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SOCIAL SPIDER OPTIMIZATION-BASED ROUTING PROTOCOL FOR AN ENERGY SUFFICIENT WSN COMMUNICATION

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ABSTRACT
Wireless Sensor Networks (WSN) have been used in a wide range of applications because of their salient characteristics. They have been deployed by various organizations to provide services to the users and customers. However, like any other networks, they have their own deficiency. The sensor nodes of WSN have been fabricated with the radio device which is capable of transmitting or receiving the radio signals within a specific range. This restricts the communication of sensor with the faraway node directly. In terms of data transmission, the source and destination would be located in different of geography. Still, to perform data transmission, they involve in cooperative transmission. Here, the energy of sensor nodes comes into play which is more essential resource for the sensor nodes. The sensor nodes come with limited power which get depleted at each data transmission. So, both energy and transmission range have great impact on the performance of WSN. This increases the need for performing cluster-based routing to maximize the lifetime of the network and improve the QoS performance. To handle this problem, a number of approaches are available in literature but they fail to achieve higher performance. For example, the hop count based approaches selects a route with least hop count but suffer to achieve higher performance due to the higher traffic present in the intermediate nodes. Similarly, the traffic-based approaches select the route based on the traffic with least traffic route. This introduces longer hop count and increases the latency which in turn affects the throughput performance. So, all the methods struggle to get the peak performance and suffer due to poor QoS performance. To handle these constraints, different approaches are presented in this research work.
Key words: WSN, CH, CM, GW, REAS.

I. INTRODUCTION
A Wireless Sensor Network (WSN) is a collection of contiguously dispersed and firm sensors which can sense, process and communicate to the base station called the sink. WSN places a major role in numerous environments where we can communicate with various networks during any circumstances including battlefield communication, home automation and Industrial Automation. Sensor nodes are usually deployed in remote and unapproachable

territories where human access is impossible. The major role of the WSN is to grasp the information efficiently from the sensor nodes and directed the gathered information to the sink. However, the deployment and the function of WSN faces several technical challenges. Most of these technical challenges emerge from the resource restrictions, such as battery power and transmission range. Since WSN mainly depends on batteries for energy, its major functions such as sensing, computation and multi-hop communication consume more energy. Energy conservation of sensor nodes which is valid in WSN communication is a key issue that is produced by WSN. Hence, there is a need for energy-efficient cluster-based routing protocols to protract the lifetime of WSNs. Basically, in clustering approach, all the sensor nodes remain as clusters. In each cluster, a sensor node is selected as the Cluster Head (CH) which has the ability to insert and delete the Cluster Members (CM) and control the cluster. The Gateway (GW) node is used for connecting the multiple clusters for multi-hop communication in WSNs. This reduces the communication overhead in multi-hop communication and also strategically selects the shortest path from the source node to the sink. The efficient selection of the CH and GW nodes reduces the energy consumption of the vi sensor nodes and increases the lifetime of the WSN. The primary challenge for cluster-based routing is in the selection of an efficient CH and GW node. Hence, REAS (Residual Energy Aware Angle-based routing protocol for Cluster-based Wireless Sensor Networks) is proposed for strategic selection of the CH and GW node using parameters, such as the residual energy of the node, angle and distance between the node and the sink. REAS uses two phases, namely, the setup phase and the steady-state phase to achieve the efficient routing of information from the source node to the sink. In the setup phase, the clusters are formed using the CMs, CHs, GW nodes, and the shortest routing path is determined. In the steady-state phase, the data is collected from the CMs and routed to the sink. The performance of REAS is studied in terms of residual energy, lifetime, packet delivery ratio, energy efficiency, and end-to-end delay. REAS protocol is implemented using Network Simulator 2 (NS2) version 2.34. The performance of REAS protocol is compared with ARPEES (Adaptive Routing Protocol with Energy Efficiency and Event Clustering for Wireless Sensor Networks) and SEECH (Scalable Energy Efficient Clustering Hierarchy) protocols by varying the number of rounds. The simulation results demonstrate the ability of REAS protocol to achieve higher residual energy, higher lifetime, higher packet delivery ratio, higher energy efficiency, and lower end-to-end delay than ARPEES and SEECH protocols.

Nowadays wireless sensor network is in the verge of development in embedded system and wireless network technology. Has a vast range of applications in workplace community environment and etc. Personal and professional aspects it provides inspiration's new source. WSN contains one of the application fields in core next generation which include civil engineering environmental monitoring industrial automation home security medical monitoring military system and transportation. Basically, a WSN contains a lot of sense or nots that can you get and since wirelessly with sense sensitive data that are gathered to a destination for further processing. The WSN consists of hundreds of minimal-cost sensors. Limited processing, transmitting capability, energy, and storage communication are the constraints of a sensor node. The humidity, temperature, motion pressure, fire, and other physical condition of the SN are monitored. the usage of WSN, preventive maintenance, and intelligent buildings. SNs are organized in both unattended as well as hostile environments which can be used to monitor battlefields, nuclear reactors, wild forest chemical plants, and among other things. Data Collection, processing, and routing have undergone a lot of research, in recent years among sensors. As a result, it is a difficult task to replace or charged the battery. The sensor node senses the environment and also sends information to the base station. A base station is a device with high capacity with unrestricted power, storage, and communication. Based on the communication and storage, it might be a mobile or a static SN. The base station will collect the data from the SN and sends it via the existing communication system to the user. Figure 1.1 depicts the communication in a WSN. Sensors are scattered in position in the environment which is important to self the characteristics and its application such as soil moisture, atmospheric humidity, temperature, air quality, etc.

