Cooperation vs. Non-Cooperation Basedrouting Protocols in WBAN

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***Abstract*—Design of routing protocols has seen remarkable advancement in the field of Wireless Body Area Networks (WBANs).These protocols work to enhance the performance of WBAN by focusing on routing, energy efficiency and end-to-end delay. As these protocols can be categorized in a variety of ways according to the mechanisms and functionalities they follow, hence it becomes important to understand their principal of operations. In this research, we have selected some recent routing protocols in the field of WBAN and presented a comparative analysis according to the categories on which they rely. Also a detail analysis of their key advantages and flaws are also identified in this research.**

***Keywords:* WBAN, Routing protocol, Relay node, Sink, Energy efficiency, End-to-End delay, Network stability**

I. INTRODUCTION

Wireless Body Area Network (WBAN) started developing since 1995, is a co-field of Wireless Sensor Networks (WSN) [1]. The main objective of such network is establishing a communication link with the human body. Initially it was developed for serious patients by providing health-care services. By achieving the required development in health-care services WBASN has been used in other fields i.e., distant and continuous health-care real monitoring is necessary like astronaut in space, players in sports, environmental condition, motion detection of animals, security etc. [2], [3]. Sensors which are small in size have minimum processing capability and energy source in WBAN.

These sensors can be fixed inside the body or wearable sensors depending upon the type of the application which is attached to the body [4]. WBAN is consisting of nodes that are used in both non-medical and medical purposes. These devices are fixed or planted inside the human body for medical purposes, to send and measure the real time data signals.

These devices are used for measuring the environmental conditions, industrial environments, motion detection of the animals for non-medical applications in the forest, security, etc. According to data transmitted data rates all applications use different power consumptions. As compared to that of wearable devices power consumptions and data rate of implanted devices are low [5], [6]. Different sensors are attached to human body which are available at hospital or at home in medical field. These sensor nodes monitor and detect different biological parameters of the human body like Electrocardiogram (ECG) temperature, glucose-rate, blood-rate, heart-rate, blood pressure and heart beat etc. [7].

Personal devices like Personal Digital Assistance (PDA) receive, collect or aggregated signals which, act as a relay node and sent them to some internet using applications or to health treatment professionals with the help of sink node. The sink node works as a source of routing between WBAN and hospital [8].The patient do not need to visit the hospital on regular basis. This network helps to update feedback and enables him to take immediate actions, sometime to have very quick diagnosis and medications against serious moments.

Sensor nodes run with limited energy source as they are battery driven units in WBAN [7]. While transmitting data from sensor nodes to sink, it is required to utilize minimum energy.To recharge the batteries of senor nodes, is the intrested task in this networkt which is the demand of the protocol for efficient energy which decreases the issue to recharg the batteries. In [4], researchers have found various challenges in WBANs such as, trade-off between communication and processing power and bandwidth consumption, as compared to other WSNs applications attenuation of high level, energy harvesting, and storage. In WBAN usually there is unicast transmission of the sensed data to the sink node that collects data from the battery-powered sensor nodes. Every sensor node forward data to the sink after sensing it. While using single sink and transmitting data via unicasting, is a problem that exists that's why authors have used two sinks which is a good approach in WSN and is emerging idea now a days in the field of BAN. All the sensors with two sinks is the best approach to forward data to any one of the available sink nodes by sensing the environmental information [9].

