ADAPTIVE CLUSTERING IN WIRELESS SENSOR NETWORK: CONSIDERING NODES WITH LOWEST-ENERGY

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ABSTRACT

In recent years, wireless sensor networks (WSNs) have gained increasing attention from researchers and scholars. One of the major issues in wireless sensor network is developing an energy-efficient clustering protocol. Hierarchical clustering algorithms are very important in increasing the network's life time. Each clustering algorithm is composed of two stages, the setup stage and steady stage. The most important point in this algorithm is cluster head selection. Cluster head selection is important because, a good clustering guarantees energy efficiency and load balancing in the network. For load balancing in WSNs, network overload should be removed from the weak nodes (nodes with lower residual energy) and transmitted to the more powerful nodes. In this paper weak nodes decide which node become cluster head. Weak node choice cluster head based on node's weight. This weight is combined of residual energy and distance. Finally, the simulation results demonstrate that our proposed distributed clustering approach is more effective in prolonging the network life-time compared with LEACH.

KEYWORDS

Wireless Sensor Network, Residual Energy, Clustering & Neighbour Weight

1. INTRODUCTION

A wireless sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. The administrator typically is a civil, governmental, commercial, or industrial entity. The environment can be the physical world, a biological system, or an information technology (IT) framework. There are four basic components in a sensor network: (1) an assembly of distributed or localized sensors; (2) an interconnecting network (usually, but not always, wireless-based); (3) a central point of information clustering; and (4) a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining. Because of the potentially large quantity of data collected, algorithmic methods for data management play an important role in WSNs [12].

WSNs have great potential for many applications in scenarios such as national security and military applications [1,2], data collection [3,4], monitoring and surveillance [5-7] and medical care [8,9]. The WSN design often employs some approaches as energy-aware techniques, in-network processing, multi hop communication, and density control techniques to extend the network lifetime. In addition, WSNs should be resilient to failures due to different reasons such as

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physical destruction of nodes or energy depletion. Fault tolerance mechanisms should take advantage of nodal redundancy and distributed task processing. Several challenges still need to be overcome to have ubiquitous deployment of sensor networks. These challenges include dynamic topology, device heterogeneity, limited power capacity, lack of quality of service, application support, manufacturing quality, and ecological issues.

Grouping sensor nodes into clusters has been widely pursued by the research community in order to achieve the network scalability objective. Every cluster would have a leader, often referred to as the cluster-head (CH). A CH may be elected by the sensors in a cluster or pre-assigned by the network designer. A CH may also be just one of the sensors or a node that is richer in resources. Clustering has numerous advantages and the best one is implement optimized management strategies to further enhance the network operation and prolong the battery life of the individual sensors and the network lifetime. A CH can schedule activities in the cluster so that nodes can switch to the low-power sleep mode most of the time and reduce the rate of energy consumption. Sensors can be engaged in a round-robin order and the time for their transmission and reception can be determined so that the sensors reties are avoided, redundancy in coverage can be limited and medium access collision is prevented. Furthermore, a CH can aggregate the data collected by the sensors in its cluster and thus decrease the number of relayed packets [10,11].

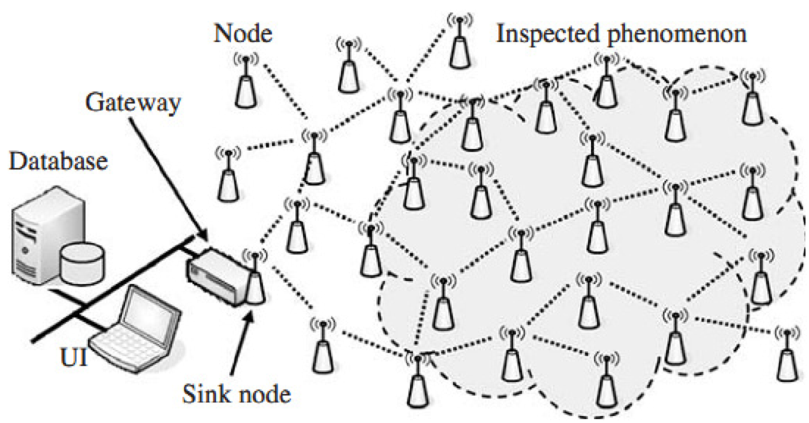

Figure 1: An example WSN scenario.

