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A novel dynamic route aware clustering (DRAC) protocol for enhancing energy efficiency by clustering concept in WSN

Sajitha M.
Research Scholar, Department of Computer Science, Karpagam Academy of Higher Education, Coimbatore, India.

Dr. S. Veni
Professor, Department of Computer Science, Karpagam Academy of Higher Education, Coimbatore, India

***Abstract*---**"Wireless Sensor Networks (WSNs)" have started to recognize clustering as among the best effective ways of saving energy. The Cluster-Heads (CHs) probably have spent higher energy than typical nodes in a WSN based on clustering, resulting in higher consumption of energy and a shorter network lifespan. To lower the consumption of energy of CHs, many energy-efficient routing techniques had already been developed and demonstrated. It is possible to reduce the consumption of energy of CHs by increasing the number of CHs nearby. Earlier research has not taken into account these conditions. Poorly balanced CH consumption of energy is also a major design concern, resulting in increased misspent energy and initial network downfall. These situations need re-creation of the shortest path route if the previously found routed path is faulty or interrupted. Extra node consumption of energy may exhaust the sensor's energy supply as a result of this reconfiguration. Researchers in the last several years also aimed to enhance the overall balance of energy through the use of huge and costly energy harvesting equipment but nothing had solved this issue. In this research, we propose a novel Dynamic Route Aware Clustering (DRAC) protocol for efficient and reliable communication in the WSN. The DRAC protocol is proposed for WSN by dynamically selecting the CHs, GW nodes, and the routing path. Sensor nodes sense the information from various environments and transmit the information to the sink using CHs or GW nodes with this DRAC protocol. *The DRAC efficiently minimizes the number of explicit control packets and also reconstructs the routing path in the path damage scenario using the state transition mechanism which is also referred to as passive clustering.* We compare and analyze the performance of the DRAC proposed protocol with ADEM's

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existing protocol in terms of its Energy-Efficiency, Packet-Delivery-Ratio (PDR), Throughput, and Routing-Overhead in the WSN.

***Keywords*---**WSN, Clustering, Energy Efficiency, DRAC, ADEEM.

Introduction

With the WSN, data is collected by sensor nodes and sent to a Base-Station (BS), the central hub of the WSN [1]. One of the hardest challenges in WSNs has been the energy constraint of sensor nodes since it has a severe influence on the network's lifespan [2]. To get around the energy shortage, some new energy-efficiency initiatives have been implemented [3]. Network longevity and energy efficiency may both be improved by clustering [4].

It is common for WSNs to be partitioned into clusters, each of which is composed of a CH node and several Member-Nodes (MNs) [5]. Data from sensors is transmitted from MNs to CHs and then to a BS throughout this kind of network. Reduced transmitting data range and reduced consumption of energy of MNs are two of the primary benefits of clustering [6]. In these designs, CHs are viewed as the governing authority that plays a representational function in the collection and transfer of data. Since they're the hubs of a cluster, CHs are subject to rapid energy degradation because of the high volume of information they handle.

As a result of much research conducted in recent years, CH consumption of energy has been reduced [7]. In these efforts, it is hoped that the traffic and consumption of energy of CHs may be lowered by adjusting the various features. The "Cluster-Size" optimizing strategies, "CH-Voting" techniques, and "Inter-Cluster" forwarding methods may all be grouped.

A "Single-Hop" and "Multi-Hop Inter-Cluster" routing protocols are the most common types of clustering routing protocols used in WSNs.All CHs come into direct contact with the BS in a single-hop scenario [8]. CHs, on the other hand, utilize data relays in the multiple-hop inter-cluster routing method. For the first time, [9] proposes a method of multi-hop data transfer. The reduced data transfer rate and lower consumption of energy are two goals of multi-hop data transmission techniques. Multi-hop data transmission techniques use CHs to transfer packets of data to the center of the CHs that they've collected. As a consequence, the CHs surrounding BS used higher energy, this causes energy voids to emerge near BS and reduces the network's lifespan. Nodes use less energy when they are clustered together, hence additional clustering on CHs reduces their consumption of energy.

This research problem statement identified that the major cause of early network mortality was found to be the CHs' uneven consumption of energy, which arises mostly from the varying increased traffic of CHs. Some ways have been developed in the previous few years to improve the energy utilization of nodes, including node placement approaches, broadcast distance management, and the addition of relays. Only a limited amount of energy is saved by any of the preceding methods. Furthermore, in this form of operation, CHs must cache all incoming packets of data and wait for the arrival of the mobility BS to their position, which adds memory consumption to the process. There are, nevertheless, no established techniques for reducing the energy fluctuation of nodes to a minimum.

The main contribution of this research is to handle the communication efficiently in WSN through a clustering based concept. In cluster-based routing, the CHs consume more energy than the other nodes. If the CHs exhaust their energy, the routing path may be destroyed which threatens reliable transmission and reduces the PDR. However, the CH connected to a poor quality link creates additional retransmission and thereby leads to unnecessary energy consumption. The proposed DRAC protocol establishes a reliable and persistent cluster-based routing path through an efficient selection of the CHs, and GW nodes in the cluster-based WSN. Hence, there is a constraint in the designing of a cluster-based routing protocol that can provide a reliable and persistent routing path for WSNs.

Hence, the design goals of the proposed DRAC protocol are:

i. To design a dynamic route aware clustering mechanism to achieve a reliable and persistent routing path for cluster-based WSNs through a dynamic selection of the CHs and GW nodes using a novel clustering metric PI.
ii. To maximize the PDR and minimize the end-to-end delay through an efficient selection of the CH and the GW node.
iii. To minimize the energy consumption and maximize the lifetime of the network by reducing additional retransmitting messages through a dynamic selection of the shortest path from the source to the sink.
iv. To develop a priority assignment algorithm that can select the CHs or the GW nodes and analyze the performance of the proposed protocol in terms of Residual-Energy, lifetime, PDR, energy-efficiency, and end-to-end delay in the WSN.

