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Bi-Communication Energy Efficient Routing Protocol (Bi-CEERP) For Wireless Sensor Networks

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Abstract: *Wireless Sensor Network (WSN) consist of several sensor nodes capable of sensing physical phenomena of its immediate environment. Sensor nodes can be distributed randomly or located in fixed place, either in a large or small geographical area. WSN communicate and transmit data with each other wirelessly, its application areas include medical, military, security, home automation, etc. The power consumption, communication technology and distance between sensor nodes have great impact on the network performance. However, energy consumption is one of the most common challenges of WSN as it affects the lifetime of the entire network. Each sensor node in the network is battery powered, thus, a well-designed WSN that effectively utilizes the energy consumption is required. This research work is aimed at introducing a novel routing protocol called, Bi Communication Energy Efficient Routing Protocol (Bi-CEERP) for Wireless Sensor Networks to optimize the energy consumption and enhance network lifetime in WSN using clustering techniques and Bi communication. This is achieved by reducing the amount of data communication and decreasing the communication distance between nodes. The simulation experiment is carried out using network simulator produce in NS3. From the result it indicated that the proposed scheme gives better performance in terms of energy dissipation and network lifetime as compared to Low-Energy Adaptive Clustering Hierarchy (LEACH). It is hoped that this scheme will help improve energy efficiency in sensor node and impact significantly in WSN.*

Keyword: *Wireless Sensor Network; Routing Protocol; Base Station; Multi-hop and single-hop Communication;*

1. INTRODUCTION

Wireless Sensor Network (WSN) consists of numbers of low-cost battery powered Sensor Nodes (SN) working together for the purpose of monitoring, capturing, and transmitting information wirelessly over a short distance within their immediate environment. In WSNs, processed data received in analogue form about the environment and converted into electronic signals which are transmitted in form of radio wave to a Base Station (BS) called sink. The base station can either be fixed or mobile node that wirelessly connect the sensor nodes to the Internet or satellite, where transmitted data can be accessed by users. The life span of WSNs can be prolonged by reducing energy consumption in the network which is one of primary objectives for designing effective WSNs routing protocol.

WSNs are applicable in various areas such as precision agriculture, preventive maintenance, traffic control, environmental monitoring, object tracking, surveillance, fire detection, home automation, medical diagnosis, etc. Despite all the advantages that the application of WSN offers, sensor network has several constraints such as energy limitation, storage capacity, processing capability, and limited bandwidth. To address some of these limitations, researchers are working on the nodes design, security and communication protocols. Hence, the design of effective and scalable routing protocol is a crucial aspect to prolong the lifetime and increase the performance of WSNs.

In WSNs, communication can be by multi-hop or single hop technique. It is a single hop technique when the base station is close to the nodes and communicate directly to each other. While in multi hop technique some nodes (aggregation nodes) act as a relay agent

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for retransmitting data received from other nodes to the base station. Figure 1. shows single and multi- hop communication.

Network sustainability in WSN depends mainly on energy resource. However, sensor nodes are battery power which are limited and energy is consumed during sensing, processing and communication with other nodes Mohaned, et al [12]. To improve the performance of the network, a great number of energy efficient routing protocol have been proposed for WSN by researchers, some includes, [17] [18]. However, more work still needed to be done in order to improve the performance of the existing routing protocol in terms of energy efficiency, load balance, delay and reliable data delivery.

This paper is divided into Five sections. Section I is the Introduction, section II is the Related work, section III is the Proposed Algorithm Section IV is the Result analysis and Section V is the Conclusion and future work.