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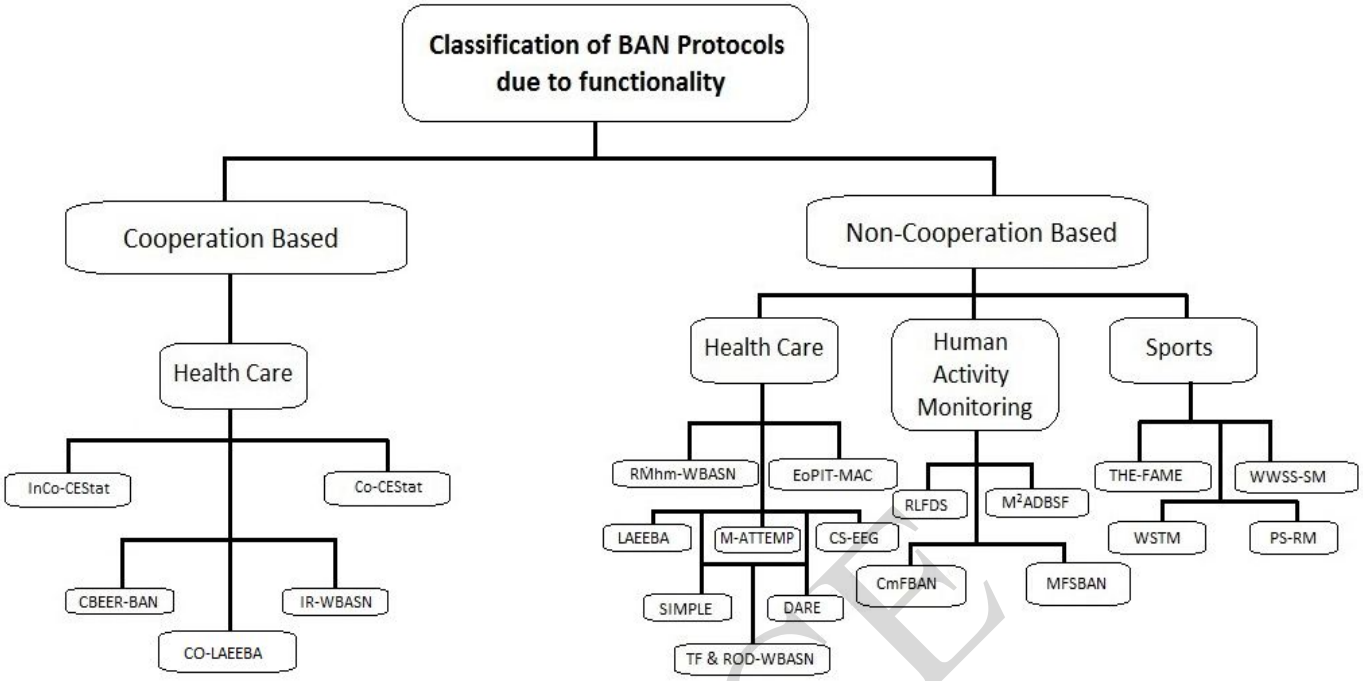


Fig. 1: Classification of WBAN Protocols based on Their Functionality

II. COOPERATION BASED ROUTING PROTOCOLS

1. *InCo-CEStat*

In [1], authors have proposed Incremental relay-based Co-CEStat protocol for the Wireless Body Area Networks (InCo-CEStat). Authors have used two relay nodes for the cooperation purpose to have quick transmission of critical data in WBAN for emergency cases. There are two relay nodes in every single sensor for their sensed data to be sent. Data is detected and gathered in three phases from sensors by relay nodes and is forwarded to specific sink node which are, the sink first aggregated and gathered the data in addition restricted the sensors to send the sensed data in their own time slots, decreased packets drop and a duplicate copy of sensed data was sent to relay nodes to the sink node.

2. *Co-CEStat*

In [2], a cooperative routing mechanism was introduced that broadcasting the nature of wireless medium for enhancing network performance. Data transmitted simultaneously of sensor nodes on efficient links and utilized cooperation between nodes. The suggested protocol utilized the advantages of cooperative and direct transmission for achieving end-to-end throughput and high stability period with more network lifetime.

3. *IR-WBAN*

In paper [3], authors present a protocol which improves the throughput and avoid single point failure in WBAN. The protocol uses Cooperative Network Coding (CNC) in many to many as Multiple Input Multiple Output (MIMO). According to proposed protocol, two relay nodes have been selected. In order to consider the single point of failure for the node, each sensor node sense the parametric data and forward to two relay node in CNC manner. Here, the advantage is that every sensor has multiple options to send. Relay nodes that forward the data to the external connected sinks. In this protocol the sink nodes are placed outside the human body. More energy is required to amplify data to the sink node, because the relay node as compared to sink node has less energy level. The relay node will die after some rounds, thus the network stability period will decrease.

4. *CBEER-BAN*

In paper [4], a “Cost Based Efficient Routing for Wireless Body Area Networks” was proposed. In this paper cost function and energy efficiency is focused on the basis of critical factor by depending upon the reliability of path. Network life time was improved by calculating the cost function. Sink node was placed at risk according to the proposed protocol. The sink node, at initial stage sent a hello message to all the sensors to inform their distance and other

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information. The sensors that acknowledged back their ids, distance and energy information to the sink. Cost function is then found by sink node.

