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An Energy-Efficient, Load Balanced Distributed Clustering and Routing Protocol for Large Scale WSNs

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Abstract: A wireless network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. These sensor nodes have some constraints due to limited energy, storage capacity and computing power. The energy consumed to route data from the sensor node to its destination raises as a critical issue in designing wireless sensor network routing protocols. In order to prolong the lifetime of wireless sensor networks, this study presents a multi-hop routing protocol with distributed clustering (ELDRL). First, in order to overcome the defect that the clusters distribute unevenly, ELDRL selects nodes as a cluster-head with regard to neighbor cluster-heads. Second, it partitions the network into different layers of clusters. Cluster heads in each layer cooperates with the adjacent layer to transmit sensor's data to the base station. ELDRL spreads the workload across the sensor network, load balancing reduces hot spots in the sensor network and increases the energy lifetime of the sensor network. Moreover, the protocol not only increases the scalability but also decreases the traffic of WSN. Simulation results show that the scheme is more efficient compared with LEACH.

Keywords: Distributed clustering, large scale sensor network, load balance, multi-hop routing, wireless sensor network

INTRODUCTION

Wireless Sensor Network (WSN) is a recent research topic. This network is composed of hundreds or thousand of autonomous and compact devices called sensor nodes. The availability of integrated low-power sensing devices, embedded processors, communication kits and power equipment is enabling the design of sensor nodes. One of the most important constraints on sensor nodes is the low power consumption requirement. Sensor nodes carry limited, generally irreplaceable, power sources. Therefore, sensor network protocols must focus primarily on power conservation. For that reason, comprehensive solutions for reducing energy consumption of nodes and the network become crucial for WSNs and suitable routing algorithms should be proposed for increasing WSNs lifespan.

Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime. The sensor will need to collect data to Sink (or base station) node in the remote monitoring applications of WSN, Sink node's control information through the collaborative interaction among the nodes sent to the designated areas. According to communication energy model (Mhatre and Rosenberg, 2004a), hierarchical routing protocols have better adaptability and energy conservation than plane routing protocols.

The energy consumption can be reduced by allowing only a portion of the nodes, which called cluster heads, to communicate with the base station. The data sent by each node is then collected by cluster heads and compressed. After that the aggregated data is transmitted to the base station. Clustering based algorithms are believed to be the most efficient routing algorithm for the WSNs. The basic principle of its efficiency is that it operates on the rule of divide and conquers. Although clustering can reduce energy consumption, it has some problems. The main problem is that energy consumption is concentrated on the cluster heads. In order to overcome this demerit, the issue in cluster routing of how to distribute the energy consumption must be solved. LEACH is considered as the most popular routing protocol that use cluster based routing in order to minimize the energy consumption; in this study we propose a new algorithm with multi-hop approach. The proposed algorithm could reduce nodes energy consumption and save nodes which are placed far from sink. Simulation results bring out that our protocol outperforms LEACH protocol in term of energy consumption, load balance, scalability and traffic.

LITERATURE REVIEW

Designing a cluster-based routing protocol requires consideration of the cluster formation, head selection, data aggregation, inter- and intra- cluster

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communications (Al-Karaki and Kamal, 2004; Akkaya and Younis, 2005). LEACH (Heinzelman *et al*., 2000) protocol randomly selects a few sensor nodes as Cluster-Heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. We discuss this in greater detail in section "The leach protocol". The TEEN protocol aims to provide event-based delivery in the network (Manjeshwar and Agrawal, 2000). PEGASIS (Lindsey and Raghavendra, 2002) aims to address the overhead caused by the cluster formation in LEACH by constructing chains of nodes instead of clusters. HEED (Younis and Sonia, 2004) extends the basic scheme of LEACH by using residual energy and node degree or density as a metric for cluster selection to achieve power balancing. Mhatre and Rosenberg (2004b) present a comparative study of homogeneous and heterogeneous networks in terms of overall cost of the network, defined as the sum of the energy cost and the hardware cost. They analyze both single-hop and multi-hop networks. The authors conclude that using single-hop communication between sensor nodes and the cluster head may not be the best choice when the propagation loss index *k* for intra-cluster communication is large (k>2). They propose a multi-hop version of the LEACH protocol (M-LEACH) and show the cases in which M-LEACH outperforms the single-hop version of the protocol. ACE (Chan and Perrig, 2004) is an algorithm that uses just three rounds of feedback to form an efficient cover of clusters across the network. It uses the node degree as the main parameter to select cluster heads. In Chiasserini *et al*. (2002) have proposed a clustering algorithm that aims at maximizing the lifetime of the network by determining optimal cluster size and optimal assignment of nodes to cluster-heads. They assume that the number of cluster-heads and the location of the cluster-heads are known a priori, which is not possible in all scenarios. Furthermore the algorithm requires each node to know the complete topology of the network, which is generally not possible in the context of large sensor networks. In Bandyopadhyay and Coyle (2003) the authors propose a distributed clustering algorithm where communication between the nodes is organized in a multi-hop manner. Using the results of stochastic geometry, the authors formulate a network energy dissipation function and find the probability of becoming a cluster head that minimizes energy dissipation. They further extend this study, generating a multilevel hierarchical network and they show that the energy savings increase with the number of levels. TPC (Choi *et al*., 2004) is a two-phase clustering scheme for energy-saving and delay-adaptive data gathering in wireless sensor networks. Each node advertises for cluster head with a random delay and the node who overhears others' advertisement will give up its own advertisement. In such a way, the network is partitioned into clusters in the first phase. In the second phase, each member searches for a neighbor closer to the cluster head within the cluster to set up an energy-saving and delay-adaptive data relay link. With the advantages of chain topology, TPC achieves a great tradeoff between energy cost and delay.

