Multi-Level Parameter Processed Model to Optimise Clustered Distributed WBAN

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***Abstract*—Numerous individuals can be monitored continuously for their physical or health updates such as the comma patient ward in a hospital or the autistic patients. A distributed Wireless Body Area Network (WBAN) forms a wide network with multiple WBANs situated in the same geographical location. Each WBAN has the individual handheld or controller device, and the region has single region control base station. The symmetric featured WBANs update the information to the base station. The small coverage and heavy parallel communication cannot ensure the direct access of the base station to each WBAN. The clustered WBAN architecture is applied in this paper to resolve these primary issues. The proposed improved architecture includes a multi-level and multi-featured evaluation for cluster generation and hierarchical routing over the network. The coverage, energy, load, density and degree parameters are applied selectively at different levels to optimise the cluster controller selection, cluster member identification and communication. The ACO (Ant Colony Optimization) integrated parametric method is applied to generate the multihop hierarchical route between nodes to the base station. The proposed architectural framework is simulated on multiple scenarios under WBAN level scalability. The comparative results are generated against the energy adaptive clustering method, LEACH (Low-Energy Adaptive Clustering Hierarchy) and gateway based energy-efficient routing protocol (M-GEAR). The evaluation results verified that the proposed architecture has reduced the energy consumption and improved the network life, energy utilisation, and packet communication effectively.**

***Index Terms*—Body Area Network; Clustered; ACO; Routing.**

I. Introduction

A WBAN [1][2] is a personalised real-time network represented as an individual. In this network, different kinds of sensing devices are located on the human body to monitor the health status of individuals. WBAN is connected to a mobile device to update the health status to a distant physician. This mobile device or any fixed sensing device in WBAN has a centralised controller to collect the body health information. This coordinator is also responsible for communicating with external devices and other WBAN devices.

In an application scenario, some individuals can be monitored collectively for their health issues, activity monitoring or behaviour observation. These multiple bodies are connected in the form of a network to deliver the captured information on a centralised device. This kind of common scheduled information transition increases the parallel flow of data over the network. This parallel transmission can result in congestion and transmission failures. Clustering is one such architecture that is adapted to avoid the parallel transmission to the centralised base station. In this architecture, the virtual intermediate receivers or controllers are set up throughout the network. These controllers are considered as the cluster heads for that particular network segment. The network segment is the dynamically generated geographical area within the coverage of a cluster head. The individuals present in that coverage can directly communicate with this cluster head. Cluster heads are capable of performing direct interaction with cluster members, neighbour cluster heads, and the base station. This communication architecture generates a hierarchical structure for efficient transmission over the network. This architecture is adaptive to the node and network level limitations of distributed WBAN and reduces the number of parallel communications.

The generation of clustered [3][4][5][6] architecture on distributed WBAN is one of critical and challenging procedural phenomenon. These challenges exist with each stage of architecture and communication formation. The clustering in distributed WBAN is dynamic and virtual, which includes the selection of cluster head and corresponding cluster members. The cluster formation has to deal with the situation of orphan nodes, cluster overload, cluster under load and bottleneck problems. This cluster formation is not a one-time activity; it means the generated clusters cannot survive for complete network life. It is a continuous and dynamic process to generate new cluster heads as the strength and node level capabilities of cluster head decreases. The cluster heads are selected based on various adaptive factors including coverage, energy and fault. The number of clusters in the network and the number of cluster members also affects the quality of communication and life of distributed WBAN. The generalised process of cluster generation and communication is depicted in Figure 1.

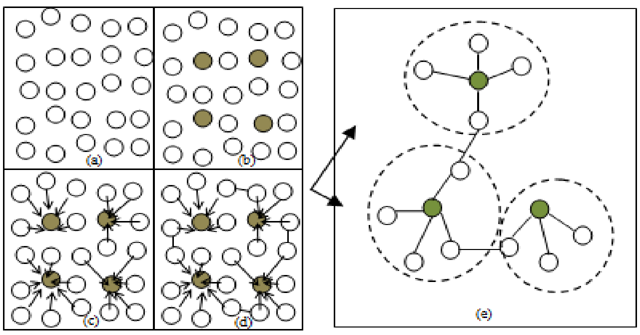

Figure 1: Generalized behaviour of Clustered Architecture

Clustering [7] in any network is basically the requirement to utilise the limited resources and capabilities of nodes in the network. The procedural behaviour of cluster generation and communication network establishment throughout between these cluster heads is shown in Figure 1. Figure 1(a) is showing the broader view of distributed WBAN with the specification of randomly located individuals with on or off body sensors. The individual WBAN is having the same number of body sensors and similar body sensing requirements as per the application. As the architecture is applied, the cluster head election is done over the network based on various parameters and constraints. Figure 1(b) is showing the selected clusters by filled dark green circles. The cluster heads have to connect and communicate with surrounding region nodes for data collection and delivery. The coverage specific cluster member selection is shown in Figure 1(c). The interactive connectivity and communication in clustered WBAN are shown in Figure 1(d). The broader view of the cluster coverage and communication establishment within WBAN and between the WBANs is shown in this Figure 1(e). The nodes also act as a gateway to enable the communication between two cluster heads. The constraint level, parameter level or algorithmic methods can be defined to enhance the significance of this clustered architecture.

In this paper, a more adaptive and effective clustering architecture is suggested to optimise the communication and life of distributed WBAN. The proposed clustered architecture is able to handle most of the critical issues of clustering without compromising the quality constraints. In this section, the brief introduction of distributed WBAN architecture and the requirement for clustered transformation is provided. The challenges and issues associated with this architecture are also described in this section. In section II, the work provided by the earlier researchers to optimise the clustered architecture and resolve various clustering issues is provided. The procedural enhancement on existing protocols and clustering methods is provided in this section. In section III, the proposed clustering architecture with algorithmic behaviour is provided. The constraint-based method is also discussed to handle associated challenges. In section IV, the comparative simulation results obtained from this model against existing clustered architectures are presented and evaluated. In section V, the conclusion reflected by the proposed work is provided.

