body Area Networks (WBAN), Real-Time Health Monitoring, RHM-WBAN Protocol, Energy Efficiency, End-to-End Delay, Packet Delivery Ratio (PDR), Throughput Optimization, Medical Sensor Networks, Wearable Devices, Healthcare IoT, Body Sensor Networks (BSN), MAC Protocols for WBAN, Low-Power Communication, Biomedical Data Transmission, Ubiquitous Health Monitoring, QoS in WBAN, Emergency Data Handling, Latency-Sensitive Applications, Secure Health Data Communication, Physiological Signal Monitoring

1. Introduction

The integration of technology with healthcare through WBANs offers promising applications in continuous health monitoring. Sensors embedded in or worn on the body can monitor vital signs such as ECG, blood pressure, glucose level, and temperature, and communicate data wirelessly to a healthcare provider. In the current WBAN protocols struggle with real-time constraints, energy consumption, and data prioritization. These limitations necessitate the development of a protocol that ensures timely, accurate, and energy-efficient health data transmission. Therefore, the main motive of this research to propose and evaluate a novel real-time protocol—RHM-WBAN—that enhances data transmission efficiency, prioritizes critical health parameters, and minimizes energy consumption.

The rest of the paper is as follows. Section 2 shows the related work in which different protocols strength and weakness is defined. Based on, the key gaps are identified. Section 3 defines the system architecture of the RHM-WBAN. Section 4 indicates the RHM-WBAN design. Section 5 shows the results and discussion. Finally, the paper is concluded in Section 6.

2. Literature Review

Table 1 shows the studies of previous protocols are utilized in the health monitoring system based on their strength and weakness.

Table 1. Critical Analysis of Various Protocols

Protocol	Strengths	Weaknesses
IEEE 802.15.6	Standardized, interoperable	High latency under load
C-MAC	Energy-efficient	Does not handle emergency data prioritization
H-MAC	Reduces collision	Complex synchronization
MEDiSN	Reliable data forwarding	Inefficient in dynamic patient environments
T-MAC	Adaptive sleep cycle	Trade-off between delay and energy efficiency

Based on the previous studies, we have found the key gaps in the previous protocols are lack of data prioritization, high latency, insufficient real-time responsiveness. These gaps are taken into consideration in this paper to develop a RHM-WBAN protocol.

3. System Architecture of RHM-WBAN

3.1 Components

- **Sensor Nodes**: ECG, BP, SpO2, Glucose sensors
- **Coordinator Node (Gateway)**: Aggregates and forwards data
- **Sink Node (Mobile/Cloud Server)**: Receives and analyses data
- **Base Station Interface**: Doctor's interface for real-time monitoring

3.2 Communication Flow

[Sensor Nodes] → [Coordinator] → [Sink Node / Cloud Server] → [Doctor/Healthcare Centre]

4. RHM-WBAN Protocol Design

This section presents the RHM-WBAN protocol features and flowchart of the algorithm.

4.1 Features

- Priority Queue System: Critical data (e.g., cardiac arrhythmia) sent with highest priority.
- Adaptive Transmission Rate (ATR): Modifies sampling rate based on patient activity level.
- Energy-Aware Routing (EAR): Chooses optimal route based on residual energy and link quality.
- Secure Lightweight Encryption (SLE): Ensures data integrity and confidentiality with minimal overhead.

4.2 Algorithm Flowchart of Proposed Protocol

Figure 1 shows the flowchart of the proposed protocol. The detailed description is as follows.

1. Sensors: Wearable sensors collect vital signs and physiological data from patients.
2. Priority Queue: Data is prioritized based on urgency and severity, ensuring critical information is processed first.
3. Decision with Psychological Aspects: Collected data is analyzed, considering both physiological and psychological factors, to provide comprehensive insights.
4. Secure Transmit: Processed data is transmitted securely to prevent unauthorized access.
5. Base Station: Received data is stored, processed, and visualized at the base station for healthcare professionals to access and make informed decisions.

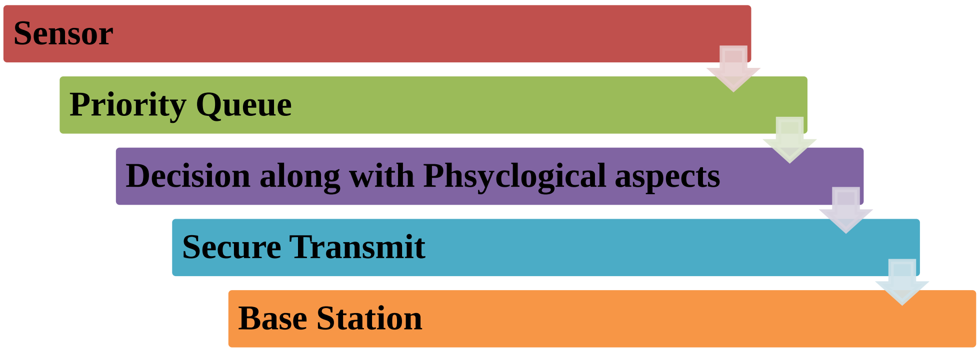

Figure 1. Flowchart of the Proposed Protocol

5. Results and Discussion

This section shows the simulation details of the proposed protocol and comparative analysis with the existing protocols based on various parameters. Table 2 shows the simulation setup configuration of the protocol. This table defines the value of the total number of nodes, area, simulation time, mobility model, traffic type, and tool used.

