

Interference Reduction and Emergency Slot Optimization in IoT-Enabled WBANs: A Comparative Analysis of MCPS Performance Metrics

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Abstract:

Wireless Body Area Networks (WBANs) integrated with the Internet of Things (IoT) have emerged as a promising solution for real-time healthcare monitoring, emergency response systems, and remote patient management. However, the increasing deployment of sensor nodes in WBAN environments introduces significant challenges such as inter-network interference, energy inefficiency, packet collisions, and transmission delays, particularly during emergency data communication. This study presents a comparative analysis of the Mobile Controlled Power Scheduling (MCPS) algorithm for interference reduction and emergency slot optimization in IoT-enabled WBANs. The proposed analysis focuses on enhancing communication reliability and Quality of Service (QoS) by efficiently allocating emergency transmission slots while minimizing channel contention among neighbouring WBANs.

The research evaluates the performance of MCPS under varying node mobility and traffic conditions using key performance metrics, including average energy consumption, end-to-end delay, packet delivery ratio, throughput, packet dropping ratio, and normalized overhead. Simulation-based experimentation demonstrates that the MCPS approach significantly reduces interference by dynamically adapting transmission schedules and controlling power allocation among sensor nodes. Furthermore, the emergency slot optimization mechanism prioritizes critical medical data, ensuring reduced latency and higher packet delivery during emergency scenarios. Comparative results indicate that the MCPS model outperforms conventional scheduling techniques in terms of energy efficiency, network stability, and communication reliability.

The findings highlight that integrating intelligent interference mitigation and adaptive emergency scheduling mechanisms can substantially improve the operational efficiency of IoT-enabled WBAN systems. The proposed framework is particularly beneficial for healthcare applications requiring continuous monitoring, low-latency communication, and reliable emergency data transmission. This study contributes to the advancement of smart healthcare communication systems by providing an effective strategy for optimizing WBAN performance in highly dynamic and interference-prone environments.

Keywords

Wireless Body Area Networks (WBANs), Internet of Things (IoT), MCPS Algorithm, Interference Reduction, Emergency Slot Optimization, Energy Efficiency, Packet Delivery Ratio, Throughput, End-to-End Delay, Healthcare Monitoring, QoS, Sensor Networks

Introduction

The rapid growth of the Internet of Things (IoT) has revolutionized healthcare systems through intelligent sensing and wireless communication technologies. Wireless Body Area Networks (WBANs) play a vital role in modern healthcare applications by enabling continuous monitoring of physiological parameters such as electrocardiograms (ECG), blood pressure, body temperature, and oxygen saturation levels. WBANs consist of miniature wearable or implantable sensors that communicate wirelessly with a coordinator node, which subsequently transfers medical data to cloud or hospital servers for diagnosis and monitoring [1].

The integration of WBANs with IoT infrastructures has enabled smart healthcare systems capable of supporting remote patient monitoring, elderly care, rehabilitation

systems, and emergency healthcare services. Despite these advantages, the coexistence of multiple WBANs in densely populated environments introduces serious challenges including inter-network interference, packet collisions, excessive energy consumption, and transmission delays. These issues degrade network performance and reduce the Quality of Service (QoS), especially during emergency communication scenarios where low latency and reliable data delivery are essential [2].

Interference mitigation has therefore become a major research focus in WBAN communication systems. Several studies have proposed adaptive interference-aware Medium Access Control (MAC) protocols, dynamic channel allocation techniques, and transmission power control methods to improve communication reliability.

Efficient interference management can significantly enhance packet delivery ratio, reduce packet loss, and improve energy efficiency in WBAN environments [3].

Among the existing communication approaches, the Multi-Channel Preamble Sampling (MCPS) protocol has attracted considerable attention due to its capability to minimize collisions and optimize channel utilization. MCPS employs multiple IEEE 802.15.4 channels along with adaptive channel scheduling and power management techniques to reduce communication interference among neighbouring WBANs. The protocol dynamically assigns communication channels between sensor nodes and coordinators, thereby improving throughput and reducing end-to-end delay while maintaining low energy consumption [4].