Two different colours of SNs are displayed by the WSN, where yellow and purple colours in the SNs either have joined or not joined the path of communication respectively. All the data a collected in the base station (BS) about the sensor nodes' position and energy in the WSN. As a result, the total number of cluster heads (CH) is defined in the base station, with assorts network into several clusters. However, the number of CHs is differed round by round because of the poor collection between the SNs. The WSNs are organized as mobile-based or static networks based on the system application's needs that are designed. Sensor devices are placed in predetermined locations to create a static WSN. If the base station does not come within the transmission range of the sensor nodes, multi-hop communication is used. Data transmission from the SN to the BS successfully is aided by a routing protocol. On the other hand, static WSNs, cannot monitor applications adequately with intrinsic mobility. Sensor nodes might be connected with the phenomena of being monitored in applications where the examples of mobile phenomena that are being monitored are animals or humans. A network like MWSN or dynamic WSN uses sensor devices. Creation of table routing structure in MWSN nodes is not possible like a static sensor network.

II. RELATED WORKS

WSNs operate in human-inaccessible terrains. The information from the sensor nodes should be routed efficiently and the energy saving measures are required. The goal of cluster-based Routing in WSN communication is to detract the energy consumption and boost the networks lifetime. This chapter discusses in detail the research work carried out by various authors for the efficient cluster-based routing in WSN. The CHs, GW nodes and routing path selection in cluster-based approaches available in the literature survey can be classified into three categories as follows:

i. Clustering and cluster head selection approach
ii. Gateway node and routing path selection approach
iii. Mobile sink-based routing and data gathering approach

Clustering and Cluster head selection approach: Routing protocols in cluster-based WSNs depend on clustering and the CH selection. Hence, it is the basic and the most important service that helps in finding the efficient routing path to reach the sink. A survey for the CH selection on cluster-based WSNs is discussed as follows. Clustering mechanism is a pivotal to achieve Energy Efficiency in WSN. Heinzelman et al. (2000) proposed the basic clustering protocol used by WSN called LEACH (Low Energy Adaptive Clustering Hierarchy). It is the most prominent energy efficient clustering protocol would deal up in distributing cluster formation.

The main objective of this scheme is to achieve energy efficiency by minimizing the energy consumption, and to ensure even distribution of the load to all the sensor nodes. LEACH protocol function is broken up into rounds. Each round consists of two faces namely the set-up face and the steady state phase. In the setup phase, the nodes are deployed, the clusters are miles and the cluster heads are tabbed. The cluster head selection is based on the predetermined value p (the desired percentage of cluster heads in the WSN). In this phase, each node can be a cluster head or a cluster member. All the wireless sensor nodes select a random number p between 0 and 1. The node with contingent number less than the desired threshold value T(n) will become the cluster head for that specific round. The threshold value is determined using the percentage of a particular node for becoming a cluster head in the current round and the set of other nodes that have not been selected as cluster heads in the last (1/p) rounds.

The improved version of LEACH protocol called LEACH-C (Centralized-LEACH) proposed by Heinzelman et al. (2002) uses a centralized clustering algorithm to form the clusters. In this scheme, all the nodes send the message relating to the position and energy level of all the nodes in the network to the sink. Based on this information, the sink determines the number of clusters, and the CH selection depends on the centralized node of each cluster. In this scheme, the energy of the sensor nodes is drained early in the setup phase to achieve global information. This scheme is not robust and has a relatively high overload. A new approach suggests the formation of clusters only once and they are fixed. The sink node decides the CH selection based on the rotation among the various nodes within the cluster. This leads to the node's flexibility in the cluster. Dhawan et al. (2014) have analyzed LEACH-F (Fixed-LEACH). In this scheme, the next CH selection is based on the status of all the nodes in the cluster. This scheme is the same as LEACH and LEACH-C.

This protocol is sub divided into two sections, namely, setup phase and data transmission phase. In the setup phase, cluster formation and cluster head selection are done. The cluster head selection is the same as LEACH but the threshold value calculation depends on the energy remaining in the node and the number of neighbor nodes. The data transmission phase depends on the chained action and the shortest path to the sink. It has given a better network lifetime compared to LEACH, but the direct routing between the cluster head and sink has drained the energy easily as there is no relay node usage which has created high energy consumption among the nodes thereby leads to an inefficient routing scheme. An unequal clustering mechanism is an effective way of establishing large number of nodes by uniformly distributing the load. Mao Ye et al. (2005) have presented EECS (Energy Efficient Clustering Scheme) for periodical data gathering applications for WSN. It follows the LEACH protocol. During the network deployment, the sink broadcasts HELLO message to all the nodes, and using this message all nodes calculate the approximate distance to the sink.

