An Event Driven approach to Scalable Energy Efficient Clustering Hierarchy in Wireless Sensor Network

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Abstract — *Wireless Sensor Networks are spatially distributed network of autonomous sensors used for monitoring an environment. To ensure that in Wireless Sensor Networks, the battery powered Clusters should complete all of its tasks, Network must minimize its use of communication resources as one of major energy costs in WSN is the energy spent on communication between nodes and sometimes it is desirable to send data to a gateway node when an event of interest is occurred at a node [15]. Then sensors will open communication only during a probable event, saving on communication costs. Interested fields in this type of network include traffic control, health care, surveillance, home automation, disaster relief, and more. In this paper we propose modification of Scalable Energy Efficient Clustering Hierarchy (SEECH) [9]. The above was designed for sensor networks where they select CHs and relay nodes separately based on the number of neighbors (degree). Low degree and High degree nodes are employed as relay and cluster head respectively. In this protocol data was sensed and information of all nodes are gathered periodically and sent to base station after aggregation by the CHs. In the proposed protocol(ED-SEECH) the event driven approach is used [1] .Data is transmitted whenever an event is reported. We evaluated the performance of our protocol with MATLAB in two different network size scenarios and we observed our protocol outperforms the SEECH protocol in terms of energy consumption and lifetime.*

Keywords- *Wireless sensor network; lifetime; relay node; scalable energy efficient clustering hierarchy; event driven*

I. INTRODUCTION

A Wireless Sensor Network (WSN) is network of distributed and self- configured sensors those are able to gather information from a physical environment. These low cost sensors are back-bone of a WSN. Due to improvement in small scale computational devices, the practical implementation of WSN, leads to hundreds and thou-sands of physically embedded sensor nodes in a single network. These sensor nodes communicate within themselves using radio frequency signals [5]. Wireless sensor nodes are equipped with computing and sensing devices, a transceiver and power components. After the sensor node is deployed, it is itself responsible for self-organizing and self-configuring an appropriate network as no human intervention is there, often with multi-hop Connections between them [11]. Sensor networks are usually untethered and unattended and need to be fault-tolerant, so that need for maintenance cost is decreased [7]. These are especially desirable in those applications, where sensors must be embedded in the structure are inaccessible for any service. The advancement in the technology has made possible for wireless sensor network to have extremely low powered devices and small nodes, which are equipped with programmable computing, wireless communication and sensing capability. The small size and low cost of the sensors makes it possible for the network to have hundreds and thousands of wireless sensors, thereby enhancing the accuracy and reliability of data and coverage area as well. Also, this is necessary that sensors should be easy to deploy. Protocols for networks must be made in such a way that the limited power is effectively and efficiently used in the sensor nodes.

II. RELATED WORK

The clustering protocols are considered as cross layering techniques for implementing energy efficient wireless sensor networks where nodes those belong to a cluster, send the sensed data to the node that belong to their cluster called cluster head, then the cluster head rejects the correlated information to reduce final data and send the aggregated data to the Base station.

The clustering approaches leads to increase in network lifetime and also improves energy efficiency by reducing overall energy consumption and balancing energy Consumption among the nodes during the network life time. So various clustering based protocols are classified according to the techniques they adopt to select cluster heads and transmitting the aggregated data to the data sink. The LEACH protocol assumes that energy consumption is equal in nodes when they are selected as cluster heads and/or non-cluster head. So cluster head selection is based on random round robin. The number of cluster heads has a variance and cluster heads does not have a good distribution. All non-cluster heads send their data to the closest cluster head. Then cluster heads send aggregated data to the data sink directly [3]. The TL-

LEACH uses two cluster head layers to reduce intra-cluster communication energy consumption. The TCAC protocol tries to balance size of clusters, and cluster head nodes send their data to the data sink directly [4]. A further approach is relay nodes can be chosen in the network along with Cluster Heads. Cluster head will transmit its data to the nearest relay node and relay node can transmit to the data sink. In this study, to increase energy efficiency there is one another method. First, two fitness functions are generated which determine competence of being cluster head or relay for each node by merely considering their energy consumption [14]. It is simply done through node degree (order) criterion (number of neighbors in definite radius). In SEECH a few nodes are selected in each round from high level energy nodes according to fitness functions, some of them are selected as cluster head and the others would play the role of relay node. Moreover, this paper is a novel distance-based method proposed to uniformly distribute cluster heads. Considering distribution and message complexity, SEECH demonstrates better performance comparing to LEACH and TCAC [9].

