 doi:10.20944/preprints201912.0142.v1

Energy Efficient Clustering and Shortest-Path Routing Protocol (EECSRP) in Wireless Sensor Networks

MUHAMMAD INAM[1,*], ZHUO LI[1,*], ZULFIQAR ALI ZARDARI[2], FAWAZ MAHIUOB MOHAMMED MOKBAL[3]

[1]Signal and Image Processing Laboratory (SIPL), Faculty of Information, Beijing University of Technology, Beijing 100124, China.

[1]Signal and Image Processing Laboratory (SIPL), Faculty of Information, Beijing University of Technology, Beijing 100124, China.

[2]Faculty of Information, Beijing University of Technology, Beijing 100124, China.

[3]College of Computer Science, Beijing University of Technology, Beijing 100124, China.

* Correspondence: Email: Inam@emails.bjut.edu.cn) M.I; zhouli@emails.bjut.edu.cn (Z.L); Tel: +86-13126573227 (M.I); Tel: +86-13651097164 (Z.L).

ABSTRACT

The sensor nodes have limited computation, sensing, communication capabilities and generally operated by batteries in a harsh atmosphere with non-replenish able power sources. These limitations force the sensor network subject to failure because most of the energy is spent on sensing, computing and data transmission. This paper introduces an Energy Efficient Clustering and Shortest-Path Routing Protocol (EECSRP) to assist Wireless Sensor Networks (WSNs) by (a) extending the lifespan of the network (b) effectively using the battery power (c) decreasing the network overhead and (d) ensuring a high packet transmission ratio with minimal delay. The delay time-based Cluster Head (CH) is elected based on the node degree, residual energy and Received Signal Strength (RSS) to accomplish the goal. Additionally, the RSS-based network partitioning is implemented to evaluate the gradient based on demand routing between source (sensing node) and destination (BS). Whenever the current CH residual energy goes under the threshold level, the proposed protocol performs the clustering process, reducing the exchange of control packets. However, the BS periodically gathers the data from every single CH which helps to reduce the collision and Medium Access Control (MAC) layer conflict. From the simulation results, it is the evident that the proposed protocol performance in terms of average end-to-end latency, packet delivery ratio, average energy consumption and control overhead is better than the well-known current protocols.
Keywords: Wireless Sensor Networks, Energy Efficiency, Cluster Head, Residual Energy, Gradient Based Routing

1. INTRODUCTION

Internet of Things (IoT) is ecology of interconnected objects and devices that send and receive data via internet. It is an imperceptible and intelligent network that communicates with each other by employing embedded technology which enables them to sense and control under diverse conditions [1]. The IoT grants immediate access with high efficiency and productivity to the information related to any object or device [2]. Wireless sensor networks WSNs operate as an intermediate that connect the real world and virtual digital world. These are highly scattered networks of lightweight, small, battery-embedded sensor nodes connected to each other and are accountable for sensing and transmitting information to the Internet. WSN plays a major role and offering most challenging solutions and attractive area for numerous application areas, such as battle field monitoring and military reconnaissance, tsunami detection, patient health

 doi:10.20944/preprints201912.0142.v1

monitoring, disaster surveillance and crises management, habitat monitoring and industrial automation etc. [3-9]. The SN – Sensor Nodes is composed of memory, processors, sensing elements, batteries and transceiver. So the network with large amount of sensor nodes disposes in target area and generates a massive amount of data, which has to pass on to the base station BS for further processing. But due to the tiny nature of sensor nodes it has a few limitations such as memory, bandwidth, processing capability and battery power [10].

It could not be argued that energy management is the first concern when developing a reliable and efficient WSN. Usually, when WSN is used for remote monitoring of the environment, a long existence of the sensor network guarantees the overall efficiency and reliability of the monitoring system, and it also maintains a great deal of human effort to preserve the sensor network functionality. By recognizing all the factors contributing to the consumption of energy to sustain all operations within the WSN, usually a huge proportion of the energy is used for communication mostly. Minimizing the overall number of transmitting hop and their average length could minimize the consumption of energy. Ultimately, the WSN's lifespan will be effectively extended as anticipated.

In WSN, the collection of data from the sensor networks can be event based, periodic or query based. In periodic data gathering, at regular intervals the sensor nodes gathers data by sensing the environment and transfer the sensed data to the base station. The routing approach acts a vital role in enhancing the life span of the network in these applications. The most practiced routing technique in WSN is divided into different classes, such as flat, location-based and hierarchical based techniques. Many energy efficient routing protocols have been proposed to solve the early energy dissipation problem and likely to succeed [11-15]. Hierarchical routing in sensors networks have three different kinds of routing based on their communication with the base station BS or sink, i.e. tree-based approach, chain-based approach and cluster-based approach. Cluster-based approach is a key contestant for improving the network life span. Cluster-based routing has attained this with lowest overhead as in figure 1. In cluster based routing, the sensor nodes are classified into clusters, a cluster head (CH) is selected from sensor nodes and rest of the members becomes the cluster members (CMs) in the same group [16]. In each cluster, every node collects the data from its surroundings periodically and transmits it to the concern cluster head. The CH aggregates the data received from all cluster members and transmit to the base station BS via single hop communication directly or through multi-hop routing. The Received Signal Strength (RSS) plays a very important role to accomplish self configuration characteristics in WSNs, where every node itself finds the neighbor nodes. Furthermore, it determines the distance to the neighbors and link quality with the intentions that it effectively constructs the reliable network with strong link quality by avoiding the collision, interference, packet retransmission and overhearing [17-19]. Therefore, it remarkably saves the battery power and enhances the network lifetime. In addition, it greatly minimizes the involved number of men and hardware complexity in network setup.

The cluster formation is the well-known and effective approach for data collection, where the sensor nodes are grouped into separated regions. Every group has a leader node in cluster, known as Cluster Head (CH) which has the responsibility to communicate with cluster members CMs and collect data from them. One vital role of the CH is data aggregation, where it eradicates the unnecessary and redundant data packets, thus minimizing the delay and overhead. The clustering lessens the routing complexity by minimizing the number of nodes and size in the routing pathway, which strengthen the efficient utilization of memory and bandwidth. In addition, it accomplishes the collision free access channel among the CM and CH by utilizing the Time Division Multiple Access (TDMA) schedule effectively. Thereby, it enhances the sensor networks scalability and stability. The unequal clustering techniques and its benefits were discussed in [20][21], where the cluster size and CH selection was investigated on the basis from distance to the BS. Furthermore, it tackles the early depletion of battery and bottleneck problem nearer to the base station.

Many algorithms have been proposed by utilizing the distributed approach and enhance the network lifetime [22-26]. LEACH algorithm enhances the network life span in comparison to direct or multi hop transmissions but have limitations still. The cluster head is selected at random basis which doesn't guarantee appropriate distribution of nodes and optimal results. The sensor nodes with low and higher residual energy have equal opportunities to become the CH of the group. Therefore, the selection of low residual energy node as CH resulting to die quickly and hence shortens the lifespan of the network [27].