The remaining sections of this research article are organized in the following sections: Section 2 discusses some recent articles related to the problem of handling energy-efficiency in WSN, Section 3 details the proposed methodologies module by module also with crisp details of an existing method, and Section 4 shows the results and comparison obtained for both existing and proposed methods with different parameters and finally, Section 5 concludes this research article.

Related Works

To combat the excessive consumption of energy of CHs, an "Energy-Efficient Multi-Hop" routing technique relying on "Grid-Clustering" was proposed by the authors in [10]. Using this approach, the election of functioning nodes is optimized by integrating characteristics including the available power of nodes, their position, and the ranges of the communication range in an attempt to reduce the consumption of energy. The "Multi-Hop" routing is used to reduce the burden of CH nodes by using communicating nodes to choose the CHs and send packets of data across clusters.

A routing strategy that uses a combination of "Sink-Mobility" and the "Clustering" is described by the authors in [11]. A weighting is allocated for every node in this system, which is based on the energy available and the distance between nodes, and the highest-weighted node within every cluster is picked as the CH. Additionally, to link the clusters together, the greedy method is employed to build an appropriate chain of CHs.

By considering "Residual-Energy", "Buffer-Size", and obtained "Signal-Strength" parameters for CH selection were considered by the authors in [12], hope to reduce or eliminate the consumption of the energy by CHs. Consideration of these factors improves the energy efficiency of CHs and extends the lifespan of the network, as shown by the numerical simulations.

The lower distance among both CHs and BS allows for lower consumption of energy by CHs is achieved through the "Energy Efficient Multi-hop Cluster-head Election technique (EEMCE)" by the authors in [13]. As a result, researchers evaluate the distance connecting nodes and the BS when making the selection of the next CH. Every cluster would choose a preliminary CH and compare its available energy to those of other nodes in almost the local cluster. Eventually, the CH would be selected according to whatever node has the most amount of Residual-Energy. In addition, the CHs located at the network's edges would use multi-hop data transfer methods to save energy.

It is suggested in [14] by the authors that an "Enhanced-Energy Optimization Routing Protocol (EEORP)" be implemented in favor of CHs and also the network to save energy. According to EEORP, a "Grid-based CH" selection method is described that takes into account both the energy weights and the declared ordering weights. To reduce energy usage in "Inter-Cluster" transferring data, authors incorporate the "Hop-Count Gradients-Vector" and "Grid-Range".

Methodologies

In DRAC protocol, a novel clustering metric Priority-Index (PI) is used to select the CHs and GW nodes dynamically. In this scheme, the selection of CHs and nodes depends on priority derived using PI to evaluate the eligibility for a CH and GW node. The sensor nodes having the highest priority are selected as the CH and GW node. DRAC consists of three phases, namely, CHand GW node selection, priority calculation, and function of DRAC using the state transition mechanism.

ADEM "Advanced Dynamic Energy Monitoring" (EXISTING MODEL)

In this ADEM protocol, energy-efficiency is achieved through an efficient selection of the CH-node and the GW-node also with the shorter path from the source-node to the BS or sink-node [15]. This ADEM is accomplished with the following phases, such as the Setup-Phase and the Steady State-Phase to enable the achievement of an efficient routing. In the Setup-Phase, the clustering was constructed using the Cluster-Members (CMs), the CHs, and GW nodes, and the shortest routing path is determined. In the Steady State-Phase, the information is collected from the CMs and routed to the sink through the CH and GW nodes. The protocol assumes all the SNs and the BS or sink as stationary, with the sink originating distant away from the field of sense, all the SNs' energy levels are equal and they have a unique ID. All the SNs are equipped with a GPS device to measure their geographical position, the SNs are capable of performing in the inactive-mode and the sleeping-mode. All the SNs have the same fixed energy and rate, and each round consists of a complete cycle for forming clusters, selecting the CH, and the GW node, and sending the data to the sink.

DRAC "Dynamic Route Aware Clustering" (PROPOSED MODEL)

Cluster Head and Gateway Node Selection Mechanism

The main challenge of the clustering mechanism is to select appropriate nodes to act as the CH and GW nodes. In DRAC protocol, the CHand GW node selection procedure depends on PI metric and is determined by those parameters, which include the Residual-Energy of the node, the path condition called link status (transmission and reception count), and the angle between the node and the sink. Initially, each node calculates the "q_{ij}" which determines its chances of being a CH or GW node. Therefore, to derive PI, "q_{ij}" is calculated.

$$q_{ij} = \frac{E_{resi}}{ETRX_{ij} \cdot E^{tx}(n, d_{ij})} \times \cos \beta_j$$

Eq→1

$$ETRX_{ij} = \frac{1}{P_{ijf} \cdot P_{ijr}}$$

Eq→2

Where "E_{resi}" is the Residual-Energy, "d_{ij}" is the distance between the nodes 'i' and 'j', and "$E^{tx}(n,d_{ij})$" is the consumption of the energy to transmit and receive "nbit" message over a distance "d_{ij}", "$ETRX_{ij}$" is the expected transmission and reception count, "$\cos \beta_j$" is the angle between the CH, j^{th} node and the sink." P_{ijf}" is the Forward-Delivery-Ratio and "P_{ijr}" is the Reverse-Delivery-Ratio.

Priority Calculations for DRAC

DRAC protocol evaluates the suitable CH and GW node candidates for routing the data packets from the source node to the sink. The node whose transmission and reception counts are high is given the highest priority. The node which contains the highest priority value is elected as the CH or GWnode respectively. DRAC assumes the sensor nodes as stationary with the ability to communicate at equal range with a unique identifier and all the sensor devices are equipped with GPS devices. The flowchart for the priority calculation mechanism of the DRAC protocol is shown in Figure 1. The CH candidates andGW node candidates perform the following steps for determining their priority.