One of the most important challenges of WSNs design is develop a method or protocol so that the randomly deployed numerous sensor nodes behave in a collaborative and organized way. Each sensor node wants to maximize its own utility function. In addition, the entire network needs balance in resource assignments to perform in a way that is useful and efficient. Network routing protocol design becomes far more critical to WSNs performance than that of from conventional communication networks. Among numerous proposed network routing protocols in past years, hierarchical routing protocols greatly contribute to system scalability, lifetime, and energy efficiency. The algorithm presented in this paper considers nodes with lowest-energy. In this algorithm the nodes with lowest residual energy determine which node become cluster head. Weak nodes choice cluster head based on combination of two following measures: (1) The node become cluster head that has more residual energy than other neighbors and (2) the distance between them is lower than other.

The rest of the paper is organized as follows. Section 2 highlights of related work. Section 3 presents our methods. Section 4 demonstrates experiments and simulation results. Finally, section 5 is the conclusions.

2. RELATED WORK

The main goal of cluster-based routing protocols is to improve energy efficiency in network nodes and increase network lifetime. Network organization to be more efficient with clustering and energy consumption is distributed in entire network. In this section we review some energy-aware algorithm in wireless sensor networks.

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH [13,14] is one of the most popular clustering algorithms for WSNs. It forms clusters based on the received signal strength and uses the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability p and broadcasts its decision. Each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load. The rotation is performed by getting each node to choose a random number ‘‘T’’ between 0 and 1. A node becomes a CH for the current rotation round if the number is less than the following threshold:

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

Where p is the desired percentage of CH nodes in the sensor population, r is the current round number, and G is the set of nodes that have not been CHs in the last 1/p rounds. Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the base-station from the CH directly. This is not always a realistic assumption since the CHs are regular sensors and the base-station is often not directly reachable to all nodes due to signal propagation problems, e.g., due to the presence of obstacles. LEACH also forms one-hop intra- and inter cluster topology where each node can transmit directly to the CH and thereafter to the base-station. Consequently, it is not applicable to networks deployed in large regions.

Low Energy Adaptive Clustering Hierarchy Centralized (LEACH-C): LEACH-C [14] is identical to the LEACH protocol as far as formatting clusters at the beginning of each round. However, instead of nodes randomly self-selecting as a CH, a centralized algorithm is performed by the sink in LEACH-C. The sink collects location information from the nodes, and then broadcasts its decision of which nodes are to act as CHs back to the nodes. The overall performance of LEACH-C is better than LEACH since it moves the duty of cluster formation to the sink. However, LEACH-C is sensitive to the sink location. Once the energy cost of communicating with the sink becomes higher than the energy cost for cluster formation, LEACH-C no longer provides good performance. Sinks may be located far from the network in most WSN applications. So, the dependence on the sink location is a major disadvantage of LEACH-C

Hybrid Energy-Efficient Distributed Clustering (HEED): HEED [15] protocol is an energy-aware hierarchical approach improved from LEACH. HEED focuses on choose appropriate CHs by adding more network information. It uses residual energy as the primary clustering parameter to select a number of tentative CHs. Those tentative CHs inform their neighbours of their intentions to become CHs. These advertisement messages include a secondary cost measure that is a function of neighbour proximity or node degree. This secondary cost is used to guide the regular nodes in choosing the best cluster to join, and to avoid elected CHs being within the same range of each other. If a CH is far from the sink, it tries to send the aggregate data to another CH instead of sending to the sink directly.