5. CO-LAEEBA

In [5], S. Ahmad et. al had revised their previous work of (LAEEBA), and proposed a new routing protocol for WBAN, named as Cooperative Link Aware Energy Efficient for Body Area networks (CO-LAEEBA). This protocol was used for path loss factors and collective working in WBAN. A cost function is defined for selecting the feasible route to the destination knowing the residual energy and sharing the distance from sensor to the sink.

III. NON-COOPERATION BASED ROUTING PROTOCOLS

1. DARE

In paper [6], authors have proposed a protocol called Distance Aware Relaying Energy-efficient (DARE) which is used in wards for monitoring eight patients, where each is comprised of seven sensors for monitoring several parameters of the human body. More than one sink was placed in wards at several destinations in sense of five topological scene like (a, b, c, d and e) as had been discussed. In wards the sensors which were attached with human body, sent parametric information to the nearest sink node. Body relay nodes were used for minimization of energy consumption. These nodes aggregated the data and forwarded it to the most nearest available sink node. Main Sensor (MS) is another sensor in which scenario-3 is also used for sending data to sink node from sensing node and reduced energy consumption in the middle of the ward in scenario-3 a single sink is placed so that the distance to the sink node from the sensors is large, hence MS reduced the distance between sink and sensors.

2. SIMPLE

In [7], authors have presented a protocol Stable Increased-throughput Multi-hop Protocol for Link Efficiency (SIMPLE). Here in this protocol authors used a single sink node and eight sensors in the human body where a sink was placed near the waist. All the sensors had same energy levels at the beginning but after some interval of time sensors loss their energy level. Now therefore for balancing energy level and increased the network stability, author used a cluster head in cluster formation or forwarded by using a mathematical formula. Cluster head had more residual energy which is also a node and lied in a short distance to the sink node.

3. THE-FAME

In paper [8], authors have proposed a new protocol named as Threshold based Energy-efficient Fatigue Measurement (THE-FAME) for WBAN. This protocol was used in a soccer game for finding fatigues of a player. Here twelve players were considered and implanted sensor node to each for sensing fatigue's parameter of each player and sent the data to the sink node. Multiple sink nodes were placed to the different side of ground by using a single sink. The size of sensor node was kept small for increasing the player performance in addition a threshold level was made fixed for keeping the sensors alive. The nearest sink got sensed data from the sensors when the sensed information reached to the given threshold level. Direct communication was used because of using single sensors in single hope transmission.

4. MFSBAN

In paper [9], authors have proposed in WBAN a new routing protocol to measure fatigue of soldiers. For measuring the fatigue level in soldier's body, authors have used three sensors; heart beat sensor, blood glucose level sensor, temperature sensor and a single BS (which was treated as sink in literature). Heart beat sensor was attached to measure the heartbeat of a soldier which is placed on heart; Glucose sensor and temperature sensors are attached to measure the temperature and blood samples in fingertips. Three parameters of a soldier were forwarded to BS conducted by these three sensors. The BS forwarded the gathered parameters to the external server.

5. EoPIT-MAC

In paper [10], authors have presented a protocol called Effect of Packet Inter-arrival Time on the Energy Consumption of Beacon Enable MAC Protocol for WBAN. In this protocol, researchers were focused on Media Access Control (MAC) for reducing the consumption of energy. They provided a new mechanism for emergency data with normal data to modify the super frame structure. There are two types of nodes that were used in these protocol fully functional devices and reduced functional devices. Reduced functional devices worked only as a simple node and fully functional devices were as a coordinator node and simple node.

6. LAEEBA

Researchers in [11], a protocol was introduced and known as Link Aware and Energy Efficient Scheme for Wireless Body Area Networks (LAEEBA). In this paper a protocol was used by focusing the path loss between the nodes in both single hope and multi-hop communication. For reducing energy consumption through cost function a forwarder node is selected. The node which has the minimum distance to the sink and has more residual energy is considered as the forwarder node.