THE LEACH PROTOCOL

LEACH (Low-Energy Adaptive Clustering Hierarchy) dynamically selects sensor nodes as cluster heads and form clusters in the network. The communications inside the clusters are directed to the cluster head, which performs aggregation. Cluster heads then directly communicate with the sink to relay the collected information from each cluster. LEACH also changes the cluster head role dynamically such that the high-energy consumption in communicating with the sink is spread to all sensor nodes in the network. The operation of LEACH is divided into rounds. Each round begins with a setup phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster-head and on to the sink, as shown in Fig. 1.

Cluster head selection: The cluster-head selection process of LEACH is as follows: every node gets a random number between 0 and 1. If the number is less than the threshold values T (n), the node becomes a CH for the current round:

$$T\,(\mathrm{n}) = \begin{cases} \frac{P}{1-P\times\left(r\ mod\left(\frac{1}{P}\right)\right)} \ if\ n \in \mathrm{G} \\ 0\ otherwise \end{cases} \quad (1)$$

where,

P : The desired percentage to become a cluster Head
r : The current round
G : The set of nodes that have not been selected as a cluster head in the last 1/P rounds

Using this threshold, each node will be a cluster-head at some point within (1/p) round. During round 0 each node has a probability P of becoming a

Fig. 1: Time line showing LEACH operation

cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next (1/p) rounds. Thus the probability that the remaining nodes are cluster-heads must be increased.

Cluster formation: Once the nodes have selected themselves to be cluster heads using the probabilities in Eq. (1) then advertise to their neighbors in the network that they are the new cluster heads. For this operation, LEACH relies on a CSMA-based random access scheme to avoid advertisement collisions from multiple cluster heads. The non-cluster-head nodes must keep their receivers on during this phase of setup to hear the advertisements of all the cluster-head nodes. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement. Assuming symmetric propagation channels, the cluster-head advertisement heard with the largest signal strength is the cluster-head to whom the minimum amount of transmitted energy is needed for communication. After each node has decided to which cluster it belongs, it must inform the cluster head node that it will be a member of the cluster. Each node transmits a join-request message back to the chosen cluster head using a non-persistent CSMA MAC protocol. This message is a short message, consisting of the node's ID and the cluster head's ID. When the cluster-head receives all join messages, it will allocate TDMA time slot information to all the nodes in the same cluster, notice nodes within the same cluster to send a TDMA message to the cluster head in its own time slot. In order to avoid signal interference near the cluster, cluster head can determine the CDMA codes which all nodes used. The CDMA codes which is used in the current phase and TDMA timing information will be sent together. When nodes within the cluster receive the message, they will send data to the cluster-head in their own time slot.

Data transmission: During the steady-state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads.

This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement). During this phase, only the cluster-heads are active all the time. The radio of each non-cluster-head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node receive all the data from the nodes in the cluster, after receiving all the data, aggregates it before sending it to the base-station.

Problems and requirements: The nodes in the sensor network are severely constrained by energy, storage capacity and computing power. The delicate design of a routing protocol is significant in order to prolong the lifetime of both the sensor nodes and the network. Distribution of sensors among the clusters is usually an objective for setups where CHs perform data processing or significant intra-cluster management duties (Gupta and Younis, 2003). Given the duties of CHs, it is intuitive to balance the load among them so that they can meet the expected performance goals (Younis *et al.*, 2003). Load balancing is a more pressing issue in WSNs where CHs are picked from the available sensors.