RRCH: RRCH [16] performs cluster formation only once to avoid the high energy consumption during clustering phase. RRCH uses a similar method to LEACH to setup clusters. Once the clusters are set up, RRCH keeps the fixed clusters and uses the round-robin method to choose the node to be the CH within the clusters. Every node has a chance to be CH during a frame. When a node has been detected as an abnormal node, the CH modifies the scheduling information and broadcasts it to the entire cluster during frame modification; then its cluster members delete the abnormal node based on the received schedule information. RRCH has the same defect of LEACH: no guarantee of cluster quality. Without the periodic re-clustering, the RRCH cannot handle clusters with bad quality, such as overlay of clusters and too small or too big a cluster size.

Energy Efficient Homogenous Clustering Algorithm [17]: In this clustering algorithm, energy efficiency is distributed and network performance is improved by selecting cluster heads on the basis of (i) the residual energy of existing cluster heads, (ii) holdback value, and (iii) nearest hop distance of the node. In the proposed clustering algorithm, the cluster members are uniformly distributed and the life of the network is further extended. This algorithm consists of six-step clustering to generate appropriate clusters.

Step 1: In the first round, BS collects information regarding location of all the nodes in the network. Depending on the density and geographical layout of the network, it virtually divides the network into 10 zones as shown in Figure 1. The objective behind this method is to ensure uniform selection of CHs throughout the layout of the network.

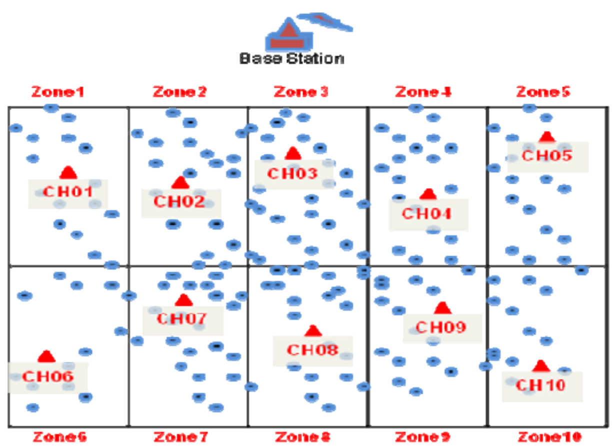

Figure 1: Virtual Distribution of Network into Zones and Selected Cluster Heads

Step 2: Since we have assumed that initially all the nodes have same maximum energy (E_{max}), the nodes in each zone have a probability p (1/number of nodes in the zone) of becoming a CH. Hence, from each zone, randomly a cluster head (CH) is selected randomly as shown in Figure 1.

Step 3: Once the CHs are formed, it broadcasts its identity to all the other nodes in the network to accept its joining request and form actual clusters. For example, CH7 and CH12 broadcast its identity to all the nodes in the network as shown in the Figure 2.

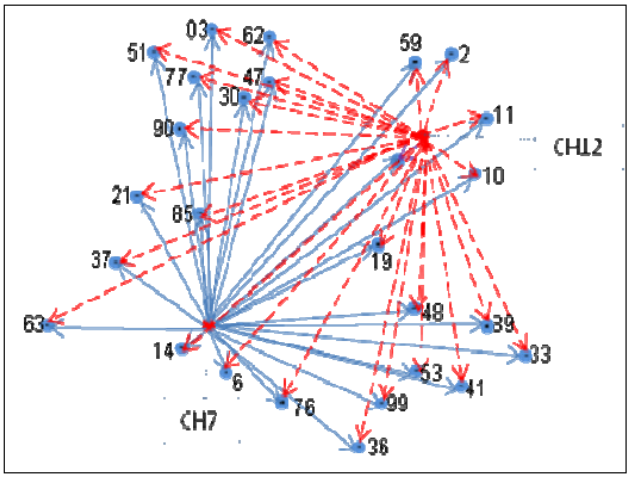

Figure 2: Broadcasting of its Identity by Selected CHs to all nodes

Step 4: The nodes which receive the joining request analyses the signal strength of the request signal. Signal strength of the CH request depends on the distance between CH and node, and physical barrier between the CH and node. Depending on the level of the signal each node sends an acknowledgement to the most preferred CH. Each CH waits for the joining request from the nearby nodes. Figure 3 illustrates joining of nodes with the CH. Left out nodes will try to join other CH nearest to it.