Load Balancing Protocol (EESAA) [28] considers the parameters such as network lifetime, stability period and throughput for WSN networks by examining and enhancing the performance of clustering algorithm. Cluster heads receive data from the sensor nodes in the same cluster, fused it and send to the base station. In the entire network, EESAA doesn't guarantee any uniform distribution of the CHs. A Cluster-Chain Mobile Agent Routing (CCMAR) Algorithm is proposed by Sasirekha et al [29], where the CH selection value of each node is evaluated on the basis of node's residual energy, the number of bits transmitted, distance from the neighbor node and amount of energy needed for the transmission of one bit. Despite this, the CCMAR algorithm lead to the isolated node problem, owing to the fact that it is unaware of the selection of CH value of the neighbors neighbor because the nodes construct a chain and send data to its nearest neighbor and by this way reach to CH. Furthermore, there should be high delay when each node send and receive data from its neighbor. An advanced algorithm is presented known as R-LEACH [30], this algorithm seek to elect a CH by taking into account the most important parameters such as initial energy, the individual sensor node remaining energy, and the optimal number of CHs in the network. The amendment is carried out in classical LEACH algorithm [31]. After the completion of every round, the non-CH nodes residual energy are examined, thus for the current round the node with higher residual energy has a higher chances for CH selection. This strategy would thwart the early depletion of energy nodes and thus prolonging the network life span. The optimal cluster formation and communication with BS using shortest path (i.e. minimum hop-count) are very important parameters for enhancing the network lifetime which are not considered by R-LEACH. Despite this, R-LEACH only consider the CH selection based on its residual energy but haven't take into account the shortest distance from BS, distance of neighbor nodes and number of neighbor nodes as input parameters.

The problems exist in literature of WSN routing are the following:

- The same node selection as a CH repeatedly may cause quick depletion of the battery energy resulting in decrease of network lifetime.
- The uniform distributions of the CHs are not properly ensured for the entire networks.
- The multiple located CHs presence in the same cluster can lead to additional collision, inference and more energy dissipation resulting in poor network performance.
- The isolated/orphan nodes left out by the CH resulting in uneven work load distribution and energy usage lead to disturbing the network.
- The shortest path routing between CH to BS by using intermediate nodes are not considered.

To address these problems, in this paper we proposed a new protocol known as EECSRP. The proposed protocol is designed based on effective routing (gradient-based on demand routing) and clustering (with respect to delay time CH selection, RSS, residual energy and number of neighbors).
The major contributions of this paper are as follow:

- To guarantee the even distribution of CH workload, the multiple CHs located within the vicinity of each other's transmission range is avoided by introducing a distributed delay time CH selection method.
- To ensure an interference and collision free communication, we focused the periodical data collection approach.
- The energy efficient approach is used by introducing a cost value based Intermediate Routing Node (IRN) to guarantee the shortest path to base station.

The remainder of the paper is organized as follows: section 2 presents the designed network model, section 3 outlined the proposed EECSRP protocol, section 4 demonstrates the approach through simulation and obtained results are used for performance evaluation. Section 5 concludes the paper and brings up some possible future work.

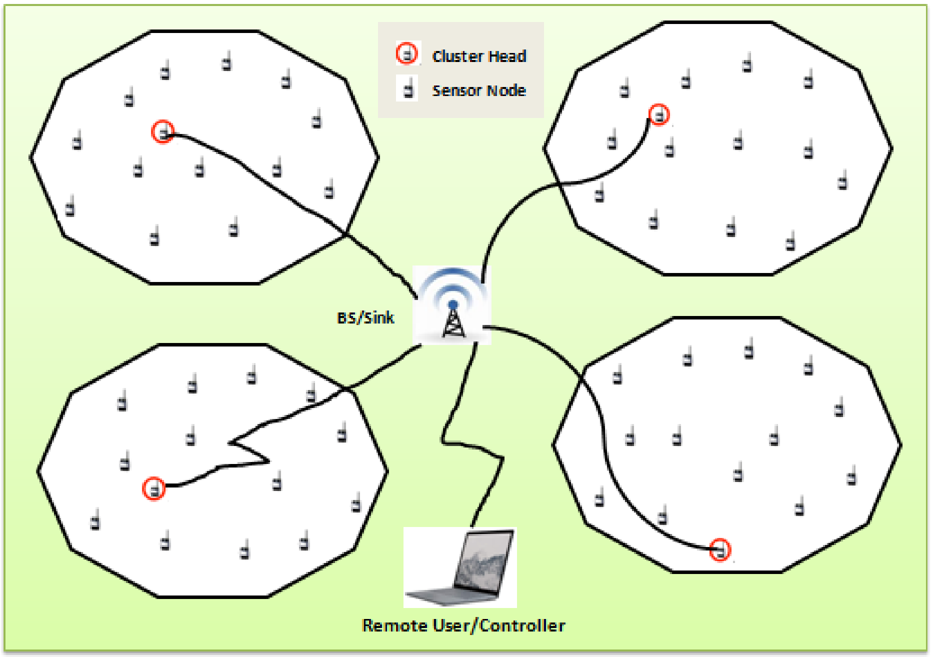

Figure.1. Typical Architecture of WSN

2. NETWORK MODEL

In EECSRP, the numbers of sensor nodes (Na) are deployed over the M x M meter^2 sensing area. The EECSRP process consists of two phases i.e. setup and steady state phase. During the setup process, the delay time-based CH selection is performed. In the steady state phase, by using the TDMA schedule, the CH collects data from the CM during the allocated time span. The CH sends the combined data to the BS using gradient-based on-demand routing at the end of the TDMA cycle. In the proposed design, the following assumptions are made:

2.1 Network Model Assumption

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

1. After the deployment, the entire sensor nodes are static.
2. All the sensor nodes are unaware of their location.
3. It is assumed that the relations between the sensor nodes are symmetrical.
4. The Nodes transmission power can be adjusted according to the distance among them.
5. The Base Station is placed at the top of the sensing field.
6. The BS is able to cover the entire targeted sensing region as it has a sufficient power of transmission.

2.2 Energy Consumption Model

In this paper the energy consumption model is akin to the model used in [32]. The required energy for data packets in the process of transmitting and receiving over the distance d is given in equation (1) and (2)

$$E_t\,(l, d) = l \times (E_{ele} + \varepsilon d^{\alpha}) \quad (1)$$

$$E_r\,(l) = l \times E_{elec} \quad (2)$$

Where E_t and E_r is the required energy of transmitting and receiving energy respectively, E_{ele} is the energy dissipation due to the electronic circuits, l is the data packets size, ε represents the energy consumption amplifier, α is the amplifying factor, α=2 is for free space model, when $d \leq d0$ and multi-path fading model, α= 4 when $d > d_o$ as shown in equation (3)

$$d_o = \sqrt{\mathcal{E}fs/\mathcal{E}mp} \quad (3)$$

Where, εfs *with* $\mathcal{E}mp$ represent the amplifier energy for empty or free space (*fs)* and multipath (*mp*) design.