Gateway node and routing path selection approach: In multi-hop communication, the sensed data need to be routed over a long distance to reach the sink which reduces the strength of the information and consumes more energy. Hence the GW nodes are required to send the information efficiently to the sink using multiple hops. The routing path selection is an important factor for achieving energy consumption in WSN, since the link or path failure causes large number of packets drop in the network. Hence the dynamic path selection is required for the achievement of a high packet delivery ratio. The following section analysis the various reviews based on GW node selection and dynamic routing path selection. Wang & Chen et al. (2013) have proposed a Link-Aware Clustering 41 Mechanism (LCM) to achieve energy efficient routing for cluster-based WSN. In this protocol, energy efficiency is achieved through a proper selection of cluster head and gateway with the help of Predictable Transmission Count (PTX). This scheme achieves reliability and energy efficiency, but the CH selection criteria considers the residual energy of the node and distance of the node which is not enough for the selection of the best cluster head or gateway node in WSN. A Passive Clustering (PC) scheme for WSN has been developed by Kwon & Gerla (2002). This mechanism describes all the nodes in the network with their own state. The receiver node changes its state depending on the sender node state and all the nodes update the new state to their neighbors, with the knowledge of the current cluster state. This passive clustering technique has reduced additional load by reducing the control packets in the network. This passive clustering uses the random CH selection procedure to reduce the battery power very quickly making the CH selection and the routing scheme inefficient.

Mobile sink-based routing and data gathering approach : In mobile sink-based WSNs, the position of the mobile sink is always in an ad-hoc manner, making the routing and data gathering more challenging. Hence the following section presents a survey of the 48 mobile sink-based WSNs. Zahhad et al. (2015) proposed (MSIEEP) Mobile Sink based adaptive Immune Energy-Efficient Clustering Protocol which rejects the energy hole problem by decreasing the total dissipating energy in communication. The above scheme uses AIA (Adaptive Immune Algorithm) in order to reduce the communication overhead control packets in the network and optimizing the required number of CH in the network. AIA identifies the location of the CH and also the mobile sink which leads to the reduced energy consumption while communicating between the CH and mobile sink. Rani et al. (2016) presented a BDEG (Big Data Efficient Gathering Algorithm) for real time data gathering using RSSI (Received Signal Strength Indicator) data communication methodology. The static approach is followed, for determining the clusters. The CH and the relay node selection considers the residual energy of the node. The data gathering in various nodes is indicated through RSSI. This scheme achieves load balancing and increases the lifetime of the sensor nodes. In this scheme, the CH selection is based only on one parameter and the total distance for data transmission is high leading to an inefficient mobile sink-based routing scheme for WSN. Takaishi et al. (2014) have proposed a methodology which describes the sink mobility utilization to assist data gathering in a densely distributed WSN. This scheme defines the modified maximization technique and the cluster optimization for compressing energy consumption. This algorithm groups the nodes based on their communicating ability.

III. SYSTEM MODEL

A WSN is a self-configurable group of contiguously dispersed and dedicated sensors, which can able to sense, process and communicate among themselves through radio signals. It can be deployed in various environments for monitoring and measuring physical conditions such as temperature, sound, pollution levels, humidity, wind velocity and so on. The data sensed from various sensor nodes are routed to the sink minimizing the energy level of the sensor nodes, which constitute the primary issue in the WSN that degrades the network's performance significantly. Cluster-based routing is one of the approaches in the area of efficient use of energy in WSNs. In cluster-based routing, the CH selection procedures are usually based on the residual energy of the node or random selection. But this is an inefficient methodology since some nodes contain high energy but the distance from the node to the base station is high, which results in early depletion of energy. In the random selection procedure, the node that contains minimum energy which is selected as the CH quickly drains the energy level, thereby reducing the lifetime of the network. In the GW node selection procedure, the nearest node to the sink is frequently selected as the GW node. But that node receives heavy messages compared to other nodes, which minimizes the energy of such nodes easily 59 leading to error-prone situations in WSNs. So, the GW node is also very important and requires careful selection. Hence, the CH and the GW node selection is an important issue in the energy efficient cluster-based routing protocol for the WSN. In this chapter REAS protocol is proposed for WSN through strategic selection of the CH, GW node and the shortest path from the source node to the sink.

