7. CoAP based Energy-aware Cluster-based Mobility Management Protocol in WBAN Health Care Environment

Mrinai M. Dhanvijay, Research Scholar, Department of Technology, Savitribai Phule Pune University, Pune, India
mrinai@yahoo.co.in
Shailaja C. Patil, Professor, Department of Electronics and Telecommunication Engineering, Jayawant Shikshan Prasarak Mandal's, Rajarshi Shahu College of Engineering Pune, India
shailaja.rscoe@gmail.com

ABSTRACT

The Wireless Body Area Network (WBAN) is the interconnection of tiny sensor nodes which is fixed or incorporated within the human body. Sensors are used to sense the biological factor of the human body like pulse rate, temperature, blood pressure, etc. These sensor nodes are integrated with a limited source of energy. The power consumption of these sensor nodes has to be reduced in order to enhance the lifetime of the network. The proposed CoAP (Constrained Application Protocol) based Energy-aware Cluster-based Mobility management Protocol (CoECMP) is designed to reduce energy consumption by creating a cluster head (CH) for a group of a cluster. The modified firefly algorithm is proposed to optimize the effective cluster head (CH) using the parameters like residual energy, distance, path loss and node density. These optimized cluster heads collects the information from the member nodes and forward the information to the client (caretaker or doctor) via WMMS (Web-of-things Mobility Management System). The proposed protocol is very much effective in reducing the energy consumption and increasing the lifetime of the network. The mobility management using handover operation is also employed when the patients move from one Base station to another base station. The numerical analysis and the result impose performance and the proposed scheme has been simulated in terms of network stability, network lifetime, and residual energy. The experimental result shows that by using the proposed protocol the energy consumption by the nodes has been reduced when compared with the previous existing protocols.

Keywords—*Cluster Head selection, cluster formation, energy consumption, Firefly Algorithm, WMMS (Web-of-things Mobility Management System), Hand over*

INTRODUCTION

Nowadays there is tremendous growth in healthcare monitoring of mobile patients using compact wireless sensor nodes [1]. Wireless sensor nodes play a vital role in health care environment. It is a platform that provides status, location, and tracking of patients. WSN provides a guaranteed infrastructure for tracking both the users and assets [2]. In WBAN, nodes are capable of expensing vital body signs such as, temperature, blood pressure, sugar level, location, heartbeat, oxygen level etc. WBAN can easily monitor aged, handicapped and people in coma stage [3].

This network interacts with IoT (Internet of Things) which means that these sensor nodes make links with internet; WBAN starts to transmit and receive signals, which reduce human interventions, which makes it very helpful to save the life of a patient in emergency conditions [4]. These sensor nodes are wearable in fashion and it transmits both the health condition and general information about the patient. The information exchanged between WBN is very sensitive and security is a main constraint [5].

In real-time, WBAN sensors sense the signs of the patient along with the biological factor and it processes and transmits it to the sink node. Doctors will access the condition of the patient through the sink node [6]. In this WBAN, the patients may change their position and location hence WBAN is not a fixed network. WBAN is separated into inter, intra and beyond WBAN communication based on their location in the human body. [7].

In these nodes, power consumption is a challenging factor and a wide range of health monitoring is assisted and the devices are equipped with limited capacity. Energy limitation is the main factor that makes the usage of WBAN [8] less. According to the application, these tiny sensor nodes are implanted inside or outside the body.

The energy consumption of the nodes fixed on the body is more compared to that of nodes fixed inside the body. MAC protocols are implied to increase the lifetime of the network. Delays and packet loss also leads to decrease in the network lifetime [9].

These sensor nodes are powered by batteries and the lifetime of these batteries is an important factor; for exampleimplanted nodes like pacemakers require at least five years of a battery lifetime. In this application, the power consumption is important to increase the lifetime of the WBAN. Several MAC protocols designed for the energyefficient reliable data transmission has poor efficiency [10] These MAC protocol based on Quasi sleep prompt algorithm used the sleep mode of the nodes in WBAN which reduces the energy consumption. This algorithm can be adopted only for fewer applications [11].