II. RELATED WORK

In an application area, multiple WBANs are connected through a common interface. The inter-BAN and intra-BAN communication are performed between the distributed individuals. While working with distributed WBAN network in an application area, various node and network level challenges exist. The localisation, clustering, and routing methods were suggested by the researchers to overcome these challenges and to optimise the network communication. In this section, the contribution of earlier researchers is discussed for optimising the distributed WBAN through clustering and other relative characterisations. A detailed exploration of various clustering techniques applied in wireless networks is described by Sucasas et al. [7]. Researchers discussed the energy, privacy, and scalability of effective methods. The scope of these methods for different application areas was also discussed by the authors.

The clustering architecture is applied to reduce the parallel communication and to gain the node level limited features. The researchers have considered various parameters and algorithmic methods for optimising the WBAN clustering. Researchers have defined the methods separately to optimise the cluster selection, cluster switching and hierarchical routing. A load balanced [3] and position adaptive clustering method was proposed to improve the effectiveness of WBAN clustering. The authors used the probability distribution method for effective selection of cluster-head. A time-static [4] and energy effective clustering method was proposed while considering the spatial distribution of mobile nodes. A self-organised [5] clustered network with periodic and query adaptive communication was proposed to optimise the distributed WBAN. The clustered architecture was sensitive to on-demand query and provides multicast and broadcast communication over the network.

Chang et al. [6] have optimised the energy consumption by using the centralised cluster based routing method. The cluster tree based structure was generated to generate uniform clusters and to achieve balanced energy consumption. Hybrid energy adaptive cluster architecture with security integration was provided by Verma et al. [8]. The key management and energy efficient communication was provided to improve the network reliability and to gain the network life. A cluster-based hybrid security framework [9] was proposed to improve the communication reliability for inter-WBAN and intra-WBAN. The authors transformed the network into energy effective clusters and applied the EKG (Electrocardiogram) based key agreement scheme. The physiological features were used to generate the key and to ensure the access for particular individuals. The key distribution, key refreshment, and neighbourhood discovery methods were defined by the authors to ensure secure and reliable communication. For each cluster session, the key pairs are generated to achieve dynamic security for inter and intra WBAN.

Ullah et al. [10] have investigated a new protocol called Dual Sink approach for clustering in Body Area Network (DSCB) to reduce the energy consumption and to improve stability in the network. The proposed protocol computes the SNR evaluation for forwarder selection based on transmission power, distance, and residual energy evaluation. The decisions are taken on each hop to identify the next effective hop and to generate the route for reliable data delivery in the clustered WBAN. A cluster-based epidemic [11] control method was proposed to generate the clusters based on physical and social information of nodes. The inter-cluster and intra-cluster optimisation was applied by using the graph theory to improve the network effectiveness. The framework observed the social interactions, data requirement, and network criticality as the decision vectors to generate the clusters within the network. The proposed framework was applied in different situations and environments.

Authors in [12] proposed LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering protocol. In this protocol, data fusion is used to reduce the amount of data to be transmitted to the base station, and cluster head rotation causes the energy load to be distributed equally among the nodes. The gateway based energy-efficient routing protocol (M-GEAR) [13] divides the network into four different regions based on their location in the sensing field, and a gateway node is placed at the centre of the sensing area. The cluster heads are selected for each region based on probability. Direct communication is used when the distance of the node is less than threshold distance otherwise data is transmitted using cluster heads and gateway node. Use of cluster heads and gateway node reduces the number of direct transmissions and hence increases the energy efficiency of the network.

An interference avoidance based group formation and clique [14] adaptive scheduling were suggested to optimise clustered WBAN. The time slot and sequence adaptive scheduling were proposed to improve network throughput. The partition driven method was also proposed for effective slot allocation and network optimisation. A stability adaptive clustering and routing method was proposed by Sharma et al. [15]. The propagation model was defined by the authors to improve the communication throughput and the network stability over the period. A central mediator [16] system was investigated for effective management of clusters by controlling the load and fault issues. The consistent and priority driven access to the WBAN entities was achieved with the lesser occurrence of communication faults.

III. Proposed Clustered Architecture

There are numerous circumstances where a single individual is monitored for health issues. Such an individual or patient either stays at home or is available in a public environment with wearable body sensors. A handheld device such as a smartphone is connected as a controller to these body sensors and updates the health information to the physician through the internet. However, in professional environments such as medical, gym or training centres, a number of patients or individuals are monitored in parallel for their health updates. Such as, in a heart clinic, several heart patients are considered as individual WBAN and monitored in parallel through common body sensors. The health updates of these patients are recorded in a centralised system where analytical and intelligent decision making is performed to conclude the health status. This kind of network actually acts as a network of networks or WBANs. This distributed WBAN network is highly critical network form because of the importance of individual nodes and associated health information.

The symmetric WBANs present in an environment communicate with the common schedule. This parallel communication can increase the network congestion and results in communication failure. The individuals or the nodes are located in a personalised area. The sensing range of these WBANs is limited, and they connect or communicate directly to the centralised base station. In such case, the multihop or aggregative communication is required. This kind of approach can increase the network communication extensively. To handle the network restriction and node capabilities, the clustered architecture is considered as the perfect approach for communication in distributed WBAN. In this architecture, the network is divided into smaller segments geographically based on the node coverage. Each coverage region has multiple WBANs. Out of these WBANs, a WBAN is selected as the controller to collect and forward data packets. In this way, the node to controller and controller to base station communication is performed in a hierarchical way for delivering the information packets to the base station. The architecture is having the various challenges of cluster generation, controller selection and route formation for effective and reliable data delivery. In the existing approach, the energy and coverage are the main criteria considered for cluster formation. The WBAN with high energy is considered as the controller node, and the multihop route is generated by selecting the high energy nodes as intermediate nodes.

