그리드 기반 무선센서네트워크에서 에너지 인지형 Landmark 선정 및 라우팅 프로토콜

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Energy Aware Landmark Election and Routing Protocol for Grid-based Wireless Sensor Network

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Abstract

In practice, it is well known that geographical and/or location based routing is highly effective for wireless sensor network. Here, electing some landmarks on the network and forwarding data based on the landmark is one of the good approaches for a vast sensing field with holes. In the most previous works, landmarks are elected without considering the residual energy on each sensor. In this paper, we propose an Energy aware Landmark Election and Routing (ELER) protocol to establish a stable routing paths and reduce the total power consumption. The proposed protocol makes use of each sensor's energy level on electing the landmarks, which would be utilized to route a packet towards the target region using greedy forwarding method. Our simulation results illustrate that the proposed scheme can significantly reduce the power dissipation and effectively lengthen the lifetime of the network.

1. Introduction

It has no bound to accrue and implement knowledge to mitigate the challenges of global world to give a viable life and a green world for human being. [2]. The Wireless Sensor Networks (WSNs) is one of the most indispensible technologies in such of practical field to monitor and control such of specific events using the micro-electronic based devices through a short term temporary or permanent networks [3].

The most important feature of sensor devices is the shortage of power backup which gives us sometimes an unexpected and undesirable event operation and event solution [5]. In WSNs, it is well known that geographical and/or location based routing is highly efficient in both dense and holes (there is no sensor in a particular area) area. GPS (Global Positioning System) is one of the good approaches to locate the position of a sensor in the networks. On the other hand, using GPS is power dissipation and extra cost for large number of tinny and low power sensor nodes.

There are several network models for WSNs, like virtual coordinate system discussed in [6] [7] [8] [9]. Those papers are represented the construction of embedding nodes into different dimensional region for the connectivity of the deployed sensors in the network. In all these protocols, the coordinate assigns for each node need huge computational cost of initial construction. Due to the reasons, the network lifetime reduces significantly. LER used three level of transmission range for its landmark election process in reference [1]. The landmark election phase of LER, sink located in the near of a grid and considered it as a first landmark. Only sink used the small transmission range but the other landmarks used the medium and large transmission range respectively to broadcast control packets. Other landmarks increase its landmark number gradually from the first landmark. Each sensor checks all recorded control packets to choose an ARP to forward data to the sink in data transmission phase. In landmark maintenance, when the residual energy of a landmark is bellow threshold, it will initiate a reelection by broadcasting the landmark reelect packet. However, this protocol which not considered the energy level and used different transmission range in each landmark election process may leads to quick death of those elected landmarks in near future. Moreover, it elect least number of landmarks near the sink may cause for the drop of the significant number of data packets from distant landmarks.

This paper introduces an Energy aware Landmark Election and Routing (ELER) protocol to construct a grid-based or landmark based structure based on energy level of each of the deployed sensors. Thus, sensors are elected as landmarks with highest energy level using a particular transmission range in a specific landmark election phase. In the election phase, a sensor is elected as a landmark and it will set its landmark number sequentially by itself. The first landmark has the least sequence number and the distant landmarks increase gradually. After the landmarks election in the grid, sensing sensor can use greedy forwarding to transmit data to the destination by using the information of neighbor landmarks.

2. Energy Aware Landmark Election and Routing Protocol

There are many routing protocols in wireless sensor network but they are commonly application-specific. So in most of the cases these are not applicable for all applications of WSNs. This work based on the assumptions: The ID of each node is unique, nodes are homogenous, energy constrained, immobile, and able to use medium and large transmission range (Wi-Fi and ZigBee) respectively, and the ratio is 2 : 1.

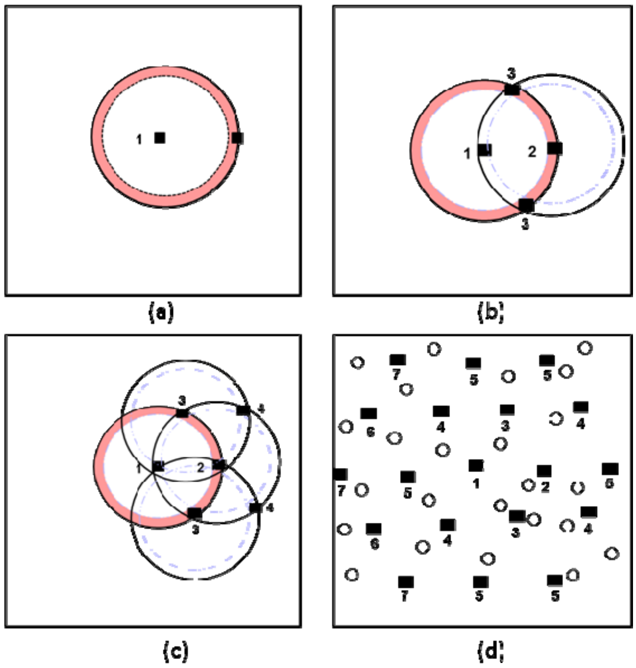
In our protocol, three parameters are defined for the sensor nodes which are elected as landmarks. The first and second one is *RS* and *EX* and the third one is residual energy on each sensor. Where *RS* is the normalized value of RSSI and the *EX* is the reference value which is similar to *RS*.