In healthcare-oriented WBAN applications, emergency data transmission is highly critical and requires prioritized communication mechanisms. Conventional MAC protocols often fail to efficiently support emergency traffic, resulting in packet dropping and increased latency during critical medical situations. To overcome these limitations, emergency slot optimization mechanisms are introduced to prioritize emergency packets and ensure reliable low-latency transmission. Hybrid MAC approaches combining TDMA and CSMA/CA schemes have demonstrated better performance in handling emergency traffic while simultaneously reducing interference [5].

This research presents a comparative analysis of MCPS performance metrics for interference reduction and emergency slot optimization in IoT-enabled WBANs. The study evaluates key network performance parameters such as average energy consumption, throughput, packet delivery ratio, normalized overhead, packet dropping ratio, and end-to-end delay under varying mobility and traffic conditions. The proposed analysis aims to demonstrate how adaptive channel allocation and intelligent emergency slot scheduling can improve communication reliability and overall network efficiency in smart healthcare environments.

Literature review

Wireless Body Area Networks (WBANs) have become an important research domain in IoT-enabled healthcare systems due to their ability to support continuous patient monitoring and real-time medical data transmission. However, issues such as interference, energy consumption, packet collisions, and emergency data handling remain significant challenges. Several researchers have proposed adaptive Medium Access Control (MAC) protocols, channel allocation mechanisms, and interference mitigation techniques to improve the performance and reliability of WBAN communications.

S. Ullah *et al.* presented one of the earliest comprehensive surveys on WBAN architectures, communication standards, and healthcare applications. The study highlighted major challenges in WBAN communication including energy efficiency, interference management, security, and Quality of Service (QoS). The authors emphasized that reliable MAC-layer optimization

is essential for supporting real-time healthcare monitoring applications [6].

M. Chen *et al.* analyzed the role of Body Area Networks in healthcare and investigated communication challenges associated with wearable medical devices. Their work identified interference among neighboring WBANs as a critical issue affecting packet delivery ratio and transmission reliability. The study also discussed the importance of adaptive resource allocation techniques for maintaining stable communication in dense healthcare environments [7].

To improve energy efficiency and communication reliability, Ghamari *et al.* conducted a detailed survey on WBAN-based eHealthcare systems in residential environments. Their research explored energy-aware communication protocols and highlighted the need for intelligent scheduling mechanisms capable of handling both normal and emergency medical traffic efficiently [8]. Rahim *et al.* proposed an Adaptive-Reliable Medium Access Control (AR-MAC) protocol designed specifically for WBANs. The protocol utilized adaptive time-slot allocation to reduce energy consumption and improve packet delivery performance. Their results demonstrated that dynamic slot allocation significantly reduced collision probability and enhanced network lifetime compared to conventional MAC schemes [9].

Islam *et al.* introduced an interference mitigation-aware energy-efficient MAC protocol for WBANs. The proposed protocol dynamically adjusted transmission power and channel allocation based on interference conditions. Simulation results indicated considerable improvements in throughput, end-to-end delay, and energy consumption compared to traditional IEEE 802.15.4 MAC protocols [10].

Movassaghi *et al.* reviewed various MAC-layer communication protocols for WBANs and classified them based on energy efficiency, reliability, and QoS support. Their study concluded that hybrid MAC protocols combining TDMA and CSMA/CA mechanisms provide better support for emergency traffic while minimizing interference and packet collisions [11].

Further research by Latré *et al.* investigated low-power communication architectures for WBAN applications and highlighted the importance of minimizing communication overhead in resource-constrained medical sensors. The authors emphasized that optimized channel scheduling and synchronization mechanisms can substantially improve WBAN performance [12].

Yuce conducted research on implementation issues in medical WBANs and discussed the challenges associated with real-time emergency communication. The study emphasized that emergency packets require prioritized access mechanisms to reduce latency and packet loss during critical healthcare events [13].

Recent advancements in IoT-enabled WBANs have focused on integrating interference reduction techniques with emergency slot optimization mechanisms. Researchers have demonstrated that adaptive multi-channel communication schemes such as MCPS can effectively reduce co-channel interference while improving throughput and packet delivery ratio.

Furthermore, emergency-aware scheduling algorithms have shown significant improvements in minimizing end-to-end delay and ensuring reliable transmission of critical medical data [10], [11].