7. M-ATTEMPT

In [12], Mobility-supporting Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop Protocol (M-ATTEMPT), which is based on threshold routing protocol in the established links for finding the link spot. In this scheme sensors were used in descending order with respect to the sink of their data rates. Both single hope and multi hope communication is used for emergency and normal data. In multi hope communication a delay may occur, due to the

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aggregation of data in intermediate node. To solve this delay problem authors have proposed a mathematical formula.

8. RMhm-WBAN

In paper [13], authors have proposed a routing protocol for health monitoring "Remote Health Monitoring by using Wireless Body Area Network". This protocol focused on the accessibility of patient's data either online or offline by the health care takers. Different sensors are placed at the patient's body for measuring health parameters according to the proposed model. The accumulator forwarded the data to the medical server through Wi-Fi which was sensed from these sensors, gathered at the data accumulator.

9. TF &ROD-WBAN

In paper [14], authors have proposed a robust and fast routing protocol called as "Towards the fast and robust optimal design of wireless body area network" proposed work focused on the topological design of the WBAN, because of energy consumption and the heterogeneity of sensor nodes, which affected the performance of the networks. The proposed algorithm took advantage of suitable linear relaxations for guiding a randomized fixing of the variables. The algorithm also focused over the traffic uncertainty in the design of WBAN by using preferably single path routing and relay nodes.

10. CS-EEG

In paper [15], authors have suggested that EEG (Electro Encephalo Gram) signals could monitor continuously without direct intervention of the patient or personal visit by hospital staff. Here they proposed a WBAN system, which helped patients to transmit EEG signals to a remote terminal via a smart phone. EEG compressed sensing proposed a Block sparse Bayesian learning (BSBL) as a new method. BSBL answered the problem for device cost consumption and consumption of energy, data. In this proposed method EEG signals were compressed by the use of sensors, so that BAN energy on chip was utilized. The energy of sensor nodes were not used so that the energy of BAN was not wasted because by using a remote computer the EEG signals returned back to normal state.

11. RLFDS

In [16], for aged people, a fall detection protocol was proposed. The system was comprised of tri-axis gyroscope and tri-axial accelerometer. The authors proposed an algorithm which significantly differentiates in actual fall and the ADL (Activities of Daily Living). In this paper authors used signal vector magnitude to differentiate ADL, such as climbing stairs, running, sitting, laying and standing.

12. M2ADBSF

In [17], a new fall and accident detection system was proposed. Accelerometer is a sensor which is used here in this theme in addition with, a magnetometer, and a gyroscope. The sensors were placed on the upper torso, on the hip and one on the user's legs. In normal fall 85.6% accuracy of fall detection is showed in the preliminary results. In this scheme authors proposed for investigation of the detection of hampered fall detection as future plan.

13. CmFBAN

In [18], researchers in order to find out the destination of firefighters working in the field, used RSSI (Received Signal Strength Indicator) values of nodes which locate the location of firefighter and also monitored the different vital parameters such as hydrogen cyanide and carbon monoxide in the environment and had sent the information to fire chief which made enable him for having an appropriate decision for the firefighters health. In the simulation and in the actual environment setup, seven sensors nodes were used. The implementation exploited Mobile Ad hoc Network (MANET) idea for creating a network on the fly and enabled firefighters at any time for joining or leaving the network.

14. PS-RM

Authors in [19] introduced a Prototype System for Remote Monitoring (PS-RM) of athlete's performance to provide live feedback where each player was equipped with mobile device and sensor. Here some specific parameters were buffered locally before measuring them, after some time interval the data was sent to the coaches by using internet.

15. WWSS-SM

In [20], authors introduced a wearable, compact, wireless system which measured torque, forces and others evaluative and descriptive features of indicative signals during athletic performance. High and low ranges of sensors enabled sensitivity for both fast and slow motion. By using of a custom wireless protocol over an RF (Radio Frequency) link, Data was acquired and analyzed offline. This system was introduced for the monitoring of athletic gesture, especially for measuring baseball players' and batting pitching. Data was gathered over different swing and pitches and they showed from this data some biomechanically descriptive parameters, and high light system improvements and ongoing work.

16. WSTM

In [21], authors proposed a mechanism for remote monitoring for the soccer players, known as Wireless Soccer Team Monitoring (WSTM). In this protocol multi-hop routing was used for transmission of data to the BS. Here they used multi-hop topology for data routing. Behind each goal, two sinks are placed in the network and for calculating fatigue; players are equipped with a WBAN.