Previously Low energy clustering adaptive hierarchy (LEACH) was implied for energy consumption. The wireless sensor nodes fixed on the patient were grouped to form a cluster and one node acted as a cluster head and the other nodes were member nodes. These member nodes send the vital signs to the cluster head (CH) and the CH transmitted the vital signs of the patient to the Base station which lead to less energy consumption [12]. In this paper, the proposed system CoAP based Energy-aware Cluster-based mobility management (CoECMP) protocol is cluster-based and it will first identify the effective clustering heads using the modified firefly algorithm and then member nodes join the CH according to their threshold. Then the cluster head node of each cluster transmits the information to the base station and in this method the power consumption is less.

The contribution of this paper includes,

- The elaborate design of CoECMP and a detailed process of information transferring process from the sensor nodes to the client.
- The newly adopted modified firefly algorithm is used for the cluster head selection and the energy consumed is reduced.
- Mobility management is implemented using hand over operation.

The systematic work is arranged as shown here: the section 2 describes about the related works in clustering of sensor nodes in WBAN. The section 3 illustrates about the, proposed cluster based CoAP-ECMP model. The section 4 deals with the results and discussion about the proposed work and section 5 describes about the conclusion.

RELATED WORKS

In WSN, the energy consumption is a great issue, because of low power batteries that are installed in the sensor nodes. The related works are summarized below, based on the clustering techniques without power consumption.

Anguraj DK et al. [13] introduced a Multi-Objective Firefly Algorithm (MOFA) in which the parameters, delay and throughput were used to select the CH. If the distance was increased the attractiveness got reduced. The attractive nodes moved towards a cluster Head to form a cluster. Member nodes send the information to cluster heads and the cluster heads forward it to the sink node and then to the hospital database. This scheme identified malevolent nodes and data transmission occurred. Even though, the energy of the malevolent nodes soon got reduced, there was a network failure associated with it.

Choudhary et al. [14] proposed an Energy budget based multiple attribute decision-making algorithm (EB-MADM). In this cluster head selection was based on, the node residual energy, the node connectivity, and the node proximity. A sensor node sensed the data and transmitted it according to two conditions; they are-data should be different from the previous one and out of threshold limits. Thus the redundant bits were removed from the transmission. These methods reduced the data traffic and increased the throughput, even though; the delay is higher during the emergency data transmission.

Saha S et al. [15] presented a clustering scheme in which nodes listened to the medium if there was any ongoing transmission. When the nodes detected the cluster head within its range, the regular operation got started. When more than one beacon was heard the node which is very close to high receiving power is assigned as cluster head. When no beacon is heard least noisy frame will be selected to transmit its beacon signal till the timer is expired.

During this period, if a beacon was heard timer stops and automatically starts the normal operation. Once the timer expired, the node assigns the position of cluster head and sends the beacon signal. This reduced some defects of clustering and it utilized the bandwidth. Still, this scheme failed to consume the energy of the sensor nodes.

Jamshidi M et al. [16] proposed an algorithm with two phases; they were scan phase and an examination phase. In the scan phase, the CH calculated the average distance. Then CH scanned the member table of member nodes with greater than average distance and saved it in a list called suspicious list. In the second phase, CH selected an experimental sample (ES) whose distance was more from CH; then each cluster heads sends the ES to other cluster heads. Every CH stored the ES of its own and other CH in a list called ES list. The cluster head with maximum distance was selected as a malicious node. All the cluster heads transmitted the information to this malicious node and this node sends the information to the base station. Malicious node would transfer the information of all other nodes continuously which lead to drop down of energy very soon.