In order to improve the energy efficiency in WSN, the routing protocols use the cluster-based routing. Different cluster-based routing protocols have been used for minimizing energy consumption through efficient selection of the CHs and GW nodes. In the previous conventional cluster-based routing protocols, the CH or GW node has been selected either randomly or based on the residual energy. proposed the SEECH protocol, in which the CH and GW nodes selection process is based on the node position. The nodes far away from the sink are selected as the CHs and the nodes closer to the sink as the GW nodes. Efficient CH and GW node selection requires more than one parameter. These issues provide the motivation to propose a cluster-based routing protocol with an efficient CH and GW node selection, considering parameters such as residual energy of the 60 node, angle and distance between the node and the sink in order to improve the energy efficiency in the WSN. In REAS protocol, energy-efficiency is achieved through efficient selection of the CH and the GW nodes along the shortest path from the source node to the sink. REAS consists of two phases, namely, the setup phase and the steady-state phase to enable achievement of an efficient routing. In the setup phase, clusters are formed using the CMs, the CHs and GW nodes and the shortest routing path is determined. In the steady-state phase, data is collected from the CMs and routed to the sink through the CH and GW nodes. The protocol assumes all the sensor nodes and the sink as stationary, with the sink located far away from the sensing field, all the sensor nodes' energy levels are equal and they have a unique ID. All the sensor nodes are equipped with the GPS device to measure their own geographical position, the 61 sensor nodes are capable of performing in the inactive mode and the sleeping mode. All the sensor nodes 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. The block diagram of REAS protocol is shown in Figure 3.1. The various stages of REAS protocol, such as CH selection, algorithm for CH selection, GW node selection, algorithm for GW node selection, cluster formation, REAS message formats, operation of REAS protocol, and intra-cluster and inter-cluster routing are discussed in the following sections.

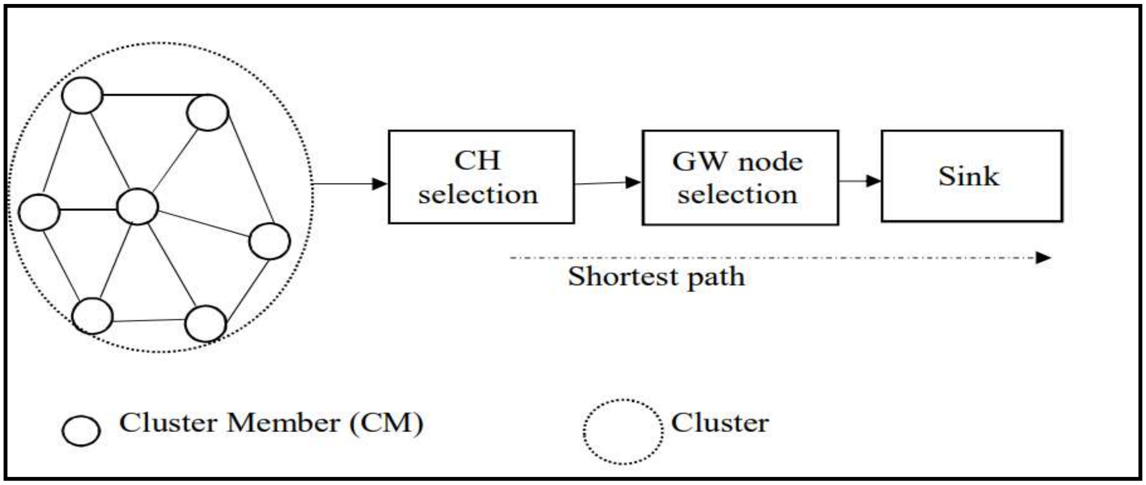

Figure 1. Block diagram of REAS protocol

Cluster Head Selection Mechanism In cluster-based routing, CH which is the backbone of the cluster performs all the required functions in the network, such as cluster formation, CM insertion, CM deletion and communication. Hence, the CH must be selected efficiently. In REAS protocol, CH selection parameters, such as the residual energy of the node, and the angle and distance between the node and the sink have been used in the CH selection procedure. The n number of sensor nodes are distributed in the network area. The source node is CH selection GW node selection Sink Shortest path 62 considered as the tentative CH (TCH) for each round. All the sensor nodes execute a CH selection algorithm to select the CHs. For example, consider node j to be the CH. Then node j calculates CHn which determines its chance for being a CH. The CH sends the CH advertisement message CHn (j) to all the sensor nodes within the region. The nodes receive the message and reply with the join message (JOIN_MSG) to that particular CH. After successfully receiving the join message from the sensor nodes in the network, the CH accepts the nodes as CMs for that particular CH. The CH sends the reply message (REP_MSG) to all CMs. Each CM sends the sensed data to the corresponding CH. The CH searches for the shortest path towards the sink and transmits all the gathered data to the sink using single-hop or multi-hop routing through the GW nodes.

The various steps involved in CH selection process are described below.

Step 1: All the sensor nodes are deployed randomly in the specified area and networks are formed.

Step 2: Initially the source node is selected as the tentative CH (TCH). 4

Step 3: All the sensor nodes estimate their residual energy, angle and distance between the node and the sink to select the CHs.