In this paper, a more effective, reliable and intelligent approach is provided to optimise each stage of clustered architecture. The proposed model has included multiple decisive parameters and used them in successive stages for cluster generation, cluster head selection, and cluster member identification. After setting up the architecture, the communication is performed through the ACO adaptive route. The multihop hierarchical route is generated between the WBANs and the base station. In this section, the proposed model with each integrated stage is explored. The broader view of the proposed model is shown in Figure 2.

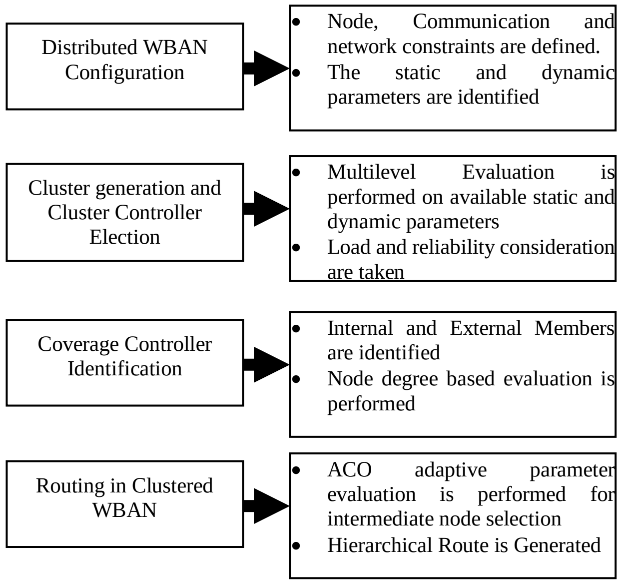

Figure 2: Broader View of Proposed Architecture.

The complete contribution of this proposed cluster optimisation for distributed WBAN is shown in Figure 2. The figure shows that the model is divided into four continuous and integrated stages. The first stage has described the architectural requirement in terms of available network features. The network strengths, node capabilities, and characterisation are described in this stage. In later stages, these parameters are used individually or collectively to take the effective decisions. Once the network is available with complete constraints, restriction, and parametric description, the cluster generation is applied over the well-configured network using static and dynamic parameters. The cluster formation is done by considering the cluster controller as the centralised unit. The featured rules are defined to select the effective cluster head, and relatively the cluster formation is done with maximum coverage to the network. After identification of the cluster controller and its coverage, its members are identified based on node degree analysis. After identification of cluster members, the design of network architecture is obtained. Now to initiate the communication, the node-to-controller and controller-to-base station communication are required. In this architecture, ACO adaptive multihop routing is performed to optimise the communication. This communication and design-driven architecture are able to utilise the limited resources sensitively and to improve the network communication and life. The detailed contribution of each of the work stage is described below with required constraints and algorithmic aspects.

A. Network Configuration

The distributed WBAN is actually a network of smaller networks. In this network, each node is itself an entity with multiple body sensors. The internal body sensors' role and communication are hybrid respective to data and criticality. In this paper, the patients are considered with eight body sensors. In each scenario, only a similar kind of individuals or patients is considered. The individual WBAN is having the controller device, which is having the complete health and Meta information about the human body. The energy of the individual nodes in distributed WBAN is the sum of energy of all body sensors. In the same way, the energy consumption on WBAN is performed concerning each integrated body sensor along with its functional participation. Along with the body sensor relative energy consumption, the role integration of WBAN in a clustered network is also featured with specific functional activity. These functions are the transmission of the packets to the controller, data aggregation, forwarding in case of multi-hop transmission and the data receiving. The energy consumption is performed on each node respective to the participation in the communication. The WBAN nodes are distributed randomly over the geographical region. The node coverage is defined as the sensing range respective to the controller of individual WBAN. After setting the node level localisations and communication characterisation, the parameters and constraints are also defined to form the clusters, cluster selection, and the route formation. These integrated parameters, their type, and role are described in Table 1.

The parameters defined in Table 1 are used individually and collectively at different stages of the clustering architecture. These parameters are the main deciding factors to provide effective clustering and to avoid the situation of overload, under load and non-coverage. The actual values considered in the simulation are described in the result section. The usage of these parameters is described with the algorithmic formulation in other subsections of this section.

B. Cluster Formation

The configured network is transformed to the clustered network using the proposed model. For this, the network is divided into smaller segments, and for each segment, the controller is identified. The size of the cluster depends on the sensing range of the individual WBAN. Level specific two or more parameters are applied for effective selection of cluster controller. At the initial level, the eligible node is identified based on probabilistic and energy value of the WBAN. At the second level, only the high energy nodes are processed under the coverage range to identify the possible members of the coverage. Each high energy node is observed as the expected controller and will observe the covered region. The numbers of nodes in the coverage are analysed along with the identification of controller existence within the coverage. If the WBAN is not overlapping the coverage of any other controller node and the node is having a feasible number of cluster members, then the node is eligible to be set as the controller. At the third level, the node degree specific coverage count is analyzed. For balanced clustering, the balanced number of nodes of each coverage count is maintained in the clusters. The algorithmic process for balanced cluster generation and cluster selection based on multi-level evaluation is shown in Table 2.

Table 1
Parameters Role and Responsibilities

Parameter	Type	Role	Responsibility	Contribution
Energy	Static	Initial Energy is the sum of body sensors and describes the node and network life. A node with High Energy is considered as an effective functional node.	Level 1 Parameter	Controller selection, Next Hop Selection
Coverage	Static	Describe the sensing range as a geometric constraint	Level 1 Parameter	Cluster formation, Controller Selection, Cluster member and Routing
Load	Dynamic	The number of parallel communication on a node or controller	Level 3 Parameter	Routing
Degree	Dynamic	Number of clusters a node covers is defined as the degree	Level 3 parameter	Cluster Member
Cluster Limit	Static	The maximum number of allowed cluster members	Level 2 Parameter	Cluster formation
Cluster Count	Static	Defined as a threshold to restrict the number of clusters in the network	Level 2 Parameter	Cluster Formation

The algorithmic process has analysed each of the nodes and performed the clustering by applying three levels of observation. At first, the prior analysis is applied to locate the feasible nodes that can be set as a controller. The probability and energy based analysis are applied to shortlist the controller nodes. At the second level, the load and density driven evaluation are done, and more filtered selection of controllers is obtained. In the final stage, the balanced degree based evaluation is done to verify the effective nodes. After these three level filters, the cluster controller and cluster region are obtained.