3. EECSRP MODEL

3.1 Cluster Formation Phase

At the start of CH selection, the sensor nodes use Carrier Sense Multiple Access and Collision Avoidance (CSMA/CA) to broadcast the HELLO message with its residual energy to their neighbors. This HELLO message is used to find out the number of neighbors, distance between them and the neighbors energy level. In proposed clustering method all the deployed nodes are eligible to take part in CH selection contest in every round as described in Algorithm 1. On the basis of node degree, residual energy and distance from its neighbors, every sensor node evaluates the delay time for broadcasting the cluster head awareness message. Until the CH is chosen, for a few rounds it does the services as the leader of the cluster and maintains the same cluster structure. It means that the selected CH will continue to run their operations until any CH throughout the cluster loses its residual energy, i.e. drops the energy level under the critical threshold. If the energy levels have dropped, then to reorganize the clusters structure, it sends the 0 bit including the data packet to the BS. After receiving the message, the BS initiates the selection process of new CH by broadcasting the new cluster formation message. Therefore, it lessens the regular cluster formation requirements and control network overhead.

a) Residual Energy

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

The normalized battery energy value (ζ_{RE}) could be obtained by considering the neighbor nodes maximum residual energy rather than the sensor node maximum energy at the time of deployment. This enable the sensor node to efficiently use the cluster formation duration for broadcasting the CH awareness message and decreases the chances of MAC layer level contention and collision. ζ_{RE} is computed by the equation (4) below.

$$\zeta_{RE} = \frac{S_r}{S_{Nm}} \quad (4)$$

S_r represents the sensor node residual energy; S_{Nm} refers to neighbor's nodes maximum residual energy.

b) Number of Neighbors

The numbers of neighbors are the nodes which are nearest nodes (one-hop routing nodes) in surroundings. To cover the targeted network region, the required least number of sensor nodes (N_l) is obtained as in equation (5) below.

$$N_l = \frac{A_{tr}}{A_{cr}} \quad (5)$$

The A_{tr} refers to the targeted region in the network; A_{cr} represents the coverage region of the sensor node. The optimum amount of cluster nodes or members (N_m) within each cluster is derived in equation (6) below.

$$N_m = \frac{N_a}{N_l} \quad (6)$$

In equation (7) the normalized form of the amount of neighbors (ζ_{NN}) are obtained, following the considerations that minimize the workload as well as ensures that there is evenness in CH energy consumption.

$$\zeta_{NN} = \frac{N_c \bmod (N_m + 1)}{N_m} \quad (7)$$

N_c represents the overall amount of the current neighbors

c) Average Received Signal Strength

The Received Signal Strength is discovered to be the significant parameter for finding out the size of the cluster. In addition, the energy dissipation of the sensor node is reduced via the reduction of the transmission gap between the CM and the CH. In equation (8) the normalized value or worth of the average RSS between these nodes (ζ_{RSS}) are given below

$$\zeta_{RSS} = \frac{\sum_{i=1}^{N_c} RSS\,(i)}{N_c \; x \; RSS_M(i)} \quad (8)$$

The RSS (i) represents the value of RSS of i^{th} node, and the RSS_M (i) refers to the maximum RSS of the i^{th} neighbor.

In the EECSRP, the Weighted-Sum-Method (WSM) [33] can be used for obtaining the optimal-weighted-sum value (η_{CF}) which is computed using equation (9) below.

$$\eta_{CF} = \alpha\zeta_{RE} + \beta\zeta_{NN} + \gamma\zeta_{RSS} \quad (9)$$

Where α+β+γ=1, and α, β, γ *refers to* the tuning parameters which relies on the selection of the application. This η_{CF} finds the value of the sensors fitness that acts as the CH, means that it will make sure that the chosen CH has large residual energy, optimum RSS, as well as optimum amount of neighboring nodes within the cluster area.

Every single sensor node checks the delay period for broadcasting the final CH awareness message (B_{dt}) based on η_{CF} as given in the equation (10) below. In the proposed technique, B_{dt} and η_{CF} are inversely proportional to each other, showing that the poor or low fitness value of the sensor node need to wait for a long time period to broadcast the last CH awareness message, which means that there is a minimal opportunity left for acting as the CH.

$$B_{dt} = (1-\eta_{CF}) \times t_{tcf} + \delta_{rt} \quad (10)$$

Here, t_{tcf} *represents* the time utilized for clustering, δ_{rt} *refers to* the random period of time which is too small ($\delta_{rt} << t_{tcf}$) for reducing the contention of the MAC layer.

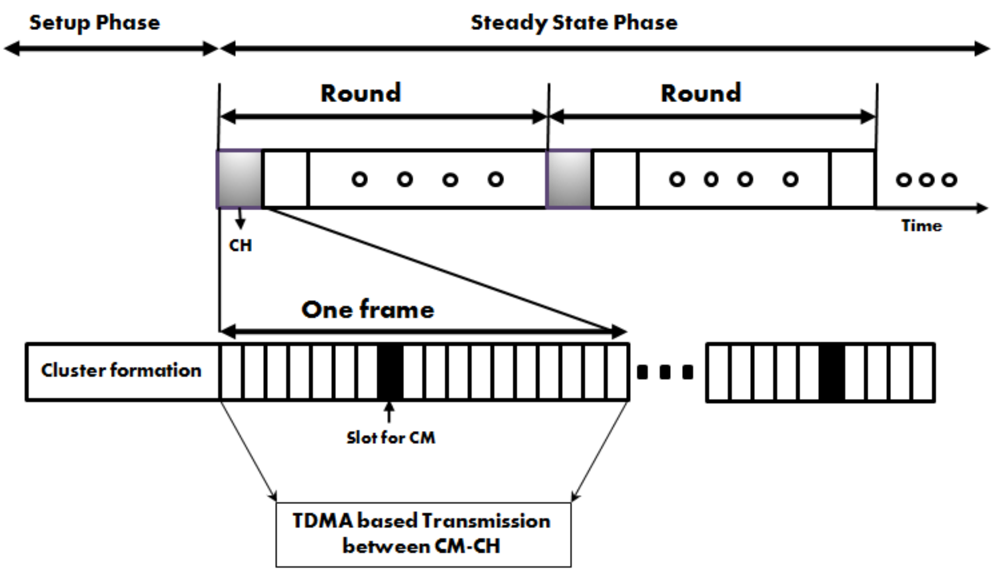

Figure.2. TDMA based transmission structure

On the occasion, when the sensor node delay time expires, it broadcasts the last CH message in its range of transmission. Any sensor node that receives a CH awareness information before the expiration of the delay time give up the CH competition to join as the CM to any nearby CH via transmitting the join request message to the concerned CH with focus on RSS signals. An isolated or orphan CH means that does not linked to receive joint request messages from its neighbors. At the end of the clustering formation, the chosen CHs transfer the approval signal to the BS via multi-hop communication to obtain its time frame for the formation of the TDMA scheme. The BS then broadcasts the schedule time to get to the selected CHs directly. The EECSRP time slot form is as shown in Fig. 2. During a steady state phase, CH divides the scheduled time frames into mini-slot and broadcasts to the member nodes in the cluster for gathering data.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

At the end of the scheduled time frame, the cluster head send the gathered information to the BS by utilizing the gradient-based on-demand routing that is explained in section (3.2).

