Ph.D. Research Proposal

Doctoral Program in "Department Name"

Emergency and Delay aware MAC Protocol for Physiological Data Transmission in WBAN Environment

by

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<Date of Submission (DD MM 20YY>

1. Introduction

Wireless Body Area Network (WBAN) is an evolution of sensor network that enable healthcare monitoring simple and time effective process [1]. Achieving better QoS and energy efficiency in WBAN is still major issue due to resource restrictions in the network. Routing [2] and MAC protocol [3] design are well known solutions for energy efficiency and QoS provisioning in WBAN. An energy efficient link aware routing protocol namely Co-LAEEBA was involved in WBAN [4]. QoS provision and energy efficiency are achieved by advanced nodes which are additionally incorporated in the network. Thus addition of advanced nodes require more energy and high cost. Self-decision about data forwarding in sensor node degrades the performance of the network. Throughput metric was improved by iM-SIMPLE multi-hop protocol with energy efficiency [5]. Here critical data is suffered from high waiting delay since TDMA scheduling is followed by the network. RelAODV [6] protocol was involved in energy aware routing in which two different modes were followed by sensor nodes. Here energy consumption in nodes indirect mode is high since all communication is carried out by direct. Early death of nodes in direct nodes decreases network lifetime. Traffic classification was performed at sensor nodes in WBAN with single sensor [7]. However, when number sensor nodes are increased then network congestion also increased. This method restricts monitoring of patient's regular data since ordinary data is dropped at sensor node itself.

TDMA scheduling was employed in WBAN that follows tree topology [8]. Here nodes presented in high level of tree are suffered from high energy consumption since it also act as forwarder node. Data scheduling and aggregation were performed in WBAN [9] for the purpose QoS enhancement. Critical Delay [15] was considered for scheduling. Both these methods drop the packet regardless while waiting time is increased. In aggregation process, all data packets (ordinary and critical) are bundled in single frame which affects the critical data transmission. TDMA scheduling based MAC protocols aware presented in [10], [11], and [12]. All these methods increase waiting time for critical data due to involvement of TDMA scheduling.

Weighted energy method [13] and ZEQoS based routing method [14] were involved in energy efficient routing. In both methods, route selection is not able to consider significant parameters. In addition, ZEQoS method introduces high complexity due to involvement of multiple modules.

2. Problem Definition

2.1 Overall Problem Statement

In WBAN, emergency and non-emergency data transmission has been done by same MAC protocol which may be TDMA. However, the conventional MAC protocols are only suitable for normal data transmission. The convention protocols are inefficient in transmitting emergency data in WBAN environment. In addition, achieving quality of service is restricted by non-optimal route selection and single sink node management.

2.2 Specific Problem Definition

This paper presents game [16] theoretic approach based relay selection strategy for WBAN in order to attain better QoS. Here each sensor node seeks a strategy with a assist of game theoretic approach to ensure optimal energy efficiency without increase in delay. Nash equilibrium is involved in deriving Nash power control solution. Then based on calculated power control solution, Nash relay selection solution is derived.

Problem:

- This approach increases complexity in relay selection due involvement of multiple computations in Nash equilibrium.

Proposed:

- Involvement of less computations minimizes computational complexity

In this paper [17], authors addressed following issues in WBAN: (i) dynamic link characteristics due to time-varying postures and environments, (ii) high energy efficiency requirement with considering the limited battery, and (iii) QoS requirement due to important health data. To mitigate these issues, this paper formulates a routing metric named as mix-cost

parameter. Then energy efficiency and resource allocation problem is formulated to minimize mix-cost by optimizing the transmission rate, transmission power, and allocated time slots.

This paper modifies [18] the super frame structure of IEEE 802.15.4 based MAC protocol to meet QoS requirements such as delay, energy efficiency and throughput. Further, each body sensor node is provided with priority value by adjusting data type and data size. Wake-up radio based sleep control mechanism with discrete time finite state Markov model incorporated for energy efficiency. Transmission is performed by Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) mechanism.

Problem:

- Priority is assigned based on senor node which is not able to consider data criticality. Thus critical or critical data is not able to obtain high priority.

Proposed:

- Packet is classified based on packet type by GRNN classifier

Priority-based Adaptive Medium Access Control (PA-MAC) protocol [19] is presented in this paper. PA-MAC protocol is involved with following processes: multiple channel utilization, data traffic prioritization, dynamic time-slot allocation, and data transfer. Here two different channels such as beacon channel and data channel are implemented in multiple channel utilization. In traffic prioritization, traffic is classified into critical traffic, on-demand traffic, normal traffic, and non-medical traffic. Two different data transfer procedure are involved for two different data such as command message transmission, and continuous data transmission.