Step 4: The node which contains the maximum value becomes the CH in the network for that particular region.

Step 5: The selected CH sends the CH advertisement message to all the sensor nodes within the region in the network.

Step 6: The sensor nodes in the network receive the CH advertisement message

Step 7: The sensor nodes respond with a reply message (JOIN_MSG) to the CH.

Step 8: CH receives the JOIN_MSG from the various sensor nodes within the region and forms the clusters and CMs.

Step 9: The CH sends the reply message (REP_MSG) to all the CMs.

Step 10: The CM respond to the selected CH and sends the sensed data to the CH.

Step 11: The CH gathers all the data and sends it to the sink using the shortest path.

IV. IMPLEMENTATION

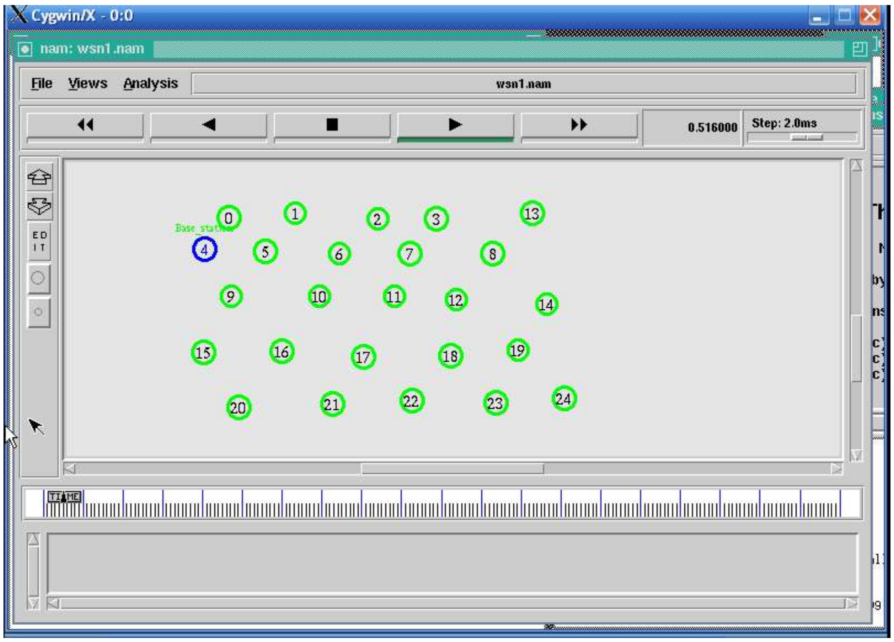

Figure 2. Selection of Cluster head from number of nodes in clustering

The above diagram represents the Selection of Cluster head among various nodes during Clustering process.

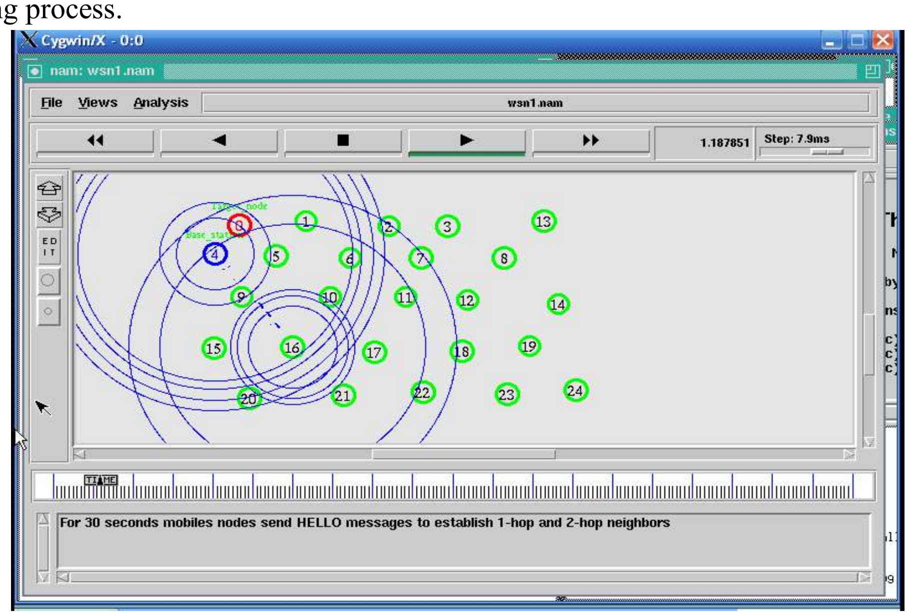

Figure 3.Clustering occurs while selecting the shortest path among nodes

The above figure represents the Clustering of various nodes while determining the Shortest path leaving the dead node empty