Algorithm 1 EECSRP Cluster Formation
Algorithm initialization:
node[v].broadcast "HELLO message"
node[v].Calculate "ζNN, ζRSS, ζRE"
node[v].Calculate "Bdt"
while *status checking* **do**
  if *node[v].Bdt==“expired*” then
  node[v].Status "final CH selection"
  node[v].Broadcast "final CH awareness message"
  else
  node[s].WaitToReceive==" CH awareness message (OR)
  node[s].WaitToExpire==Bdt"
  end
  if *node[s].Receive*=="CH awareness message && node[s].Bdt!= Expire" **then**
  node[s].Status "Cluster Member CM"
  node[s].Send "join request message"
  else
  node[s].WaitToReceive=="CH awareness message (OR) node[s]. Wait To expire==Bdt"
  end
  if *node[v].Receive*=="join request message" **then**
  node[v].Calculate "Number of CM registration"
  else
  "Isolated/Orphan CH"
  end
end
Last step: the CH and Orphan CH send the CH approval registration message to the BS.

3.2 Gradient-based On-demand Routing

The specific EECSRP routing network architecture is given in Figure. 3. The nodes in the sensors region are grouped horizontally into layers at the beginning of the node deployment on the basis of sensor node's transmission range (T_r). At the start, the base station broadcasts the INITIALIZATION MESSAGE with layer ID by utilizing the transmission power to reach up to transmission range T_r, the sensor nodes that receive this INITIALIZATION MESSAGE construct the layer 1. The BS then increases the level of signal power in the nT_r rate and broadcasts the INITIALIZATION MESSAGE again, where n is the layer index number. The process continues until the entire region of the network is covered. In addition, the sensor nodes use RSS to identify the distance from the BS. The CH in the n^{th} layer gathers information from its CMs and transmits the collected information to the BS through intermediate layers. Therefore, the source CH initiates the discovery process of route by sending the QUERY PACKETS route discovery message which is composed of the CH-ID, Layer-ID, Hop Count (HC) and distance between the CH to BS dCH-BS. For every single sensor node the gradient value is determined with respect to Layer-ID to locate the fastest route to access the BS. For each hop in the network the hop-count HC value is updated to hold the minimum hop count to the BS.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

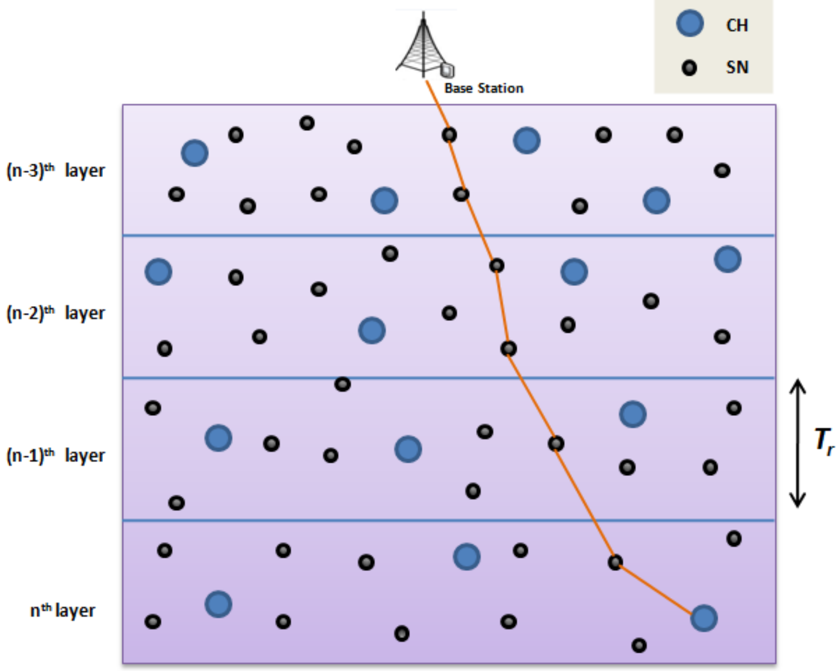

Figure.3. EECSRP Architecture

Moreover, in the distributed algorithm based CH selection the overlapped cluster formation is unavoidable; this is due to the fact that it produces the decision based on the local information. The EECSRP architecture is illustrated in Fig.3 focusing on the sensor nodes connections with the CH which means that the cluster member belongs to the corresponding CH.

To compute the Intermediate Routing Node (IRN) cost value based on the distance from the BS and residual energy is given in equation (11).

$$\text{Cost value} = \frac{d_{CH-BS} - d_{IRN-BS}}{HC\ x\ \text{Tr}}\ x\ \frac{S_r}{S_{Nm}} \quad (11)$$

Where HC is hop count, d_{CH-BS} refers to the distance between BS and CH, and d_{IRN-BS} refers to the distance from IRN to BS.

$$\text{IRN 1 Cost Value} = \frac{d_{CH-BS} - d_{IRN1-BS}}{1 * Tr} * \frac{S_r}{S_{Nm}} \quad (12)$$

$$\text{IRN 2 Cost Value} = \frac{d_{CH-BS} - d_{IRN2-BS}}{2 * Tr} * \frac{S_r}{S_{Nm}} \quad (13)$$

The $d_{CH-BS} - d_{IRN-BS}$ is normalized by $HC \times T_r$ that is the shortest cut to get the BS by seeking the IRN routing to BS efficiently as provided in equation (11).

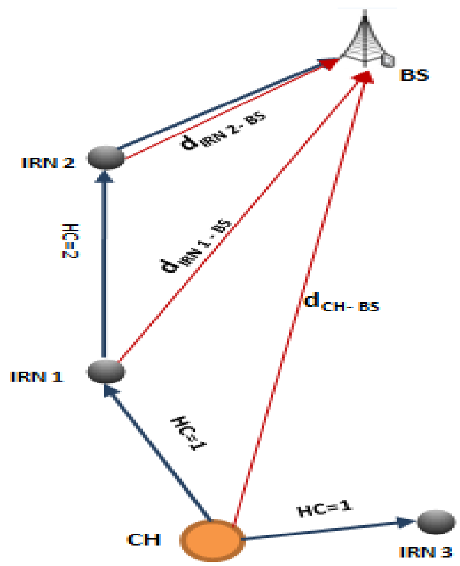

Figure.4. IRN Selection

The reason is that the efficient use of its transmission range guarantees the minimum hop-count and the involved number of sensor nodes. Here, the sensor node's residual energy is normalized by S_{Nm} that lessens the opportunity of low energy node to be elected as IRN. Fig. 4 clearly shows that HC computes the normalized value between 0 and 1. Furthermore, the distance consideration minimizes the IRN 3 chance by reducing its cost value, which is nearly negative.