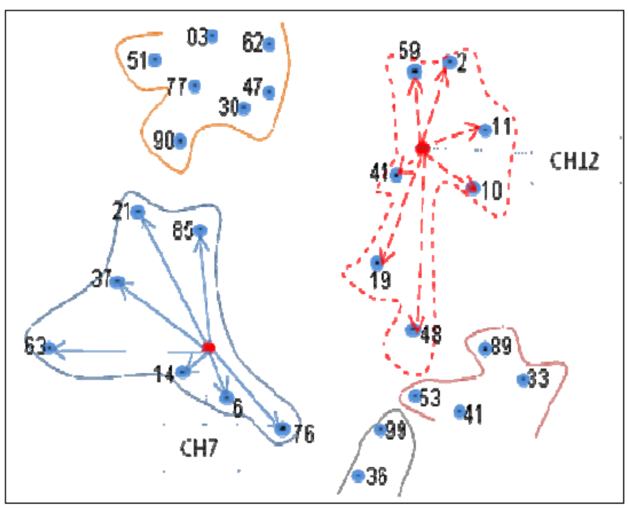

Figure 3: Nodes analyzing the signal strength from the CHs

Step 5: The CH prepares the data sending schedule and sends it to its members within the cluster.

Step 6: The CH receives data from each node, compresses the data and sends it to the BS.

In this algorithm new CH is selected by checking the residual energy of existing CHs. If it is below a threshold level (T), new CH is to be selected depending on the following criteria:

- A node has not become a CH for the past (1/p) – 1 rounds.

- The factor $(E_{Current})/(E_{Max})$ should be nearest to one; ($E_{Current}$=current residual energy of the node and E_{Max}=initial energy level of the node)

- The most preferred next CH is the node nearest to the existing CH (hop, h=1). Figure 7 illustrates formation of new CH and re-orientation of the cluster.

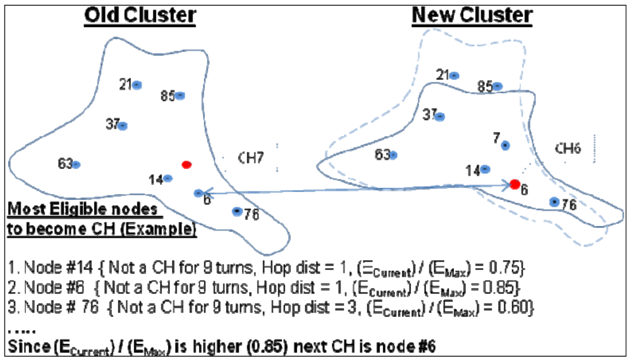

Figure 4: Re-orientation of the Cluster in view of new CH Selection

3. PROPOSED METHOD

This paper presents an algorithm for operate in distributed environment. The main idea of this algorithm is that the weak nodes are responsible for selecting cluster-head. The weak nodes select cluster-head from their neighbors that have biggest weight for it. This weight depends on residual energy and distance between them. Assumptions for this algorithm in wireless sensor networks are as follows:

- The nodes in the network are considered stationary.
- The nodes are left unattended after deployment.
- Nodes are location-aware, which can be defined using GPS.
- Each node has access only to information its neighbors in one hop.
- All nodes have similar capabilities, processing, communication and initial energy.
- The transmission ranges of nodes are adjustable. All the nodes can directly communicate with the sink.
- The sink is static.

The operation of proposed algorithm is divided in rounds. Each round start with an initial stage when the clusters are organizes, and follows with stable stage when the data are transferred to the BS. To organize cluster in initial stage we proposed four phases that cluster head are selected by low-energy nodes and based on the weight of the nodes. The weight of each node calculates from residual energy and distance between them.

Phase1: Create a list of neighbors with the weight of each neighbor

Nodes exchange HELLO messages that obtain neighbor nodes residual energy and its location. After that weight of each node (j) for node (i) is calculated from the following formula.

$$W_{ij} = \frac{\text{residual energy}_j}{\sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}} \quad (2)$$

Phase2: cluster-head selection by the weak nodes

In this phase, each node has list of neighbor with their weights. Nodes with lower residual energy decide which nodes of neighbors become cluster head. These weak nodes find best cluster head from its neighbor based on biggest weight, after that send Become-CH message for it.