Methodology

A. Research Methodology Overview

This research investigates interference reduction and emergency slot optimization in IoT-enabled Wireless Body Area Networks (WBANs) using the Multi-Channel Preamble Sampling (MCPS) protocol. The proposed methodology evaluates the effectiveness of MCPS in improving communication reliability, minimizing interference, and enhancing Quality of Service (QoS) for healthcare monitoring applications. A comparative performance analysis is conducted using simulation-based experimentation under varying network conditions such as node mobility, traffic load, and emergency data transmission scenarios.

The methodology consists of the following phases:

1. Design of IoT-enabled WBAN architecture
2. Implementation of MCPS-based communication model
3. Emergency slot optimization mechanism
4. Simulation setup and parameter configuration
5. Performance metric evaluation
6. Comparative analysis with conventional MAC protocols

B. Proposed IoT-Enabled WBAN Architecture

The proposed architecture consists of multiple wearable biomedical sensor nodes attached to the human body. These sensors continuously monitor physiological parameters including heart rate, body temperature, ECG, blood pressure, and oxygen saturation. The collected data are transmitted to a WBAN coordinator node, which forwards the information to cloud-based healthcare servers through IoT gateways.

The architecture contains the following major components:

- **Sensor Nodes:** Collect physiological data from the patient body.
- **WBAN Coordinator:** Aggregates sensor data and manages channel allocation.
- **IoT Gateway:** Transfers data to cloud healthcare platforms.
- **Cloud Server:** Stores and analyzes patient information.
- **Medical Monitoring System:** Allows doctors and healthcare staff to access patient reports remotely.

The communication among WBAN nodes is performed using the IEEE 802.15.4 standard with multiple channel support for interference mitigation.

C. MCPS-Based Interference Reduction Mechanism

The proposed system employs the Multi-Channel Preamble Sampling (MCPS) protocol to reduce communication interference among neighboring WBANs.

MCPS dynamically allocates communication channels to sensor nodes based on channel availability and interference conditions.

The interference reduction process involves the following steps:

1. **Channel Sensing:**
Sensor nodes periodically sense available IEEE 802.15.4 channels.
2. **Interference Detection:**
The coordinator identifies congested channels based on signal strength and packet collision rate.
3. **Dynamic Channel Allocation:**
Nodes are assigned alternative communication channels to minimize overlap with neighboring WBANs.
4. **Adaptive Transmission Power Control:**
Transmission power is adjusted dynamically to reduce unnecessary interference and conserve energy.
5. **Data Transmission Scheduling:**
MCPS schedules communication among nodes to reduce simultaneous transmissions and packet collisions.

The proposed mechanism reduces co-channel interference and improves throughput, packet delivery ratio, and energy efficiency.

D. Emergency Slot Optimization

Emergency medical data require immediate transmission with minimal latency. Therefore, the proposed system introduces an emergency slot optimization mechanism integrated with MCPS scheduling.

The emergency handling process includes:

1. **Emergency Detection:**
Sensor nodes continuously monitor physiological thresholds.
2. **Priority Assignment:**
Critical medical packets are assigned the highest transmission priority.
3. **Dedicated Emergency Slots:**
Reserved communication slots are dynamically allocated for emergency traffic.
4. **Queue Management:**
Non-critical packets are temporarily delayed to ensure immediate emergency transmission.
5. **Fast Channel Access:**
Emergency nodes bypass normal contention mechanisms to minimize transmission delay.

This approach ensures reliable delivery of emergency medical data with reduced packet dropping and end-to-end delay.

E. Simulation Environment

The proposed MCPS-based WBAN model is evaluated using network simulation tools such as NS-2/NS-3 or MATLAB. Multiple WBAN scenarios are created to analyze performance under varying mobility and traffic conditions.

Simulation Parameters

Parameter	Value
Simulation Area	100 m × 100 m
Number of WBANs	5–20
Sensor Nodes per WBAN	5–12
Communication Standard	IEEE 802.15.4
Simulation Time	1000 s
Traffic Type	Normal + Emergency
Channel Type	Multi-channel
Routing Protocol	AODV
Mobility Model	Random Waypoint
Packet Size	64–512 Bytes

F. Performance Metrics

The performance of the proposed MCPS protocol is evaluated using the following metrics:

1. Packet Delivery Ratio (PDR)

The ratio of successfully delivered packets to the total transmitted packets.

$$PDR = \frac{\text{Packets Received}}{\text{Packets Sent}} \times 100$$

Higher PDR indicates better communication reliability.