The n^{th} layers CH relays the QUERY PACKET to $(n-1)^{th}$ layer sensor nodes and it continues until it reaches to the base station by hop to hop communication. The QUERY PACKET in the direction of the base station updates the cost value of all visited intermediate routing nodes. At last, the QUERY PACKET pass through the highest cost value within the pathway to the source CH. Then, the source CH sends the fused data via the traverse reverse path which guarantees reaching the BS using the minimal hop count and also ensures to achieve uniform energy consumption and load balance of the sensor nodes. As illustrated in Fig. 5 the CH (source) initiates sending QUERY PACKET towards the Sink/BS (destination). The QUERY PACKET collects and updates every cost value of the IRN within the direction to the destination. BS chooses the optimum cost value route with traversing the QUERY PACKET towards the CH (chooses Path 2). Furthermore, the use of Layer ID, HC and CH-ID avoid the redundant packets and loop formation.

The EECSRP features are stated below:

- The proposed protocol taking into account the residual energy in CH selection process which avoids the minimal power sensor node that is elected as the CH.
- The CH selection on delay time basis assists in providing the best distributed CHs across the overall network region while avoiding the orphaned/isolated nodes.
- The Received Signal Strength based CH selection saves the notable amount of sensor node's energy and extends the network lifespan significantly.
- The designed protocol does not choose CH frequently as LEACH protocol do, this helps it to avoid the additional overhead control as well as making the design of the system easy.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

- The IRN selection relies on the distance from the base station and residual energy of sensor node and layer-ID; such that a chosen pathway uses the minimum hop count and the shortest route to get the BS by efficient way to save energy.
- The optimal amount of CMs within every cluster assists in offering preferable CH load-balancing as well as reduction of the work load; thereby the untimely sensor node death is avoided.

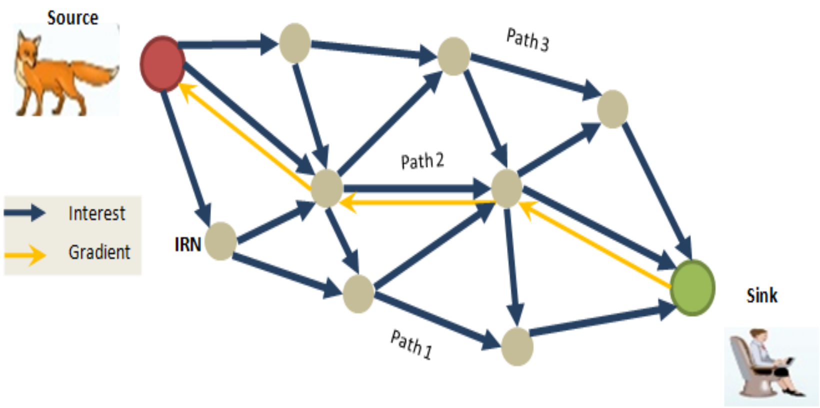

Figure.5. Sample for the gradient-based on-demand routing

4. RESULTS WITH DISCUSSION

For simulation and analyzing performance the Matlab 2017a is utilized to carry out the efficiency of the proposed EECSRP protocol by comparing with other three protocols named R-LEACH, CCMAR and EESAA. Table 1 highlights the simulation arrangement of the proposed EECSRP.

Table 1. Simulation Setup

Simulation limit	Values
Targeted Network region	200 x 200 *meter*^{2}
Number of nodes	100
Antenna transmission range	*90m*
Packet size	*512bytes*
Control packet size	*25bytes*
Sensor node initial energy	1 *joule/battery*
E_{elec}	50*nJ/bits*
E_{amp}	1.3*fJ/bits/m*^{4}
E_{aggr}	5*nJ/bits/signal*

4.1 Average energy consumption

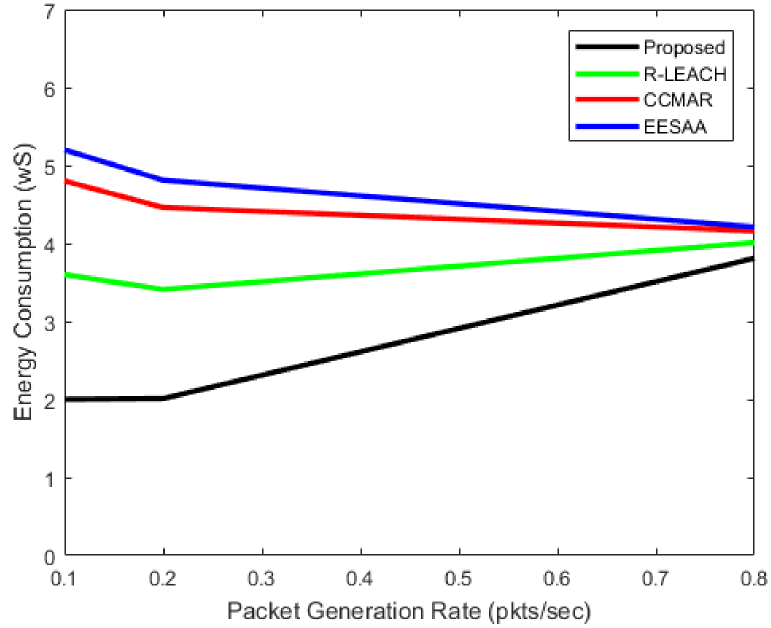

Figure.6. Comparison of the average energy consumption with 20 nodes in the network

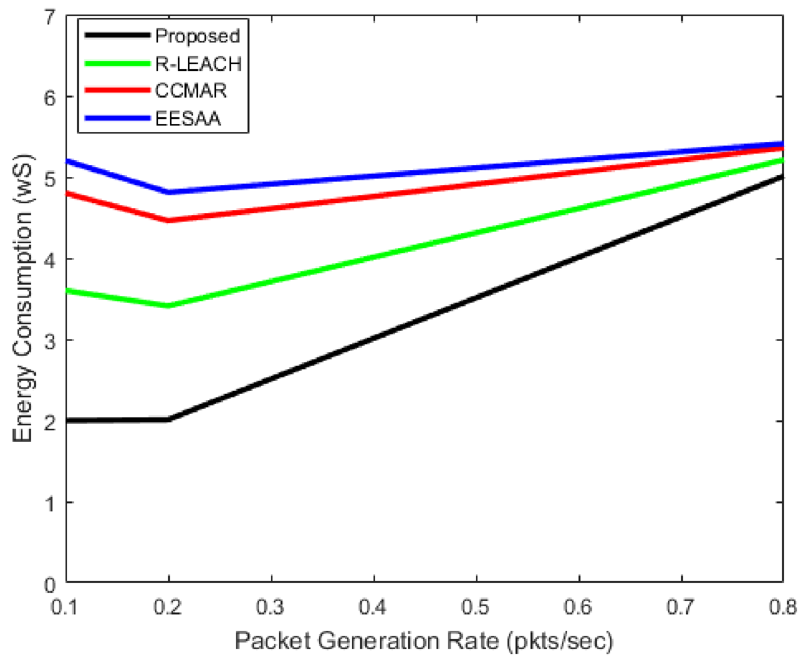

Figure.7. Comparison of the average energy consumption with 40 nodes in the network

Fig.6 and Fig.7 illustrates that the standard EECSRP energy utilization is minimal than R-LEACH, CCMAR and EESAA, when compared the average energy consumption with 20 and 40 nodes in the network respectively. That is for the reason that the packets are delivered to the sink node by few hops as possible in EECSRP. In the proposed protocol, the selected CHs rely on the amount of neighbor nodes, such that it guarantees the minimum CH work load. Moreover, it uses the periodical information collected from the CMs through TDMA scheme that avoids information collision as well as interference, thus lessening the retransmission of data while conserving the battery power notably. Furthermore, by taking into account the RSS in the CH selection greatly saves the battery power by lowering the transmission distance since the nodes have the energy adjustment capability which relies on the distance between them. It is noted that the proposed EECSRP protocol is able to achieve a notable reduction in end to end delay when compared with the R-LEACH, CCMAR and EESAA respectively.