C. Coverage Controller Identification

After the election of the cluster controller and cluster region, the next task is to identify the effective communicating member of the cluster. The effective member decision is made dynamically just before initiating the communication. The cluster member decision depends on two main criteria called membership strength and degree of the node. The membership strength is here defined as the distance from the controller. To distinguish the node, a coverage limit is set to identify the internal and external nodes. The internal nodes are strongly bounded to the controller node and perform the single-hop communication with the controller. Whereas, the external nodes are comparative distant nodes, that generate the multihop route between the node and the controller node. The external nodes

Table 2
Multi-Level Multi-Parameter based Cluster Formation

```
ClusterFormation(WBANs)
/*WBANs is the list of body network represented by the controller with all positional, energy and communication level characterisation*/
{
1.  For i=1 to WBANs.Length /*Analyze all WBAN nodes for controller election*/
    {
2.  If (WBANs(i).Prob>PThreshold And WBANs(i).Energy >EThreshold ) /*Level 1 features implied to obtain eligible clusters*/ {
3.  CoverageNodes=GetCoverageWBANs (WBANs(i), CoverageRange) /*Identify the nodes in same coverage of each eligible WBAN*/
4.  if (Any(CoverageNodes)<>Controllers) /*Level 2 Analysis: Identify Controller in same coverage*/
    {
5.  if (CoverageNodes.Count>LThreshold) /*Level 2 Analysis: Overload Condition
    {
    Print "Cluster Overload"
    }
6.  Else if (Controllers .Count>CThreshold) /*Level 2 Analysis : Balanced Cluster formation */
    {
    Print "No more clusters can be formed"
    }
7.  Else
    {
8.  Degrees=GetDegreeCount(CoverageNodes)    /*Level 3 Analysis : Balanced Cluster Formation*/
9.  If (Balanced(Degrees)=True)
    {
    Controllers.Add(WBAN(i)   /*Node satisfy all three levels of eligibility is set as controller node
    }
    }
    }
10. Return Controllers
    }
```

Table 3
Rules for Coverage Controller Identification

```
CoverageControllerIdentification(Node, Controllers)
/*Node is the WBAN for which the controller identification is performed, Controllers is the list of available controllers*/
{
1.      CControllers=GetCoverage(Controllers,Range, Node)/*Identify controllers within coverage*/
2.      Controller=GetMinimumDistance(Node,CControllers) /*Identify the closest controller*/
3.      If(Distance(Node,Controller)<ICoverage) /*The Node present in internal coverage of controller will perform direct communication to controller*/
        {
4.      PerformCommunication(Node,Controller)   /*Perform single hop communication*/
        }
5.      ElseIfNode.Degree=1 /*Single controller in range*/
        {
6.      PerformCommunication(Node,Controller)   /*Perform multi hop communication*/
        }
7.      Else
        {
8.      Controller=GetEffective (CControllers) /*Get controller with minimum load and minimum load*/
        PerformCommunication(Node,Controller)   /*Perform multi hop communication*/
        }
}
```

are not bounded to a specific controller. For external nodes, the node degree is evaluated. The external nodes with degree 1 are directly communicating coverage controller using multihop path. The external nodes with higher degree analyse all the possible controllers under load and distance parameters. The minimum distance and low load based controller is elected as the coverage controller. The rule formulation of coverage controller identification is shown in Table 3.

D. ACO based Routing

In a clustered network, the communication is performed at two levels. In the first level, the node to controller communication is performed. This communication can be single hop or multi-hop. The internal nodes perform the single-hop communication, and the external nodes use other intermediate nodes for route formation to the controller node. The second level communication is between the controllers and the base station. This communication is generally multihop which uses other controllers as intermediate nodes. In this proposed architecture, the multihop route is generated using parameter adaptive ACO (Ant Colony Optimization) method. The route formation method and the integration of ACO are described in this section.

ACO is the swarm based approach in which the behaviour of ants is considered as the backbone to generate an optimised solution. In this approach, the ants explore the region and generate traces in search of food source. The ants can follow different paths if some obstacle occurs over the current path. As an ant discovers the food source, a back trail is generated to inform the other ants about the location of food source. This path generation between the ant and food source is actually the discovery of route. The identification of food source is represented by the constraints applied to identify the best path. In this way, ACO can generate and optimise communication route. ACO is the heuristic algorithm which can observe maximum possible solution in effective time. ACO is able to ensure a reliable and efficient routing solution. In this paper, the multihop hierarchical path is generated using the ACO approach. The complete process of ACO is divided into two directions called forward ant based route inspection and backward ant based effective route discovery.

Before initiating the route formation, the ACO initialises the ants at random locations over the network. The constraints such as the destination recognition, effective parameter specification are also defined while deciding the task for ants. The cache capability is integrated with these ants to take the decision. After this, the forward ant initiates at the source node with the specification of the sink node. The forward ants search for the possible paths to the destination and generate the pheromone track for reverse mapping. The forward ant collects the information about possible neighbours along with relative constraints. This information is stored as a possibility on each ant. The process is repeated until the destination is not recognised by the ant. Once the destination reaches, the backward ant initiates and kills the forward ant. The possible paths are analysed, and the optimised constraint adaptive path is obtained. In this paper, coverage, energy, and load are the parameters considered for effective route generation. The optimised path information is transferred to the source using backward ant. ACO also applies the route maintenance phase if some route failure occurs. A low energy intermediate can result in the failed route formation. The probabilistic analysis is applied in such case to identify the next possible node for effective route maintenance. The ACO adaptive route formation algorithm is shown in Table 4.