But in SEECH the data is transmitted periodically, which again leads to more energy dissipation. Because sometimes there is no change in information, but data is collected and reported to the data sink periodically. In Event-driven routing protocol, every node decides whether to report data or not, based on its threshold values. If sensed value and a change in sensed value is more than the threshold, than the node must turn on its transmitter and report it to the cluster head. TEEN is suited for time based applications and is quite efficient in terms of energy consumption [2].

So our proposed work is modifications in SEECH that the nodes will transmit data whenever an event occurs. The remainder of this paper is organized as follows: section II describes network model and assumptions Section III describes the event driven SEECH protocol in detail and Section IV evaluates the ED-SEECH performance using simulation results and finally section V concludes the paper.

III.   NETWORK MODEL AND ASSUMPTIONS

We consider here a wireless sensor network consists of N sensor uniformly deployed over a network to monitor the environment, such as temperature. There are several assumptions about underlying network model and sensor nodes given below [9]:

- The Base Station is located far away from the sensing field. The Sensor nodes and Base station are stationary after deployment.
- The Sensor nodes are location–unaware. Means these are not equipped with GPS.
- When an event occurs in a network, the sensor nodes will detect it those have that event in their sensing range.
- All the Nodes have same resources and capabilities. Nodes are capable of acting in low power sleeping mode.
- All the sensors can control their power level to adjust the transmission power depending on the distance to the desired recipient.
- The links in the network are assumed to be symmetric. Node can estimate distance from one node to another node based on the power of received signal if the transmitting signal power of a node is known.

In this paper simplified model used for communication energy consumption is used. Depending on the distance between transmitter and receiver, the multi path fading ε_m(d^4 power loss) and free space ε_f (d^2 power loss) channel model are employed. The energy required for transmitting a L-*bit packet* over distance *d* is:

$$E_{tx} = \begin{cases} lE_{elec} + l\varepsilon_f d^2 & d \leq d_o \\ lE_{elec} + l\varepsilon_m d^4 & d > d_o \end{cases} \qquad (1)$$

Electronic energy E_{elec} depends upon some factors including digital coding and digital modulation, while the energy of amplifier depends upon the transmission distance and the SNR acceptable and a threshold distance is d_o [8]. It is assumed here that cluster head spends E_{DA} amount of energy for cluster data aggregation.

IV.   PROBLEM FORMULATION

In wireless sensor network the sensor nodes are used for the communication. These nodes are operated with the help of batteries the energy consumption of the node will affects the efficiency of the system. Various energy efficient protocols have been designed to enhance the efficiency of the system. By decreasing the energy consumption the life time of the network is increased and thus the efficiency of the system also increases. The Cluster head selection is considered as one of the efficient method for the decreasing of the energy consumption in the wireless sensor network. Selection of cluster head is one of the major issues. Traditionally various clustering algorithms have been designed to for the selection of the Cluster head in the network but were not as efficient as required. The major problem was the energy consumption if the Cluster head is far away from the sink the more energy is required. Later on the concept of the relay nodes was introduced the life time of the relay node and the Cluster head should be more for efficient network. So SEECH is the best method for cluster head and relay node selection and provides the energy equalization considering various Scenarios comparing with LEACH and TCAC. In SEECH nodes are transmitting their data periodically to the cluster heads but

sometimes the aggregated information is same as the previous value. So that is wastage of energy so event driven technique can be introduced to further enhance the lifetime.