4.2 Average end to end delay

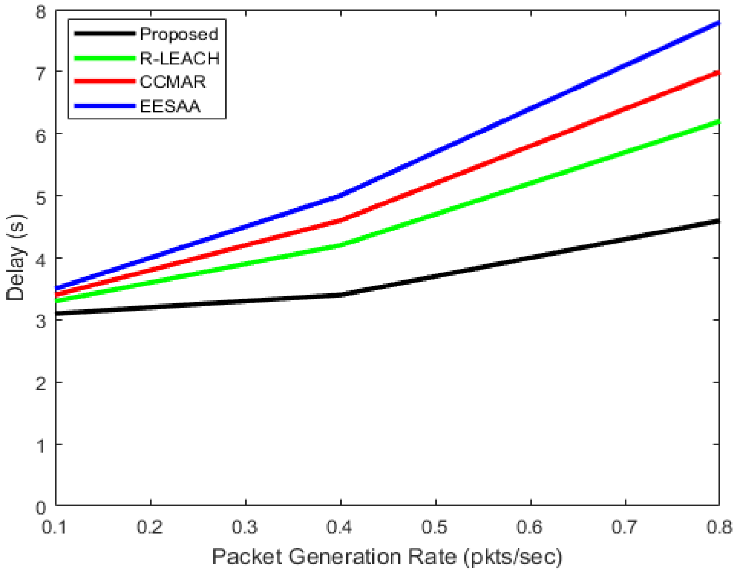

Figure.8. Comparison of the average end to end delay with 20 nodes in the network

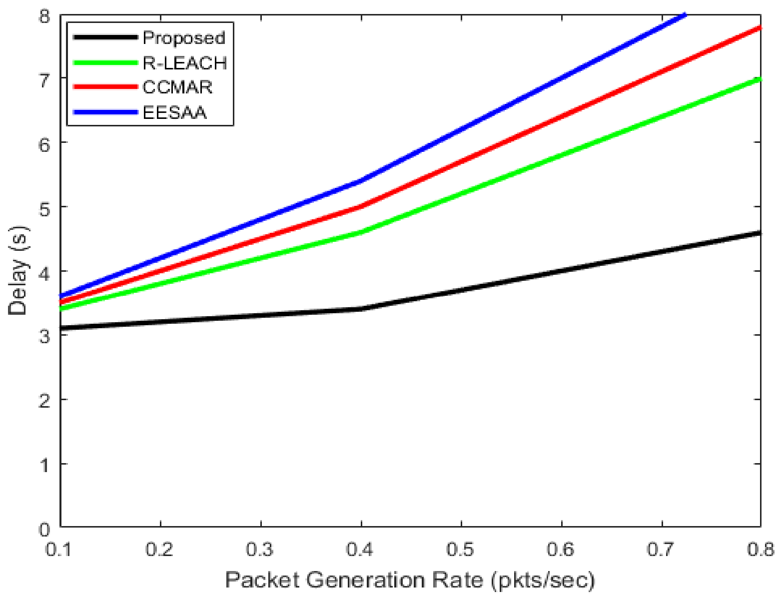

Figure.9. Comparison of the average end to end delay with 40 nodes in the network

Fig.8 and Fig.9 highlights that EECSRP average end to end delay is smaller than R-LEACH, CCMAR and EESAA respectively; this is because the EECSRP gradient based routing that uses the shortest path to reach the base station. The packets are delivered to the sink node by the fewer hops in EECSRP that decreases the transmission delay. During the routing from source to destination, the IRN selection relies on the distance from Layer-ID and base station. This guarantees the less number of sensor nodes used to arrive at destination. Furthermore, the CH utilizes the QUERY PACKETS to choose the best pathway focusing upon the cost value, such that the link failure is avoided and establishes the stability of path between the CH and BS. A common understanding is that the designed protocol accomplishes minimal average end-to-end delay when compared to R-LEACH, CCMAR and EESAA respectively.

4.3 The number of the packet delivery to base station

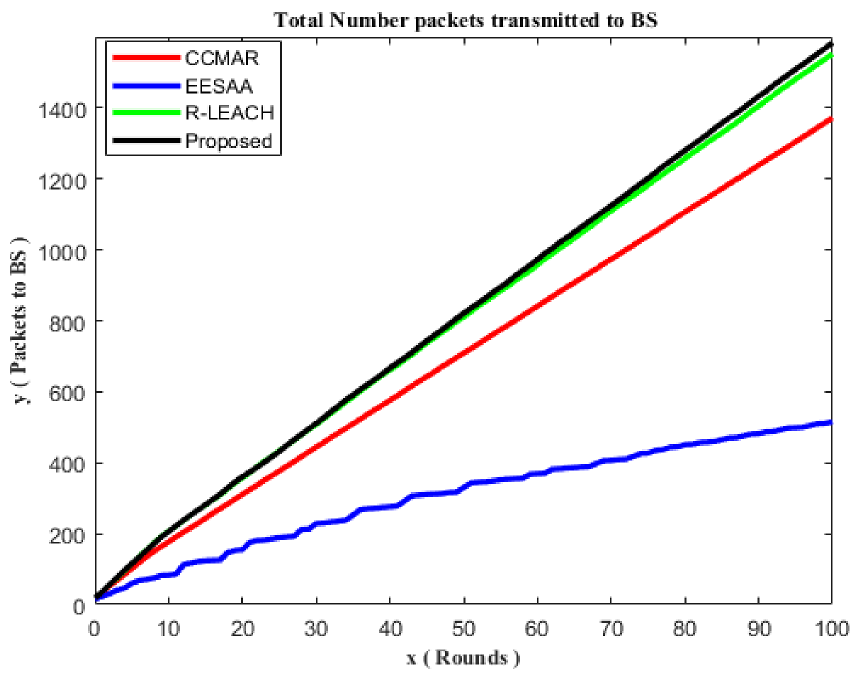

Figure.10. Number of Packets Transmitted to BS

Fig. 10 highlights that the packet delivery to base station BS of the proposed EECSRP is better than R-LEACH, CCMAR and EESAA respectively. The EECSRP accomplished a notable rising in packet delivery as compared to R-LEACH and outperformed the CCMAR and EESAA protocols in packet delivery to BS respectively. The reason is the delay time selection of CH guaranteeing the appropriate CH distribution which makes the links available to the whole network and avoiding the orphaned nodes within the sensing region. The EECSRP constantly sends packets to base station, as the BS allocate different time slots to CH for gathering the information from the cluster members CMs and sending it to BS.