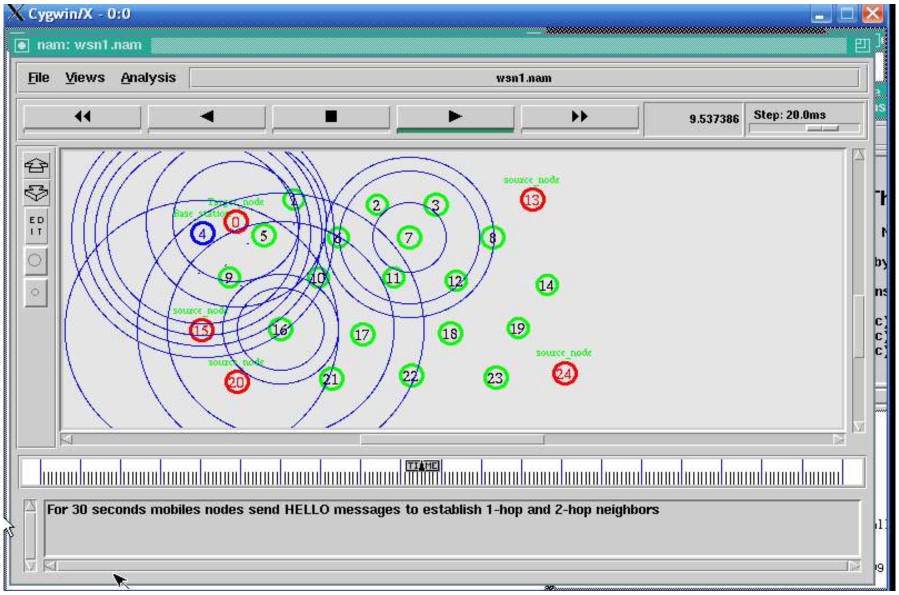

Figure 4.Group of Clustering among various nodes.

The above diagram represents the Clustering of nodes in various path while considering the shortest path with Cluster head and declaring the dead nodes

V. PERFORMANCE ANALYSIS

The various metrics used to study the performance of REAS protocol are defined as follows.

(i) Residual Energy: It is the mean value of the remaining energy of all the alive sensor nodes when simulation ends.

(ii) Lifetime: It is the ratio of the number of alive nodes to the number of rounds.

(iii) Energy Efficiency: It is the ratio of the total number of data delivered by the node to the total energy consumed by the node.

(iv) Packet Delivery Ratio: It is the ratio of the total number of data packets received by the sink to the total number of data packets sent by the source node at a specific time period.

(v) End-to-end delay: The time required for a data packet to be transmitted across the sensor network from the source node to the sink.

The performance of REAS protocol is studied by varying the number of rounds in the network. Figure 2. illustrates the residual energy of the sensor nodes decreases when the number of rounds increases. REAS protocol achieves 13.1 percent and 6.1 percent higher residual energy 78 when compared to ARPEES and SEECH protocols respectively. Since REAS selects the efficient CHs and GW nodes by strategically selecting parameters, such as residual energy, angle and distance between the node and the sink, which reduces the unwanted utilization of energy in the sensor nodes. Hence, the residual energy of REAS protocol is higher than ARPEES and SEECH protocols.

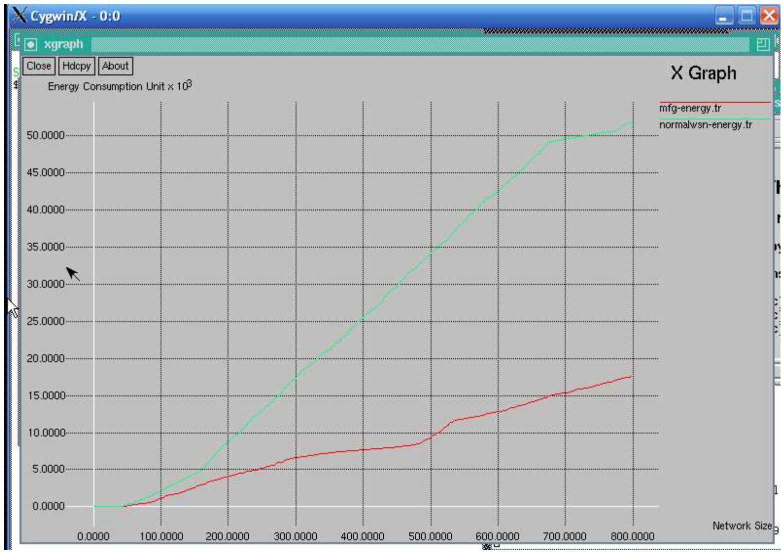

Figure 5: Comparison of Residual energy of DLSR with Normal System

The above graph represents the total residual energy of the proposed delay tolerant system and conventional WSN, here that we are proving the suggested delay tolerant system having better residual energy

