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***Abstract*— Clustering is an efficient approach to capitalize the energy of energy constraint sensor nodes in wireless sensor networks. Clustering schemes do not guarantee formation of clusters with equal number of nodes. So data frames transmitted by the nodes vary. TDMA schedule of nodes of smaller cluster is smaller than others that results more number of data frames and hence more energy consumption. The non uniform energy consumption of nodes affects the load balancing of network and these nodes are more prone to die earlier than others. In this paper, an improved scheme for cluster head selection is proposed. Clusters having variable frame slots for nodes are applied to E-LEACH and improved E-LEACH to make the cluster more load balanced. Simulation is carried out in NS-2 to analyze the performance of E-LEACH and improved E-LEACH with variable frame length. Variable frame slot scheme for clusters is also measured with the varying distance of base station from the field. Simulation results show that clustering with variable frame length has an improvement of 7% in node death rate over E-LEACH and an improvement of 9% in node death rate over improved E-LEACH. Results suggest that variable frame length scheme improves the performance of clustering schemes for WSNs and have most significant result at base station located at 75m from the field.**

Keywords: Clustering, E-LEACH, Variable Frame Slots

I. INTRODUCTION

Sensor nodes [1] [2] are energy constrained because they carry a limited energy. Because nodes are deployed randomly in a harsh environment so replacement or recharging of battery is not quite possible. Energy consumption in transmission is directly proportional to the square of the distance between transmitter and receiver. So communications being the major energy consuming process, design of data centric wireless sensor networks [1] [2] [3] [4] focus on energy efficient data gathering.

Clustering [1] of nodes is a scalable and energy efficient process for wireless sensor networks. In conventional clustering, network is divided into small group of nodes called cluster. One node from each cluster is selected as a cluster head [1, 3]. All the remaining nodes in the cluster send their data to their respective cluster head. Cluster head aggregate the data and sends to the base station. This scheme works far better than direct transmission but network depends on lifetime of cluster head and cluster head consumes more energy than other nodes and may die early.

Low Energy Adaptive Cluster Hierarchy (LEACH) [5] suggests rotation of role of cluster head among nodes randomly. A node will be a cluster head for a round and after which re-clustering is done with a new cluster head for each cluster. Every node has the possibility of being a cluster head. Because cluster had selection is done randomly, energy load balancing is achieved among the sensor nodes in the network.

An improvement over LEACH (E-LEACH) [6] suggests selection of cluster head by their remaining energy when the energy level of nodes drops below 50% of the initial energy. Node having maximum energy is selected as cluster head.

However clustering schemes do not guarantee exactly equal number of nodes as cluster head during different rounds and clusters do not have equal number of nodes. Due to this toothed cluster formation, nodes of smaller cluster have smaller TDMA schedule than the others. So these nodes send more data frames to their respective cluster head over a round. As a result, cluster head of that cluster has to send more aggregated data to the base station. So all nodes of a smaller cluster transmit larger number of data, causing deplete their energy faster as compared to others. This makes overall consumption of network uneven.

A variable frame slot scheme is implemented for a cluster having nodes less than the desired. Sensor nodes adjust the number of data frames to be transmitted in a distributed manner. Simulation is carried out in NS-2 [8], with MIT uAMPS [9] sensor network framework, for E-LEACH and improved E-LEACH. Results show that variable frame length scheme improves the performance of E-LEACH and improved E-LEACH. Effect of base station distance from the field is also analyzed with the proposed scheme. Results shows that base station distance of 75m from the field have most significant results.

The rest of paper is organized as follows. Section 2 shows literature on clustering, section 3 describes Energy-LEACH protocol, and section 4 narrates the variable frame length scheme. Section 5 shows simulation setup, section 6 shows results and section 7 conclude the work.

II. LITERATURE OF CLUSTERING FOR WSN

Communication of data is the most energy consuming process of nodes. Clustering of nodes in a cluster is an energy efficient approach by avoiding the long distance communication of nodes. In static clustering scheme, clusters are fixed and one node acts as a cluster head for each cluster. Cluster head is responsible for gathering data of nodes in the respective cluster and for sending the data o base station located at far distance. A cluster head node is consuming more energy than other nodes and hence is more prone to energy failure. Cluster head node failure results in loss of data of that cluster.

LEACH scheme does the selection of cluster head randomly among the nodes during each round. Operation of LEACH is carried out in two phases during a round: *set-up phase* and *steady phase*. During the set-up phase, a sensor node chooses a random number between 0 and 1. If this random number is less than the threshold T (n), the sensor node is a cluster-head. T (n) is calculated as in equation (1)

$$T(n) = \begin{cases} \dfrac{P}{1-P*(r \bmod \frac{1}{P})} & if \quad n \in \quad G \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Here P is the desired percentage to become a cluster head; r, the current round; and G, the set of nodes that have not being selected as a cluster head in the last 1/P rounds. After the cluster-heads are selected, the cluster-heads advertise to all sensor nodes in the network that they are the new cluster-heads.