Problem:

- Here guaranteed time slots (GTSs) are presented for data transmission. however, GTS is same for normal data and critical data which increases waiting time and transmission time for critical data.

Proposed:

- Critical data is transmitted within direct communication which minimizes time consumption

This paper presents WBAN architecture with dual sink nodes [20]. First sink node is placed on front-body and another one is placed on the back-body of human. The major objective of this work is to achieve line-of-sight communication through cluster formation. After clustering, the sink nodes act as CHs and the body sensors act as member nodes. If the data is critical then it is transmitted via single hop otherwise it is transmitted through multi-hop communication. For optimal forwarder selection, SNR and link quality metrics are considered.

Problem:

- Clusters are formed in a random manner, thus the node located far away from the CH suffers with large amount of energy consumption
- Although emergency data is transmitted in single-hop, it has to wait for its TDMA slot which increases delay
- The considered parameters for forwarder selection are insufficient to achieve better QoS and energy efficiency since the data transmission is affected many other parameters like residual energy, load etc.

Proposed:

- Critical data transmission is performed without time delay.

3. Proposed Work

To overcome aforementioned problems in WBAN, our proposed research work concentrate on energy efficient MAC protocol and routing with the aim of QoS enhancement. Proposed research work is concentrated on energy efficiency and QoS enhancement through a novel WBAN architecture. A novel WBAN architecture is designed with body sensor nodes (BSN), coordinator, critical sink node (E-SN), sink node (SN), monitoring server, and end users. Here E-SN is responsible for emergency data transmission which leads to reduced transmission time.

3.1 Novel MAC Design

In this work, *Delay and Emergency Aware MAC* protocol is designed with the aware of criticality of data. Here data type is included in MAC header as follows,

Data type	Binary representation
Critical	00
Near-critical	01
Ordinary	11

Critical data is transmitted to coordinator within direct communication in order to assure minimum delay for critical data.

3.2 Data Routing

Near-critical and ordinary data are transmitted to coordinator by *Preceding-knowledge based Weighted Routing (PWR)* algorithm. Here routing is performed by selecting best next hop node with respect to available energy which is formulated by the **Spotted Hyena Optimization (SHO).** PWR based routing also consider past experiences on data transmission in order to minimize routing overhead. In PWR weight value for each node is computed by considering major routing metrics such as residual energy, distance, link stability, delay, transmission power etc.

3.3 Optimal Sleep Scheduling

Energy consumption by idle listening is minimized by optimal sleep scheduling process supported by a novel *Reinforced Sleep Scheduling (RSS)* algorithm. In RSS, sleep scheduling is performed with the consideration of criticality of sensor node. Coordinator is responsible for performing sleep scheduling in the network. The sleep scheduling decision is made by SARSA algorithm.

3.4 Deep Data Classification

Coordinator classifies incoming packets by **Gated Recurrent Neural Network (GRNN)** classifier. After classification, packets are assigned to corresponding sink node in the network. In both sink nodes, throughput metric is further improved by performing *Frame Aggregation* process. Finally, proposed WBAN architecture is evaluated in terms of following performance metrics,