LEACH requires cluster-head nodes to send their aggregated data directly to sink (or BS). However, if the cluster head is far away from the sink, they might expend excessive energy in communication and run out of their energy at earlier stage. Furthermore, single-hop transmission may be quite expensive when the sink is far away from the cluster heads. Unbalanced energy consumption results in the premature network partition that disables the network functioning, although there may be much residual energy left. On the other hand, the latter may not be optimal with respect to energy efficiency, as it can burn energy evenly to keep network connectivity and maintain network functioning as long as possible. Let us give a simple example to demonstrate what uneven energy depletion results in and how the proposed scheme ELDRL works to balance energy consumption.

A wireless sensor network is illustrated in Fig. 2. In LEACH, cluster-heads, which are far away from the sink (critical area), run out of their energy quickly because they have to use much energy to send the collected data packets to sink. Whenever this occurs, there will be many living nodes; thus, the network

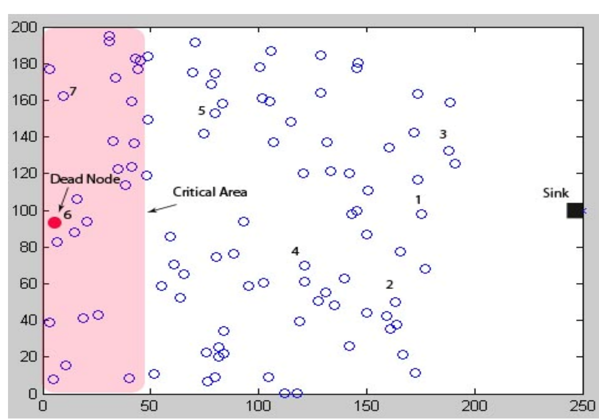


Fig. 2: Illustration of critical area in WSN

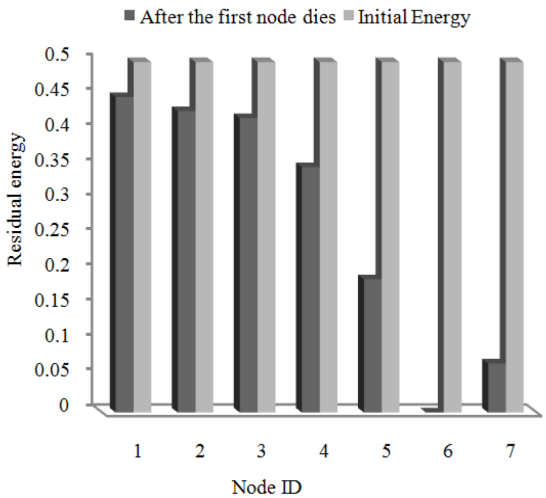


Fig. 3: Energy dissipation

connectivity is affected. The residual energy histogram in Fig. 3 presents simulation results, which confirms this phenomenon.

How can we protect critical area? More precisely how can we balance energy consumption between critical area and the other areas? The ELDRL could route the packets from critical area through other areas where there are more nodes and energy before the energy on the nodes in critical area is exhausted. Thus, critical area is protected properly. By this way, both energy efficiency and energy balance are taken into account.

THE PROPOSED SCHEME

In this study we propose a routing protocol called ELDRL based on LEACH protocol to balance the energy consumption of sensor nodes in order to solve the overload energy consumption problem. The network life time of ELDRL is broken down into a number of rounds and each round starts with the setup phase, where cluster-heads are selected and they form clusters. Then cluster-heads construct multi-hop routes to BS using neighbor cluster-heads. In order to solve the problem of overload energy consumption and to minimize the diversity of the energy consumption among nodes, ELDRL uses a distributed clustering and multi-hop routing.

Distributed clustering: The cluster-head selection process is as follows: In the setup phase the clusters are formed by the nodes themselves using the following equation:

$$mT\,(n) = \begin{cases} \dfrac{P}{1-P\times\left(r \bmod \left(\frac{1}{P}\right)\right)+LOD} & if\ n \in G \\ 0\ otherwise \end{cases} \quad (2)$$

where,

P : The number of clusters
r : The current round number
LOD : The Lack of Desire of a node to be selected as a cluster-head depending on its neighbor cluster-heads