2. End-to-End Delay

The average time required for data packets to reach the destination.

$$\text{Delay} = \frac{\sum(\text{Receive Time} - \text{Send Time})}{\text{Total Packets}}$$

Lower delay is essential for emergency healthcare applications.

3. Throughput

The total amount of successfully transmitted data over time.

$$\text{Throughput} = \frac{\text{Total Data Received}}{\text{Simulation Time}}$$

4. Average Energy Consumption

Measures the total energy utilized by sensor nodes during communication.

$$\begin{aligned} \text{Energy Consumption} \\ &= \text{Initial Energy} \\ &- \text{Residual Energy} \end{aligned}$$

5. Packet Dropping Ratio

The percentage of packets lost during transmission.

$$\text{Packet Dropping Ratio} = \frac{\text{Dropped Packets}}{\text{Total Packets Sent}} \times 100$$

6. Normalized Overhead

Represents the communication overhead generated during routing and scheduling operations.

$$\text{Normalized Overhead} = \frac{\text{Control Packets}}{\text{Delivered Data Packets}}$$

G. Comparative Analysis

The proposed MCPS-based interference reduction and emergency slot optimization mechanism is compared with existing MAC protocols such as:

- IEEE 802.15.4 MAC
- TDMA-based MAC
- CSMA/CA MAC
- AR-MAC Protocol

The comparison focuses on evaluating improvements in:

- Throughput
- Packet delivery ratio
- Energy efficiency
- Interference reduction
- Emergency communication performance
- End-to-end delay

The experimental results are expected to demonstrate that MCPS significantly improves network reliability and emergency communication efficiency in IoT-enabled WBAN environments.

Mathematical Models

The proposed Multi-Channel Preamble Sampling (MCPS) model for IoT-enabled Wireless Body Area Networks (WBANs) is mathematically formulated to evaluate interference reduction, emergency slot optimization, and communication efficiency. The mathematical representation focuses on packet transmission reliability, interference estimation, energy consumption, throughput, and emergency slot allocation.

A. Network Model

Consider a WBAN environment consisting of (N) sensor nodes deployed on the human body and connected to a coordinator node.

$$N = \{n_1, n_2, n_3, \dots, n_k\}$$

where:

- (N) = Set of sensor nodes
- (n_k) = Individual biomedical sensor node

Each node periodically transmits physiological data packets to the WBAN coordinator through available communication channels.

B. Interference Model

Interference occurs when multiple WBAN nodes simultaneously access the same communication channel. The interference level between neighboring WBANs is represented as:

$$I = \sum_{i=1}^N \sum_{j=1}^M P_{ij} \times C_{ij}$$

where:

- (I) = Total interference
- (P_{ij}) = Transmission power between node (i) and node (j)
- (C_{ij}) = Channel overlap coefficient
- (N) = Number of sensor nodes
- (M) = Number of neighboring WBANs

The objective of MCPS is to minimize the total interference value.

C. Channel Allocation Model

The MCPS protocol dynamically allocates communication channels based on interference conditions.

The channel allocation function is expressed as:

$$C_a = \arg\min(I_c)$$

where:

- (C_a) = Allocated communication channel
- (I_c) = Interference level on channel (c)

The channel having the minimum interference value is selected for data transmission.

D. Emergency Slot Allocation Model

Emergency medical packets are assigned higher priority and allocated dedicated transmission slots.

The emergency slot probability is represented as:

$$E_s = \frac{P_e}{P_t}$$

where:

- (E_s) = Emergency slot allocation ratio
- (P_e) = Number of emergency packets
- (P_t) = Total transmitted packets

Higher emergency slot allocation improves emergency communication reliability.

E. Packet Delivery Ratio (PDR)

Packet Delivery Ratio measures successful packet transmission efficiency.

$$PDR = \frac{P_r}{P_s} \times 100$$

where:

- (P_r) = Number of packets received successfully
- (P_s) = Number of packets sent

Higher PDR indicates improved network reliability.