Sundararaj V et al. [17] presented a variable step size firefly algorithm (VSSFFA) using the parameters such as headcount, node degree, energy and distance. The fireflies are unisex and it attracts using the brightness. When the distance reduces the brightness increases and it decreases with the increase in distance. The low brightness nodes move towards the brighter nodes to form a cluster. The fitness function of CH was evaluated based on distance, residual energy, node degree, and headcount. The best location was chosen using these attributes and the sensor which was near to the best location was assigned as the cluster head. These cluster heads sends messages to the other nodes in the specified area and form a cluster using the request and accept messages. Now the cluster head transmits the information to the base station. The cost of placing the header node was reduced in this method, even though there was some unnecessary energy drainage.

Ullah Z et al. [18] proposed a Dual Sinked Software defined Networking approach using clustering in a BAN. In this, two sink nodes were used in a human body and all other sensors fixed on the body formed two clusters under these sink nodes S1 and S2. These sink nodes had good battery power, memory, and transmission power compared to other sensors fixed in the body. If any of the critical data was sensed by any of the sensors in the body then it transmitted the critical data to the sink node, which means; to the cluster head. These sink nodes would send the information to the base station. This concept improved throughput and delay but there were little gaps regarding energy consumption.

Isabel RA et al. [19] presented an Improved Evolutionary Particle swarm optimization (IEPSO). The aim of this algorithm was to make the fittest node as a CH. PSO is that concept in which head searches for the food spot and the birds altogether move towards that spot. In this, the fittest node is obtained by the entire location they move. The main goal of this algorithm was to position the CH nodes in the best possible position. This CH node collected data from the cluster and transmited it to the base station. The energy dissipation was quite high due to alive of nodes in the entire transmission.

Ullah Z et al. [20] proposed an E-HARP (Energy efficient Harvested-Aware clustering and co-operative Routing Protocol) focused on energy efficiency and on the path loss of the sensor nodes which was fixed on the patients. In this, the sensor nodes fixed on the human was grouped into two clusters using two fixed sink nodes. These sink nodes collected the information from the cluster heads and forwarded it to the client via the base station. The sensor node in this WBAN harvested energy from the solar and on behalf of this energy the network lifetime increased. Moreover, there is a little gap in fulfilling the reduction of energy consumption.

In the previous papers regarding the energy consumption in WBAN the authors considered only the network lifetime using the sleep and alive nodes. The sensor nodes in WBAN were designed with limited power and the energy was maintained for the entire communication to save the life of the patient. For this purpose, the proposed CoAP based Energy-aware Cluster-based mobility management (CoECMP) protocol was implemented in which the sensor nodes of the patients were grouped under a cluster head (CH). These CH nodes collected the information from the member nodes and forwarded it to the client-side via WMMS. Using this, the energy consumption of the nodes got reduced by grouping the nodes under CH. The energy efficient nodes were selected as CH. The cluster head was changed for every iteration. Handover operation was also performed to maintain the communication to retrieve the information while the nodes were moving. The existing methods had gaps in satisfying the above needs.

DESIGN OF HEALTH CARE ENVIRONMENT USING CLUSTER-BASED COAP

This section describes the architecture of the CoAP based Energy-aware Cluster-based Mobility management Protocol (CoECMP) and it gives a clear note about its implementation. This protocol is designed to reduce the power consumption of each node in the network and manage the data communication throughout the network. Fig. 7-1 shows the architecture of the proposed system.

A. ARCHITECTURE OF THE CLUSTER-BASED CoECMP

In this proposed system model, the sensor nodes are placed on a human. The energy efficient node is selected as cluster head and other nodes are member nodes. The data transmission in this BAN network is processed through the cluster Head and this cluster head maintains overall information of the sensors in a human body. The components of this proposed system are COAP sensors, Web-of-things Mobility Management system (WMMS) and COAP clients.