Phase3: become cluster head and advertise it

Each node received this message (Become-CH), become cluster head and send Advertise message to all neighbors. Other nodes that received Advertise message save this neighbor cluster head in cluster head list. In end of this phase each node has list of cluster head that exist in its neighbor.

Phase4: join to best cluster head

Every node find best cluster head (based on weight) from cluster head list and send Join message for it.

Stable stage: After the initial stage, proposed algorithm uses the sequence of nodes merging into the current cluster as the schedule. Each cluster member gets its assigned role and starts to send data to CH in turns. This algorithm uses the ''TDMA + CDMA" model as the MAC layer protocol structure. During this stage, proposed algorithm adopts the TDMA frame for intra-cluster communications and for inter-cluster communication, we adopted an assumption: all the nodes have the capability to communicate with the sink directly, which is from the model used for LEACH.

4. Simulation and Analysis

In this section presents comparison between proposed algorithms and two most important hierarchical routing protocols, LEACH and LEACH-C. This comparison is evaluated using Network Simulator NS-2.34 [18]. To reduce the impact of random network deployment, we considered several random network topologies to get the average results. The simulated WSNs consist of 100 homogeneous sensor nodes randomly deployed within the sensing field from (0, 0) to (100, 100). The number of clusters is set to be 5 percent of the total nodes with K = 5. The base station locations is located at (50, 50), which is the center of the network area. The simulations continued until all the nodes in the network had consumed all their energy. Furthermore, the data message size was fixed at 500 bytes; with 25 bytes representing the length of the packet header. Simulation parameters are shown in Table 1.

Table 1 Simulation parameters.

Parameter	Value
Node number	100
Sensing filed range	(0, 0)–(100, 100)
Channel bandwidth	1 Mbps
E_{elec}	50 nJ/bit
ϵ_{fs}	10 pJ/bit/m2
ϵ_{mp}	0.0013 pJ/bit/m4

E_{fusion}	5 nJ/bit/signal
Data rate	5 TDMA frames per 10 s
initial energy	1 J/node
Exchanged message size	
Data packet size	500 bytes
Schedule message	225 bytes
Other message	25 bytes

The assumption for energy consumption of the sensor is due to data transmission and reception (Figure 5). Cluster head is also consuming energy for the data aggregation before it sends the data to BS. Using these parameters, a simple energy dissipation model of radio and processor hardware is presented as follows.

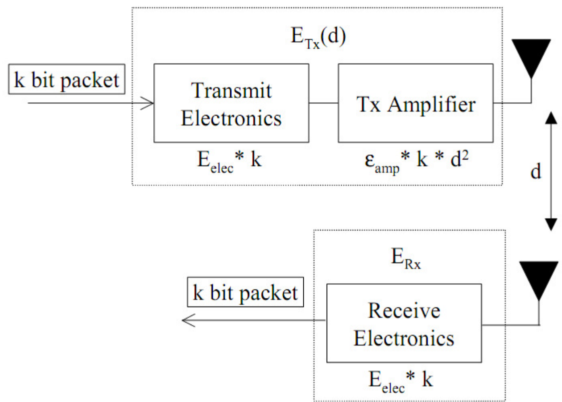

Figure 5: Radio Energy Model

Receiving energy wasting: energy consumption for receiving a bit is E_{elec} that is dependent on to the coding and modulation. Energy consumption for receiving an n-bit message is equivalent to

$$E_{Rx} = n * E_{elec} \quad (3)$$

Transmitting energy wasting: in this simulation is considered both the free space and the multipath fading channel models. When the distance between the transmitter and receiver (D) is larger than a specified threshold distance, d_0, the channel switches to the multi-path fading model.

$$E_{Tx} = n * E_{elec} + n * \epsilon_{fs} * D^4 \quad (4)$$

Otherwise the channel follows the free space model

$$E_{Tx} = n * E_{elec} + n * \epsilon_{mp} * D^2 \quad (5)$$

Computation energy wasting: Data aggregation and calculate the weight of the neighbors cause computation energy wasting.

$$E_{com} = E_{fusion} * Size_{Signal} * Number_{Signal} \quad (6)$$

To perform data aggregation, cluster heads compress received data and consumed energy based on E_{com} [19].