We divided the setup phase into the cluster numbers. In other words, the cluster-heads are selected one by one. Once a node has selected itself to be cluster-head using Eq. (2), the cluster-head node must let all the other nodes in the network know that it has been chosen as the cluster-head for the current round. To do this, the cluster-head node broadcasts an advertisement message containing its *Id* to *BS* using carrier-sense multiple access CSMA MAC protocol. When BS receives the first cluster-head-advertisement, it sets a timeout and then it broadcasts a message in the network. This message is a small message containing the cluster- head's ID. After receiving this message by nodes in the network, each non-cluster-head node will give up trying to become candidate cluster-head (algorithm 1). Then, the candidate cluster-head broadcasts a message (n_LOD) with short range which contains the value to invite the non-cluster-head nodes in its neighborhood to modify their LOD (at first all nodes' LOD are zero). We set the value here 0.2. A sensor node may receive a number of n_LOD messages from its nearby cluster-heads. Each time a non-cluster-head node receives n_LOD messages adds them to its own LOD and new LOD with higher value is replaced with the old one (algorithm 2). By doing this, the probability of the nodes, which are placed next to the cluster-heads, to become cluster-head in the next cluster-head selection decrease because of a lower threshold (higher LOD), according to Eq. (2). As such, the distribution of cluster-heads will be distributed. When the time that BS set (timeout) runs out, BS broadcasts a message to continue the cluster-head selection. This process is repeated till there is no candidate cluster-head. Afterwards, the cluster-heads advertise that they are the new cluster-heads and non-cluster-head nodes choose a proper cluster-head (like LEACH). When round changes, LOD of nodes are set zero. The whole process is illustrated in Fig. 4.

Figure 4a is the nodes deployment in the network. In Fig. 4b a node selects itself using Eq. (2) as a cluster-head and it sends a message to BS to inform other nodes not to try to be cluster head. Then, the selected

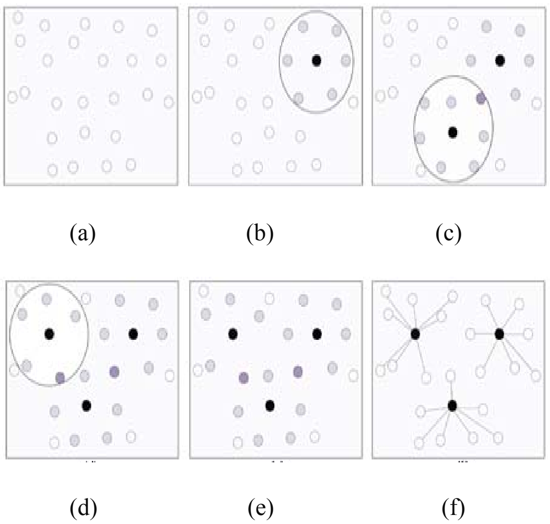


Fig. 4: Distributed clustering steps

Cluster-Head (CH) sends n_LOD message to its neighbor nodes, which is shown with a circle around the CH, to reduce their chance to become CH at the next cluster-head selection by modifying their LOD parameter. When the BS's defined time for the cluster head to send n_LOD message finishes, the cluster-head selection process for choosing another CH is started again. In Fig. 4c CH selection continues and another CH is selected. Due to low chance of the nodes, which have been placed next to the CH, they are not selected as CH. This process goes on till there is no candidate CH. In Figure 4e, when all CHs are defined, they send an advertisement message to non-cluster-head nodes which they are CHs. In Fig. 4f the non-cluster-heads choose a proper CH according to the CH's signal strength.

Algorithm 1: The distributed cluster election:

- Sensor selected as cluster-head s
- s_send (s.id, TOBASESTATION, "I am cluster head")
- BS_send (s.id, BROADCAST, "New cluster head", "Stop being candidate cluster head")
- n_LOD ← value
- neighbor_LOD (s, n_LOD, TONEGHBORS)

Algorithm 2: Modifying the LOD of neighbor nodes

```
neighbor_LOD (ch, n_ LOD)
{
   q←neighbor (ch)
   While (q not empty) {
   If (q is not cluster head) then {
   new_LOD = q.LOD + n_LOD;
   q.LOD← new_LOD;
   }//end if
   If (timeout receive from BS) then
   exit Function;
   }//end if
   }//end while
}
```

Multi-hop routing: Since communication is believed to dominate the energy consumption of a sensor node (Heinzelman *et al*., 2000) and sensor nodes are usually provided with limited energy resources. The imbalanced traffic load distribution is very harmful and it could cause the nodes far to a BS to die at an earlier stage. Hence, multi-hop communication in sensor networks is expected to consume less power than the traditional single hop communication. Furthermore, the transmission power levels can be kept low, which is highly desired in covert operations. Multi-hop communication can also effectively overcome some of the signal propagation effects experienced in a long-distance wireless communication. In the multi-hop communication, therefore, the data which are collected by the cluster-head far away from BS node must be forwarded by the other cluster-head closed to BS node.