Table 4
ACO based Routing

```
Routing(Src, Dst)
/*The WBAN routing is performed between the node to controller and
controller to base station. This hierarchical route is applied between
each pair of node-controller and controller-base station*/
{
1.      Distribute(ANTS) /*Distribute N ants randomly for route
discovery towards a destination with constraint specification*/
2.      If Src<>Dst /*Repeat Process Till Destination not occur*/
        {
3.      Process Each ANT for identification of the next effective
neighbour within coverage called NNode
4.      If NNode=Null        /*No neighbor identified*/
        {
5.      Move back to previous hop and repeat process
        Routing(Src,Dst)
        }
4.      Set NNode.Status=Visited /*Avoid the dual coverage of
node*/
5.      Include node in feasible path list with associated constraints
        Path.add(NNode)
        Routing(Src,Dst)
        }
6.      Else /*Destination Identified*/
        {
7.      Evaluate possible path and identify effective energy and load
adaptive path
8.      Apply BackwardAnt for a decision on the optimised route
9.      Perform communication on the optimised route
        }
}
```

The route formation process shown in Table 4 is represented as a recursive process applied on each ant in parallel to generate possible paths. After specification of source and destination nodes, the random ants are distributed over the network. Each ant senses the next neighbour available within the coverage under the minimum distance parameter. If no such node is identified, the ant moves back to the previous hop, and the route is regenerated from that position. If it is a valid node, then it is included in path list, and the process is repeated till the destination does not occur. As the destination located by the ant, the energy and load based evaluation are performed for effective route selection. The backward ant is processed to inform the route to the source node. Now the communication is performed through that route. This routing phenomenon is applied in a hierarchical way between node-to-controller and controller-to-base station.

In this section, the proposed optimised clustering model is defined with an exploration of each work stage. The algorithmic specification and constraint exploration are also done. The simulation of this model is done on different size scenarios. The simulation results and verification of the significance of the proposed clustering model are provided in the next section.

IV. Results and Discussions

The evaluation of the performance of the proposed clustering method is provided in this section. The comparative evaluation is performed against the energy adaptive clustering model and against standard LEACH [12] and M-GEAR [13] protocols. The simulation of these existing clustering standards, adaptive energy scheme, and proposed model is performed on multiple networks under scalability concern. In a broader view, distributed WBAN is generated with 50, 100, 150 and 200 WBANs. The evaluation of these models is done regarding network life, packet communication, and network energy parameters. The constructed WBAN is a network of randomly distributed WBANs. Each WBAN is itself a network with multiple sensing devices. The distributed scenarios are generated with eight body sensors integrated WBANs. The initial energy of WBAN is the sum of energy of all body sensors. The network is constructed in the geographical region of 100x100 meters, and the sensing range of WBAN is 30 meters. The energy consumption on data transmission and reception is 50nJ whereas the energy consumption on forwarded data is10nJ. The communication is performed for a maximum of 4500 rounds. The round based analyses are here generated by considering the communication rounds as an effective observation point. The scalability based comparative evaluation is also provided later in this section.

One of the effective parameters to analyse the performance of any WBAN network is network life. The WBAN network is represented by energy nodes. As the communication is performed, some amount of energy is consumed. A network is called alive if it has at least one alive node. The network life can be estimated by the number of alive nodes in the network. Initially, when communication begins, all network nodes are alive. Figure 3 shows the comparative evaluation of the proposed clustering method against LEACH, M-GEAR, and energy adaptive method. The evaluation is done regarding alive nodes to evaluate the life of the network for each of the existing and proposed clustering methods. Figure 3 x-axis represents the communication rounds, and the y-axis shows the number of alive nodes.

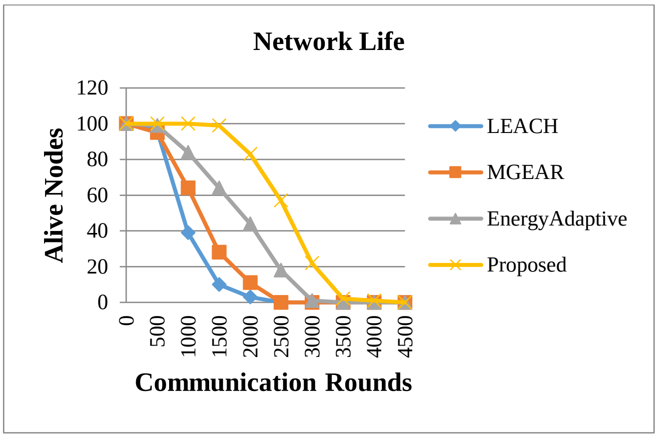

Figure 3: Network Life Analysis

Initially, all the 100 nodes in the network are alive. The numbers of alive nodes are 96 for LEACH Protocol, 95 for M-GEAR, 99 for energy adaptive routing scheme and 100 for the proposed approach after 500 rounds of communication. It shows that the energy consumption is comparatively balanced in the proposed approach. The figure also shows that the LEACH protocol starts losing its nodes frequently and after 2000 rounds only three nodes are alive. M-GEAR protocol provides better results than LEACH protocol, and the number of alive nodes is 11 after 2000 rounds, and still, the network life is not over till 2424 rounds. From Figure 3 it can also be seen that the adaptive energy method comparatively provided more effective results and network survive up to 3000 rounds. The evaluation results from Figure 3 identified that the proposed model had improved the network life up to 4000 rounds and still one node is alive. The observations identified that the proposed clustering method is more stable and balanced to generate the clusters and improved the network life effectively. The comparative results signify that the network life in case of the proposed approach is much higher than the existing approaches. This is due to the fact that the existing LEACH and M-GEAR protocols are probability based cluster head selection methods. In these protocols, there is a high possibility of selecting a low energy node as the cluster head which is not an optimal way to select a cluster head. In an adaptive energy scheme the cluster head selection is made on the basis of energy and probability, but in our proposed work the selection of cluster head is made using energy, probability and load parameters. Using these parameters leads to an optimised cluster head selection which in turn increases the network lifetime as only nodes with high residual energy, high probability, and low load are selected as cluster heads. Use of ACO method by the external nodes and multi-hop routing by cluster heads to send data to base station further decreases the communication distance and increases the network lifetime.