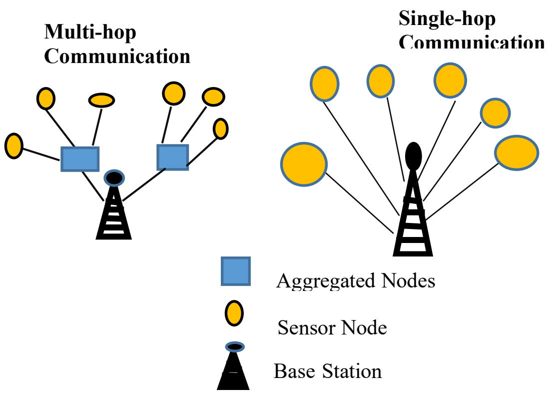

Figure 1. Multi-hop and single-hop Communication

1.1 Applications

With applications in the entertainment, travel, retail industry, disaster and emergency management, wireless sensor network technology has the potential to alter the way we work, live, and conduct business. It creates a more alluring way to keep track of environmental conditions and close the gap between the real world and the virtual one. WSNs have a variety of uses, such as geophysical monitoring (seismic activity), precision agriculture (soil management), habitat monitoring (tracking animal herds), transportation (traffic monitoring), military systems, and commercial processes (supply chain management) [1,10]. Wireless Sensor Networks (WSNs) have played and will continue to play a significant role in our daily lives thanks to advancements in Micro-Electro-Mechanical Systems (MEMS). Wired sensors have been used by humans for many years, from simple activities like monitoring temperature to complex tasks like monitoring vital signs in hospital patients. In this new area of design, wireless sensor networks offer unanticipated applications [2]. There are countless applications, ranging from military ones like target surveillance and battlefield mapping to building context-aware houses where sensors can keep an eye on security and offer automated services catered to each user individually [13]. One example of such a program is Smart Dust [28,7]. But this new technology raises a lot of design challenges [17] that, until recently, were not thought to be possible for these uses. A number of applications that call for ongoing monitoring and the detection of particular events use sensor networks. The military uses surveillance and monitoring on the battlefield, intelligent missile guidance systems, and the detection of attacks using weapons of mass destruction like chemical, biological, or nuclear weapons [19].

The WSNs are used for environmental applications, such as animal habitat exploration and the detection of floods and forest fires [24]. Sensors are incredibly helpful for patient monitoring and diagnosis. Biosensors are inserted into patients' bodies to track physiological variables including heart rate and blood pressure. The information gathered in this way is sent on a regular basis to notify the concerned doctor when an anomaly is found. Instead of being restricted to a hospital bed all the time, such a setup allows patients more flexibility of movement. Biosensors have become so sophisticated because to rapid MEMS technology improvements that they can now accurately identify allergies and provide corresponding diagnoses [17, 21].

2. RELATED WORK

WSN has generated a lot of interest in research community in recent years and several energy efficient routing protocols/algorithms have been developed to enhance its network lifetime. In this section, the reviews of the related literatures are discussed. Priyankara et al

[14] Proposed a Hybrid Multi-Hop Routing Protocol which combine clustering and multi hop routing communication algorithm, where the node that is near the sink perform a multi-hop network and node that is far from the sink perform clusters to optimize energy consumption and prolong the network lifetime in WSNs. In contrast, it causes extra overhead in the network when the numbers of event increases.

A Mobility-Based Routing Algorithm was proposed by Kawecki and Schoeneich [8]. in their paper they presented a routing algorithm based on the use of mobility of the nodes in the delay and disruptive tolerant. They assumed that the greater mobility of node result in higher number of contacts with other nodes and higher probability in message delivery which will enhance delay and energy efficiency in WSN. The protocol performed well, however when using matric and mapping it acquired additional overhead in the network.

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In their work, Susila and Arputhavijayaseivi [27]. proposed Multipart Layer Node Deployment and Computational Techniques with Finest Cluster Head Selection for Network Lifetime Enhancement. In their approach, they used a homogenous merged layer node deployment system which has a threshold-based cluster head selection mechanism for clustering routing protocol of sensor networks. To optimize the energy consumption, they made use of multiple path and scheduling data transmission rate at each node to extend network lifetime, prevent congestion and increase reliability. Each node maintains two queues for incoming data and three queues are used in forwarding the data. All the node in the network act as scheduling unit and priority number is assigned to each of them, packet received by nodes are place in the appropriate queue which will later be selected based on priority number from the queue for transmission. The approach ensures high rate of reliability, thus, it does not provide a way to detect the failed node and the queuing process, which can cause delay in delivery of some packet.

A Multi-Hop Routing Algorithm for Wireless Sensor Network was proposed by Cisse [5]. In his scheme, he used a virtual backbone to improve the network lifetime and reduced the number of packets lost. The cluster head was selected based on residual energy and node degree which minimize energy consumption in sensor network. But the use of repeated advertisement causes flooding in the network.