We use of the three metrics for analyze and compare the simulation results: network lifetime, energy wasting and number of received data packet at base station.

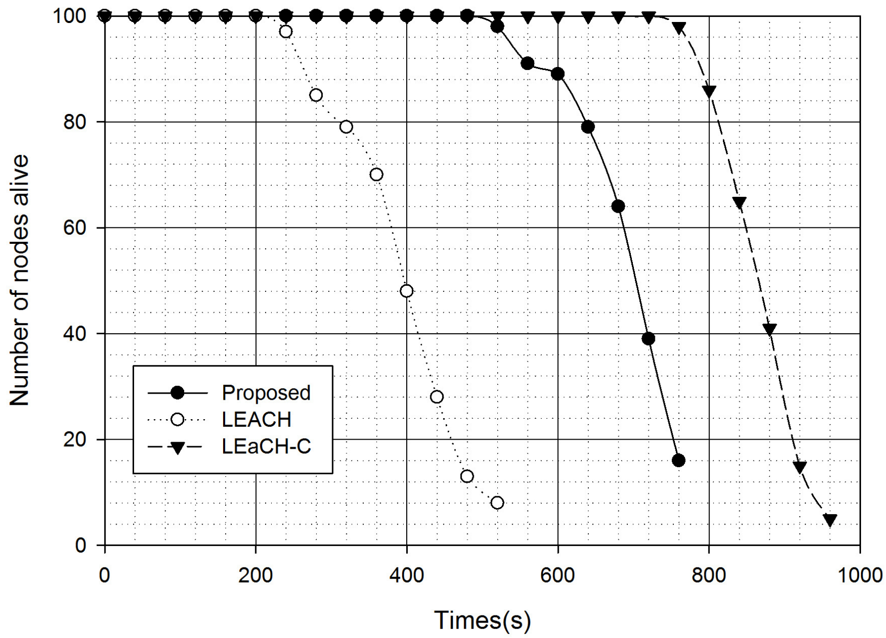

Figure 6: Network life time, the sink at (50, 50).

Figure 6 shows the proposed algorithm has a greater lifetime than the LEACH as can be seen. The proposed algorithm has smaller lifetime than the LEACH-C but It should be noted that LEACH-C is a centralized algorithm and the proposed algorithm is distributed algorithm without need any global information.