In the network construction phase, all the participating sensor keep the information of control packets from the neighboring landmarks named (*NLM*), which consist <*lm_id, lm_num, lm_usedlevel, lm_energylevel, RS, EX*>, where *lm_id* is the unique ID of a landmark, *lm_num* is the sequence number of elected landmark, *lm_usedlevel* is the used transmission range, *RS* is the normalized value of RSSI from received *NLM* packet and *EX* is the required expected level (1/4*x* where *x* is the used *RS* level).

Our protocol is conducted with three phases. The first phase called initial landmark election phase, sink start to elect a node to become a landmark and the new landmark will continue the election process sequentially by broadcasting the *NLM* packets using 2*R* (Wi-Fi 200m) transmission range covering the whole network. The second phase called data forwarding phase, once a sensor node sense information from the environment and forward it to the landmark or sink using greedy method. After receives data from a normal sensor, the landmark forwards it up to the sink by landmark to landmark. The third phase namely local maintenance phase, when energy level of a landmark will below the threshold, it will be initiated a local method for landmark reelection.

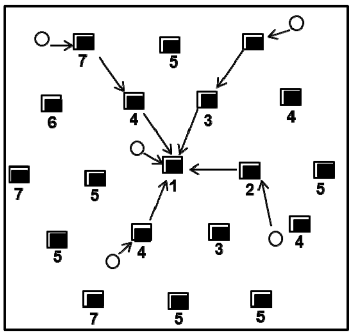
2.1. Initial Landmark Election Phase

To represent a perfect situation of our protocol in a grid-based structure, we have to assign the sink near the center of the grid as a first landmark to initiate network construction shown in Figure 1(a). The sink first sets its *lm_id* = the ID of itself, *lm_num* = 1, *lm_usedlevel* = large, *RS* = 2 and *EX* = 0.25, then broadcast a *NLM* packet using the large transmission range (2*R*). It sets a timer t_a that depends on the used *RS* level to receive the acknowledgement (ACK) message(s) from the *NLM* received nodes. Nodes receive the *NLM* and update its *RS* by normalizing the RSSI and store the information of *NLM* packet. It will check its *RS* level, if it less then *EX*, it will set a timer like sink then broadcasts an ACK message with its ID and energy level using the same transmission range. After receives the ACK messages, sink will set another timer t_n to receive the *NLM* packet from the next probable landmark node. Each node sort out the ID with highest energy level, the ID of a node with highest energy level will become a new landmark. When the timer expires, it will broadcast a *NLM* packet with *lm_id* = the ID of itself, *lm_num* = (maximum the *lm_num* of all recorded *NLM* packets) + 1, *lm_usedlevel* = large, *lm_energylevel* = residual energy of itself, *RS* = 2 and *EX* = 0.25. Sink received the *NLM* packet from the node with highest energy level within its timer and when the timer expires, it will broadcast a (Notification of Elected Landmark) *NEL* packet. In all the figures, the sink node and landmarks are marked as black rectangle shape.



(Figure 1) Landmark election process in a grid

In the initial landmark election process all nodes will use the large transmission range until cover the grid by elected landmarks. Figure 1(b) shows an elected landmark which is *lm_num* = 2 broadcast a *NLM* packet. Like sink, the landmark and the other node(s) in the intersection region set a timer to receives the ACK message(s) from each of new landmark in that intersection region. The nodes in that region received the ACK message(s), sort out the list and the ID of a node with highest energy level will become a new landmark. Then it updates its *NLM* packet and broadcast it. In Figure 1(c) shows the new landmarks *lm_num* = 3 broadcast *NLM* packets and after receives the *NLM* from *lm_num* = 3, the landmark *lm_num* = 2 broadcast the *NEL* packet. This election process will continue recursively to elect landmarks in the grid shown in Figure 1(d).