Equally, Qiong and Rui [15]. Presented a Routing protocol for Wireless Sensor Networks Using K-means and Dijkstra Algorithm. In their technique, the sink node uses K-means clustering algorithm to divides sensor nodes into K-uniform clusters and assigned head of each cluster in the first round, then uses Dijkstra algorithm with head position to calculate the shortest path from every head to the sink node. The cluster heads election uses both residual energy level and Euclidean distance of node as criterion for selection of cluster head, when the cluster head energy get depleted, nodes that are closer to the cluster head and have maximum energy becomes the new cluster head. With this, load is balanced.

A Multi-Objective Optimization Algorithm Based on Sperm Fertilization Procedure Method for Solving Wireless Sensor Optimization Problem in Smart Grid Application was proposed by Shehadeh and Ramli [22]. The algorithm maximizes the probability of target detection to minimize dissipation of energy in the network. However, since the number of sensors deployed are minimized, the algorithm will only be suitable in a small network. In another work, Rasheed et al [17]. Presented an Energy-Efficient Mechanism Techniques to Eliminate Energy Holes. The authors achieved this using sleep and wake-up mechanism for nodes to retain energy. This approach finds the maximum distance of the nodes in order to calculate the maximum energy for data transmission. In this technique, the energy level of nodes is first check before data can be transmitted. However, as the mechanism dynamically maintains the traffic rate base on maximum energy but fails to consider the delivery rate and the buffer capacity of the active node in order to adjust and predict the delivery rate of the active path.

In another research, A Lightweight and Dependable Trust System for Clustered Wireless Sensor Networks was proposed by Li and Du [10] to minimize energy consumption and memory space in sensor network. It shows that higher throughput was achieved, though it failed to consider packet delay during data transfer.

An Eminent Routing Protocol to Truncate the Energy Expenditure in Wireless Sensor Networks was proposed by Gnanambigai and Rengarajan [6] The proposed model works towards reducing the number of participating nodes and routing overhead to claim energy efficiency in sensor networks, which in turns prolong the network lifetime by forwarding data to sink with limited energy. The technique is used to anticipate energy delay index to improve network lifetime. However, it did not consider the delay in data transmission.

A Novel Scheme for Energy Efficient Internet of Thing Based on Wireless Sensor Network was proposed by Rani [16] In their approach, they used multi-hop data aggregation techniques by forming coordination in hierarchical clustering to reduce transmission distance. Simulation result shows that the algorithm performed very well in terms of energy optimization and delivery time. Thus, do not take account of packet loss as a result of buffer overflow as only one mobile sink is in charge and takes the responsibilities of data collection in the network.

An Aware Diffusion Semi-Holistic Routing Protocol Routing Protocol for Wireless Sensor Networks was developed by Samara and Hosseini [20] He uses a non- incremental machine learning techniques to give preference to healthier and shorter path for less energy consumption. In this technique, packets are classified as critical, urgent, and normal and different priorities and resource are assigned to them, paths are chosen using mathematical formula based on merit criteria. The protocol is inefficient in the sense that it allocates resources based on how the packet are classified. This classification causes in balance in the network. The protocol also gives preference to shorter path which will lead to drain of energy along the path quickly and later affect the network lifetime.

Similarly, Sukhwinder [26] Presented an Energy-Efficient Data Collection Techniques in Wireless Sensor Networks. In their scheme, multipath routing is design to improve the lifetime, latency and reliability of WSNs by discovering multi paths between source and base station. In this technique, more than one routing path is available to transmit data, hence, if one path fails an alternative path will be used for data

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transmission. Energy is conserved by switching into sleep mode when sensor node is not involved in routing path. In the contrast, the latency of data delivery will be increase.

Improving Energy-Efficiency for Wireless Sensor Networks was developed by Cengiz and Dag [4]. In his approach, clusters are formed during set up phase, and the nodes are to stay in the same cluster during the entire network operations. With these techniques, energy dissipation is decrease significantly and the lifetime of the network is prolonged. However, forming clusters during setup phase may hinder other nodes in the joining process which will limit data transmission by such nodes.