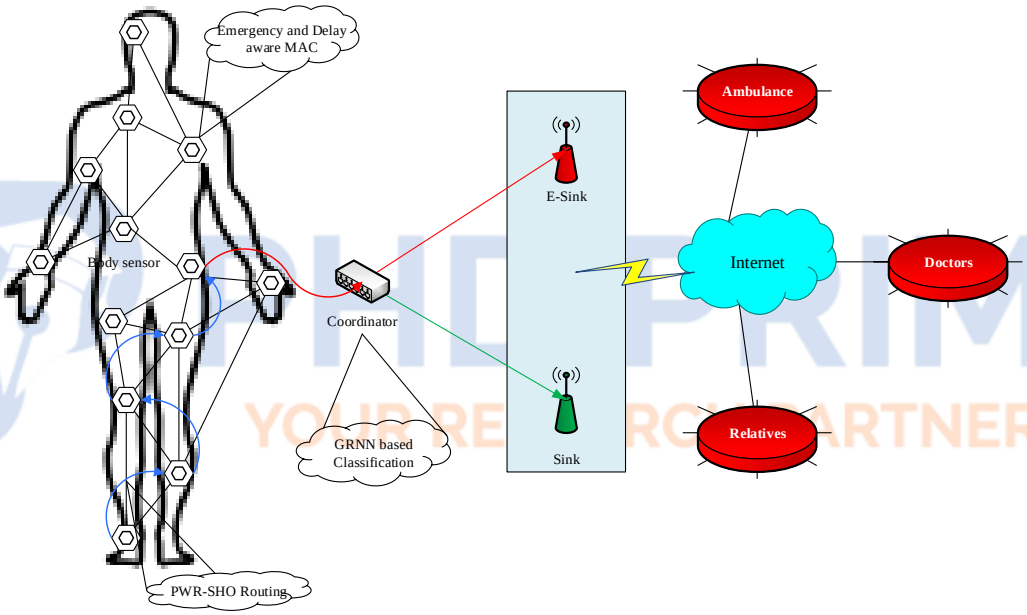
For Non-Emergency Data

- Network lifetime
- Residual energy
- Throughput
- Dropped packets
- Delay
- Packet Delivery Rate

For Emergency Data

- Network lifetime
- Residual energy
- Throughput
- Dropped packets
- Delay
- Packet Delivery Rate

Overall Architecture



IV. PRIOR WORKS

Paper: 1

Title: Energy efficient routing for critical physiological parameters in wireless body area networks under mobile emergency scenarios

Concept:

This paper deals with energy efficiency in WBAN environment. WBAN is constructed with several body sensor nodes. The body sensors are dedicated to monitor the body condition of the patient to aid in remote health monitoring. In general, it has many applications in the IoT. However, the deployed sensors are energy constrained and has limited energy resources. Thus, this paper presents a routing protocol for the critical data in WBAN environment. In WBAN, the critical data refers to the data which is higher than threshold level.

Paper: 2

Title: An Efficient and Reliable Directed Diffusion Routing Protocol in Wireless Body Area Networks

Concept:

This paper presents a directed diffusing routing protocol for WBANs. This paper focuses on minimizing energy consumption in the network. The direction and rate of data transmission is indicated by the concept of gradient. The major criterion for optimal route selection is hop count.

The data is diffused directly through the route which has minimum hop count. For that each node maintains the gradient information of its neighbour nodes with shortest path. The authors have highlighted that this work is not suitable for emergency applications of WBAN. Since, it has large delay.

Paper: 3

Title: Investigation and performance analysis of MAC protocols for WBAN networks

Concept:

Quality of Service is also enhanced by efficient MAC protocols in WBAN. In this paper, performance of different MAC protocols is analyzed and classification of MAC protocols also performed. In this paper, IEEE 802.15.6 standard, IEEE 802.15.4 standard, and time-out MAC (TMAC) protocols are analyzed under different working condition. For different types of data MAC protocols are classified as event-driven, query-driven, and continuous delivery model.

Paper:4

Title: Co-LAEEBA: Cooperative link aware and energy efficient protocol for wireless body area networks

Concept:

In this two routing protocols namely LAEEBA and Co-LAEEBA are introduced in this paper. In both protocols, path selection is performed based on hop count and cost function for each sensor in WBAN is computed. Coordinator or sink node compute cost function for each sensor in terms of distance with sink node and residual energy. Upon computed cost function, each sensor node made decision about its state whether being forwarder node or not. Then route with minimum hop is selected for data forwarding while critical data is transmitted by single hop communication. In Co-LAEEBA protocol, transmission is performed with assist of advanced nodes.

Problem:

- Here forwarding decision is made by sensor node itself which leads to ineffective process. If more sensor nodes made decision on not being forwarder, then transmission is not reliable in the network
- Co-LAEEBA protocol requires additional advanced nodes with high energy which leads to additional cost

Proposed:

- In proposed work, scheduling is performed by coordinator with the help of GSS algorithm
- Single E-SN is required in our work instead of multiple advanced nodes

Paper: 5

Title: iM-SIMPLE: iMproved stable increased-throughput multi-hop link efficient routing protocol for Wireless Body Area Networks

Concept:

This paper attempts to improve SIMPLE protocol in order to support mobility of sensor nodes in WBAN. Here forwarder node selection is performed based on distance and residual energy. Similarly critical message transmission is performed through single hop communication. Arm movement mobility is supported in iM-SIMPLE protocol and this protocol follows time division multiple access (TDMA) for data transmission.