V. EVENT DRIVEN SEECH PROTOCOL

This protocol works in the same manner as SEECH works, but data by nodes is transmitted when an event crosses the threshold value. The protocol starts with the Start phase, where all nodes collect the information about their neighbours n_i in a particular range for which RNG radius is defined. The obtained data is shared with other nodes of the network. At the end of start phase each node derives its degree $deg_i = n_i/max\{n1, n2, \dots\dots, nN\}$. The Calculated information is used in the next rounds.

A. Cluster Head Selection

The Nodes with more degrees are more suitable choice for cluster head. The main advantage of using this method is that more number of nodes must be covered by lesser number of cluster heads using low power for communications. The procedure for this cluster head selection is as follows: Firstly, some nodes are selected as the tentative cluster head using above method. Then, number of these nodes, as much as required, introduce themselves to the network; these nodes are called cluster head candidates. The other nodes in the network go to sleep and called member nodes. Afterwards, all the candidates execute a simple algorithm so that the final cluster heads can be selected. In SEECH protocol, each node i calculates P_{ci} which determines the chance for being a tentative cluster head.

$$P_{ci} = \begin{cases} \dfrac{E_{res_i} \times deg_i}{P_c - tot} & E_{res_i} \geq E_{av}(1 - \lambda) \\ 0 & else \end{cases} \qquad (2)$$

In this equation E_{res_i} denotes residual energy of node i and it is included to protect the low energy nodes. In first round initial energy of nodes ($E_{initial}$) is substituted for residual energy in equation. Furthermore, λ (which is a number in (0, 1) and usually is set to be 0.9) does not give low energy nodes any chance and $P_c - tot$ is as follows:

$$P_c - tot = \frac{E_{av} \times \sum_N deg_i}{2K_{CHC}} \qquad (3)$$

E_{av} *is* average residual energy of nodes in the current round, which is calculated and broadcasted by the cluster heads in previous round and during the cluster formation. When P_{ci} is calculated, every node generates a random number in (0, 1) range and compares it to P_{ci}. If the generated number is smaller than P_{ci} ,then the node considers itself as the tentative cluster head.

B. Event Detection

In Event Detection, whenever a change occur in the sensed value, the nodes sends data to the cluster heads,
- Hard Threshold (HT)**:** It is threshold value for sensed attribute. This is absolute value of attribute after that, the sensor node sensing its value must turn on its transmitter and transmit report to its cluster head [6].
- Soft Threshold (ST)**:** It is the small change occurred in value of sensed attribute, due to which node turns on its transmitter and transmit data to the cluster head.

The sensor nodes sense the environment continuously. At the start a parameter from set of attribute reaches to its hard threshold, and then the node turns on its transmitter and transmits the sensed information. Sensed value is stored in internal variable in the sensor node, termed as the sensed value (SV). In the next step the Sensor nodes will send data in the cluster period, only when both the given conditions are right. Current value of sensed attribute should be more than the hard threshold value. The current value of sensed attribute varies from SV by the amount equal to or more than the soft threshold value. Whenever node sends the data, SV is made equal to current value of sensed attribute [12].

The hard threshold tries to decrease the number of data transmissions by allowing the sensor nodes to transmit data only when sensed attribute is in range of interest. Further the soft threshold value reduces the number of data transmissions by eliminating all transmissions which must have occurred when there is a little or no change occurs in the sensed attribute. Main features of above scheme are as follows:

- The critical time information reaches the user instantaneously. So, event detection scheme is more suited for time critical information sensing applications such as temperature.
- The transmission of message consumes more energy than sensing the data. So, even if the nodes are sensing continuously, the energy consumption of nodes in this scheme can be much less than the proactive network, because data transmission in this network is done less frequently.
- The soft threshold can vary, depending upon the sensed attribute and target application.
- The lesser value of soft threshold gives more accurate view of network, at an expense of increased consumption of energy. Thus, user can control trade-off between accuracy and energy efficiency.
- At the every time change of cluster, attributes broadcasts a fresh and so, user can change them as needed.

The drawback of event driven scheme is that, if thresholds values are not reached, the sensor nodes will never communicate with each other. Then the user will never get any information from the network and never come to know that in network even if all the nodes die. Thus, the scheme is not well suitable for the applications where user needs to get information on regular basis. Another problem with the scheme is that the implementation should have to ensure that in the cluster there are no collisions. So the possible solution for the above stated problem can be CDMA [1].