Another protocol called Threshold Based toward Energy Efficient Big Data Gathering in Wireless Sensor Network was developed by Sujithra and Venkatesan [25]. Using transceiver scheduling to increase the lifetime of sensor network. In their techniques, they classified cluster members as active and passive cluster member based on the threshold. The idea is to reduce data gathering latency by limiting the amount of data to be transmitted, which in turns reduce the energy consumption and prolong the network lifetime. However, it failed to consider the fact that, if the amount of data transmitted is reduced it will affect the efficiency of the network in terms of data delivery. Furthermore, Rashid et al [8]. proposed an Improving Energy Conservation algorithm in Wireless Sensor Networks using Energy Harvesting System. In this approach, sensor nodes are divided into member nodes and cluster heads. Member nodes sense data and transmit to cluster head, while cluster head perform data aggregation of all received data and transmit it to base station. Thus, the hierarchy increased topology management overhead.

A Novel Energy Efficient Routing Protocol EACBM for Scalable Wireless Sensor Networks was developed by Singh and Jain, [23]. It uses the principle of clustering and multi hop transmission for transmitting data to base station to minimize energy consumption in sensor node. The concept of sub clustering to suppress those areas of sensor nodes where cluster head cannot access data due to the distance was adopted. However, the protocol could not effectively perform in a dense network as sensor node will be affected by network size.

The literature reviewed revealed that several energy efficient routing algorithms have been proposed in recent years and found that, the existing routing protocol are still facing energy efficiency limitation issues. In order to improve in the existing algorithm, we therefore, proposed Bi-communication routing techniques using both mobile and static sink with concept of clustering algorithm, to optimize energy consumption and extend network lifetime in WSN.

3. PROPOSED ALGORITHM

Our proposed algorithm in this research work consists of the use of mobile and static sink to communicate with the Cluster Head (CH) called Bi- communication Energy Efficient Routing Protocol (Bi-CEERP). it comprises of multiple sensor nodes distributed across the network, divided into grid size within a limited field. However, each sensor node in the network possesses a fixed range of communication and communication can only be successful within the communication range (R). The static sink is stationary while the mobile sink is moving around the network to collect data from CH to reduce the energy consumption because of data transmission. Each sensor node is equipped storage resources that store sensed data and network information, before transmitting it to CH which in turn transmits it to either mobile or static sink nearer to it. The decision is made to prolong the network lifetime.

The entire network is divided into equal size grid and each grid contains a set of static sensor nodes, as shown in Figure 2a in each set, clusters are formed, and a Cluster Head (CH) is elected based on its residual energy, and each CH has a maximum communication range of 400 meters. The distributed sensor nodes are aware of their locations in the network by means of localization model. Hence, location information of mobile and static sink is also known. The mobile sink moves around within the network with a stop time to collect sense data from CH, while the static sink is stationed at the center of the network to collect and transmit information to the nearest CH and each CH must be connected to at least one sink the information sensed by individual nodes are transmitted to CH which in turn transmits to either the mobile or static sink nearer to it, as shown in Figure 4. Consequently, prolong the network lifetime. The scheme focuses on: Grid and cluster formation, election processes, data transmission, sink management and load balance.

3.1 Grid and Cluster Formation

The procedure for cluster formation includes CH election and joining process between the CH and its respective Cluster Member (CM). The formation of cluster is initiated within each grid as shown in Figure 2b and assumed that sensor nodes are aware of their locations in the network and at the initial stage, they all have equal energy. The sensor node at the center of each grid automatically became the CH and advertise itself, as shown in Figure 2c. Other cluster members transmit their information to the CH as shown in Figure 2d. A new CH is re-elected based on the residual energy of sensor nodes. Periodically, there is intra-cluster communication between CM and CH within each grid to ascertain the level of energy in the nodes.

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3.2 Election process

Cluster Heads are re-elected only when their residual energy decreases below the threshold of 15%. If the energy level of a CH is less than the threshold value, re-election process is initiated, and a new CH is elected. Consequently, the sensor nodes in each grid calculate their residual energy and compare it with that of other nodes. If a particular node residual energy is higher than the other nodes, the node is elected as CH in that grid. The elected node sends a broadcast message declaring itself as the new CH and each node replay with an acknowledgement and then starts transmitting its data to the new CH.