Problem:

- In iM-SIMPLE protocol, critical data also follows TDMA scheduling which increases transmission delay for critical data transmission

Proposed:

- Critical data is transmitted through direct which resolves the problem of transmission delay

Paper: 6

Title: An Energy Efficient Method for Secure and Reliable Data Transmission in Wireless Body Area Networks Using RelAODV

Concept:

In this paper energy efficient data transmission is realized by Reliable Adhoc On-demand Distance Vector (RelAODV) protocol. Sensor nodes are follow two different modes such as relay mode and direct mode. In direct mode, data is transmitted from sensor node to sink node through single hop communication whereas relay node nodes perform multi-hop communication. Before data transmission, data are classified by on sensor processing at each sensor and classified data are transmitted by RelAODV protocol.

Problem:

- Involvement of packet classification at each sensor node increases energy consumption at sensor nodes
- Energy consumption for nodes in direct mode is higher than nodes in relay mode since single hop transmission consumes more energy
- Network lifetime is increased due to early dead of nodes in direct mode

Proposed:

- Packet classification is performed at coordinator which minimizes overhead at sensor nodes and MAC header format also modified according to packet type
- Critical data only transmitted by direct while other data transmission is performed by PWR algorithm
- Network lifetime is extended with the help of GSS and PWR algorithms.

Paper: 7

Title: Reducing Power Consumption in Wireless Body Area Networks-A novel Data Segregation and Classification Technique

Concept:

This paper focuses on minimizing power consumption in WBAN through data classification. In this work single sensor node is deployed in WBAN and medical data is classified at sensor node into urgent, semi-urgent, and non-urgent data. Urgent data is transmitted immediately while non-urgent packets are dropped. Semi-urgent data is buffered or dropped accordance to network traffic. Then routing is performed by two different routes. First route is involved with sensor node to gateway to server. Second route is selected in case of gateway failure.

Problem:

- This method is not able to handle multiple sensor nodes since when number nodes increases then congestion in the network also increased.
- Energy consumption at sensor node is high due to involvement of classification process
- This method doesn't support regular monitoring of patient since regular data is dropped at sensor node

Proposed:

- Proposed WBAN network is capable of handling multiple sensors without increase in congestion
- Energy consumption at sensor nodes is minimized by efficient routing and scheduling processes and packet classification is performed at coordinator.
- Ordinary data also transmitted by the network.

Paper: 8

Title: A Novel Energy Efficient MAC Protocol for Wireless Body Area Network

Concept:

This paper presents a quasi-sleep scheduling based MAC protocol for energy efficient data transmission in WBAN. In this method, hardware of sensor node is modified in order to

support critical transmission. Here nodes are deployed in tree topology and TDMA based scheduling is performed based on level in which node is deployed (i.e.) node in bottom level is assigned with small time slot and number of time slot is increased with increase in level in tree. Based on assigned time-slot nodes are changed their state into sleep and transmission simultaneously. When critical message is detected then wakeup alarm is triggered by coordinator in order to wake up all sensor nodes for transmission.

Problem:

- Critical data transmission also follows tree topology which increases transmission time
- Nodes present in high level of the tree are suffered from high energy consumption since high level nodes are responsible for data forwarding

Proposed:

- Critical data is allowed to follow direct communication
- Energy consumption among sensor nodes is balanced and minimized by both PWR and GSS algorithms

Paper: 9

Title: WBAN data scheduling and aggregation under WBAN/WLAN healthcare network

Concept:

This paper introduces a scheduling scheme and data aggregation scheme for WBAN healthcare environment. IEEE 802.15.6 and IEEE 802.11.e standards are utilized for this work. Here critical delay which is a new parameter is introduced for scheduling at personal server. Data from same WBAN are scheduled accordance to critical delay. Personal server aggregates all data packets into single data frame in order to improve data aggregation. Then aggregated data from all WBANs are scheduled based on number of critical messages at inter-WBAN scheduler.

Problem:

- In this method if waiting delay is higher than maximum tolerate delay, then that packet is dropped regardless type of the packet.
- Critical packets also encapsulated in single data frame which leads to higher transmission delay for critical message.

Proposed:

- Packet drop is eliminated or held in rare case due to the involvement of PWR algorithm**.**
- Same type of data are aggregated into single frame after classification.