Once the sensor nodes receive the advertisement, they determine the cluster that they want to belong based on the signal strength of the advertisement from the cluster heads. The sensor nodes inform the appropriate cluster head that they will be a member of that cluster. Afterwards, the cluster head assigns the time on which the sensor nodes can send data to the cluster-heads based on a TDMA approach. During the steady phase, the sensor nodes transmit data to their respective cluster head. Each node sends data to respective cluster head during its time slot and minimizes the consumption of energy by entering into sleep mode for remaining time period. Cluster head aggregates data and sends to the base station. After a certain period of time spent on the steady phase, re-clustering is done.

ESCAL [7] uses LEACH as its base but the cluster heads do not send the aggregated data directly to the base station. A Cluster head send the data to nearby cluster head that is close to the base station and conserve the energy by not sending the data to a long distance.

III. ENERGY – LEACH

One of the disadvantages of the LEACH is that the cluster head rotation does not take into account the remaining energy of sensor nodes. A node may not have sufficient energy to carry out the whole round and can be selected as a cluster head. E-LEACH applies both LEACH and new approach for cluster head selection. When the remaining energy is larger than 50% of the initial energy of a node, the LEACH algorithm is applied as in equation (1). Otherwise a new approach which considers the remaining energy in each node is applied as in equation (2).

$$T(n) = \begin{cases} \dfrac{P}{1-P*(r \bmod \frac{1}{P})} * 2P * \dfrac{E_{residual}}{E_{init}} & if \quad n \in \quad G \\ 0 & \text{otherwise} \end{cases} \qquad (2)$$

Here P is probability to become a cluster head, $E_{redidual}$ is remaining energy of node and E_{init} is initial energy of a node. If value of T(n) is larger than a number between 0 and 1 it becomes a cluster head.

After selection of cluster head, cluster formation is done. A cost is calculated by each node to join a cluster, which includes the remaining energy and signal power strength of cluster head. A node joins the cluster head of largest cost value.

$$\text{Cost (i)} = \text{CH (i)}_{\text{remaining energy}} + \text{CH (i)}_{\text{signal strength}} \qquad (3)$$

Here CH (i) $_{\text{remaining energy}}$ and CH (i) $_{\text{signal strength}}$ are remaining energy and signal strength of Cluster Head (i). Nodes calculate the cost value and join the cluster head with maximum cost value by sending the join message to cluster head.

Each cluster head decides a TDMA time schedule and informs the member nodes about the schedule. The nodes then transmit the sensed data to the cluster head during its timeslot. A sensor node sends data to cluster head only when a certain condition is satisfied such as “Does the temperature exceed 30 degree?” If condition is not satisfied, nodes go to sleep mode to reduce energy consumption.

In this paper, Improved E-LEACH is also taken for cluster head selection as

$$T(n) = \begin{cases} \frac{P}{1 - P*(r \bmod \frac{1}{P})} * P * \frac{E_{residual}}{E_{init}} & if \quad n \in G \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

IV. VARIABLE FRAME SLOTS CLUSTERING SCHEME FOR WSNS

The frequency of data reporting by nodes is a function of number of nodes in the cluster, duration of TDMA slot and time required by the cluster head for data aggregation and transmission to base station. If a network consists of N number of sensor nodes and during a particular round S is the number of nodes in the TDMA schedule of a cluster, Ts is the time required for node to transmit a data frame to its cluster head and CAT is the number of time slots required for the related cluster head aggregation of cluster data and its transmission to base station then the frame time is

$$FrameTime = (CAT + S) \times Ts \qquad (5)$$

Nodes send their data during their time slot and go into sleep mode for Frame Time duration to conserve energy. Cluster head is expected always to be active.

The number of data frames (F) a node transmits, during a round T, may be calculated as

$$F = \frac{T}{(CAT + S) \times Ts} \qquad (6)$$

From equation (6) it can be observed that, when number of nodes in a cluster S is small, nodes in such cluster transmit more number of data frames to their cluster head. After aggregation, this cluster head has more data to transmit to base station than other cluster heads. This large number of transmissions will cause more energy consumption to nodes of small cluster.

To reduce the energy consumption of nodes of small cluster and to keep them alive for longer time, the frame rate is proposed to make adaptive to S. In an ideal condition, expected number of nodes in each cluster S (E) may be written as

$$S(E) = \frac{N}{P} \qquad (7)$$

When S < S (E), the frame time in (4) is modified as

$$FrameTime = (CAT + S(E)) \times Ts \qquad (8)$$

With use of (8), number of frames transmitted during a particular round by nodes in clusters with smaller node degree, are expected to get reduced. During time slot (S (E)-S), cluster head has nothing to do and hence shall be allowed to sleep mode to save energy, after transmission of aggregated data to base station. Thus variable frame rate is expected to increase the network lifetime.