At the starting of every round, there exists (N_a) number of HELLO messages which are transmitted for node finding and awareness concerning the status of the nearby/neighbors nodes. N_{CH} are the total number of awareness messages broadcast by CH and to join the cluster as CM the (N_a - N_{CH}) number of the cluster join messages sent by the sensor nodes. The cluster head CH sends the (N_{CH}) number of cluster head registration approval messages to BS. The cluster head CH uses these (N_{CH}) control packets number for TDMA scheme.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

Thus, for cluster formation the total number of control packets utilized in every round $O(T)$ is computed in the equation (14).

$$O(T) = 2(N_a + N_{CH}) \approxeq O(2N_a) \quad (14)$$

Where, N_{CH} *refers to* CHs number.

In EECSRP the utilized quantity of the control packets are less than that of R-LEACH, CCMAR and EESAA respectively when compared. This is because, when CH residual energy goes below the threshold level so the proposed protocol select new CH for communication with CMs and BS. Furthermore, the CH selection on delay basis avoids unnecessary searching of orphan/isolated nodes and reduces the network overhead effectively. Additionally, the QUERY PACKET flooding from all directions can be avoided by the use of gradient based routing.

4.4 Network life time

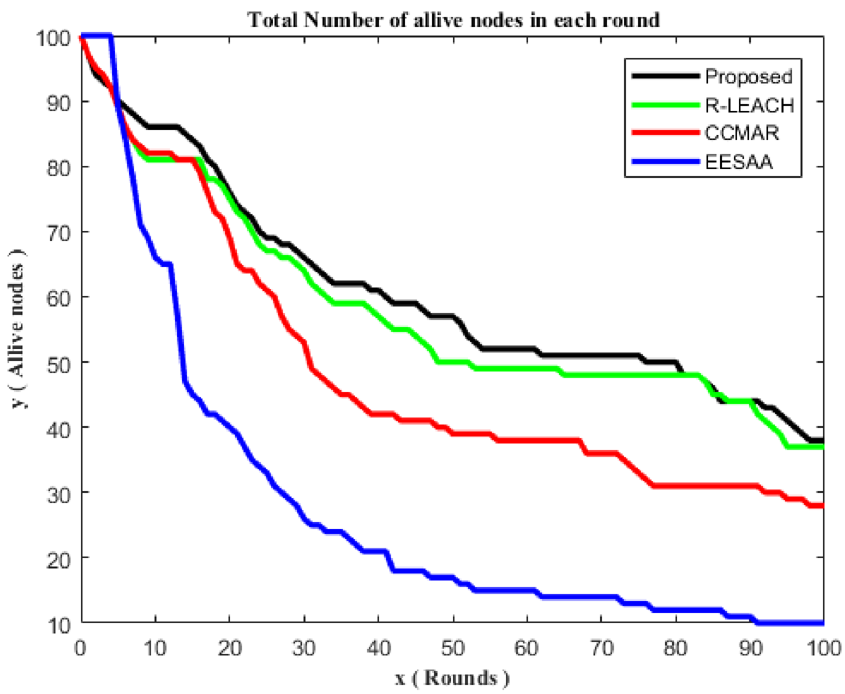

Figure.11. Number of alive nodes in each round

Fig.11 highlights that the proposed technique guarantees that the sensor nodes life time is more than other three protocols R-LEACH, CCMAR and EESAA respectively, owing to the fact that proposed clustering techniques guarantees a well distributed CHs along the network and in addition establish the balance load among the CHs. Furthermore, the CH selection as well as IRN relies on the sensor nodes residual energy which avoids the early consumptions of the battery power. Moreover, the normalization of the residual energy is carried out by the use of maximum residual energy of the neighboring nodes, such that it guarantees the equal distribution of energy consumption load of the sensor nodes. Since, from simulation results it is observed that the optimum sensor nodes amounts are active till the end of the lifespan of the battery.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 December 2019 doi:10.20944/preprints201912.0142.v1

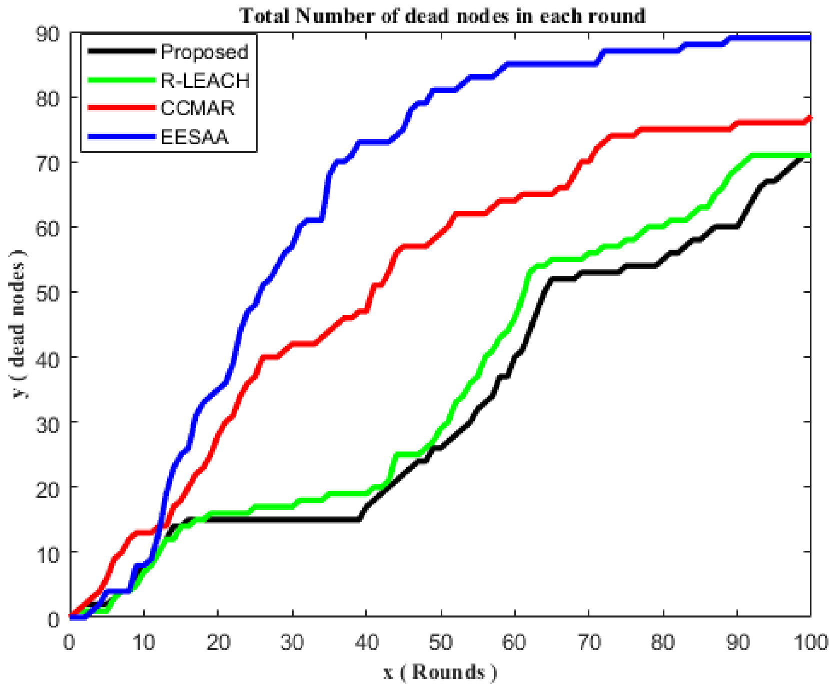

Figure.12. Number of dead nodes in each round

The important aspect in wireless sensor network is the network lifetime, which has been increased by the proposed technique. Fig. 12 illustrate that the R-LEACH, CCMAR and EESAA protocols nodes death occurred prior than EECSRP when compared, thus it helps to prolong the network lifespan. The network lifespan can be determined from the nodes death in network, the nodes death occurred after the other three protocols. The R-LEACH performed well as compared to other two protocols when compared with EECSRP protocol which is great achievement of the proposed protocol.

5. CONCLUSION

Since network lifetime and nodes energy are two major constraints in designing any routing protocol for WSN, to a large extent research has been made to accomplish the goal. Therefore, the enhanced routing process is required to effectively increase lifetime of the network by decreasing the nodes energy dissipation. In this paper the EECSRP protocol is proposed which use clustering mechanism and gradient based on-demand routing by collecting data from target sensing region and forward it to base station via shortest route. The proposed mechanism provides a consistent performance in packet delivery, average energy consumption, control overhead, and average end-to-delay, which is well adapted to periodical based data collection application such as structural health monitoring, smart farming, machine preventive maintenance, water irrigation management etc. From the simulation results, it revealed that the efficiency of the proposed protocol is better than R-LEACH, CCMAR and EESAA.