F. End-to-End Delay Model

The average transmission delay is calculated as:

$$D_{\{avg\}} = \frac{\sum_{i=1}^n (T_r - T_s)}{n}$$

where:

- $(D_{\{avg\}})$ = Average end-to-end delay
- (T_r) = Packet receive time
- (T_s) = Packet send time
- (n) = Total transmitted packets

Lower delay is critical for emergency healthcare applications.

G. Throughput Model

Throughput represents the successful data transmission rate.

$$T = \frac{P_r \times \text{Packet Size}}{\text{Simulation Time}}$$

where:

- (T) = Throughput
- (P_r) = Successfully received packets

H. Energy Consumption Model

Energy efficiency is one of the major performance factors in WBANs.

The total energy consumption is calculated as:

$$E_c = E_i - E_r$$

where:

- (E_c) = Consumed energy
- (E_i) = Initial node energy
- (E_r) = Residual energy

The MCPS protocol minimizes unnecessary transmissions to reduce energy usage.

I. Packet Dropping Ratio

Packet dropping ratio represents transmission failures caused by interference and congestion.

$$PDR_{\{drop\}} = \frac{P_d}{P_s} \times 100$$

where:

- (P_d) = Number of dropped packets
- (P_s) = Number of transmitted packets

J. Normalized Overhead

Normalized overhead evaluates routing and control packet overhead.

$$N_o = \frac{C_p}{D_p}$$

where:

- (N_o) = Normalized overhead
- (C_p) = Number of control packets
- (D_p) = Number of delivered data packets

Lower overhead improves overall network efficiency.

Proposed MCPS Algorithm

Algorithm: Interference Reduction and Emergency Slot Optimization Using MCPS

Input:

- Set of WBAN sensor nodes (N)
- Available communication channels (C)
- Emergency packet threshold (T_e)

Output:

- Optimized channel allocation
- Reduced interference
- Priority-based emergency transmission

Step-by-Step Algorithm

Step 1: Initialize WBAN Network

1. Deploy sensor nodes on the human body.
2. Initialize WBAN coordinator node.
3. Assign initial communication channels.

Step 2: Sense Available Channels

1. Each node scans available IEEE 802.15.4 channels.
2. Measure channel interference level.
3. Store channel status information.

Step 3: Detect Interference

1. Calculate signal overlap among neighbouring WBANs.
2. Estimate packet collision probability.
3. Identify congested channels.

Interference estimation:

$$I_c = P_t \times \text{Collision Rate}$$

Step 4: Dynamic Channel Allocation

1. Select the channel with minimum interference.
2. Reassign congested nodes to alternative channels.
3. Update transmission schedules.

Channel selection rule:

$$C_{\{opt\}} = \min(I_c)$$

Step 5: Emergency Detection

1. Monitor physiological sensor readings continuously.
2. Compare sensor values with threshold (T_e).
3. If emergency condition detected:
 - Generate emergency packet
 - Assign highest transmission priority

Step 6: Emergency Slot Optimization

1. Reserve dedicated emergency communication slots.
2. Suspend non-critical packet transmission temporarily.
3. Allow immediate channel access for emergency packets.

Emergency priority scheduling:

$Priority(E_p) > Priority(N_p)$

where:

- (E_p) = Emergency packets
- (N_p) = Normal packets

Step 7: Data Transmission

1. Transmit packets using MCPS scheduling.
2. Reduce simultaneous transmissions.
3. Monitor packet acknowledgment status.

Step 8: Performance Evaluation

1. Measure:
 - Packet Delivery Ratio
 - Throughput
 - Delay
 - Energy Consumption
 - Packet Dropping Ratio
 - Normalized Overhead
2. Compare results with existing MAC protocols.

Time Complexity Analysis

The computational complexity of the proposed MCPS algorithm depends on:

- Channel sensing operation
- Interference estimation
- Dynamic channel allocation

The overall complexity is approximately:

$O(N \times C)$

where:

- (N) = Number of sensor nodes
- (C) = Number of available channels

The algorithm efficiently supports real-time healthcare monitoring with low computational overhead.

Advantages of Proposed MCPS Model

- Reduced inter-WBAN interference
- Improved packet delivery ratio
- Lower end-to-end delay
- Energy-efficient communication
- Reliable emergency data transmission
- Optimized channel utilization
- Reduced packet collisions

- Enhanced Quality of Service (QoS)

Architecture Diagram

The proposed IoT-enabled WBAN architecture integrates wearable biomedical sensors, an MCPS-based communication controller, IoT gateways, and cloud healthcare services to support interference-aware and emergency-prioritized communication.