C. Relay node Selection

The Nodes which are closer to Base station decreases the transmission cost. So the designed protocol must prevent the network selecting these nodes as the cluster heads so that their energy can be saved for data transmission to Base station. Next, the nodes those cannot be cluster heads but they may lead to the higher intra-cluster energy consumption i.e. the nodes those have lower chance of being a cluster head can be elected as the relay nodes [13]. So the cluster head choses nearest relay node to transmit information to the Base station. The selection of the relay node is done in the same manner as the cluster head [9].

$$P_{ri} = \begin{cases} \dfrac{E_{res_i} \times (1 - deg_i)}{P_r - tot} & E_{res_i} \geq E_{av}\,(1 - \lambda) \\ 0 & else \end{cases} \qquad (4)$$

Where

$$P_r - tot = \frac{E_{av} \times \sum_N (1 - deg_i)}{2K_R} \qquad (5)$$

E_{res_i} is included here to protect the low energy nodes and K_R is the sufficient number of the tentative relay nodes. When P_{ri} is calculated, each sensor node generates one random number and compares it to P_{ri} and if is lesser, the node considers itself as the tentative relay node.

VI.   METHODOLOGY

The methodology of the proposed work is defined as below:

- Firstly the network parameters like energy, bandwidth etc are initialized to a network which consists of the number of nodes.
- Hard threshold values and soft threshold value are initialized. A random number is generated for every node to check the change in data [1].
- After the initializations of the network parameters, next step is to divide the network in different regions. This is done because relay nodes are always chosen in the area which is close to the Base station [9].
- Next step after dividing the network into the region is to calculate the degree of nodes in two sections.
- Now, the calculation of the Pci is done. This is done basically to perform the Cluster head selection after the calculation of the degree of the nodes.
- After the selection of the Cluster head, next step is to perform the degree calculation of relay node selection.
- Now, for the selection of the relay nodes the calculation for P_{ri} is done. After the calculation the relay nodes are selected.
- Finally the communication is performed after the selection of the relay nodes and the Cluster head. If the value of data at some node is more than the threshold value then the node transmits its data to the cluster head. Otherwise wait for some event to occur (current value should be greater than Threshold value)
- The Cluster head will further send data to the relay nodes and finally the data is send to the sink by the relay nodes.
- After the communication is done, the calculation of the performance parameters is done for the evaluation of the performance of the network.

VII.   SIMULATION RESULTS

In this paper we have focused on energy efficiency. To evaluate protocols from energy efficiency perspective we employed lifetime criterion. There are various definitions for lifetime in literature. In periodic data collection applications the proper definition of lifetime is the time span between start of network operation and the time when first node dies. The simulation models and programs are developed by MATLAB tool. From our point of view the proposed technique is more efficient and it may lead to energy efficiency improvement in different network sizes. To assess this claim the performance of Event driven SEECH is compared with SEECH in two scenarios with different sizes; small, medium and large. TABLE I describes the parameters of proposed scenes in details.

Table I: Parameters of Simulation for different scenarios

Parameter	First Scene	Second Scene
Area	100*100	100*100
Location of Data Sink	(50,175)	(50,200)
N (number of nodes)	100	400
$E_{initial}$	0.5J	
E_{tx} (transmission energy)	50nJ /bit	
E_{DA}	5nJ/bit/signal	
ε_f	10pJ /bit/m^2	
ε_m	0.0013pJ/bit/m^4	
d_o	87m	
Packet Size	4000 bits	
H_t (Hard threshold)	100	
S_t (Soft Threshold)	2	