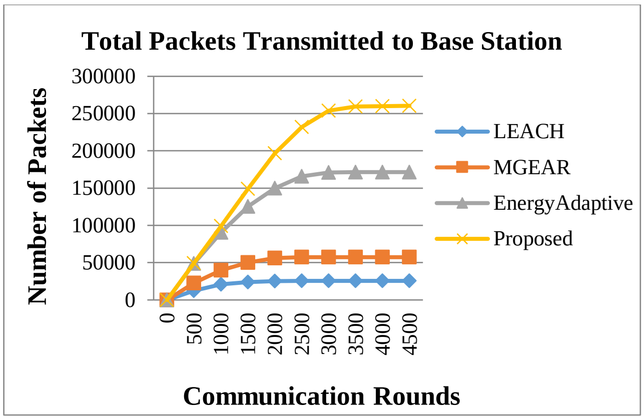

Figure 4: Total Packets Received.

In a network, only alive nodes can participate in the network. For instance, only one packet is transmitted by each of the alive nodes. The packet communication analysis is shown in Figure 4 for 4500 rounds, and the evaluation is successfully performed in terms of transmitted packets. The comparative results are generated in this figure against LEACH, M-GEAR, and energy-based clustering methods. In the initial phase of communication, the packet communication gap is lesser between the existing methods and the proposed protocol. However, as the number of dead nodes is increased in LEACH, M-GEAR and energy-based method, the packet communication in these methods decreased. In the end, the figure identifies that there is a larger gap between the packet communication in existing methods and proposed approach. The packet communication in case of the proposed approach is improved effectively because of more number of available alive nodes.

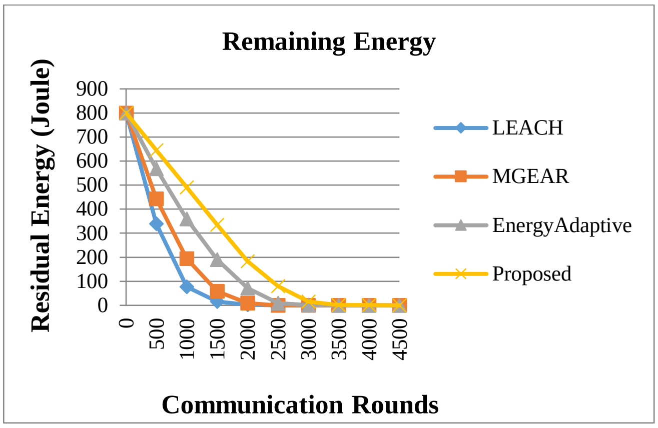

Figure 5: Remaining Energy.

As the body area network is an energy-based network and the available energy in the network represents the strength of this network which allows the network to participate in the communication. Figure 5 shows the comparative evaluation regarding remaining energy in the network. In this figure, the x-axis represents the communication round, and the y-axis represents the network energy. The figure shows that initially, the energy level is the same for all clustering approaches. But, as the communication progresses, the energy loss is high in LEACH, M-GEAR, and energy adaptive clustering approach. In these methods, the number of clusters is higher, and the cluster head switching is done more frequently. It increased the energy consumption in the each of the existing clustering-based methods. The proposed approach has defined an effective and adaptive method to utilise the available resources. The number of cluster heads is optimised by setting a threshold value for the total number of cluster head that can be chosen in the network. The number of cluster heads is set to 0.3 times the number of nodes in the network. This reduces the number of clusters in the network. The figure shows that the energy consumption is comparatively linear and effective in case of the proposed approach. The overall evaluation verifies that the proposed approach has led to a decrease in energy consumption of nodes in the network as compared to existing LEACH, M-GEAR and energy adaptive schemes.

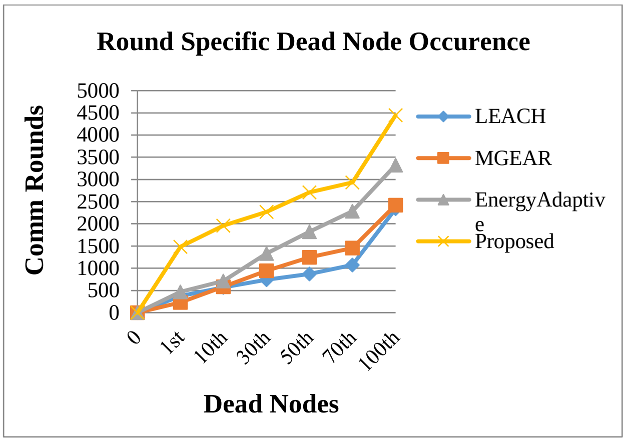

Figure 6: Round Based Dead Node Occurrence.

Each node of distributed clustered WBAN is initially alive, but as the communication is performed the node starts losing its life and the packet communication, and alive nodes start reducing. In earlier results, the communication is performed for 4500 rounds. However, to track the actual network life, the communication is performed until the network is alive and the number of rounds for which the network keeps alive is recorded. Figure 6 shows the observations on the maximum lifetime of the network. In this figure, the y-axis represents the communication rounds, and the x-axis represents the occurrence of dead nodes. The figure shows that the dead nodes occur more frequently in LEACH, M-GEAR, and energy based clustering approach. The first node in LEACH, M-GEAR, energy-based and proposed clustering approach dies at 374, 233, 467and 1485 rounds respectively. It shows that the energy consumption is most unbalanced in M-GEAR protocol and most effective in the proposed protocol. All nodes go dead in LEACH, M-GEAR, energy-based and proposed clustering approach at 2340, 2425, 3324 and 4445 rounds respectively. The observations identified a significant gain in the network life by using the proposed clustering approach.