Our idea is using the free space model in place of the two-ray ground model and balance the energy consumption. To do this, after cluster formation the BS will broadcast its Identifier (ID) over the common control channel. All cluster heads which are one hop away from BS will record the BS ID as the next hop and they will form layer one. Now the layer one cluster-heads broadcast their own ID and the number of their layer using their default low power level. The message format is (ID, Level). Then, the cluster-head one hop away from layer one calculates the distance between each candidate from the layer one and itself to obtain a distance set. The cluster-head selects the minimum distance as the communication distance to next hop and then marks itself as level 2, mark the ID as its next hop cluster head ID. Finally, the cluster-head in layer 2 sends a join message to the selected next hop cluster-head in lower layer. The next hop cluster-head will allocate a time slot as its member node and the cluster head in upper level become a member of lower level. Similarly, the cluster-head in layer 2 will broadcast their ID and the number of their layer. All undiscovered cluster heads, one hop away from layer 2, will reply to this message and the processing will be done as described above. This process continues till no new cluster head is discovered. By doing so, the cluster-head in farther distance becomes a member node of a cluster in the closer distance (Fig. 5).

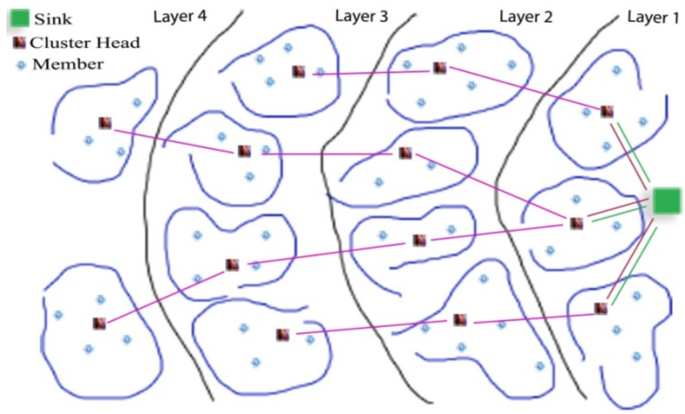


Fig. 5: Partitioning of network into layers

Time slot 1	Time slot 2	Time slot 3	Time slot 4	Time slot 5	Time slot 6

Fig. 6: TDMA schedule

The faraway cluster-head sends data that has been aggregated to the closer cluster-head (the next hop cluster) at its own TDMA slot time by using spreading code of the closer cluster rather than direct transmission to BS. Low level cluster-heads will allocate longer time slots to their member high level cluster-heads because they have more data to send compared to simple members. Figure 6 shows the time slot issued by a cluster-head having four simple member nodes and two upper cluster-heads as member nodes.

In Fig. 6, time Slots 1 to 4 are allocated to simple members and Time Slot 5 and 6 are allocated to upper level member cluster-heads.

At this point, it is worthy to emphasize the sleep mechanism. Nodes have been sleeping at all time, except during their transmission time. This mechanism further improve the energy saving. Once all the data from all the nodes within a cluster are transferred to the associated cluster head at the end of each frame, the cluster-heads fuse the data and then send the fused data to the closer cluster-head in low level using a fixed spreading code and CSMA (Carrier Sense Multiple Access) approach. After a certain period of time spent on the steady phase, the network goes into the setup phase again and enters another round of selecting cluster heads.

Radio energy dissipation model and assumptions: According to the radio energy dissipation model illustrated in Fig. 7, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an *L*-bit message over a distance, the energy expended by the radio is given by:

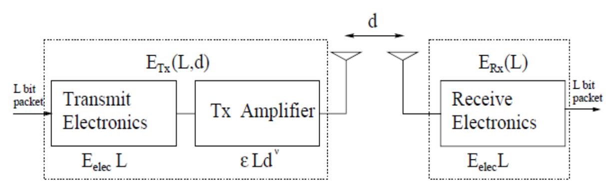


Fig. 7: Radio energy dissipation model

$$E_{Tx}(l,d) = \begin{cases} L \cdot E_{elec} + L \cdot \varepsilon_{fs} \cdot d^2 \text{ if } d \le d_0 \\ L \cdot E_{elec} + L \cdot \varepsilon_{mp} \cdot d^4 \text{ if } d > d_0 \end{cases} \quad (3)$$

The energy consumption of sending data includes transmitting circuit loss and power amplification loss. E_{elec} denoted the energy of transmitting circuit loss, is the same in sending and receiving model. When transmit distance less than d_0 uses free space model, ε_{fs} denoted its energy needed. When transmit distance greater than d_0 uses multi-path attenuation model, ε_{mp} denoted its energy needed. The energy consumption for receiving L bit data as in:

$$E_{Rx}(l) = L \cdot E_{elec} \quad (4)$$

Distance between cluster heads d, can be measured as follows. The cluster-head in lower level transmits a signal with power P_{out}. Then, the power of the received signal at the cluster head j, in the higher level is $P_j = \frac{P_{out}}{d_j}$. Therefore, d_j can be measured as:

$$d_j = \frac{P_{out}}{P_j} \quad (5)$$

When the number of clusters is N_c, the average number of members for each cluster is $\frac{N}{N_C}$, the number of frames per round is F_n, the packet size is s and P is the transmit probability of each node. Therefore, the total number of bits transmitted to the cluster head for each cluster by each round is:

$$S_1(N_c) = [\mathrm{N}/N_c]F_n P_s \quad (6)$$

Hence, the overall data of member nodes in each round is:

$$L_m = N_c S_1(N_c) \quad (7)$$

We adopt the aggregation model in Yu *et al*. (2004) to describe the aggregation operation. The amount of data after aggregation for each round is:

$$S_2(N_C) = \frac{S_1\,(N_C)}{\left[\frac{N}{N_C}\right] Pagg - agg + 1} \quad (8)$$

where, agg is the aggregation factor. Hence, the aggregated data of cluster heads to transmit to next cluster heads is:

$$L \;\; = N_c S_2(N_C) \quad (9)$$

SIMULATION RESULTS

In this section, we evaluate the performance of ELDRL by comparing it with the LEACH protocol. Our experiments consider 100 nodes deployed randomly in 100×100, 200×200 and 300×300 different square monitoring areas. We placed the sink at (x+50, y/2) of areas. The initial energy of a node is set to 0.25 and 0.5 Joules.

The size of the message that nodes send to their cluster heads is set to 4000 bits. Table 1 shows the system parameters for our simulation model. For a cluster-based algorithm like LEACH the metric LND (last node die) is not interesting since more than one node is necessary to perform the clustering algorithm (Handy *et al*., 2002). Hence, we limit the discussion of algorithms in this study to the metrics FND (First Node Die) and HND (Half of the Nodes Die). Table 2 shows the number of dead nodes over time (rounds). It can be clearly seen that data transmission using ELDRL can reduce the number of dead nodes significantly compared to LEACH in the same time. In other words, our proposed protocol can prolong the network lifetime significantly than LEACH.

Table 1: Parameters

Parameters	Values
E_{elect}	50 nJ/bit
(If $d_{to\,BS} \leq d_o$) ε_{fs}	10 pJ/bit/m^2
(If $d_{to\,BS} > d_o$)ε_{mp}	0.0013 pJ/bit/m^4

Table 2: Lifetimes using different amounts of initial energy for the sensors

Field	Energy (J/node)	Protocol	Round first node dies	Round half of the nodes dies
100×100	0.25	LEACH	346	490
		ELDRL	372	550
	0.50	LEACH	727	985
		ELDRL	764	1118
200×200	0.25	LEACH	99	320
		ELDRL	313	444
	0.50	LEACH	171	695
		ELDRL	614	900
300×300	0.25	LEACH	22	117
		ELDRL	83	301
	0.50	LEACH	49	200
		ELDRL	233	538

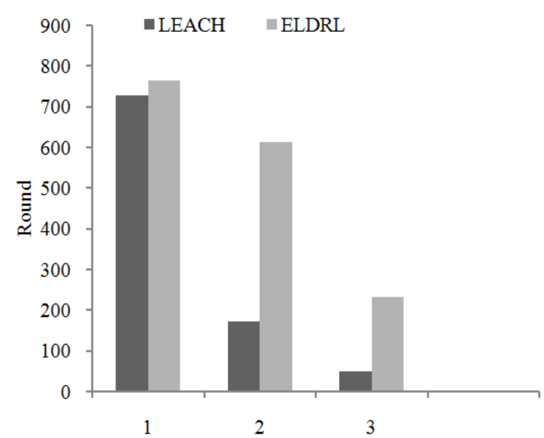
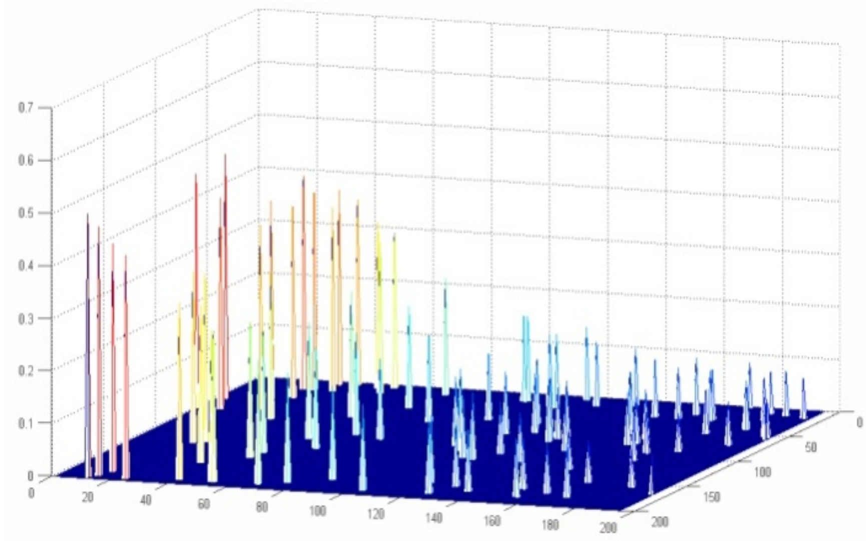