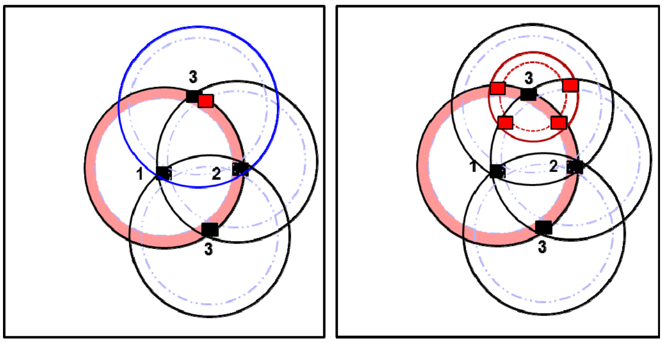
(Figure 2) Data forwarding from source nodes to the sink

2.2. Data Forwarding Phase

In the data forwarding phase, each sensor checks all recorded *NLM* packets to choose an ARP (Auxiliary Routing Path) to forward data to the sink in a greedy basis. Figure 2. shows, the sensing nodes forward their sensing data to the convenient landmark and landmarks forward it to the sink using the same method.

2.3. Local Maintenance Phase

In our work, when the residual energy of a landmark will below the threshold, a local landmark election is incorporate to distribute the energy and enhance to lengthen the lifetime of the network. If there are several nodes in that intersection region, the landmark node of low energy will initiate a reelect request by broadcasting a *LM_REELECT* <*id*> packet using the medium transmission range *R* (ZigBee 100m). The request packet received nodes in that intersection region will broadcast ACK messages using the medium transmission range *R*. Each node in this region will keep the ID and residual energy level from each ACK message(s) and elect a node with highest energy level. The ID of a node with highest energy level will become a new landmark shows the red color rectangle in Figure 3(a). Then new landmark node broadcast a *NEW_NLM* packet using medium transmission range *R*. After receives the *NEW_NLM* packet, initiator landmark broadcast a *NEL* packet using large transmission range 2*R* and it will become a normal node.



(a) (b)

(Figure 3) Landmark reelection process

In other aspect, if there is no another node in that region, the landmark node with low energy broadcast a *LM_RELECT* <*id*> using the medium transmission range. The nodes in the new intersection regions will broadcast ACK messages and elect nodes with highest energy as new landmarks shown red color rectangles in Figure 3(b). Then the new landmark nodes will broadcast *NEW_NLM* packets using the medium transmission range *R*. The initiator landmark receives the *NEW_NLM* packets and broadcast a *NEL* packet using the large transmission range 2*R* and finally it will be a normal node.

3. Performance Evaluation

We used NS2 (Network Simulator) [13], a discrete event simulator, to implement this simulation considered only ideal case. The primary performance measurement is the increased network lifetime due to energy awareness on cost of construction and data routing. Moreover, we are interested in how this comparative measure scales with network size. Sensor network may involve thousands of nodes, thus scaling to large size network is essential for a routing protocol to be applicable to sensor networks.

The experimental results are represented ELER compare with LER respect to different criteria. We assumed, the large transmission range 2*R* of each sensor is 200m, medium range *R* is 100m, 1 bit control and sensing packets. The used power consumption model in this simulation is described as follows: to run the transmitter and receiver electronically, the radio consumes = 50nJ/bit energy, cost in free space to amplifying signal is = 10pJ/bit/m^2 and multipath model is = 0.0013pJ/bit/m^4 to send data at an acceptable signal to noise ratio (SNR). So the transmission cost for the transferring k-bit message to a distance d is given by the following equation (1) and (2).

$$E_{Tx}(k,d) = kE_{elec} + kE_{fs}\ d^2, \quad d > d_0 \qquad (1)$$

$$E_{Tx}(k,d) = kE_{elec} + kE_{mp}\ d^4, \quad d \geq d_0 \qquad (2)$$

Where d_0 is the threshold distance and

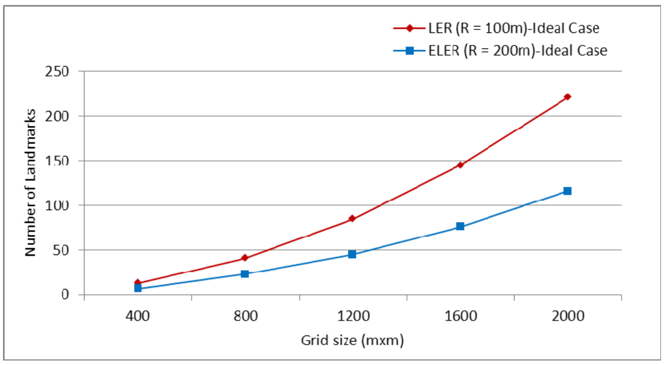
$$d_0 = \sqrt{\frac{E_{elec}}{E_{mp}}}$$