3.3 Assumptions

The following assumptions are considered for the proposed protocol:

i. Sensor nodes are all stationary after deployment

ii. The sensor nodes are uniformly distributed in the network field with random deployment

iii. Sensor nodes have the same capability (homogeneity) in data transmission

iv. Sensor nodes can calculate their residual energy and compare it with other existing ones

v. There are two sinks: one mobile and one static within the network

vi. Data is always available to be sent by sensor node

Pseudocode 1: ***Cluster head re-election procedures***

Input: *Residual energy of nodes in a cluster Erx, cluster head CH, threshold value TV, threshold value of cluster head TCH, cluster members CM. Energy percentage of cluster head Enper_ch. Node in cluster (i)*

Step 1 for node i = 1 TO N

Step 2 Calculate center node using K-Means Algorithm

if (node i=center) then node i = CH

Send message CH ⟶ CM

If received (ACK)

Else resend

Step3 CM transmit data to CH

Step 4 Initialize the minimum threshold value min= (Ei) of CH

Step 5 Compute threshold value

Max-min= (Ei)

Step 6 IF ((Energy level for CH) < (available threshold energy value)) then

CH start election process

Step 7 Compare CH to CM for Erx

Max_Erx = Mx(Ei)

Select node with Mx(Ei)

Node = CH

Step 8 CH send ⟶ msg as CM

Step 9 CM send ⟶ acknowledgement

Step10 CM transmit data to CH

Step11 go to step 6 and perform all operation continuously

End process

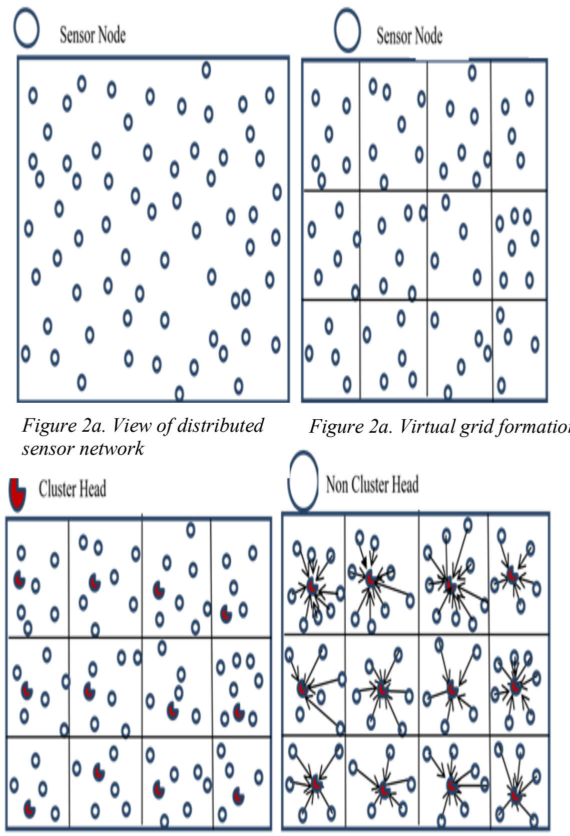

Figure 2a. View of distributed sensor network *Figure 2a. Virtual grid formation*

Figure 2c. Cluster head selection *Figure 2d. Joining process and cluster formation*

Figure 2. Data transmission and sink management

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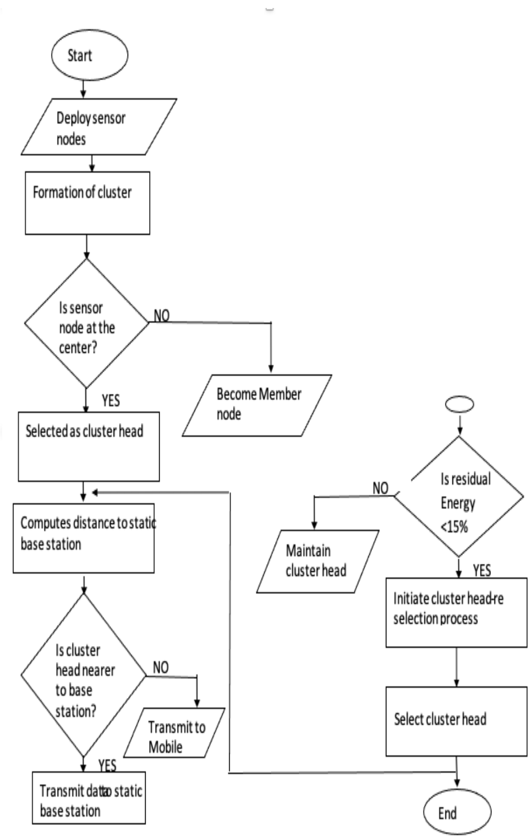