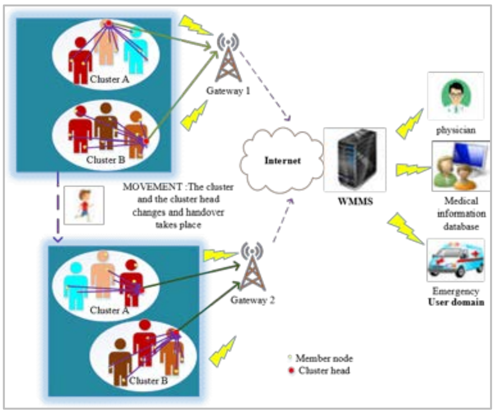

Figure 7-1 Architecture of the CoAP based Energy-aware Cluster-based Mobility management Protocol (CoECMP).

This framework consists of hundred sensor nodes, which are fixed on the human body (patients). These sensor nodes are grouped to form a cluster by selecting some nodes as cluster heads and others as member nodes. These cluster heads gather the information from the member nodes and forward it to the gateway 1. Due to the mobility of patient if any sensor nodes moves away from a particular network. Handover operation takes place and it transmits the information through gateway 2. Then the information retrieve from the gateway is forwarded to the WMMS via internet. This WMMS forward the information to user domain (doctor, medical information database, emergency).

The cluster head selection process takes place according to the attributes given by the proposed algorithm. Then the cluster head ID is distributed to all the sensor nodes. All the sensor nodes receive the ID of the cluster heads. Then the nodes send the reply POST message to the cluster head to form a cluster. Hence at the end of the configuration phase, the details of the total sensor get updated on the cluster head.

The cluster head transmits the data to the WMMS through the gateway and then to the client (Caretaker). In WMMS, the permanent IP address is denoted as P_Addr of the CoAP device node that’s listed at the healthcare database. Then, the temporary IP address is denoted as T_Addr of the gateway and H_flag denotes the handover standing of the set of sensors. Then the data initialization takes place using WMMS system and the client-server sensor node is selected as the group head. This is executed by sending a POST topic of all the sensor nodes through the cluster head to the WMMS. Then the WMMS sends a response message that is created to all sensor nodes through the cluster heads. The information from the sensors is sent to the WMMS through the gateway. The cluster head sends a post request. This request is forwarded by the WMMS through the gateway to the client. The clients will respond to cluster head with an acknowledgment. Then the client sends the control messages to the WMMS and WMMS forwards it to the cluster heads. During data transmission, the sensor sends multicast information to collect the data of the sensors in the network.

Next, the handover operation is performed while the user is moved from one base station (BS) to another BS without terminating the session. During this process, when the signal strength falls below a particular range the handover is carried out by sending the request for holding messages. Hence in the final stage, the group head changes its communication from the first gateway and gets attached to the second gateway for further communication in the body network. Because of this handover operation the WBAN transforms the information without any loss of data which can save the precious life of the patient who is critical. The proposed model of cluster-based COAP consists of energy consumption at the sensor nodes and mobility management throughout the communication network. Fig. 7-2 shows the signal flow diagram which explains the flow in the basis of three phases, they are; configuration phase, initialization phase and hand over operation.

1) Procedure for clustering using CoECMP: WBAN system consists of a set of sensors fixed on the human body. These sensor nodes include Blood pressure sensor, motion sensor, ECG sensor, pulse rate sensor, EMG sensor etc. These sensor nodes are fixed on different parts of the body. The sensor nodes sense the vital signs of the human body and send it to the cluster head. For enormous number of nodes there is a WBAN installed on the human body and these nodes are grouped to form clusters each having its own cluster heads. After receiving data every CH forwards it to WMMS. In this, configuration phase is partitioned into two:

- Cluster head selection process
- Cluster formation

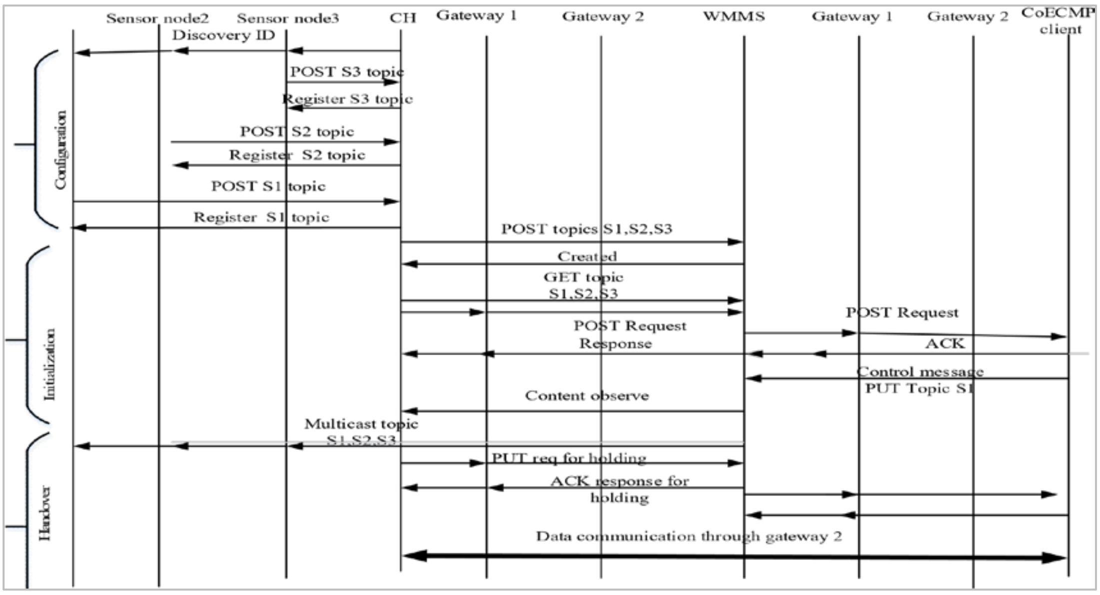

Figure 7-2 Process flow of the CoAP based Energy-aware Cluster-based Mobility management protocol.

a) Cluster head selection process: In the configuration phase, the clustering of the nodes takes place; there are a number of nodes fixed in a WBAN. These nodes are grouped under a cluster head to form a cluster. Here the modified Firefly Algorithm is used for the cluster head selection process. In this, the cluster head selection is assigned using a fitness function. The attributes to find the fitness function is the distance, residual energy, node density, and path loss.

To improve the execution and the lifetime of the network the fitness function has to be improved. Firefly is the little insect which emits light. These insects are unisexual and its attractiveness is based on the brightness of the light. According to the light intensity, it will attract other fireflies having low light intensity. When the distance increases the light intensity gets decreases. The firefly algorithm is used to find the perfect cluster heads in a WBAN. Here the fitness function is based on the parameters given. A Modified firefly algorithm is proposed in which the residual energy, distance, path loss, and node degree are the primary attributes. These parameters are used to find the best cluster head. Based on the values obtained from the above fitness function the final cluster head is predicted.

The mathematical investigation of the cluster head selection process is shown below. The fitness function is calculated to improve the network lifetime and also to make the network energy efficient.

The residual energy of a node is the overall energy saved by the node and is calculated as,

$$E_{Res}^{(i)} = \left[E_t^{(i)}(k, dist_{BS}) + N_D^{(i)} \times E_r^{(i)}(k)\right] \quad (1)$$

Where $N_D^{(i)}$ denotes the number of sensor node. $N_D^{(i)} * E_r^{(i)}(k)$ is the total energy received from the sensor nodes. Once receiving the information from all the nodes, the sensor node which is elected as a cluster head will transmit the information to the base station.

The transmitted energy based on the data transmitted is given by,

$$E_t(k, dist) = \begin{cases} k * E_{ele} + k * E_{fs} * d^2 \ if \ d < 0 \\ k * E_{ele} + k * E_{mp} * d^4 \ if \ d \geq 0 \end{cases} \quad (1)$$

For receiving the information that is send from the base station to the sensor nodes in WBAN, energy is required and the receiver energy is computed as,

$$E_r(k, d) = k * E_{ele} \quad (2)$$

Where E_{ele} denotes the electronic energy consumed by the node. $K * E_{fs} * d^2$ and $k * E_{mp} * d^4$ denote the amplifier energy with respect to the distance.