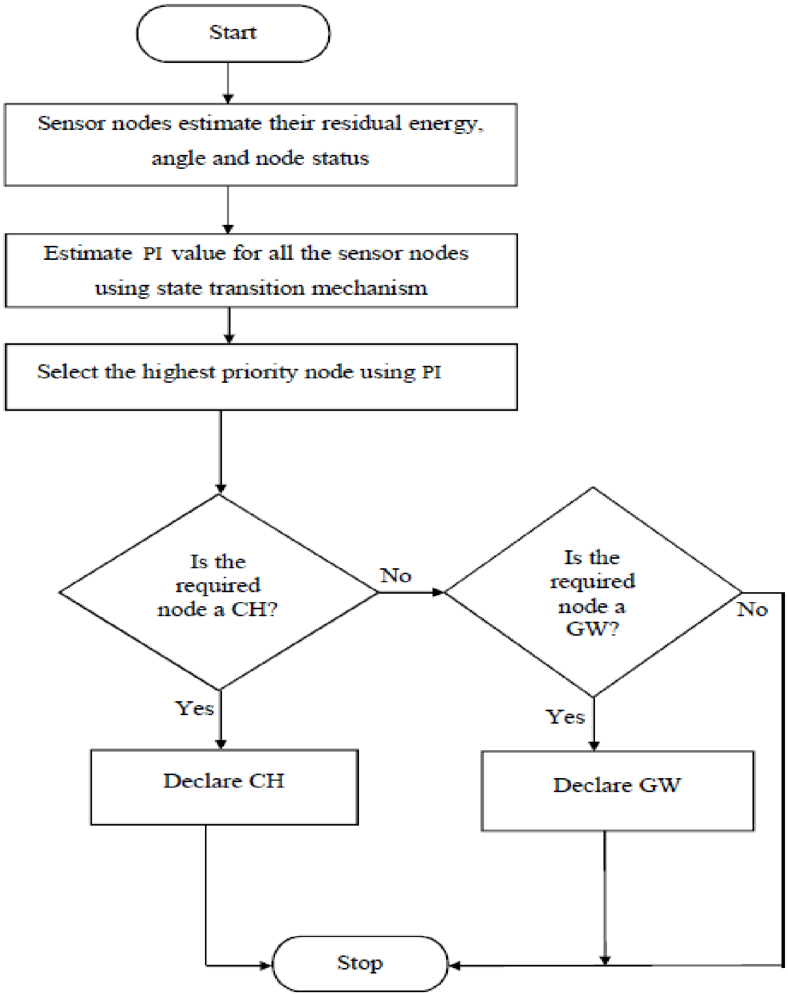

Figure 1. Flowchart for priority calculation mechanism

Step 1: All the sensor nodes are deployed randomly in the specified area.
Step 2: The sensor nodes estimate their residual energy, link status, and the angle between the node and the sink to select the CHs and GW nodes.
Step 3: The CH selection or GW node selection procedure is initiated and the PI value for the CH candidate or GW node candidate is estimated.
Step 4: A candidate which derives a higher PI value is declared as the highest priority node.
Step 5: The highest priority node is selected as the CH or GW node depending on the network requirement.

DRAC Operation

DRAC protocol achieves a reliable and persistent routing path through a dynamic selection of the CHs and GW nodes using a novel clustering metric PI. It uses the cluster state transition mechanism for the dynamic selection of the CHs and GW nodes. In this mechanism, all the nodes have an external cluster state and the CH and GW nodes are the key participants. The cluster state transition mechanism depends mainly on six cluster state transition conditions, namely, IN (in state), ORD (ordinary state), CH_RY (cluster head ready state), GW_RY (gateway ready state), CH (cluster head state), and GW(gateway state). The cluster state transition mechanism using PI is shown in figure 2.

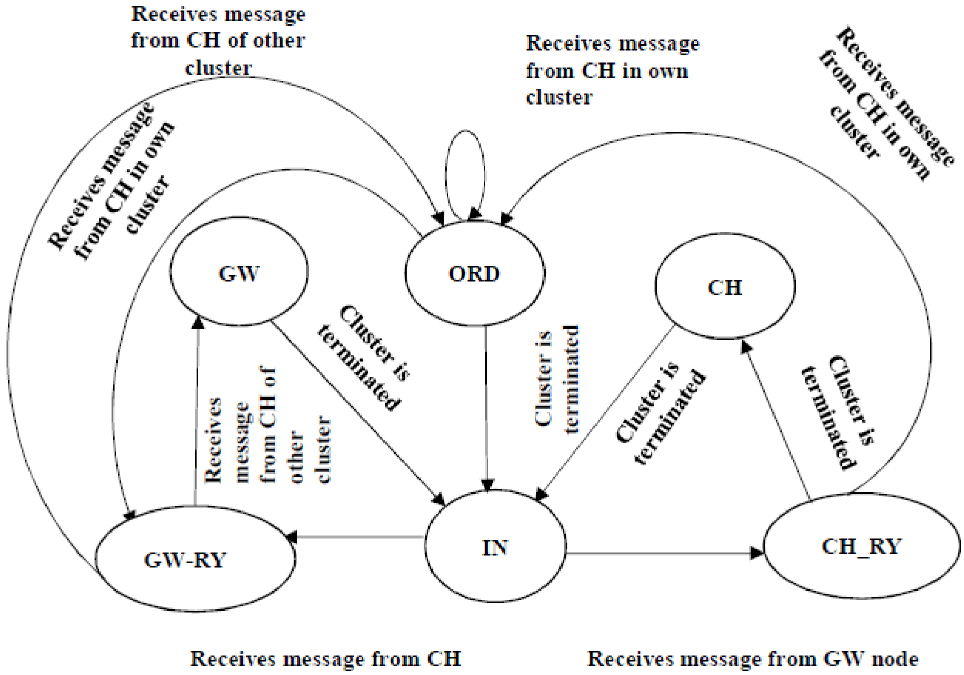

Figure 2. Cluster state transition mechanism using PI

Initially, all the nodes are in the IN state. While sending the information to the sink, the source node transits from the IN to the CH_RYor GW_RY state depending on the message received from the CH or the GWstate. The eligible sensor nodes in the CH_RY and GW_RY states compute PI values. The highest priority node is selected as the CH or GW node.PI selects an efficient CH or GW node with good link quality.