To achieve the required results the area is divided into three parts. The nearest region to the base station has maximum numbers of relay nodes. And cluster Heads are less than half in this area than other areas of the network. The hard threshold (H_t) is assumed as 100 and soft threshold (S_t) is assumed as 2. The various values of Cluster Head Candidates, Cluster heads and Relay nodes are $K_{CHC} = 8,13$,$K_R = 10,11$, $K_{CH} = 3,5$ and RNG=55m, 52m respectively for the scene 1 and scene 2.The simulation results of scene1 and scene 2 are given below:
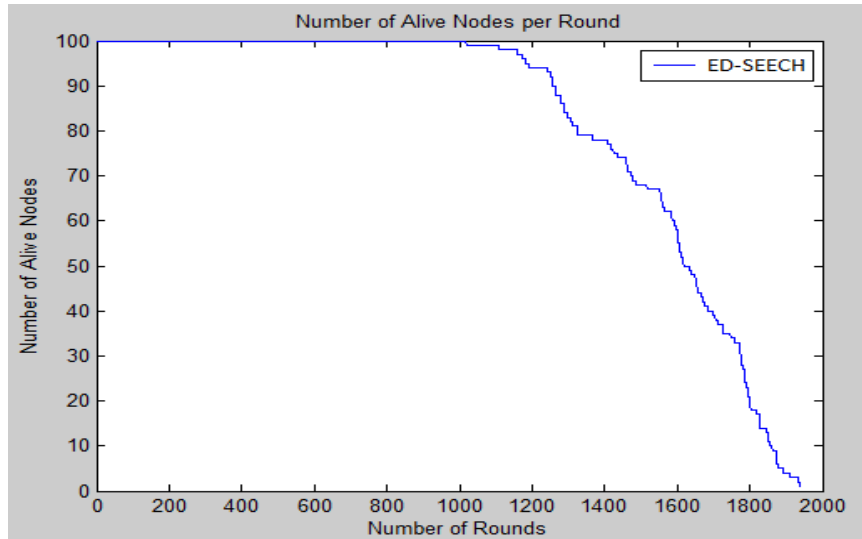
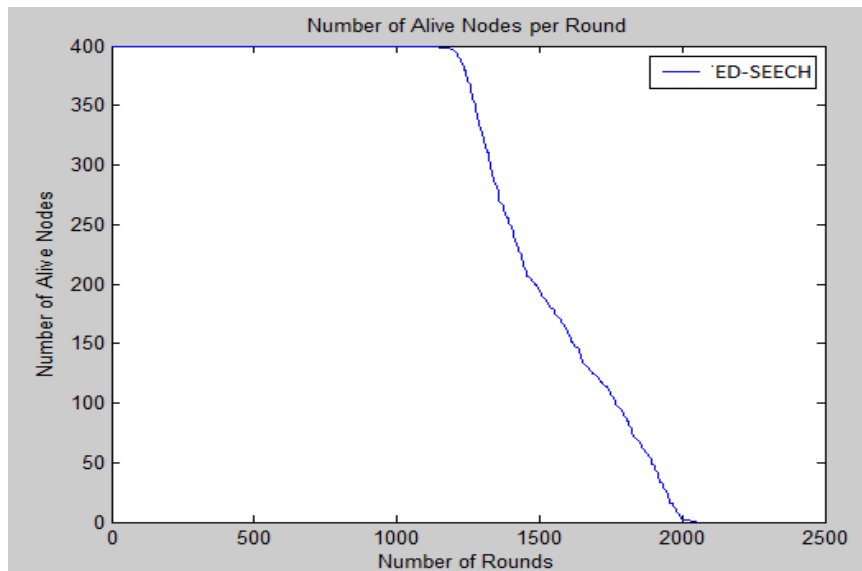*Figure 1: Number of Alive nodes per round for Scene 1*

Figure 2: Number of Alive nodes per round for Scene 2

The time span from start to first node dead is called FND (First Node Dead) which is operational lifetime of the network. Also average life span of all nodes in the network is called AND (Average Node Dead). Another measure is LND (Last Node Dead) which is the time span from time zero to the time when there is no alive node in the network. Alive node is a node whose battery is not completely depleted. Figs. 1 and 2 depict number of alive nodes during simulation time in terms of round. For a summarized comparison FND, LND, and AND measures belonging to the graphs are presented in TABLES II (a), (b) and (c) . In small scenario (100 nodes) SEECH protocol maintains the network operational 4 rounds more than SEECH. The value is 91 in second scenarios.