Path loss in WBAN is based upon two factors they are frequency and distance. Distance is an important factor because the range of the WBAN is limited,

$$PL^{(i)} = \alpha \times \log_{10}(d) + \beta \times \log_{10}(f) + Ndf \quad (3)$$

Where α and β are the linear fitting co-efficient (-27.6, 46.5). N_{df} is the normally distributed variable (157 dB). *f* and d are the frequency and distance.

The distance between the nodes is taken into consideration because it is also an important factor to reduce energy consumption. In this, the distance dist (i, j) is the Euclidian distance between the node i and node j. Here the distance of i and j is calculated using equation (5),

$$dist(i, j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (4)$$

Node density is the node which is placed in the dense area of the network and is selected as a cluster head. The node degree of the node i is calculated by the equation (6) which is given below,

$$N_D^{(i)} = \left|Nb_r^{(i)}\right| \quad (5)$$

In the above equation, $Nb_r^{(i)}$ represents the set of nodes at the one-hop distance from node i.

From the above function the residual energy, path loss, distance and node degree are used to make a fitness function to make an efficient node as a cluster head,

$$F^{(i)} = w_1 \times E_{res}^{(i)} + w_2 \times PL^{(i)} + w_3 \times dist(i, j) + w_4 \times N_D^{(i)} \quad (6)$$

Where w^1, w^2, w^3, w^4 are the weights for the parameters, $0 \leq w^1, w^2, w^3, w^4 \leq 1$. The values are adjusted as per the application of the WBAN.

According to the firefly algorithm, the intensity of the fireflies is calculated. In this proposed algorithm firefly is the set of sensor nodes. The intensity $I_f^{(i)}$ of the firefly is calculated as per the equation given below,

$$I_f^{(i)} = \frac{1}{r}\sum_{j=1}^{r} F^{(j)} \tag{7}$$

In every iteration, numbers of fireflies are populated and each firefly evaluates the intensity value that is $firefly_{best}$. Remaining fireflies updated their node by randomly selecting the nodes of $firefly_{best}$. Then the calculation of the intensity of the fireflies is done again and each firefly compares the intensity of the fireflies with the $firefly_{best}$. If any of the updated fireflies gets better intensity than the previously selected $firefly_{best}$ then it will be considered as the $firefly_{best}$. The process continues till the iteration ends. These finally selected cluster heads perform the process of the transmission, reception, and aggregation of information with minimal loss of energy from the residual energy.

The Algorithm of the cluster head selection based on the firefly is shown below,

1	Initialization
2	Set of sensor nodes $\{n_1, n_2, n_3 \ldots\ldots\ldots\ldots\}$ is the input
3	Each node calculate $E_{Res}^{(i)}, PL^{(i)}, dist(i, j), N_D^{(i)}$.
4	All the nodes calculate the fitness function using the equation (7)
5	Fireflies are generated and each firefly is the cluster head.
6	calculate the intensity based on the equation (8)
7	The node, which is having maximum intensity, is the firefly best.
8	Update the nodes randomly as per the firefly best.
9	Calculate the intensity values.
10	if(a new set of fireflies is more than the firefly best) then
11	current firefly is considered as the cluster head
12	else
13	firefly best is considered as cluster head.
14	Repeat steps 8 to 14 until it met the termination criteria.

b) *Cluster formation process.* Following the selection of the cluster head, this cluster head broadcasts the Discovery ID message to the sensor nodes in its sensing region. The nodes which are in the transmission range of the cluster head node replies to the cluster head within a time slot with a requisition message POST ID topic. Then the cluster head counts the total number of the POST ID topic and confirms the nodes by sending Register ID topic message. The sensors which receive the register ID are the members of a particular cluster. The member nodes send the information to the cluster heads. It helps in low energy transmission while sending the information to the cluster head.