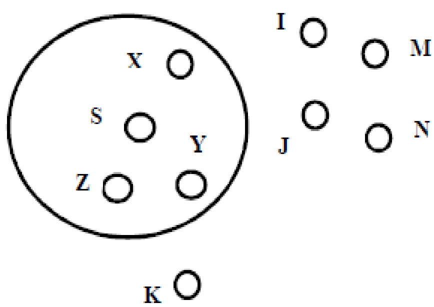

Figure 3(a). Cluster state transition mechanism using PI Example (a)

Figure 3 shows an example of the DRAC protocol function with a cluster state transition mechanism using PI. Consider node 'S' as the source node and 'N'as the destination node called a sink. All the sensor nodes in the specified area are deployed randomly, and initially, all the sensor nodes are in the IN state, as shown in Figure 3 (a).

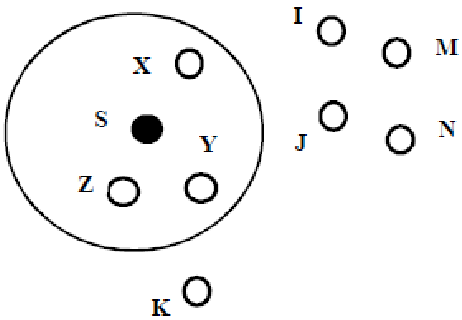

Figure 3(b). Cluster state transition mechanism using PI Example (b)

When node S initiates sending the message to N, it checks the cluster state of all the neighbor nodes in the cluster. Node S becomes the CH node due to the absence of neighbor nodes, as shown in figure 3 (b).

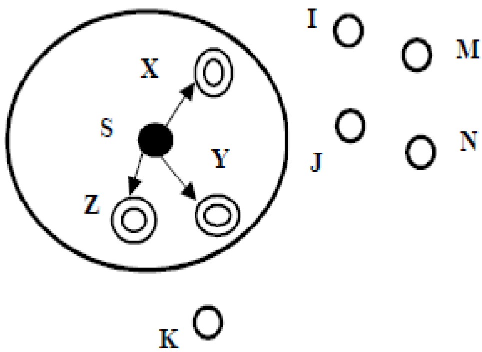

Figure 3(c). Cluster state transition mechanism using PI Example (c)

Node S sends the message to its neighbor to find out the GWnode. The nodes X, Y, and Z are in the IN state, receive the message from node S, and become the GW_RY state. All the nodes perform PI estimation to become a GW node as in Figure 3 (c).

Node X has no GWneighbors, so it successfully becomes a GW node and starts communicating to the source node S. This leads to the understanding that the proposed DRAC determines only one node as the GW node. If more than one node is in theGW_RY state within the communication ranges (e.g., nodes Z and Y), DRAC performs the priority algorithm as shown in Figure 3 (d).

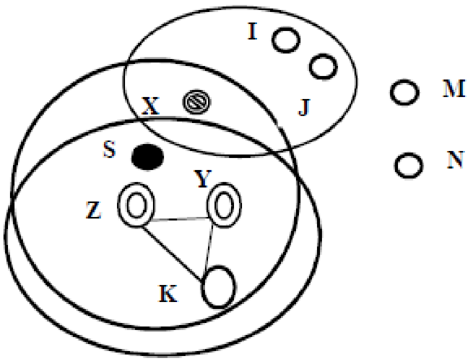

Figure 3(d). Cluster state transition mechanism using PI Example (d)

For example if P_y =7 and if P_z =6, node Y becomes a GW node because $P_y > P_z$ as shown in Figure 3.3 (e), then node Z immediately goes into the ORD state. Now cluster one is formed and the two GW nodes (nodes X and Y) send the message.

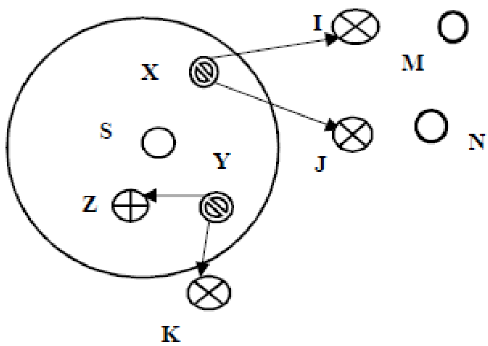

Figure 3(e). Cluster state transition mechanism using PI Example (e)

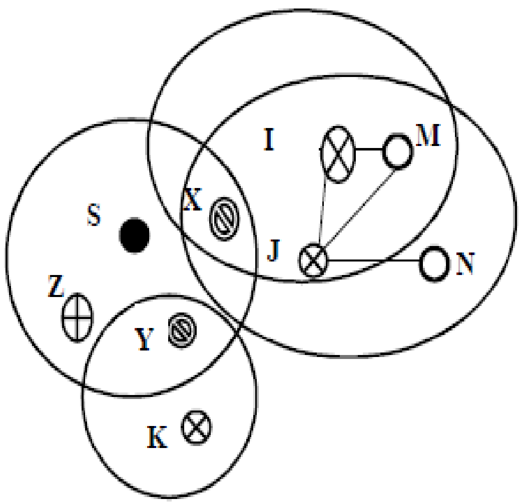

Figure 3(f). Cluster state transition mechanism using PI Example (f)

On receiving the message from node X, nodes I and J enter the CH_RY state. Similarly, node K enters the CH_RY state on receiving the message from node Y. Node Z goes into the ORD state because there are no CH neighbors as shown in Figure 3.3 (f).

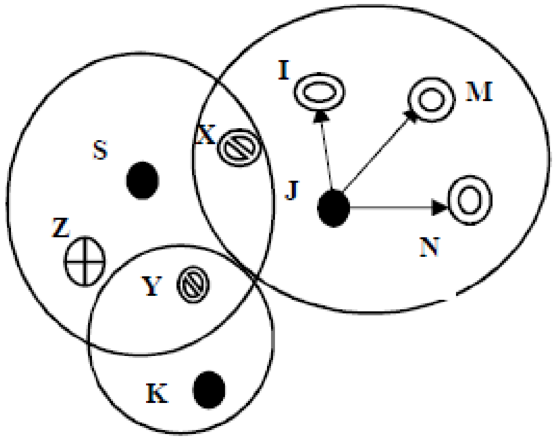

Figure 3(g). Cluster state transition mechanism using PI Example (g)

The node K becomes the CH node because it has no neighbors, hence cluster two is formed. The nodes I and J compete with each other to become a CH for example if P_I= 6 and if P_J = 7, then node P_J>P_I, so node J successfully becomes the CH as shown in Figure 3.3 (g), When nodes I, M and N receive the message from node J, they become the GW_RY nodes.