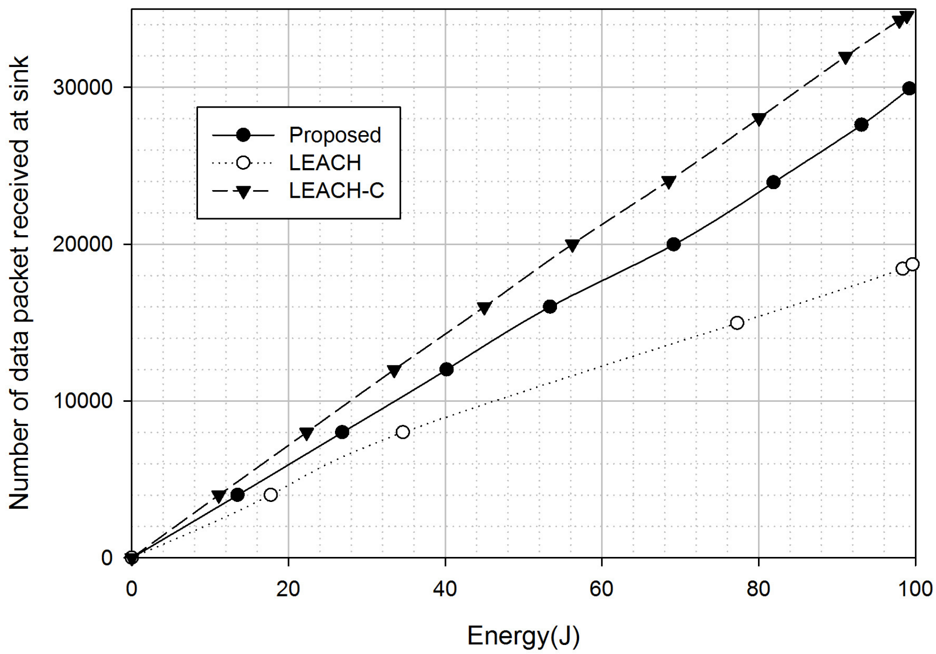

Figure 7: Total energy dissipation versus the amount of data packets received to the sink

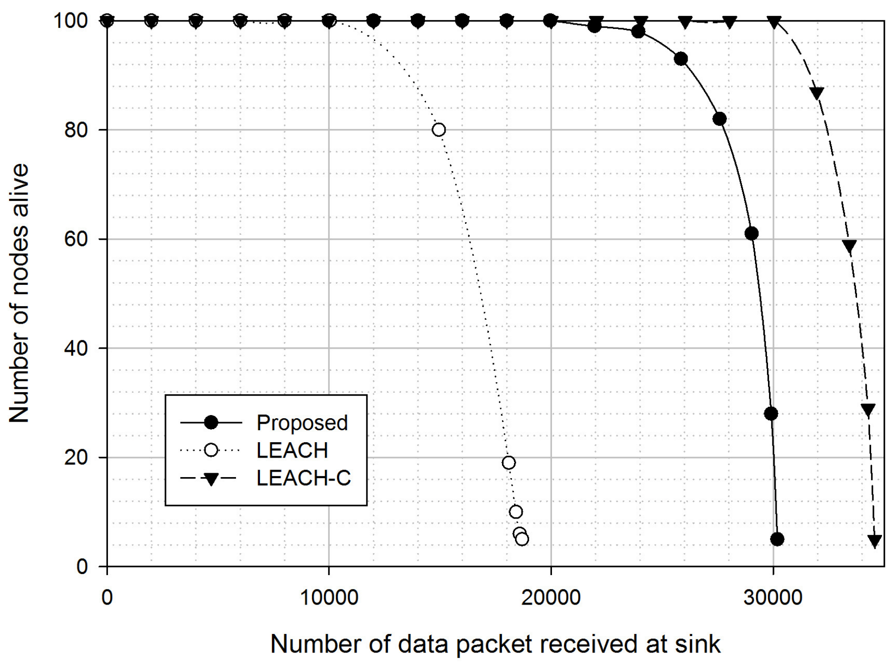

Figure 8: Number of nodes alive versus the amount of data packets received at the sink

Figure 7 shows the relationship between energy loss and the amount of data packets received at the sink. In proposed algorithm Data reach to the sink with less energy consumption than LEACH. Energy consumption for sending data packets to the sink in this algorithm approximately likes energy consumption in LEACH-C.

Figure 8 shows the number of data packets received at the sink. Similar to The proposed algorithm received data packets more than LEACH and less than LEACH-C at the sink. When the last node died, the sink in proposed algorithm received approximately 30,000 data packets, and LEACH received 18,000 data packets and LEACH-C received 34,000 data packets.

5. CONCLUSIONS

To the limitations of wireless sensor networks, many algorithms have been proposed with different goals. To increase the network life time is very important to consider nodes with low energy. This paper presents an algorithm, first, it has consider to the nodes with low energy and these nodes determines which nodes become cluster-head, The second, cluster head selection based on the weighting of the neighboring nodes that the weights were calculated based on the energy residual and distance between nodes.

Simulation for 100 nodes had expanded in a network 100 * 100 m^2 showed better performance than two well-known protocols, LEACH and LEACH-C. In all cases, the proposed algorithm show better performance than LEACH and it has result almost like LEACH-C. It should be noted that LEACH-C is a centralized algorithm and the proposed algorithm is distributed algorithm without need any global information.

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