In the initialization phase, the selected cluster heads transmit the vital signs of the human body to the base station. The initialization phase is done with the help of the WMMS system using the sensor node that is the cluster head which was selected in the previous phase. The nodes in the WBAN which are related to the WMMS exchange the control messages. Then the verification process is carried out between the client and the server. The data exchange takes place between the client-server using Encryption Standard Cipher Feedback Message Authentication Code (AES-CFMAC) algorithm. This is done by sending the POST messages with the registered topics to the mobility management system and the client. Based on these messages, the WMMS maintains the information of each body sensors. During data transmission, the sensor sends multicast information so as to collect the data of the sensors in the network.

Handover is a necessary process because in WBAN the sensors are fixed in the human body and the person will be moving from one place to another. The network area of the nodes gets changed according to the mobility of the patients.

The mobility management is done through the handover process. In the hand over process the cluster head will detect the RSS from the gateway 1. The node finds the Radio Signal Strength (RSS) and accomplishes to connect gateway 1 from the sink. The RSS from the gateway 1 drops below the threshold value and the nodes prepare for handover operation. The message using the PUT request/response message along with H_Flag is forwarded to WMMS. If the set of body sensors assessed along with H-flag set to 1, then it is in the handover status. If the H_Flag set to 0, then the sensors are not in handover status. A lifetime binds the P_Addr of a set of body sensors and T Addr of gateways is effective. At the time of handover operation, the H_Flag can stop packet loss of the nodes. A pair of network domains coated by gateway1 and gateway 2 will acquire a new temporary IP address from gateway 1. In order to update the gateway, the node sends a PUT request message to WMMS. As the WMMS receives the PUT request message for binding the update, the T_Addr and H_Flag are updated in WMMS. During this process, the cluster head node and web client can exchange their data during handover operation without packet loss.

NUMERICAL RESULTS

The analysis of CoECMP is based on network stability, network lifetime and residual energy. In the proposed scheme, energy consumption is very much reduced. This can be mathematically analyzed and compared with the existing schemes like Co-Laeeba and E-HARP regarding energy efficiency.

A. NETWORK LIFETIME

Network lifetime denotes the total lifetime of the network. The lifetime of the WBAN is based on the lifetime of the sensor nodes. The sensor nodes are mostly battery operated and it has limited energy and this energy would have to be saved to improve the lifetime of the network. Here the analysis is done by comparing with previous protocols: Co-Laeeba and E-HARP. The simulated result of the lifetime of the network is analyzed using the number of rounds the sensor nodes survive. Fig.7-3 clearly shows that in the previously generated algorithms the nodes start to die from 6500th round itself. In our proposal, the last node is surviving above the maximum of more than 16000th round. The network lifetime of the CoECMP is higher as compared to that of the previous algorithms. The effective selection of the CH makes the network lifetime enhanced.

B. NETWORK STABILITY

The network stability is computed based on the time before the death of the first sensor node in the body area network. It is one of the primary criteria to estimate any of the strategies in the sensor network. It can also be defined as the total period of the sensor node alive. The analysis of the network stability of the proposed system is compared with the previous systems and the result is shown below. This shows that the network stability is increased in the CoAP based Energy-aware Cluster-based mobility management (CoECMP) than the previous schemes. This improved performance of the proposed protocol regarding network stability is due to the efficient cluster head selection and cluster formation.