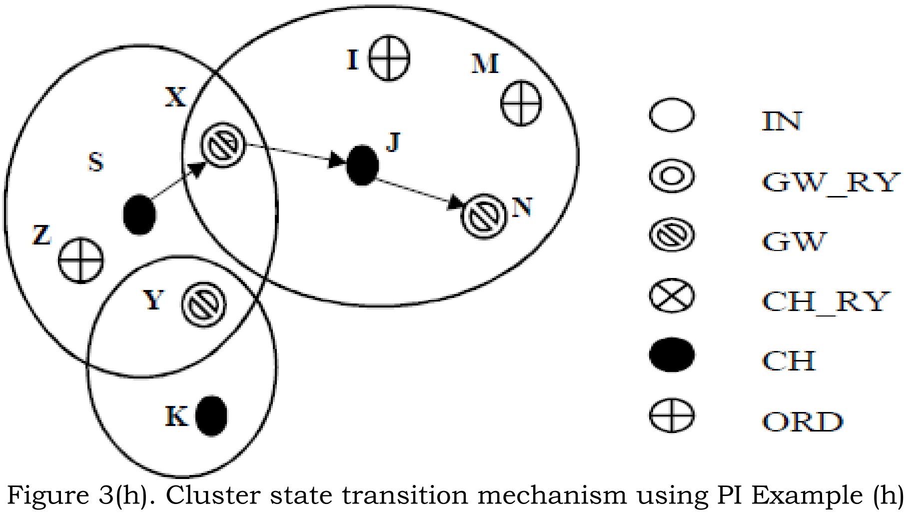

Figure 3(h). Cluster state transition mechanism using PI Example (h)

Node N is the sink, so it should be given the highest priority compared with nodes I and M, and cluster three is formed. The nodes I and M immediately go into the ORD state due to the absence of CH neighbors as shown in Figure 3.3 (h). From this example, it is clear that DRAC forms the cluster structure including three clusters, CHs, and GW nodes and determines a dynamic routing path from the source node to the sink. Thus, DRAC efficiently minimizes the number of explicit control packets using the state transition mechanism thereby reducing the additional retransmission messages in the network.

Algorithm for Cluster State Transition Mechanism using PI

The algorithm for the cluster state transition mechanism is discussed below.

Step 1: Sensor nodes are randomly deployed in a specified area and form the network.

Step 2: Each round uses six cluster state transition conditions, such as IN(in state), ORD (ordinary state), CH_RY (cluster head ready state), GW_RY (gateway ready state), CH (cluster head state), and GW(gateway state).

Step 3: A sensor node receives a message depending on its current state and changes its current state depending on the sender message.

Step 4: Sensor nodes change their state to IN state.

Step 5: Source node S initiates communication to sink N and checks the node state of all neighbors in the cluster.

Step 6: Node S starts searching the neighbor nodes to select the CH or GWnode.

Step 7: If more than one node is eligible to become the CH and GW node those nodes change their state to the CH_RY and GW_RY states respectively.

Step 8: PI is calculated for all the sensor nodes, and the node with the highest priority is selected as the CH or GW node.

Step 9: After selecting the CH the clusters are formed and the GW nodes are identified. The remaining nodes inside the cluster again go into the ORD state.

Step 10: The GW node starts searching for the sink. If the sink is available, the state terminates otherwise again it starts searching the CH.

Step 11: Thus, a reliable and persistent routing path is selected from the source node to the destination node through a dynamic selection of the CHs and GW nodes.

The flowchart to describe the CH selection and routing using the state transition mechanism is shown in Figure 4. The flowchart to describe GW node selection and routing using the state transition mechanism is shown in Figure 5. The routing table for DRAC is created using the state transition mechanism with PI value. It contains six fields, such as eligible GW_RY nodes, PTRC value, selected GW node, eligible CH_RY nodes, PI value, and selected CH as shown in Table 1.

Table 1.
DRAC Routing Table

Eligible GW_RY Nodes	PI Value	Selected GW Node	Eligible CH_RY Nodes	PI Value	Selected CH
X	No neighbor nodes	X	S	Source node	S
Z	6	Y	I	6	J
Y	7		J	7	