V. SIMULATION SETUP

To evaluate the performance of scheme different parameters were set in network simulator NS-2 [8] with incorporation of MIT uAMPS [9] project (NS-2 Extension). NS-2 is widely accepted and used simulator among the network research community. It has the capability to simulate both wired and wireless environment

A. Assumptions.

Simulations are carried out with following assumption:

- The channel was assumed to be symmetrical and to have only system losses and not the propagation loss.
- All nodes were assumed to be equipped with similar facilities.
- The nodes were considered to be deployed in a random fashion across the network and once deployed were assumed to be static.
- The nodes were considered to die only when their energy is exhausted. Sudden failure of nodes was not considered.
- The sink node or the base station was assumed to be located outside the network and is considered to be constraint free.
- The nodes were assumed to have sufficient range to reach each other.
- The nodes were assumed to have the capacity to eliminate data redundancy and to reduce the communication load through data aggregation.
- The nodes were assumed to be equipped with CDMA facilities.

B. Energy Model

Radio energy model [5] used for this study uses a 914 MHz radio. The node radio energy consumed in transmission is as

$$E_{Tx}(m,d) = \begin{cases} m \times E(elec) + (m \times E_{fs} \times d^2) \; d < d_0 \\ m \times E(elec) + (m \times E_{amp} \times d^4) \; d \geq d_0 \end{cases} \qquad (9)$$

Where, *m* is the number of bits transmitted, *d* is the distance between transmitter and receiver and do is the distance constant referred as crossover distance. And for receiving the *m* bit message the node radio consumes as

$$E_{Rx}(m) = M \times E(elec) \qquad (10)$$

As communication cost is considered to be much larger than computational cost, the contribution of computations to the energy consumption is considered to be negligible in this analysis. The assumed energy required for running the transmitter and receiver electronic circuitry *E(elec)* is 50nJ/bit and for acceptable SNR required energy for transmitter amplifier for free space propagation E_{fs} is 100pJ/bit/m2 and for two ray ground E_{mp} is 0.0013pJ/bit/m4. The crossover distance d_0 is assumed to be 87m.

C. Simulation Model

Simulation parameters used are listed in the table 1.

Parameters	Values
Network Area	100m × 100m
Number of nodes	100

Base station location	(50,175)
Distance of the base station	0,25,75,125
Clusters to be formed	4
Operating frequency	914 MHz
Header packet size	25 bytes
Data packet size	500 bytes
Initial energy	2 Joules
Bandwidth	1 Mb/s
Propagation model	Two ray ground

Table 1: Simulation Parameters

VI. SIMULATION RESULTS

Death Rate is the measurement of number of node dead in the field with time. A node death can be some physical damage or a node might be out of energy. A network is reliable if the node death rate is low. A reliable network will have a better data gathering rate i.e. units received at base station will also be high.

TABLE 1 Node death rate at base station distance 0m

Nodes Dead	**Simulation Time in Seconds**			
	E-Leach	**E-LEACH with variable frame slot**	**Improved E-Leach**	**Improved E-LEACH with variable frame slot**
10	347	358	356	368
20	369	381	378	390
30	388	397	392	399
40	405	414	406	411
50	418	426	423	427
60	436	450	437	449
70	449	464	459	469
80	461	477	464	481
90	474	488	478	487
96	485	501	489	498

TABLE 2. Node death rate at base station distance 25m

Nodes Dead	**Simulation Time in Seconds**			
	E-Leach	**E-LEACH with variable frame slot**	**Improved E-Leach**	**Improved E-LEACH with variable frame slot**
10	376	420	393	405
20	404	446	417	429
30	426	454	438	450
40	452	458	458	478
50	463	488	477	500
60	468	515	487	519
70	475	538	509	547
80	483	559	522	566
90	505	588	541	593
96	547	607	553	620

TABLE 3. Node death rate at base station distance 75m

Nodes Dead	**Simulation Time in Seconds**			
	E-Leach	**E-LEACH with variable frame slot**	**Improved E-Leach**	**Improved E-LEACH with variable frame slot**
10	402	422	445	485
20	433	448	476	524
30	451	466	496	550
40	474	490	515	568
50	493	517	524	580
60	512	536	535	595
70	535	555	554	607
80	560	574	572	626
90	588	599	596	661
96	602	643	629	684

TABLE 4 Node death rate at base station distance 125m

Nodes Dead	**Simulation Time in Seconds**			
	E-Leach	**E-LEACH with variable frame slot**	**Improved E-Leach**	**Improved E-LEACH with variable frame slot**
10	331	368	380	453
20	350	391	405	477
30	379	414	417	493
40	399	439	428	502
50	419	459	438	513

60	447	476	457	522
70	476	498	489	537
80	507	517	511	559
90	525	543	537	581
96	569	583	571	609

Simulation results show that base station located at a distance of 75m from the field has the most significant results. With variable frame slots for cluster, there is 7% improves in node death rate for E-LEACH and 9% improvement for Improved E-LEACH.

VII. CONCLUSION

In this paper, effect of variable frame slots is analyzed on clustering scheme. Clustering schemes, E-LEACH and improved E-LEACH do not guarantee equal number of nodes in clusters. That unequal distribution of nodes to clusters leads to non uniform energy consumption of nodes. Cluster with less number of nodes is more energy consuming. A variable frame slot scheme is implemented to adjust the number of frame slots for smaller clusters. The scheme improves the performance of E- LEACH and improved E-LEACH significantlly in terms of node death rate.

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