To generate more effective and robust results, the observations are taken for different size networks. The distributed WBAN is generated with 50, 100, 150 and 200 nodes. The communication is performed for 1500 rounds for each of these networks. These networks are processed by the LEACH, M-GEAR, energy adaptive and proposed level feature adaptive clustering methods and the observations are taken in terms of packet communication, remaining energy and network life.

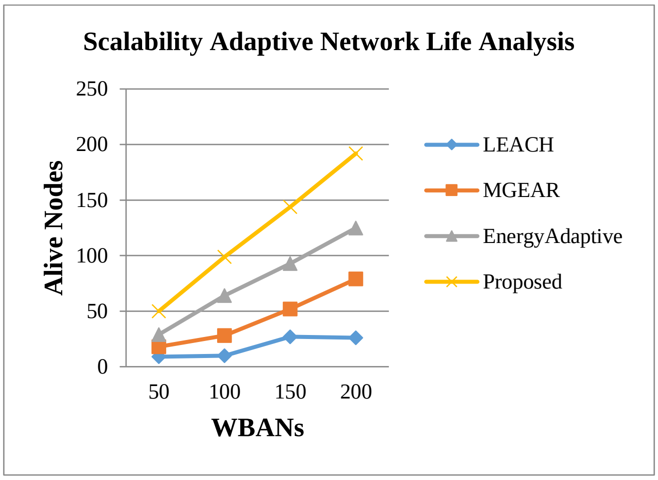

Figure 7: Scalability Adaptive Network Life Analysis.

A distributed WBAN network is considered alive if the network has at least one alive node. The network is more active if it has a higher number of alive nodes. The network life can be estimated by identifying the number of alive nodes in the network. Figure 7 shows the comparative evaluation of LEACH, M-GEAR, energy-based clustering approach and the proposed approach regarding network life under scalability vector. In this figure, the x-axis represents the number of WBANs in the network, and the y-axis shows the number of alive WBANs in the network. The figure shows for smaller networks the number of alive WBANs (or nodes) is almost the same for all existing and proposed clustering methods. However, as the network size is increased to 100, 150 and 200 nodes, the network life is improved in the case of the proposed approach. The proposed approach uses the coverage, energy and node degree based analysis for balanced clustering and cluster member election. This balanced approach is more significant as the network size grows and causes unbalancing in the network. The result of Figure 7 also shows that the network life is improved for the larger networks by using the proposed approach.

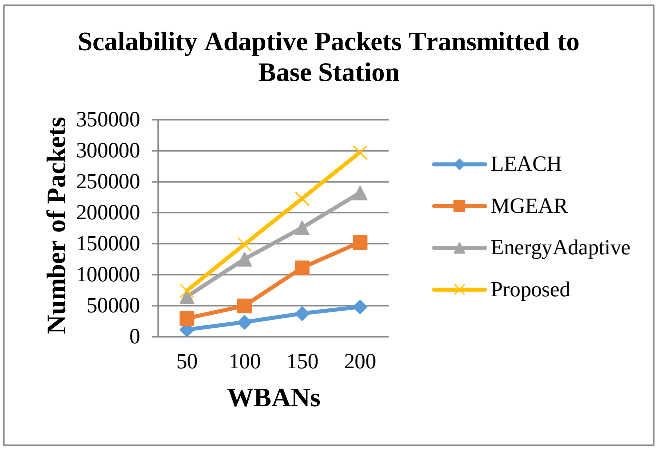

Figure 8: Scalability Adaptive Packet Transmission Analysis

Another evaluation on these scalable WBAN networks is performed regarding packet communication in the network. Each alive node in the network performs the packet communication in each communication round. Figure 8 is showing the packet communication analysis over the distributed WBAN for each network. In this figure, the x-axis represents the number of WBANs in the distributed network, and the y-axis represents the number of packets communicated. The figure shows that the packet communication in case of proposed level featured WBAN is effectively higher than LEACH, M-GEAR, and energy adaptive clustering methods for each network with a different number of WBANs. For the smaller network of maximum 50 nodes (or WBANs), the packet communication is almost same for all existing methods and proposed method having a slightly higher number of packets transmitted. However, as the network size grows, the packet communication gap is effectively increased in the case of the proposed clustering approach.

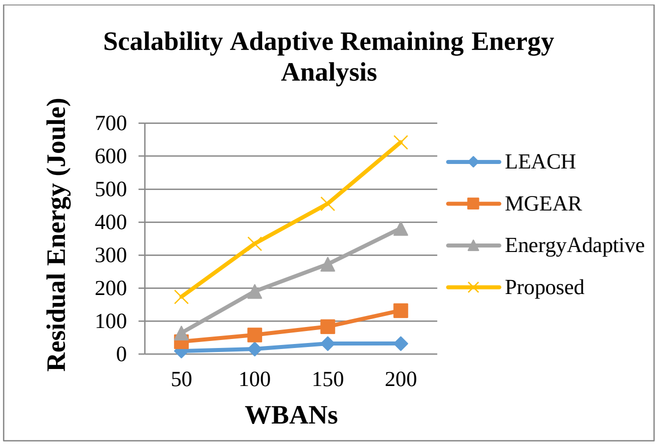

Figure 9: Scalability Adaptive Remaining Energy Analysis

The network energy based comparative evaluation for scalable networks is shown in Figure 9. The figure shows the comparative observation on network energy for LEACH, M-GEAR, energy-based and proposed level adaptive clustering approach. The figure shows that there is a smaller difference in energy consumption for small size networks. As the network size increases, the energy consumption in LEACH, M-GEAR, and energy based approaches increases. The results identified that the remaining energy in the proposed clustering architecture is higher than that of any of the existing approaches.

Another extension to observe the effectiveness of the proposed method is provided in Figures 10 and 11 by performing the communication for each network until the network survives. The communication is performed for four different networks of size 50, 100, 150 and 200 nodes.