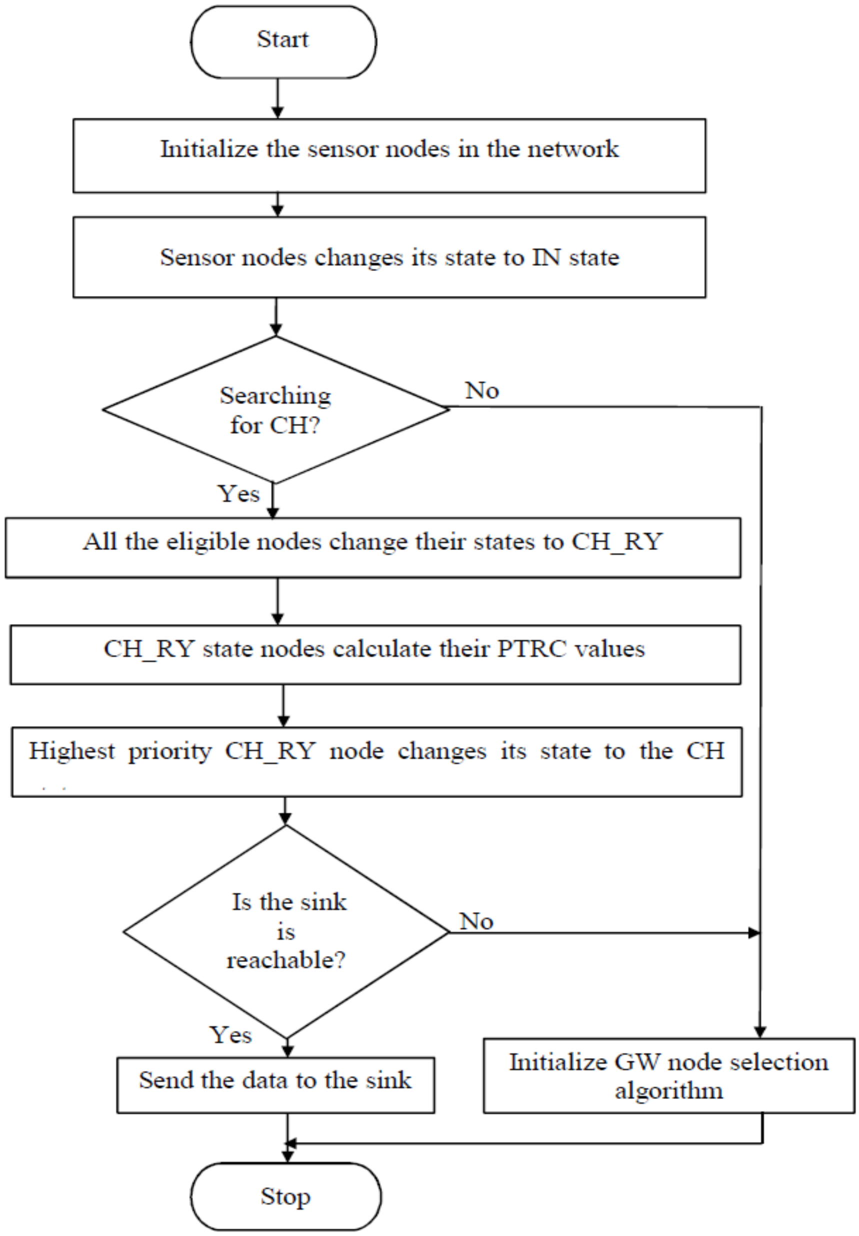

Figure 4. Flowchart for CH selection and routing using state transition mechanism

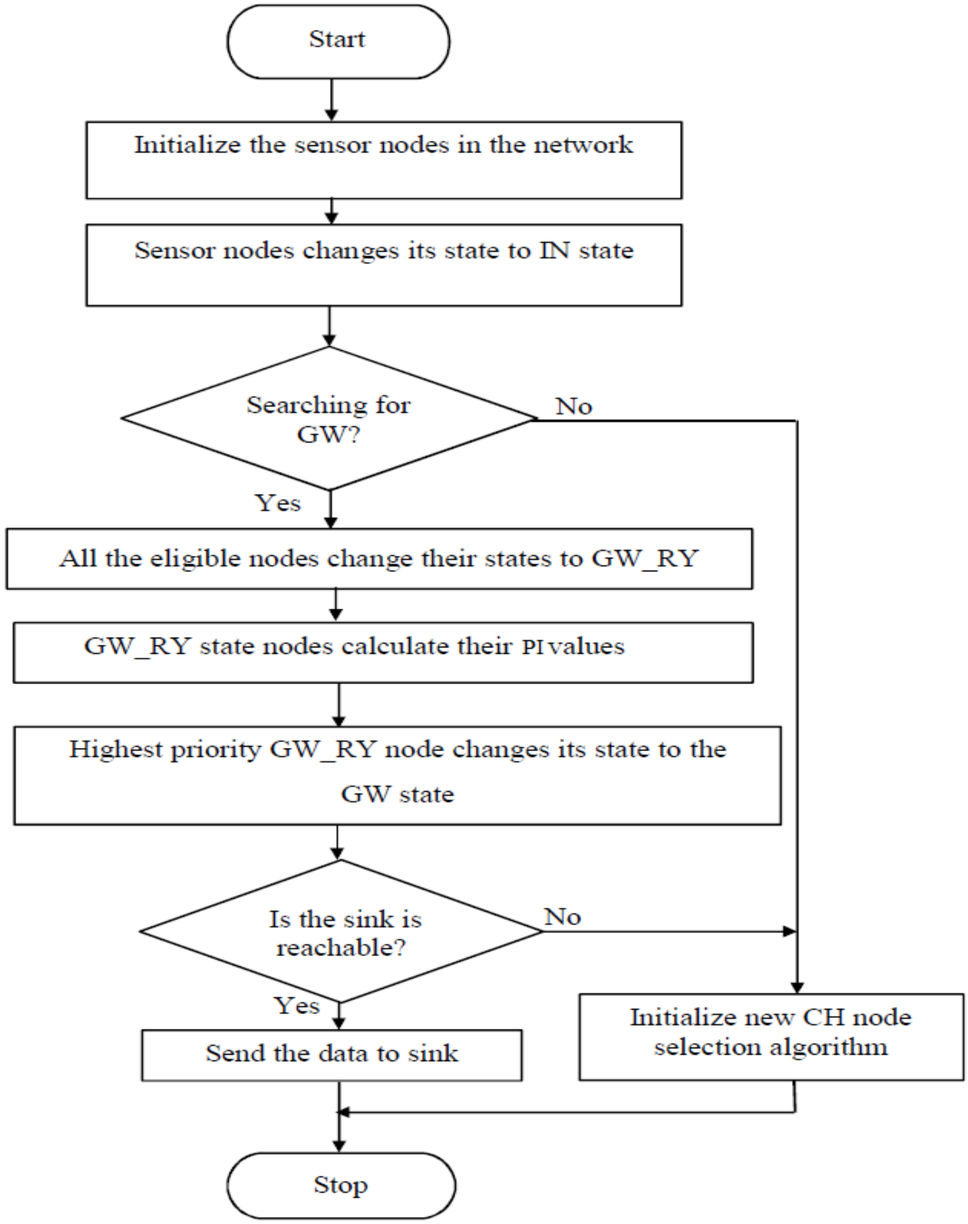

Figure 5. Flowchart for the GW node selection and routing using state transition mechanism

Results and Discussions

The Ns2 simulator was used to test the proposed routing algorithm in which the battery module was utilized to build the sensor nodes. The nodes are interactive and are periodically woken by a message from the individual CH. The sink node is separated from the source nodes at the closest location. The higher-energy nodes will send a message and the other nodes will respond. Following the feedback from the neighboring nodes, the higher-energy nodes are set as the CH. Thus, the node is allocated an id and therefore the target node is set for packet transmission. For simulation, the route will be built using a suggested routing algorithm and path loss model. We have compared here with the existing ADEM protocol with this proposed DRAC protocol.