Figure 3. Flow chart for the proposed scheme

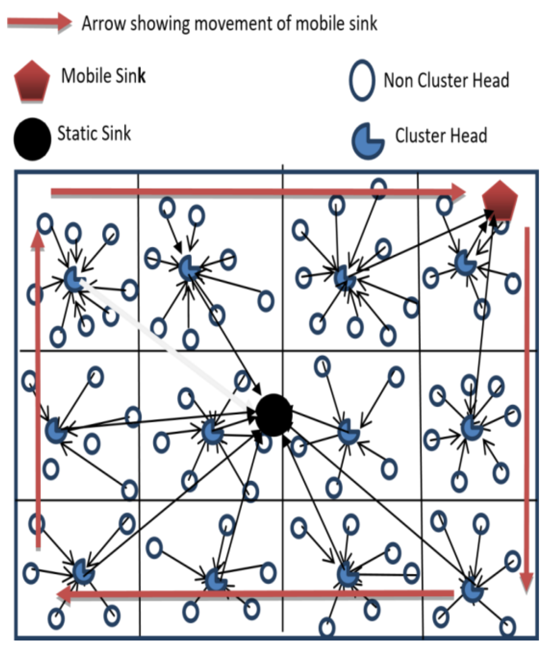

Figure 4 View of Mobile and Static Sink

To minimize the energy consumption in the network, mobile and static sinks are used to reduce the data communication between CH and the sink.

i. For Static sink: the sink is located at the center of the network as shown in Figure 4. The sink broadcast a message advertising its location in the network. Each CH is connected to at least one sink and it transmit its data to the sink closer to it. The message contains the following information: sink type (static or mobile), CH ID, Hop distance between the corresponding sink and the message. Haven received the message, the CH compute the distance and if the distance is within the communication range, CH transmit its data to the sink.

ii. For mobile sink: the mobile sink moves randomly from one point to another in the network to collect data from cluster head as shown in Figure 4, each time the mobile sink stops at a new grid, it also broadcast a hello packet but only at a particular grid. The cluster head replies with an acknowledgement and starts transmitting its data to the mobile sink. Periodically, there is inter-sink communication to ensure that error does not occur during transmission.

TABLE I PARAMETERS AND VALUES

PARAMETER	VALUE
Network area	500 x 500 meter2
Number of sensor node	100
Data packet size	512 byte
Control packet size	33 byte
Initial energy	1Joues
Sink speed	5, 10, 15, 20, 25, 30, m/s
Static sink	Stationary
Mobility Model	Random way point movement
Eelsc	50Nj/bit/m2
Efs	10PJ/Bit/m2
emps	0.0013pJ/bit/m4
Edd	50 nj/bit/ message
Elow	0.2 nj / sec
Routing protocol	Bi-Communication
Length of broadcast message	80-400 bytes
Simulator time	100 sec
Communication Radius	100m

4. RESULTS AND ANALYSIS

In this section, we evaluate the performance of the proposed protocol (Bi-CEERP) by comparing it with Low Energy Adaptive Cluster Hierarchical (LEACH). The Network Simulator-3 is used to implement the algorithm. The choice for the comparison was based on the fact that both protocols belong to the same categories of hierarchical structure routing protocol. Secondly, the former uses both mobile and static sinks while the later uses a static sink. We performed the experiment using the parameter stated in table 1 above to show the behavior of the proposed protocol with that of LEACH with emphasis on energy consumption, and network lifetime.