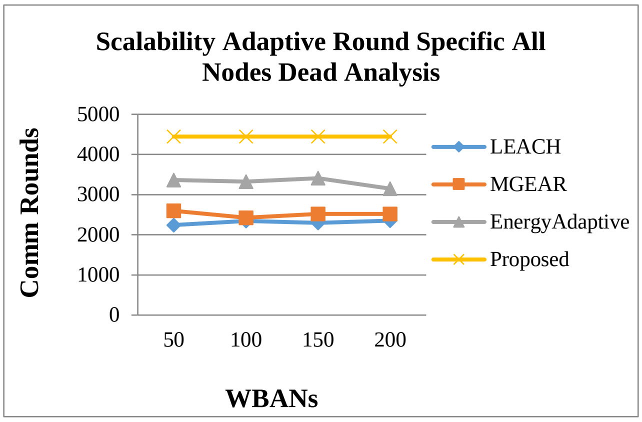

Figure.10. Round Based All Nodes Dead Analysis

In Figure 10, the evaluation of network life is presented by observing the network survival until any of the nodes is alive in the network. In this figure, the x-axis represents the number of WBANs in the distributed network, and the y-axis represents the communication rounds. The figure shows that the network life for each network size is less than 3000 rounds for both LEACH and M-GEAR protocols. The adaptive energy method has improved the network life up to 3500 rounds, but it is lesser than the performance of the proposed approach. The proposed clustering method has achieved the maximum network life for all networks over 4000 rounds. The observations identify a significant increase in network life is achieved for the proposed approach.

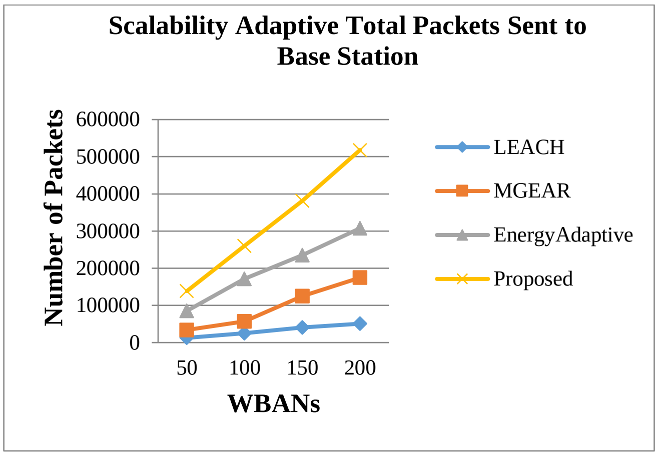

Figure.11. Total Packets Transmission Analysis

In Figure 11, the total packets communication is performed on four different networks until the network survives. As the network size increases, the packet communication in the network is increased for each clustering approach. The figure shows that the total packets transmitted to the base station in case of the proposed approach are extensively higher than LEACH, M-GEAR and energy-based approach.

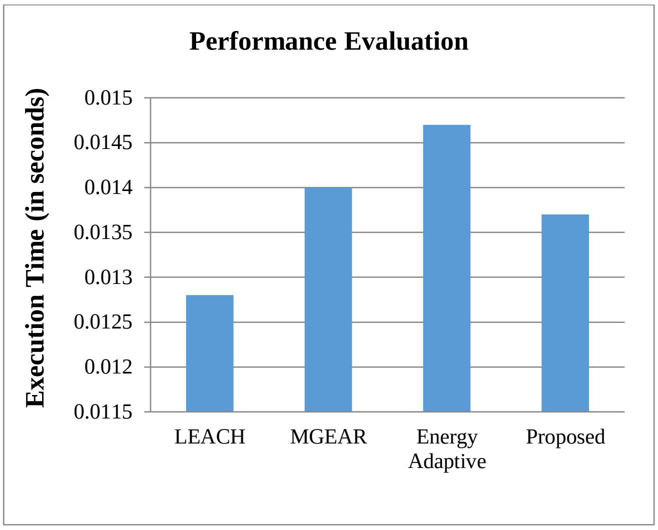

Figure.12. Performance Analysis

Another evaluation parameter to identify the effectiveness of the proposed clustering method is the time taken to perform the clustering and communication in the clustered network. Figure 12 has provided the comparative evaluation of average time taken to divide the network into clusters and deliver the data packet from node to base station. The figure shows that the performance of the proposed method is effective than M-GEAR and energy adaptive protocols. The adaption of more parameters and distributed evaluation of effective neighbour has increased the time in case of the proposed approach. Even though execution time has increased, still significant and adaptive performance is achieved for the proposed clustering approach.

V. CONCLUSIONS

Distributed WBAN is the network defined with randomly positioned patients or individuals representing an ad-hoc body network. To avoid the parallel communication, the cluster architecture is implied in such situations. The existing cluster generation methods LEACH and M-GEAR select cluster heads by probability whereas adaptive energy scheme uses energy as the main constraint for cluster formation, cluster controller election, and route formation. In this paper, an effective clustering architecture is suggested for WBAN network. In this architecture, multiple parameters are applied at different levels to optimise the cluster formation effectively. At first level, the energy and probability vectors are considered to identify the effective WBAN nodes. At the second filtration level, the load, density, and degree-based evaluation are performed for effective cluster selection. At the third level, the degree and controller to WBAN bonding are analysed to optimise controller selection. Once the clustering is done, the ACO based routing method is applied to generate the hierarchical route. The comparative validation of the proposed approach is provided against LEACH, M-GEAR, and energy adaptive clustering methods. The proposed architecture is applied to four different WBANs with 50, 100, 150 and 200 nodes. The comparative evaluation is done regarding network life, packet communication, and network energy parameters. The evaluation results verified that the proposed model improved the network life and network communication and reduced the energy consumption effectively. The time taken to deliver the packet is also evaluated to observe the performance of the method. The results identified that the proposed scheme is more significant than LEACH, M-GEAR and energy adaptive protocols. Data in a WBAN is very crucial, and any kind of data tampering can prove to be fatal. The work can further be extended by taking into consideration the heterogeneity of the network nodes and securing the inter-WBAN communication using some cryptographic schemes.

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