Energy Efficiency

The percentage of the total transmission generated with the total energy consumed is termed energy efficiency. If further data are transferred efficiently over a specified volume of energy consumption, there will be a solution for energy efficiency increases. A wider term for energy efficiency is also termed "The use of less electricity to deliver the same function may be defined as energy efficiency". In these contexts, energy efficiency is considered a device that provides a higher precision of event detection with the same amount of energy consumption. Table 2 and Figure 6 demonstrated energy efficiency results using ADEM and DRAC. Here the DRAC in transmission with various packet sizes in the WSN gives better energy efficiency.

Table 2
Energy Efficiency

Packet Size (Bytes)	ADEM	DRAC
20	96.43	98.57
40	92.32	94.48
60	88.78	90.89
80	84.12	86.34
100	80.12	82.34

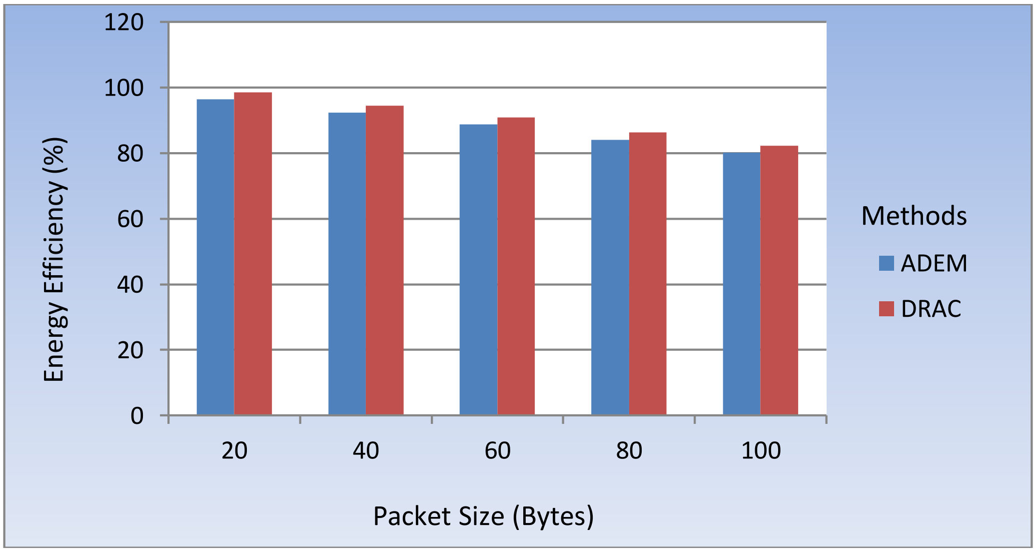

Figure 6. Energy Efficiency

Packet Delivery Ratio (PDR)

The PDR is the ratio of the number of packets sent to the destination successfully, to the sum of packets sent from the source. This metric demonstrates how a protocol should send packets to the respective destination. The high transmission ratio thus suggests improved efficiency of the protocol. Table 3 and Figure 7 demonstrated PDR output using ADEM and DRAC. When comparing ADEM with a DRAC by various packet sizes, the proposed DRAC gives a better PDR.

Table 3
Packet Delivery Ratio

Packet Size (Bytes)	ADEM	DRAC
20	97.23	98.45
40	96.12	97.48
60	95.34	96.14
80	94.32	95.52
100	93.12	94.22

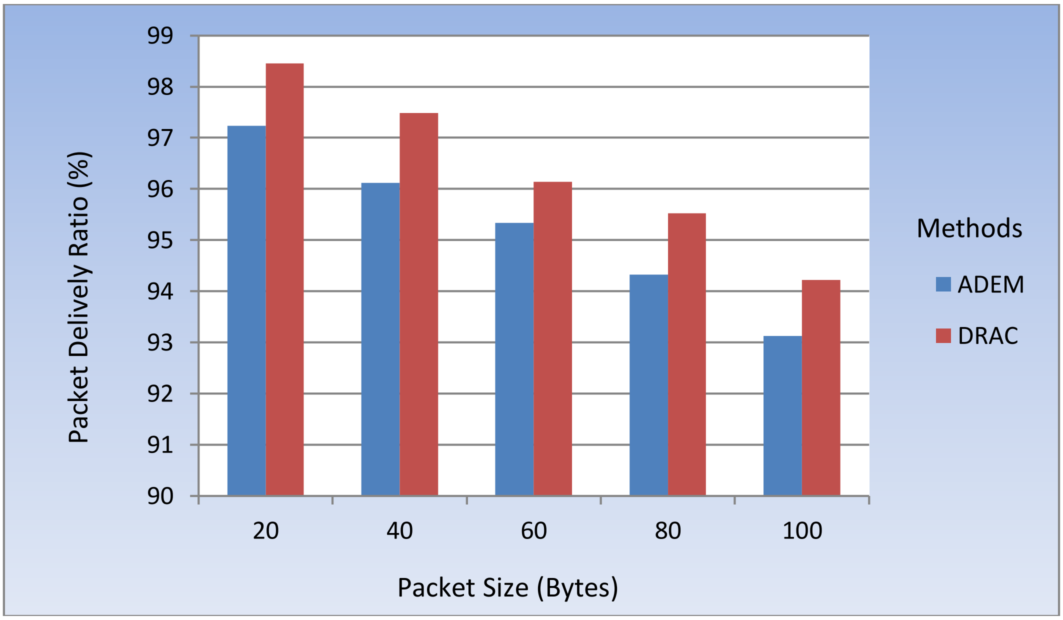

Figure 7. Packet Delivery Ratio

Throughput

The throughput is also an important criterion for energy efficiency. The number of data units transmitted in a given time frame is indicated as a Throughput. This function allows us to measure accurately the volume of information transmitted. By considering the threshold levels in sensor nodes, the CH can be rotated to increase the performance and that helps to reduce the packet loss. Table 4 and Figure 8 give the level of throughput of ADEM and DRAC with various transmission rates. When comparing the proposed DRAC provides a better throughput rate under any circumstance.