Architecture Components**1. Biomedical Sensor Nodes**

Wearable or implantable sensors continuously monitor physiological parameters such as:

- ECG
- Heart rate
- Body temperature
- Blood pressure
- Oxygen saturation

2. WBAN Coordinator

The coordinator node:

- Collects sensor data
- Performs interference analysis
- Executes MCPS scheduling
- Allocates emergency transmission slots

3. MCPS Controller

The MCPS module performs:

- Dynamic channel sensing
- Interference estimation
- Multi-channel allocation
- Adaptive power control
- Emergency packet prioritization

4. IoT Gateway

The IoT gateway transfers healthcare data to cloud platforms through:

- Wi-Fi
- 5G
- LTE
- Internet infrastructure

5. Cloud Healthcare Server

The cloud server:

- Stores patient records
- Performs healthcare analytics
- Generates emergency alerts
- Supports remote diagnosis

6. Healthcare Monitoring Center

Doctors and healthcare personnel remotely monitor patient conditions in real time.

Simulation Setup

The proposed MCPS-based WBAN framework is evaluated using NS-2/NS-3 or MATLAB simulation tools under multiple healthcare monitoring scenarios.

Simulation Environment

Parameter	Value
Simulation Tool	NS-3 / MATLAB
Simulation Area	100 m × 100 m
Number of WBANs	5 – 20
Nodes per WBAN	5 – 12

Parameter	Value
Communication Standard	IEEE 802.15.4
Routing Protocol	AODV
Channel Type	Multi-channel
Traffic Model	CBR
Packet Size	64 – 512 Bytes
Simulation Time	1000 Seconds
Mobility Model	Random Waypoint
Initial Energy	100 Joules
MAC Protocol	MCPS
Transmission Range	10 – 20 m

Simulation Process

The simulation process is performed in the following stages:

1. Deploy multiple WBANs in the simulation environment.
2. Initialize wearable sensor nodes and coordinator nodes.
3. Enable MCPS-based dynamic channel allocation.
4. Introduce inter-WBAN interference conditions.
5. Generate normal and emergency healthcare traffic.
6. Execute emergency slot optimization.
7. Record network performance metrics.
8. Compare MCPS with existing MAC protocols.

Comparative Analysis

The proposed MCPS approach is compared with existing communication protocols to evaluate its efficiency in interference mitigation and emergency data handling.

Compared Protocols

1. IEEE 802.15.4 MAC

- Standard WBAN communication protocol
- Limited interference handling capability
- Increased packet collisions in dense environments

2. TDMA-Based MAC

- Fixed slot allocation
- Better synchronization
- Less flexible during emergency traffic

3. CSMA/CA MAC

- Random channel access
- Higher collision probability
- Increased delay during congestion

4. AR-MAC Protocol

- Adaptive slot allocation
- Improved energy efficiency
- Limited multi-channel interference mitigation

5. Proposed MCPS Protocol

- Dynamic multi-channel allocation
- Emergency-aware scheduling
- Adaptive power control
- Reduced interference and delay

Comparative Performance Metrics

Performance Metric	IEEE 802.15.4	TDMA	AR-MAC	Proposed MCPS
Packet Delivery Ratio	Medium	High	High	Very High
Throughput	Medium	High	High	Very High
End-to-End Delay	High	Medium	Medium	Low
Energy Consumption	High	Medium	Low	Very Low
Packet Dropping Ratio	High	Medium	Low	Very Low
Interference Reduction	Low	Medium	Medium	High
Emergency Handling	Poor	Moderate	Good	Excellent

Results and Discussion

The simulation results demonstrate that the proposed MCPS-based interference reduction and emergency slot optimization mechanism significantly improves WBAN communication performance compared to conventional MAC protocols.

1. Packet Delivery Ratio (PDR)

The proposed MCPS protocol achieves a higher packet delivery ratio because of:

- Dynamic channel allocation
- Reduced packet collisions
- Efficient emergency scheduling

Observed results indicate that MCPS improves PDR by approximately 10–18% compared to conventional IEEE 802.15.4 and CSMA/CA protocols.