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Table II:

(a) Comparison of SEECH and proposed protocol for FND
(b) Comparison of SEECH and proposed protocol for AND
(c) Comparison of SEECH and proposed protocol for LND

Scene	Protocol	FND	
		Round	FND over FND of SEECH
Scene 1 (100 nodes)	SEECH	1028	1
	Proposed protocol	1032	1.003
Scene 1 (400 nodes)	SEECH	1016	1
	Proposed protocol	1107	1.08

(a)

Scene	Protocol	AND	
		Round	FND over FND of SEECH
Scene 1 (100 nodes)	SEECH	1054	1
	Proposed protocol	1615	1.53
Scene 1 (400 nodes)	SEECH	1093	1
	Proposed protocol	1485	1.35

(b)

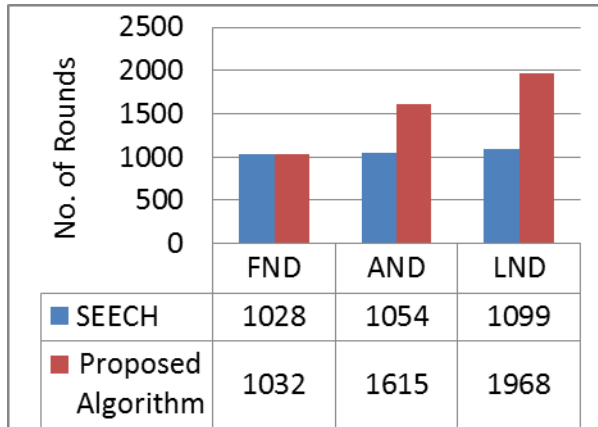| Scene	Protocol	LND	
		Round	FND over FND of SEECH
Scene 1 (100 nodes)	SEECH	1099	1
	Proposed protocol	1968	1.79
Scene 1 (400 nodes)	SEECH	1140	1
	Proposed protocol	2019	1.77

(c)

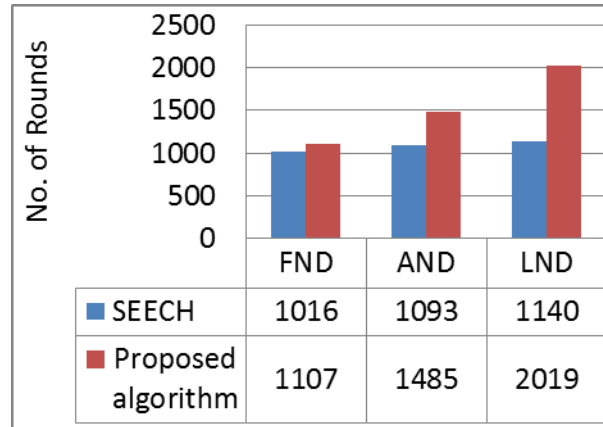*Figure 3: comparison of lifetime in Scene 1*

Figure 4: comparison of lifetime in Scene 2

Figure 3and 4 illustrates the comparison of SEECH with proposed protocol for the various values of FND, AND and LND. So Event Driven SEECH protocol has provided better results than SEECH.

VIII.   CONCLUSION

The energy-aware clustering of distributed sensors is so important to save the power during monitoring and data gathering of smart space and extreme environments. In this paper a scalable energy efficient clustering hierarchy (SEECH) protocol was proposed where the network nodes categorized in three layers as member nodes, cluster heads and relays. The proposed ED-SEECH protocol is simple with low message overhead suitable for event based data gathering applications in harsh and remote environment that prolong network lifetime more than SEECH protocol where the network longevity was examined for two scenarios. The simulation results of ED-SEECH are 3%, 8 % better if FND is calculated For AND the results are 53 % and 35 % better and after considering LND the results are 79% and 77 % better. Simulation results demonstrated that for ED-SEECH protocol, the network lifetime is better than SEECH protocol for first, second scenarios respectively.

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