Table 4
Throughput

Transfer Rate (Kbps)	ADEM	DRAC
100	97.12	98.32
200	95.53	96.73
300	93.12	94.22
400	91.23	92.53
500	89.12	90.72

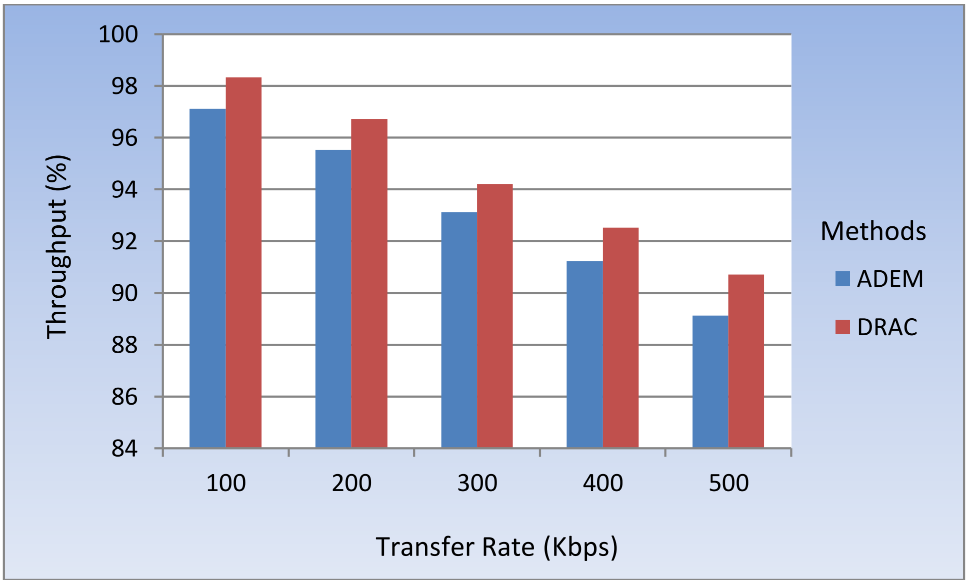

Figure 8. Throughput

Routing Overhead

Many nodes are interested in sending the packets from source to destination as node density grows. Thus, overhead routing grows as well. A path from source to destination is either influenced by an increase in node speed or by a delay. Once again, the construction of paths or path exploration must be begun to tackle the overhead routing. A large number of packet controls are needed in the protocol to retain the area size, pick the boundary nodes and modify the behavior. The routing overhead also increases with increased node capacity. Table 5 and Figure 9 show the efficiency of overhead routing with anADEM and DRAC. Here the proposed DRAC demonstrates low overhead routing while it is compared to ADEM for different node sizes.

Table 5
Routing Overhead

Number of Nodes	ADEM	DRAC
200	5.12	3.42
400	8.34	6.14
600	14.21	12.41
800	23.12	21.42
1000	32.56	31.66

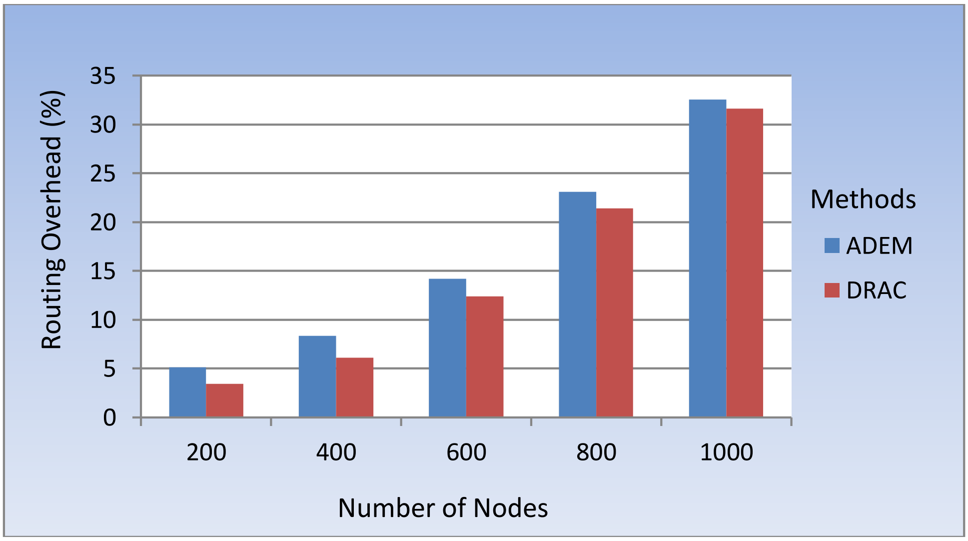

Figure 9. Routing Overhead

Conclusion

In this research paper, a new efficient cluster-based routing protocol for WSN called DRAC has been proposed. This makes a dynamic selection of the CHs, GW nodes, and the shortest path using a novel clustering metric PI, which selects the CHs and GW nodes using parameters, namely, the residual energy, link status, and angle between the node and the sink using the cluster state transition mechanism. This mechanism depends mainly on six cluster state transition conditions, namely, IN (in state), ORD (ordinary state), CH_RY (cluster head ready state), GW_RY (gateway ready state), CH (cluster head state), and GW (gateway state). The DRAC protocol efficiently minimizes the number of explicit control packets using the state transition mechanism. Thus, DRAC minimizes the energy consumption of the sensor nodes in the network. The simulation results of DRAC are implemented using NS2 that accomplishes in comparison to the ADEM protocol, the DRAC delivers better Energy-Efficiency, PDR, and Throughput, as well as reduced Routing-Overhead. We hope to analyze network lifespan assessment through advanced bio-inspiring routing protocols in the future.

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