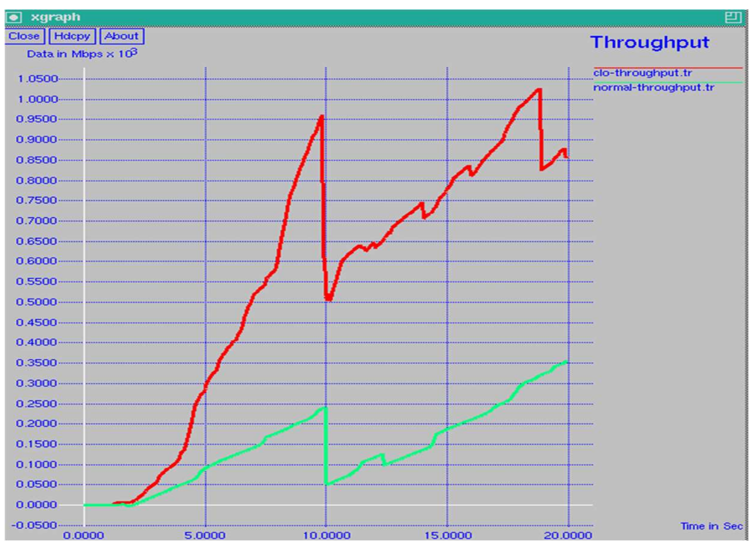

Figure 6: Comparison of Throughput of DLSR with Normal System

The above graph represents the total throughput of the proposed delay tolerant system and conventional WSN, here that we are proving the suggested delay tolerant system having better packet delivery ratio.

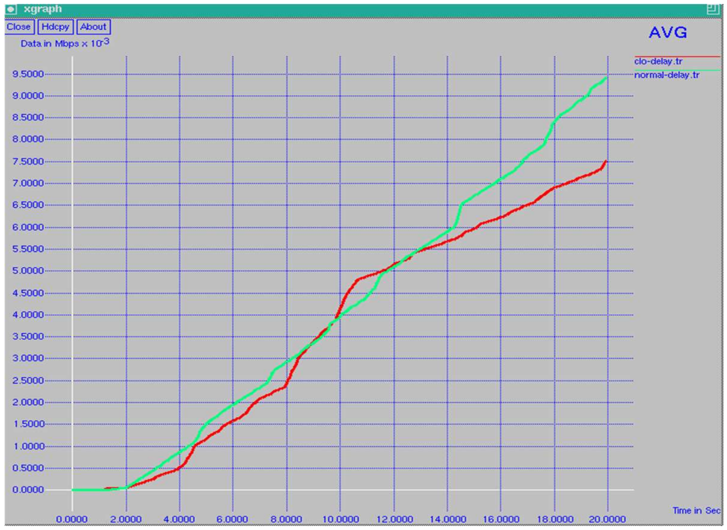

Figure 7: Comparison of Average Delay of DLSR with Normal System

The above graph represents the Average Delay of the proposed delay tolerant system and conventional WSN. Here that we are proving the suggested delay tolerant system having better Delay less Communications.

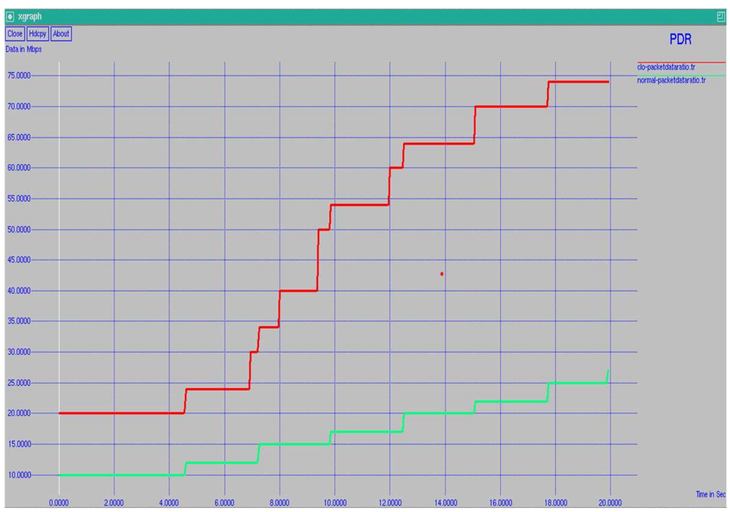

Figure 8: Received Signals Strength of 30 nodes with Link Stability Estimation

The above graph refers to the overall packet loss ration of the system with respect to the 30 nodes. Here we setting threshold value of 65 %. Based on the threshold value nodes with least delivery ratio considered as void nodes.