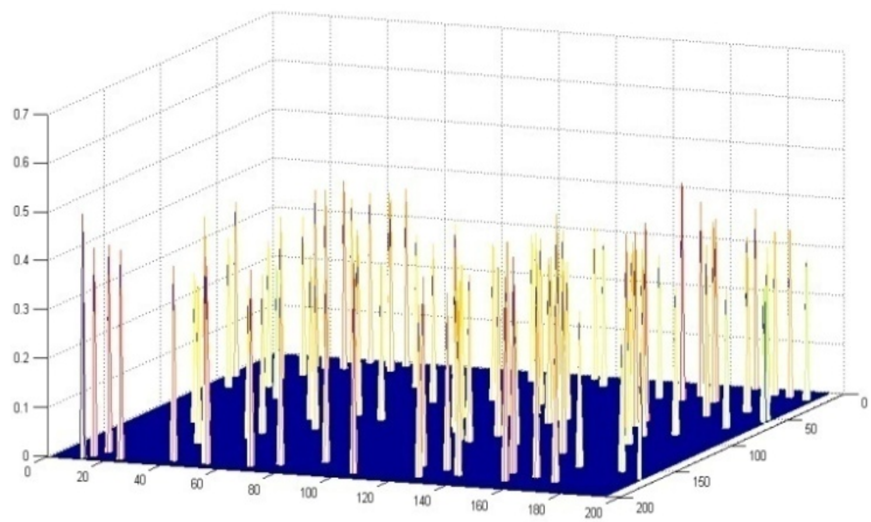
Fig. 8: Results for a network with different field of sizes for ELDRL when the first node dies

Figure 8 demonstrates results for a network with different field of size when the first node dies. The number of 1, 2, 3 separately represents field size 100*100, 200*200 and 300*300 m, respectively. The results show when the size of the network becomes larger, the ELDRL performs better than LEACH.

Load balance: Energy consumption is a metrics to measure the efficiency and the lifetime of WSN. Figure 9 and 10 show a snapshot of energy consumption by using two different routing protocols when the first node dies. In the figures, x and y axis stand for the location of sensors and z axis is the energy



(a) LEACH



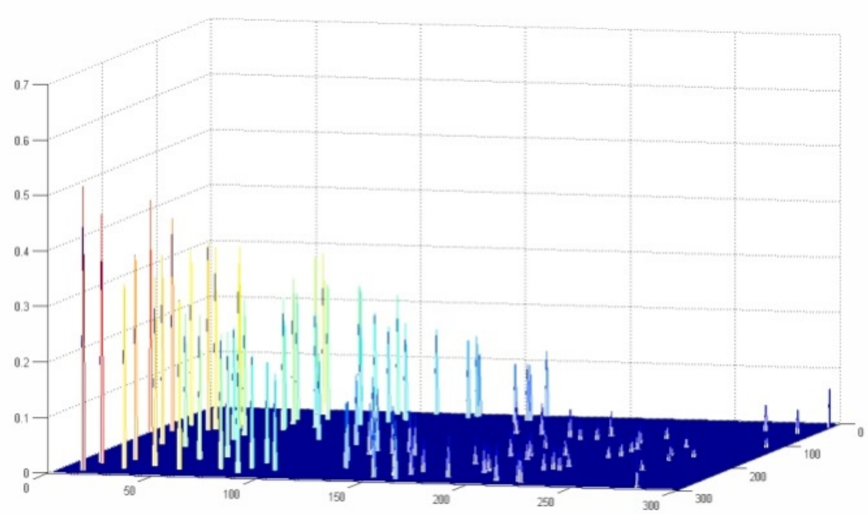
(b) ELDRL

Fig. 9: Energy consumption when the first node dies where the field is 200 m^2 and sink located in (250, 100)