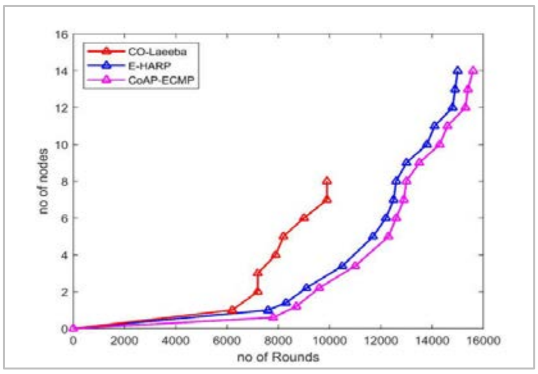

Figure 7-3 Analysis of network lifetime

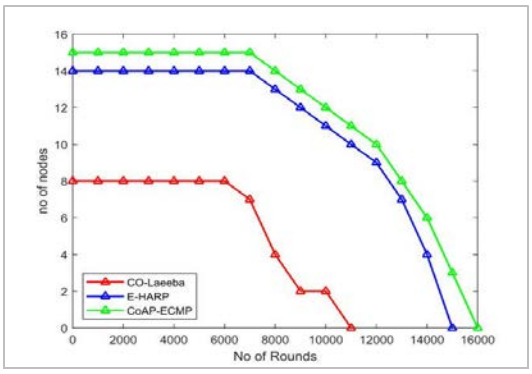

Figure 7-4 Analysis of network Stability

C. RESIDUAL ENERGY

The residual energy refers to the remaining energy of a sensor node in a BAN. In WBAN the energy is absorbed by processes like sensing, processing, transmitting and receiving of the information. To enhance the network lifetime and the network stability the energy consumed by the sensor nodes must be reduced. Few of the previous techniques took effort to minimize energy consumption. Figure 5 shows the comparison of the proposed protocol with the previous schemes like Co-Laeeba and E-Harp in terms of the residual energy. It clearly indicates that the energy of the nodes stays long for the proposed system. It concludes that the proposed protocol works efficiently in reducing the energy of consumption.

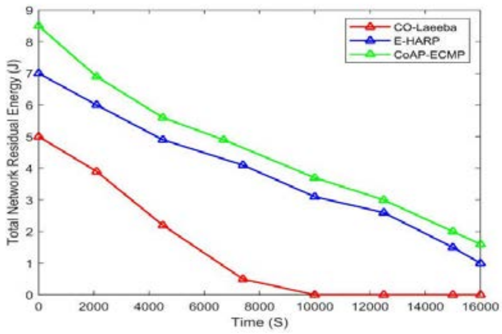

Figure 7-5 Analysis of Residual energy

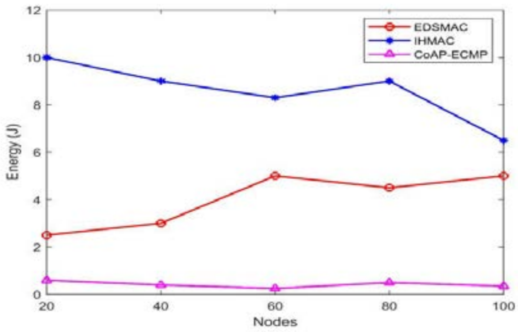

Figure 7-6 Analysis of Energy Consumption

D. ENERGY CONSUMPTION

Energy consumption is always a great issue in the WBAN network. Our proposed CoECMP achieved good energy consumption when compared to previous IHMAC and EDSMAC protocols. The average energy consumption using the proposed protocol is less than 6.5 micro Joule in each nodes. Because of the better enhancement in the energy consumption of the sensor nodes in WBAN the lifetime of the network increases.

CONCLUSION

In this paper, the CoAP based Energy-aware Clusterbased Mobility management Protocol (CoECMP) is presented in which the energy consumption is reduced by cluster Head selection process using the modified firefly algorithm and the optimization is done using the parameters residual energy, distance, path loss, and node density. In particular, in this paper the cluster formation takes place and it reduces the energy consumption by distributing the load evenly to all sensor nodes. The average energy consumption in each node is less than 6.5 micro Joules. The handover operation is also integrated into the network to get the information without loss when the sensor moves from one base station to another base station. The comparative performance is evaluated between E-HARP, CO-Laeeba, and CoECMP in terms of residual energy. Our performance analysis results confirm that the total energy consumption of using the proposed CoECMP is reduced when compared with that of using existing schemes.

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