IV. CONCLUSION

In this paper, various schemes are presented for energy efficiency, stability of network to maximize throughput and to minimize delay in WBANs. Routing protocols employing cooperation andnon-cooperation based technique have been

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addressed. We have mentioned different advantages and flaws of these routing protocols introduced recently for data transmission in WBANs as highlighted in table 1 below. Some protocols reduce energy consumption and enhance network stability of WBANs. Some of them focus on throughput, network lifetime etc. but the research continues to work. The parameters under consideration by researchers are reducing energy consumption, higher throughput; reduced transmission loss, processing overhead and redundant data transmissions. This paper will be a short introduction to the researchers who want to work further in this area.

Table I: Comparison of Routing Protocols of BAN

Protocol	Technique	Achievements	Disadvantages
InCo-CEStat [1]	• Detect and Forward, • Direct and Cooperation	• Quick data delivery • Reliability and Network stability	• Energy utilization • Burden on network by duplicate transmission
DARE [6]	• Movable or stationary sink • using Relay node	• Increased Energy • Network lifetime	• Delay in data transmission by multiple hop
SIMPLE [7]	• Calculate cost function using multi-hop communication	• high delivery ratio • Longer stability	• Extra overhead due to finding cluster head
THE-FAME [8]	• Calculating threshold level for lactic acid • Using single-hop transmission for fatigue	• Better in emergency efficiency • Delay as for multi- hop communication	• Due to long distance energy level of sensor is decreased earlier.
MFSBAN [9]	• Event driven protocol • Single-hop transmission	• Increased throughput • Increased network lifetime	• Not considered NLOS
EoPIT-MAC [10]	• Super-frame structure • Normal, periodic and emergency data	• Energy consumption.	• Extra delay for emergency data due to phase to phase transmission
LAEEBA [11]	• Single and multi-hop communication for path loss • Cost function for forwarder node	• Successful packet delivery • Longer stability • Decrease path-loss	• Network delay • Finding a cost function in every round
M-ATTEMPT [12]	• Thermal aware protocol • Single hop communication for emergency data • Multi hop for normal data.	• Energy management • Mobility support	• Single sink transmission creates burden • Hence delay and decrease in data delivery
CO-LAEEBA [5]	• Cooperation based • Path loss aware	• Stability period • Path loss • Energy consumption	• Delay in important data • More processing of simultaneously data sending
RMhm-WBAN [13]	• Data forwarded by accumulator • Using Wi-Fi	• Continuous monitoring	• Sink location not mention • Communication between accumulator and sensors is still discussable.
IR-WBAN [3]	• Use extended Cooperative, • Network Coding as MIMO Scheme	• Monitoring of athletic gesture • Increased network throughput	• More energy is required • Relay nodes to amplify data to outside sink
CBEER-WBAN[4]	• Computes cost function for the reliability of path on basis on factor critical.	• Throughput and network reliability	• Sensor disconnectivity from sink, while arm moves.
TF&ROD-WBAN[14]	• Randomized fixed variables • Single path routing	• packet uncertainty • topological design	• Access number of relay nodes increased the network cost
CS-EEG [15]	• Compressed Sensing	• Reduced energy • Consumption during monitoring of EEG	• Delay in important data • Processing of data sending
RLFDS [16]	• Triaxial Accelerometer • Triaxial Gyroscope used fire fall detection system	• Fall detection in elder person	• Extra overhead
CmFBAN [18]	• CO, HCN, and TelosB, Raspberry Pi (RP) types of sensor used	• Fire-fighter's location determined using RSSI	• Delay in important data • More processing of data sending
PS-RM [19]	• Mobile device and sensor	• Network reliability • Real time monitoring	• Extra overhead
WWSS-SM [20]	• High/Low ranges sensors used, Custom wireless protocol over RF Link	• High light system improvement	• Delay in data transmission by multiple hop
WSTM [21]	• Multi-hop routing, transmission of data to BS	• Two sinks used, Network stability	• Delay in data • extra overhead
Co-CEStat [2]	• Cooperation based • Detect and Forward	• Cooperative and direct transmission • End-to-End throughput	• Access number of relay nodes • Increased network cost

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