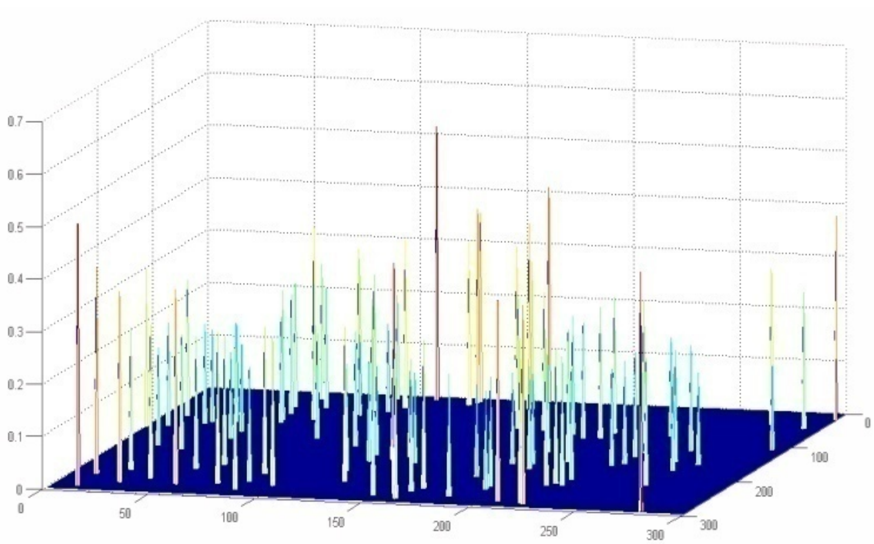
consumption. It is better that the load of the traffic be distributed more uniformly throughout the network. So a good routing protocol should have a feature of load balance to extend the lifetime of the sensor network. We can find that the energy consumption in LEACH is very imbalanced where the field size is increased as shown in Fig. 9a and 10a. Sensors located on the edge of the sensor field consume much more energy. The ELDRL balances the energy consumption a lot. From Fig. 9b and 10b, we can see that the energy consumption distribution is not related with the location of sensors, i.e., sensors have different distance to the sink consume approximately similar energy.

Traffic: Another important advantage of ELDRL, illustrated in Fig. 11 and 12, is the traffic statistic, in which ELDRL is less than LEACH at the same time point (round). In Fig. 11, field is 200 m^2 and sink located in (250, 100) and in Fig. 12 field is 300 m^2 and sink located in (350, 150). In original LEACH each cluster-head after aggregating the data of members sends it to the sink directly. But in ELDRL the original data is aggregated in each cluster-head on routing path, which results in lots of correlated data being filtrated out, therefore, the traffic is reduced.

The LEACH protocol can obtain better latency performance compared to ELDRL. The reason is that



(a) LEACH



(b) ELDRL

Fig. 10: Energy consumption when the first node dies where the field is 300 m^2 and sink located in (350, 150)

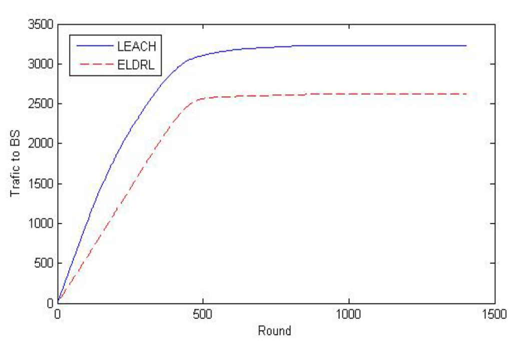


Fig. 11: Snapshot of the network traffic (field 200 m^2)

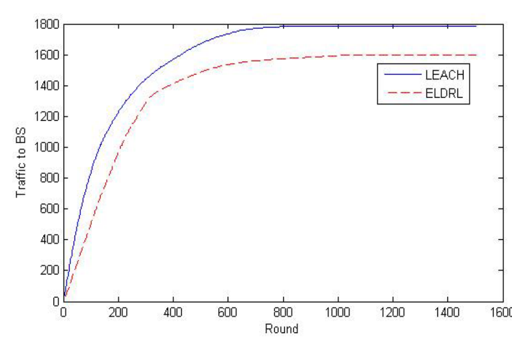


Fig. 12: Snapshot of the network traffic (field 300 m^2)

the multi-hop operation in the ELDRL will increase the latency and thus result in a less number of data packets sent to the sink for a given period of time. However, the better latency performance of the LEACH protocol comes from the more energy consumption compared to the proposed scheme. Especially, in the fading channel environment, LEACH protocol will consume much more energy due to its single-hop transmission from the cluster heads to the sink, which will result in less network lifetime and less total number of transmitted packets.

CONCLUSION

In this study, first, we propose distributed clustering algorithm, to prevent selecting adjacent nodes as cluster-heads. Second we propose multi-hop routing algorithm to minimize energy consumption of sensor nodes and to reduce the unbalance of cluster-head energy depletion. Furthermore, ELDRL can reduce the traffic of the network and satisfy the demand of WSN application. Our simulation results show that LEACH is not as efficient as ELDRL specially in large area. This is because we use distributed cluster selection and multi-hop routing, so it can produce better clusters and routes that require less energy for data transmission.

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