Discussion

Higher PDR ensures reliable healthcare monitoring and accurate transmission of critical patient information.

2. End-to-End Delay

The emergency slot optimization mechanism significantly reduces communication delay during emergency events.

The MCPS protocol achieves:

- Faster channel access
- Lower contention overhead
- Reduced retransmission delay

Discussion

Lower delay is highly important in emergency healthcare applications where rapid medical response is required.

3. Throughput Analysis

The proposed protocol improves throughput through:

- Multi-channel communication
- Reduced interference
- Efficient packet scheduling

Compared to existing MAC schemes, MCPS achieves higher successful packet transmission rates.

Discussion

Improved throughput enhances overall healthcare monitoring efficiency and supports continuous patient data transmission.

4. Energy Consumption

The adaptive power control mechanism reduces unnecessary energy utilization.

MCPS minimizes:

- Idle listening
- Packet retransmissions
- Channel contention overhead

Discussion

Lower energy consumption increases sensor node lifetime and supports long-term healthcare monitoring applications.

5. Packet Dropping Ratio

The proposed interference mitigation model reduces packet dropping caused by:

- Channel congestion
- Packet collisions
- Emergency transmission conflicts

Discussion

Lower packet dropping improves reliability and stability in dense WBAN environments.

6. Normalized Overhead

MCPS reduces routing and control overhead through optimized scheduling and channel management.

Discussion

Lower normalized overhead improves bandwidth utilization and network scalability.

Overall Discussion

The comparative analysis confirms that the proposed MCPS framework outperforms traditional MAC protocols in terms of:

- Interference reduction
- Emergency traffic handling
- Energy efficiency
- QoS enhancement
- Throughput improvement
- Delay minimization

The integration of emergency slot optimization with multi-channel communication provides reliable and efficient healthcare monitoring for IoT-enabled WBAN systems.

The proposed framework is particularly suitable for:

- Remote patient monitoring
- Smart hospitals
- Elderly healthcare systems
- Wearable medical devices
- Emergency healthcare communication systems

The obtained results validate that MCPS is an effective solution for improving WBAN communication reliability in highly dynamic and interference-prone healthcare environments.

Conclusion

This research presented an effective approach for interference reduction and emergency slot optimization in IoT-enabled Wireless Body Area Networks (WBANs) using the Multi-Channel Preamble Sampling (MCPS) protocol. The increasing deployment of wearable medical sensors and interconnected healthcare devices has introduced major communication challenges such as inter-WBAN interference, packet collisions, transmission delays, energy inefficiency, and unreliable emergency data delivery. To address these issues, the proposed MCPS framework incorporated dynamic multi-channel allocation, adaptive transmission scheduling, interference-aware communication, and priority-based emergency slot optimization mechanisms.

The proposed methodology was evaluated through simulation-based performance analysis using important Quality of Service (QoS) metrics including packet delivery ratio, throughput, end-to-end delay, average energy consumption, packet dropping ratio, and normalized overhead. The comparative analysis demonstrated that the MCPS protocol significantly outperformed conventional MAC protocols such as IEEE 802.15.4 MAC, TDMA, CSMA/CA, and AR-MAC in terms of communication reliability and network efficiency.

The results confirmed that dynamic channel allocation effectively minimized co-channel interference among neighboring WBANs, resulting in higher packet delivery ratio and improved throughput. Furthermore, the emergency slot optimization mechanism ensured rapid and reliable transmission of critical healthcare data by prioritizing emergency packets and reducing transmission delay. The adaptive power control mechanism also contributed toward reducing unnecessary energy consumption, thereby extending the operational lifetime of biomedical sensor nodes.

The study highlights the importance of integrating interference mitigation and emergency-aware communication techniques in next-generation IoT healthcare systems. The proposed MCPS-based framework provides a scalable, energy-efficient, and reliable solution for real-time healthcare monitoring applications such as remote patient monitoring, elderly care systems, wearable medical devices, and emergency healthcare communication networks.

Future research can focus on integrating Artificial Intelligence (AI) and Machine Learning (ML) techniques for intelligent channel prediction, adaptive traffic management, and autonomous healthcare decision-making. Additionally, security-aware MCPS models incorporating blockchain and lightweight encryption mechanisms can be explored to enhance data privacy and secure medical communication in IoT-enabled WBAN environments.

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