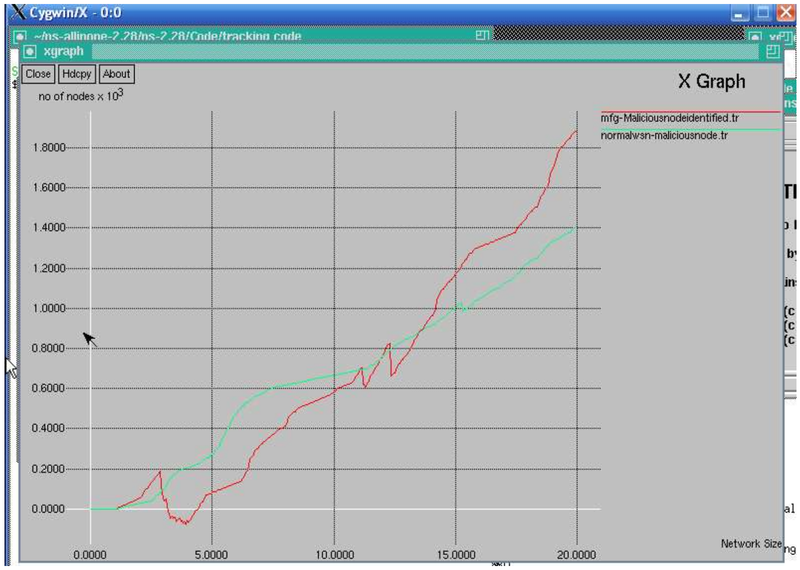

Figure 9: Comparison of End-to-end delay of DLSR with Normal System

The above graph represents End to end delay of the proposed delay tolerant system and conventional WSN.

VI. CONCLUTION

Now-a-days, WSNs are essential for mankind finding versatile and challenging applications in various fields, such as monitoring and tracking. Cluster-based WSN is an emerging research area with great challenges, especially in routing. Energy efficiency is the major issue in WSNs due to various factors, such as sensing, computation and especially routing. Although several cluster-based routing mechanisms have been proposed, some routing issues still have to be addressed, based on the CH selection, GW node selection, routing path selection and routing with mobile sink in the network. Moreover, as different cluster-based routing protocols select the CHs and GW nodes depending on parameters, such as residual energy or random selection, they maximize the energy consumption of the nodes which deplete the energy of the sensor nodes in the network. Hence, an efficient cluster-based routing protocol is required, which minimizes the energy consumption of the sensor nodes through efficient selection of the CH and GW node using parameters that include the angle and distance between the node and the sink, and the node status. This aims to be the major contribution of this research.

REFERENCES

1. Abbasi, A & Younis, M 2007, ‘A survey on clustering algorithms for wireless sensor networks’, Computer Communications, vol. 30, no. 14, pp. 2826-2841.
2. Abderrahim, M & Najib, E 2013, ‘Passive Clustering for Efficient Energy Conservation in Wireless Sensor Network’, International Journal of Advanced Computer Science and Applications, vol. 4, no. 1, pp. 110-115. 3. Alhasanat, I, Khaled, D, Matrouk, K, Haitham, A, Alashaary & Ziad, A 2014, ‘Connectivity-Based Data Gathering with Path-Constrained Mobile Sink in Wireless Sensor Networks’, Wireless Sensor Network, vol. 6, no. 6, pp. 118-128. 4. Aouad, S, Abdelillah, M & Ganami Driss, EI 2013, ‘Advanced Energy

Efficient Passive Clustering Mobility in Wireless Sensor Networks', American Journal of Applied Sciences, vol. 10, no. 12, pp. 1558-1569.

5. Arumugam, G & Ponnuchamy, T 2015, 'EE-LEACH: development of energy-efficient LEACH protocol for data gathering in WSN', EURASIP Journal on Wireless Communications and Networking, vol. 5, no. 1, pp. 1-9.
6. Asaduzzaman, A & Yun Kong, H 2010, 'Energy Efficient Cooperative LEACH Protocol for Wireless Sensor Networks', Journal of Communications and Networks, vol. 12, no. 4, pp. 358-365.
7. Aslam, M, Munir, E, Rafique, M & Hu , X 2016, 'Adaptive Energy Efficient Clustering Path Planning Routing Protocols for Heterogeneous Wireless Sensor Networks', Sustainable Computing: Informatics and Systems, vol. 12, no. 1, pp. 57-71.
8. Aslam, M, Wang, F, Hu, X, Asad, M, & Munir, EU 2017, 'Multi hopping Multilevel Clustering Heterogeneity-Sensitive Optimized Routing Protocol for Wireless Sensor Networks', Journal of Sensors, vol. 1, no. 1, pp. 1-14. 127
9. Attea, A & Khalil, EA 2011, 'A new evolutionary based routing protocol for clustered heterogeneous wireless sensor networks', Applied Soft Computing, vol. 12, no. 7, pp. 1950-1957.
10. Baranidharan, B, Srividhya, S & Santhi, B 2014 'Energy Efficient Hierarchical Unequal Clustering in Wireless Sensor Networks', Indian Journal of Science and Technology, vol. 7, no. 3, pp. 301-305
11. Bhatia, T, Kansal, S, Goel, S & Verma, A 2016, 'A genetic algorithm-based distance-aware routing protocol for wireless sensor networks', Computers & Electrical Engineering, vol. 56, no. C, pp. 441-455. 12. Biradar, R, Sawant, S, Mudholkar, R & Patil, V 2011, 'Multi-hop Routing in Self-Organizing Wireless Sensor Networks', IJCSI International Journal of Computer Science Issues, vol. 8, no. 1, pp. 286-293.