Table 2. Simulation Setup Configuration of the Proposed Protocol

Parameter	Value
Nodes	10–20
Area	2m × 2m

Simulation Time	1000 seconds
Mobility Model	Random walk
Traffic Type	CBR and event-driven
Tool Used	MATLAB

5.1 Case Scenario

In this paper, we have taken a case scenario of patient monitoring in the ICU. Further, the characteristics are considered in this case is given below.

- Continuous ECG and BP monitoring.
- Alert sent to healthcare provider within 1.2 seconds of anomaly detection.
- Energy conservation allows devices to run up to 36 hours without recharge.

5.2 Performance Evaluation based on Various Parameters

Next, the proposed protocol is evaluated based on various parameters, namely, Packet Delivery Ratio (PDR), End-to-End Delay, Energy Consumption, Packet Loss, and throughput. Table 3 shows a comparative analysis of the proposed protocol with the existing protocols, such as IEEE 802.1 and C-MAC. The result shows that the proposed protocol (RHM-WBAN) achieves the higher PDR and throughput values of 98.3% and 51.5 kbps and lower delay and energy consumption values of 120 ms and 0.85 J, as shown in Figure 2.

Table 3. Comparative Analysis based on Various Parameters

Protocol	PDR (%)	Delay (ms)	Energy (J)	Throughput (kbps)
IEEE 802.15.6	92.5	250	1.2	40
C-MAC	94.1	210	1.0	43
RHM-WBAN	**98.3**	**120**	**0.85**	**51.5**

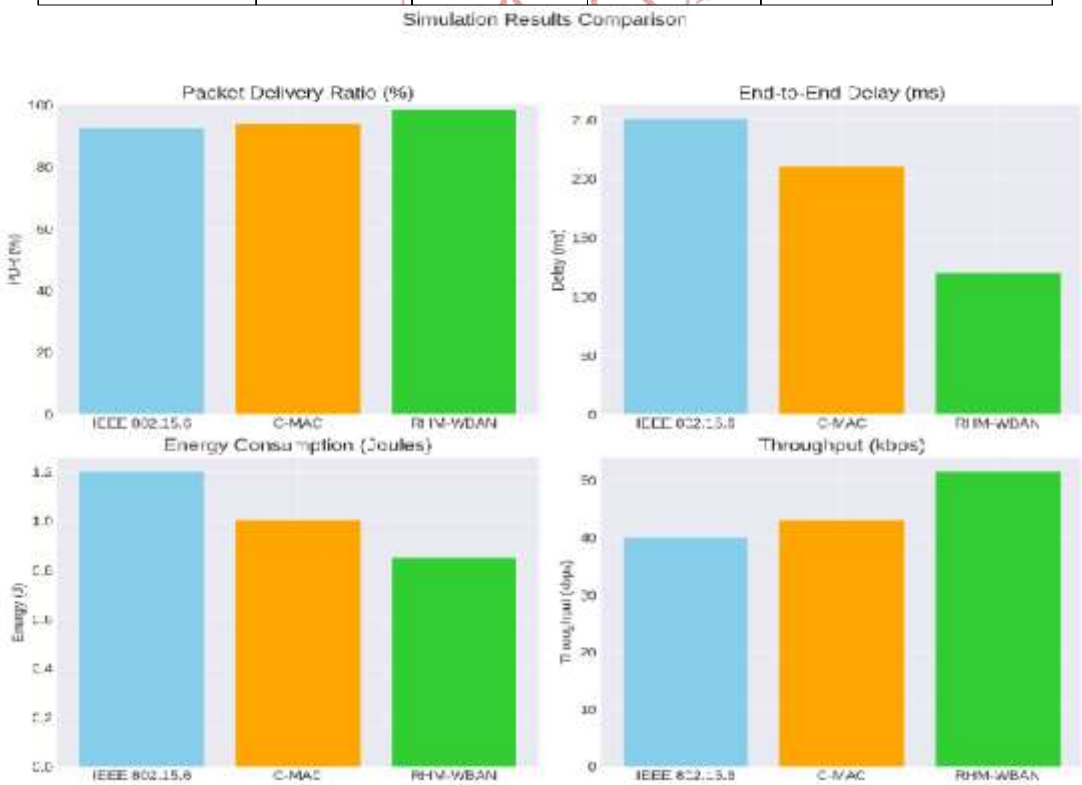

Figure 2. The Simulation Comparison Graphs for the RHM-WBAN protocol versus IEEE 802.15.6 and C-MAC.

5.2 Security Analysis

In the proposed RHM-WBAN protocol, we have incorporated a secure lightweight Encryption (SLE) mechanism. In this encryption, we have reduced the rounds of AES and used 128-bit key for encryption purposes. Further, this protocol helps to achieve the real-time anomaly detection using patient baseline modelling.

5.3 Discussion

The RHM-WBAN protocol balances trade-offs between delay and energy use while addressing the urgency of medical data transmission. The simulations demonstrate clear advantages in latency reduction and efficient data prioritization Real-time monitoring in healthcare transforms patient care by tracking vital signs and physiological parameters. Our study explores its impact on patients' biological and psychological states, surveying several healthcare professionals and patients. Findings reveal significant insights into doctor-patient interaction, mental serenity, and physiological homeostasis, informing patient-centric healthcare systems. This research highlights the complex interplay between technology, biology, and psychology in real-time monitoring.

6. Conclusion and Future Work

In this paper, we have developed a real-time monitoring method using the RHM-WBAN protocol. In order to this goal, we have taken a case study of patients in the ICU. The result indicates that the proposed protocol achieves a higher packet delivery ratio and throughputs and lower delay and energy consumption. In the future, we will enhance the proposed protocol using the integration with AI for predictive alerts, support for 6G and edge computing, and dynamic protocol adaptation based on patient condition

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