The Simulation results show that Bi-CEERP outperformed LEACH in terms of energy conservation as shown in Figure 5. This is due to the adoption of integrating the concept of dual sink and cluster formation. Therefore. It limits wide broadcast since packet transmission is restricted within each cluster and nodes only transmit data to the CH within the grid. Secondly, the transmission distance is reduced using dual sink which help in conserving energy and in turn prolonging network lifespan.

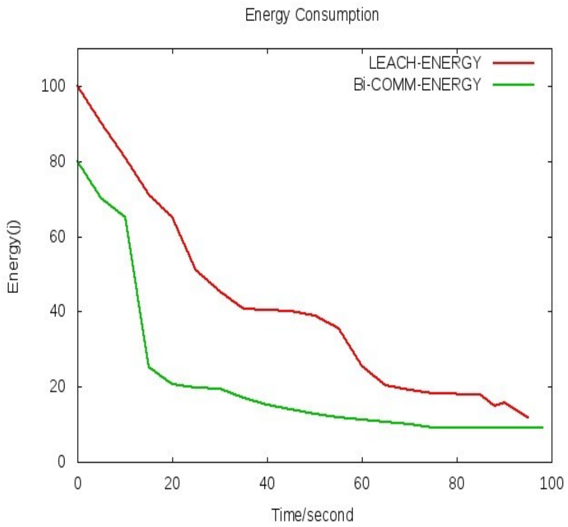

Figure 5. Energy consumption

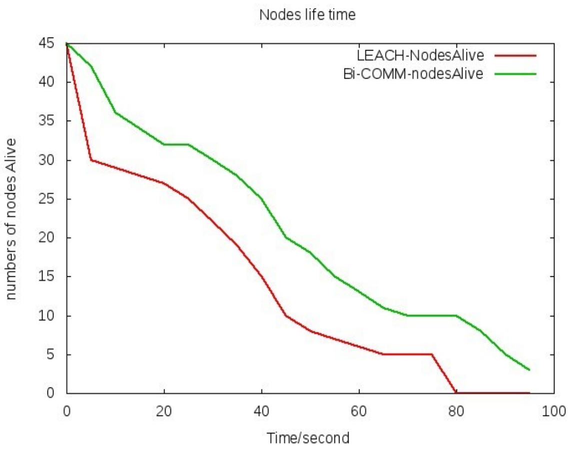

Figure 6. Alive Nodes

Similarly, Figure 6. illustrates the number of alive nodes. The result shows that Bi-CEERP performed better than LEACH in the number of alive nodes. In LEACH the number of alive nodes decrease gradually and at a certain point in time, the graph shows abrupt decrease of all nodes at 80 seconds of simulation time. While the Bi-CEERP, the nodes were still alive up to about 100 seconds of the simulation time. This is because the cluster head is selected based on energy level and the use of two sinks which facilitate data transmission between the cluster head and the sink.

5. CONCLUSION AND FUTURE ENHANCEMENT

In this research work, the Bi- CEERP routing algorithm is compared with LEACH routing algorithm. The results obtained show that Bi-CEERP enhances the network lifetime significantly in comparison with the LEACH routing algorithms. The major reason of this improvement is that in the Bi- CEERP routing protocol, the CH communicate to either mobile or static sink using the minimum communication distance to the sink, which decreases the energy consumption in the whole network and increases the network lifetime. Secondly, Bi- CEERP increases the network lifetime more than LEACH due to grid formation and clustering. This technique makes the system capable of reducing the number of communications and processing time, and as a result, saves more energy and balance the load in the network. Thus, the network lifetime increases.

The proposed schemes mostly deal with energy efficiency in routing protocol and has open the following research areas. Wireless sensor network can improve energy efficiency in MAC layer. Internet of things (IOT) can also be another research area where wireless battery power devices can be directly connected to *the* internet. Supports multiple static or mobile sinks will be a promising research direction to bring energy-efficiency.

The requirement of security is also an emerging area of research. A lightweight security mechanism that requires low power, and less computing cost can be developed for secure routing. Additionally, the design of efficient routing protocol specific to real-time applications, which can offer to improve the Quality-of-Services (QoS) like latency, reliability, packet loss and throughput can also be considered.

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