Paper: 10

Title: Medium Access Control for Wireless Body Area Networks with QoS Provisioning and Energy Efficient Design

Concept:

This paper presents a MAC protocol to attain better QoS with energy efficient in WBAN. Here Time Division Multiple Access (TDMA) is utilized and transmission order is dynamically adjusted. Channel status and application context of WBAN play vital role in dynamic transmission duration adjustment. Synchronization overhead is minimized with the assist of presented synchronization scheme. TDMA based MAC protocol resolves problems such as collisions, idle listening, and overhearing. This paper also suggests sleep scheduling for sensor nodes in order to improve energy efficiency.

Problem:

- Here all data are considered with same criticality which increases delay for critical data transmission

Proposed:

- Data type is identified by modified Emergency and Delay aware MAC header

Paper: 11

Title: An Energy Efficient Routing Protocol for Wireless Body Area Sensor Networks

Concept:

This paper aims to minimize power consumption and to maximize stability through reliable energy efficient routing. Forwarder node is selected based on distance with sink node, distance with sensor nodes, and residual energy of that node. TDMA based scheduling is involved in data transmission and critical data is transmitted in single hop in order to minimize transmission delay for critical data.

Problem:

- Here two sensors are assigned only for critical data sensing which is not sure at all-time critical time is generated.
- Since TDMA scheduling is incorporated, critical data also wait until its time slot will be arrived.

Proposed:

- Additional sensors are not required since available sensors are capable of sensing critical data also
- Critical data is able to transmitted within direct communication

Paper: 12

Title: Cluster Based Energy Efficient Routing Protocol Using ANT Colony Optimization and Breadth First Search

Concept:

Authors in this paper focused on improving network lifetime, energy efficiency, and load balancing by incorporating cluster based energy efficient routing protocol in WBAN. Ant Colony Optimization (ACO) and breath first search strategies are combined for cluster formation. Cluster Head (CH) is responsible for data aggregation and CH rotation also enabled to

extend network lifetime. TDMA scheduling is involved in data transmission. Hop count and residual energy are considered as major constraints for route selection.

Problem:

- Here critical message transmission also enabled through CH which increases delay for critical data.
- TDMA scheduling increases waiting time for critical data.

Proposed:

- Critical data is transmitted within direct communication

Paper: 13

Title: Weighted Energy-Balanced Efficient Routing Algorithm for Wireless Body Area Network

Concept:

This paper attempts to balance energy consumption among WBAN nodes by effective Dynamic Routing Algorithm (DRA), and Improved DRA algorithm. In DRA algorithm, distance metric and estimated transmission energy are considered as routing metric and Dijkstra algorithm is employed to derive path with minimum energy consumption. And transmission is performed through the optimal path selected by DRA. Improved DRA also follows DRA but it assigns weight values based on residual energy to each node. In improved DRA, weigh value also considered as routing metric.

Problem:

- Route selection is not efficient since major routing metrics are not considered.
- Critical data also follows same routing algorithm which leads to higher time consumption

Proposed:

- Route selection is performed by considering significant parameters as weight value

- Critical data is transmitted with in direct communication which minimizes transmission time significantly

Paper: 14

Title: ZEQoS: A New Energy and QoS-Aware Routing Protocol for Communication of Sensor Devices in Healthcare System

Concept:

In ZEQoS method four different modules are included to improve QoS in WBAN. Four modules are: (i) packet classifier module, (ii) hello protocol module, (ii) routing services module, and (iv) QoS aware queuing module. Packet classifier is responsible to classify incoming packet into hello packet and data packet. Hello packets are redirected to hello packet module in which neighbor table construction and routing table construction are take place Data packets are further classified at routing module based on criticality and QoS aware queuing module maintains multiple queues for data packets accordance to the packet type.

Problem:

- Involvement of multiple modules increases complexity of the system

Proposed:

- Less complexity is involved

Paper: 15

Title: Priority consideration in inter-WBAN data scheduling and aggregation for monitoring systems

Concept:

This paper concentrated on designing an inter-WBAN data scheduling and aggregation to resolve the Quality of Service requirements. In this work the authors try to tolerate the tradeoff between delay and throughput. Two scheduling mechanisms are involved in this work one is

with aggregation and other one is without aggregation, those mechanisms are named as Inter-WBAN Scheduling and Aggregation (IWSA) mechanism and IWS mechanism. The scheduler estimates critical delay and arranges in the increasing order, so that the incoming packets are served in this basis. Based on critical delay packets are scheduled for transmission in order minimize delay for delay sensitive packets.

Problem:

- Not able to consider other major routing metrics

Proposed:

- Weight value in PWR algorithm is computed by considering major significant parameters

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