REFERENCES

[1] J. Chase, "The evolution of the internet of things," Texas Instruments, 2013.

[2] D. Bandyopadhyay and J. Sen, "Internet of things: Applications and challenges in technology and standardization," Wirel. Pers. Commun., 2011, vol. 58, no. 1, pp. 49–69.

[3] L. Tan and N. Wang, "Future internet: The internet of things," in 2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE), 2010, vol. 5, pp. V5--376.

[4] Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. Wireless sensor networks: a survey. Comput Network 2002; pp. 393–422.

[5] Rao, V. & Kar, S. "Energy efficient routing in wireless sensor networks via circulating operator packets" Wireless Networks (2019) Vol. 25, Issue 6, pp 3063–3080.

[6] B. Rashid and M. H. Rehmani, "Applications of wireless sensor networks for urban areas: A survey," Journal of Network and Computer Applications, Vol. 60, 2016, pp. 192–219.

[7] A. J. AL-Mousawi and H. K. AL-Hassani, "A survey in wireless sensor network for explosives detection," Computers and Electrical Engineering, 2017, pp. 1–17.

[8] M. Inam, Z. Li, A. Ali, and A. Zahoor, A novel protocol for vehicle cluster formation and vehicle head selection in vehicular ad-hoc networks," Inter- national Journal of Electronics and Information Engineering, vol. 10, no. 2, 2019, pp. 103-119.

[9] S. R. Barkunan, V. Bhanumathi, and J. Sethuram, "Smart sensor for automatic drip irrigation system for paddy cultivation," Computers & Electrical Engineering, Vol. 73, 2019, pp. 180–193.

[10] C. Walravens and W. Dehaene, "Low-power digital signal processor architecture for wireless sensor nodes," IEEE Transactions on Very Large Scale Integration (VLSI) System, Vol. 22, no. 2, 2014, pp. 313–321.

[11] Abbasia Ameer Ahmed, Younisb Mohamed. A survey on clustering algorithms for wireless sensor networks. Comput Commun October 2007;30(15):2826–41.

[12] Muyiwa Olakanmi Oladimeji, Mikdam Turkey and Sandra Dudley, HACH: Heuristic algorithm for clustering hierarchy protocol in wireless sensor network, Applied Soft Computing 55(C) (2017), 452–461.

[13] Anindita Roy and Debashis, Energy Efficient Clustering Protocol Based on K-Means (EECPK-Means)-Midpoint Algorithm for Enhanced Network Lifetime in Wireless Sensor Network, IET Wireless Sensor Systems, pp 1–11, May, 2016.

[14] Y. Song , C. Gui , X. Lu , H. Chen , B. Sun , A genetic algorithm for energy-efficient based multipath routing in wireless sensor networks, Wirel. Pers. Commun. 85 (4) (2015) 2055–2066 .

[15]. Xie, Benyin, and C. Wang. An Improved Distributed Energy Efficient Clustering Algorithm for Heterogeneous WSNs. Wireless Communications and NETWORKING Conference IEEE, 2017:1-6.

[16] Zhou X, Wu M, Xu J. BPEC: an energy-aware distributed clustering algorithm in WSNs. J Comput Res Develop 2009;46(5):723–30.

[17] N. Meghanathan, “Link selection strategies based on network analysis to determine stable and energy-efficient data gathering trees for mobile sensor networks,” Ad Hoc Networks, Vol. 62, 2017, pp. 50–75.

[18] Y. Liao, H. Qi, and W. Li, “Load-balanced clustering algorithm with distributed self organization for wireless sensor networks,” IEEE sensor Journal, Vol. 13, 2013, pp. 1498–1506.

[19] V. Bhanumathi and R. Dhanasekaran, “RSS based energy efficient scheme for the reduction of overhearing and rebroadcast for manet,” Procedia Engineering, Elsevier, Vol. 38, 2012, pp. 2463–2472.

[20] S. Gajjar, M. Sarkar, and K. Dasgupta, “Famacrow: Fuzzy and ant colony optimization based combined mac, routing, and unequal clustering cross-layer protocol for wireless sensor networks,” Applied Soft Computing, Vol. 43, 2016, pp. 235–247.

[21] S. Lee, H. Choe, B. Park, Y. Song, and C. Kim, “Luca: An energy-efficient unequal clustering algorithm using location information for wireless sensor networks,” Wireless Pers Commun., Vol. 56, no. 4, 2011, pp. 715–731.

[22] R. Velmani and B. Kaarthick, “An efficient cluster-tree based data collection scheme for large mobile wireless sensor networks,” IEEE Sensors Journal, Vol. 15, no. 4, 2015, pp. 2377–2390.

[23] S. Deng, J. Li, and L. Shen, “Mobility-based clustering protocol for wireless sensor networks with mobile nodes,” IET Wireless Sensor Systems, Vol. 1, no. 1, 2011, pp. 39–47.

[24] M. Tarhani, Y. S. Kavian, and S. Siavoshi, “Seech: Scalable energy efficient clustering hierarchy protocol in wireless sensor networks,” IEEE Sensors Journal, Vol. 14, no. 11, 2014, p. 3944–3954.

[25] H. Taheri, P. Neamatollahi, O. M. Younis, S. Naghibzadeh, and M. H. Yaghmaee, “An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic,” Ad Hoc Networks, Vol. 10, no. 7, 2012, p. 1469–1481.

[26] M Inam, AA Ikram, M Ahmad "Hierarchical energy efficient routing protocol (HEERP) for wireless sensor networks (WSN)" Int J Comput Sci Telecommun, Vol. 04, 2013, p. 25-29.

[27] J. Xu, N. Jin, X. Lou, T. Peng, Q. Zhou, and Y. Chen, “Improvement of LEACH protocol for WSN,” in Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on, 2012, pp. 2174–2177.

[28] Ansam ENNACIRI et al. " Load Balancing Protocol (EESAA) to improve Quality of Service in Wireless sensor network" Procedia Computer Science 151 (2019), p. 1140–1145

[29] S. Sasirekha and S. Swamynathan, “Cluster-chain mobile agent routing algorithm for efficient data aggregation in wireless sensor network”, Journal of Communications and Networks, Vol. 19, no. 4, 2017, pp. 392–401.

[30] T.M. Behera et al "Residual Energy Based Cluster-head Selection in WSNs for IoT Application" IEEE Internet Of Things Journal, Volume: 6 , Issue: 3 , June 2019, p. 5132-5139.

 doi:10.20944/preprints201912.0142.v1

[31] J. Xu, N. Jin, X. Lou, T. Peng, Q. Zhou, and Y. Chen, "Improvement of LEACH protocol for WSN," in Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on, 2012, pp. 2174–2177.

[32] J. Ren, Y. Zhang, K. Zhang, A. Liu, J. Chen, and X. S. Shen, "Lifetime and energy hole evolution analysis in data-gathering wireless sensor networks," IEEE Transactions on Industrial Informatics, Vol. 12, 2014, pp. 788–800.

[33] K. Deb, "Multi-objective optimization using evolutionary algorithms," Wiley, 2002.