The receiving cost for the k-bit message for distance d is given by the following equation (3):

$$E_{Rx} = kE_{elec} \qquad (3)$$

3.1. Optimized Number of Landmarks in a Large Scale Sensor Network

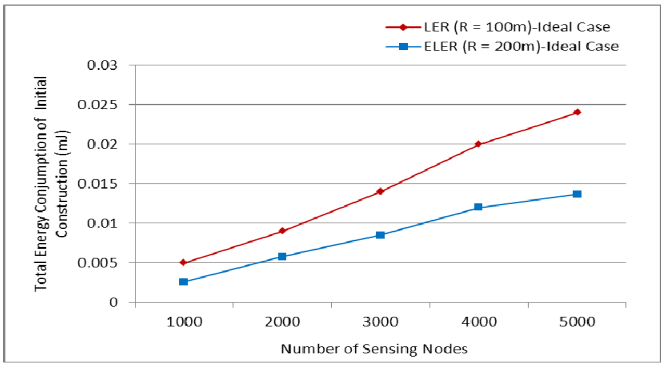
To simulate this protocol, for the landmarks election in a 2000m^2 grid, 5000 sensor nodes are randomly deployed. The result in Figure 4. shows ELER reduce the significant number of landmarks (47.51%) by increased the broadcast range 100m to 200m as well as with properly distributed than the LER. We considered one node in each intersection region for this simulation and it also induces more nodes in each intersection region consume more energy for broadcast more control packets.



(Figure 4) Total number of landmarks respect to grid size

3.2. Energy Efficiency in Initial Construction

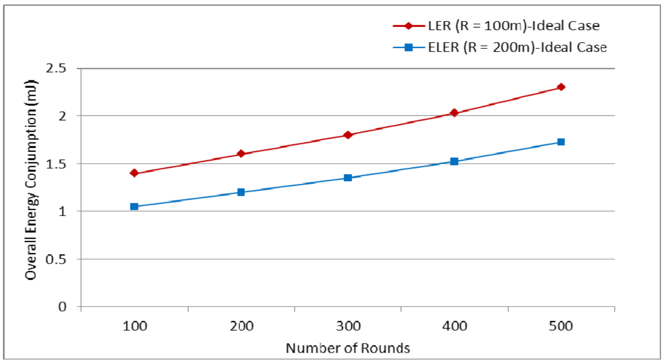
The construction cost shown in Figure 5. There are 1000 to 5000 nodes randomly deployed in a 500m^2 grid in initial construction phase in different rounds. As it is, the energy consumption depend on the number of elected landmarks, ELER consumes 0.03% less energy in the landmarks election phase due to the less number of elected landmarks than the LER.



(Figure 5) Energy consumption in initial construction phase

3.3. Routing Efficiency

There are 5000 nodes deployed in 500m^2 grid and randomly chosen 2000 nodes to transmit data to the sink by the elected landmarks. Figure 6. shows the overall energy consumption of construction and routing of ELER and LER., Where deployed sensors used maximum 2.5 hops distance in ELER and 5 hops distance in LER in data routing from source to the sink. The result shows ELER consumes less energy due to the decreased number of hops by using the large transmission range rather than the medium range.



(Figure 6) Overall energy consumption

4. Conclusion

Wireless sensor network in a vast area will provide a communication bridge between the physical world and tremendously growing information infrastructure. An important enabler for these systems to be capable of facile deployment of sensors in a sensing field and routing with no or limited human assistance. New distributed protocol for network construction and data routing to implement embedded algorithms and to allow users to easily access and task the sensor network. In this paper, we proposed an energy aware protocol for landmarks election and routing in a grid-based wireless sensor networks to reduce the initial cost for constructing the network and in routing to forward data from sensing nodes to the sink. Moreover, we used a simple greedy forwarding method efficiently to reduce the hop distance in data forwarding. Finally our proposed protocol based on energy aware in its network construction and data routing can significantly reduce the energy consumption and increase the lifetime of the network. In future, we would like to enhance this protocol for a mobile sink as well as with deployed mobile sensor nodes in a dynamic shape of region.

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