An Energy Efficient Routing Protocol for extending Lifetime of Wireless Sensor Networks by Transmission Radius Adjustment

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Abstract
Wireless Sensor Networks needs energy efficient routing protocols for increasing the network lifetime. The energy consumption of sensor nodes can be decreased by reducing the transmission radius range. In this proposed work an Energy Efficient Routing Protocol (EERP) is developed for wireless sensor network by adjusting the node transmission radius and conserves the node energy. EERP follows on demand routing method for packet forwarding from source to destination. When the node's energy reaches certain threshold then node reduces its transmission radius again in order to achieve less energy consumption under the circumstance. The transmission range distribution optimizations for networks are developed in order to obtain the maximum lifetime. Analysis of the solution shows that network lifetime improvement can be obtained through optimization comes at the expense of energy-inefficiency and a wasting of system resources. The simulation results shows that EERP protocol outperforms the existing routing protocols in terms of network lifetime, energy consumption and has a balanced network load and routing traffic.

Keywords: energy, lifetime, routing, transmission radius, wireless sensor network

1. Introduction

Wireless Sensor Network consists of tens or thousands of sensor nodes scattered in a physical space and one or more Base stations or Sinks. Even thought developed for military applications now they find a wide variety of civilian applications also. Some of the applications are Target tracking, Animal monitoring, Vehicle monitoring. Normally sensor nodes are randomly arranged in a network area that always works under the bad conditions and it is practically impossible to recharge theses nodes. It is essential that the network be energy efficient and load balance in order to extend the lifetime of the network [1].

There are many approaches available to extent the networks energy efficiency. Routing plays an important role in that. According to the networks structure, the routing protocols can be classified into flat, hierarchical and location based. The hierarchical routing protocols are more energy efficient than flat and location based since they use the data aggregation to save the energy spent in delivery of redundant data between neighboring sensor nodes [2]. Hierarchical based routing take a cluster-based approach [3]. A few sensor nodes are elected as Cluster Heads (CHs) to collect data from their cluster members. Then CH aggregates the data and reports the aggregated information to the base station. Cluster members have low energy consumption, as they transmit their data to its nearby CH. For better load balance, the role of CH is rotated among cluster members. Numerous hierarchical-based routing protocols have been proposed to route data to the base station.

2 Related Works

LEACH (Low Energy Adaptive Clustering Hierarchy) [4] is a cluster-based protocol that uses data fusion and randomized rotation of the CH to evenly distribute energy load among all nodes. However, the drawback of LEACH is that the dynamic cluster formation causes a mass of overheads that increase the networks energy dissipation. Also LEACH does not consider the energy of each node. So the nodes that have relatively small remaining energy can be the CH. This makes the networks lifetime shorter.

PEGASIS [5] protocol improves LEACH on energy efficiency and network lifetime. It organizes sensor nodes into a chain so that the sensor node on a chain can communicate with one neighbor and only one node can be chosen as cluster head to sent data to the end user. This protocol has been shown a better performance than LEACH. However, there are still some limitations in PEGASIS. Firstly, the sensing data from networks are time sensitive but the chain topology introduces excessive delay that causes collection data out of date. Secondly, the greedy algorithm can keep the minimum distance of each hop while cannot achieve the optimal routing in the whole network.

Thirdly, the single cluster head may become a bottleneck. ECR(Energy-efficient Chain-cluster Routing)[6] is a simple but efficient cluster-head- leader selection criterion, which prolongs the time of the first node die in the network and improves the energy efficiency. It selects the cluster-head-leader according to maximum rest energy criterion to balance the network consumption. ECR protocol performs the higher energy efficiency than LEACH and PEGASIS. Even though the performance of ECR protocol is good, it has some drawbacks. It uses greedy algorithm for cluster head selection, it causes some delay. The premature death of a cluster-head-leader may cause the emergence of a blind point in the network coverage and decrease the quality of network surveillance.

TEEN (Threshold-sensitive Energy Efficient sensor Networks) [7] protocol was proposed for time-critical applications. Here sensor nodes sense the medium continuously, but the data transmission is done less frequently. A cluster head sensor sends its members a Hard Threshold (HT), which is the threshold value of sensed attribute and a Soft Threshold (ST), which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. The main drawback of this scheme is that, if the thresholds are not received, the nodes will never communicate and the user will not get any data from the networks at all. Also it has the overhead and complexity associated with forming clusters at multiple levels and the method of implementing threshold-based functions.

In Energy Efficient Routing Protocol (EERP), a node reduces its maximum transmission radius only to reach the farthest neighbor before it sends the first packet. The on-demand route discovery process is initiated whenever a source sensor node needs to communicate with another node for which it has no routing information in its route table. When remaining energy reaches in order to achieve less energy reaches the threshold. Network topology may change when a node disappears or radius readjustment, and route maintenance is initiated when this happens.

3 Proposed Protocol

The Energy-Efficient Routing Protocol is a plane on demand energy-saving routing protocol. EERP is composed of initial transmission radius selection, route discovery, transmission radius readjustment and route maintenance. In order to save energy, sensor node reduces its max transmission radius only to reach the farthest neighbor before it sends the first packet. The route discovery process of EERP is on-demand. In EERP, source node and destination node can communicate with each other in two different paths. Accordingly, EERP supports the asymmetric link. In order to slow down the remaining energy's consumption speed, sensor node must readjust the transmission radius when remaining energy reaches the threshold. Network topology may change when a node disappears or radius readjustment, and route maintenance is initiated when this happens.

3.1 Transmission Radius Selection

When a sensor node comes into the network, it uses the maximum transmission power and transmission radius to send packets. As a result of node distribution, maximum transmission radius is usually longer than the distance between node and its farthest neighbor, which causes the waste of energy. The shadow area of Figure 1 represents the energy waste when a node sends packets with the max transmission radius. In EERP, in order to save energy, sensor node adjusts its transmission radius only to reach the farthest neighbor before it sends the first packet.

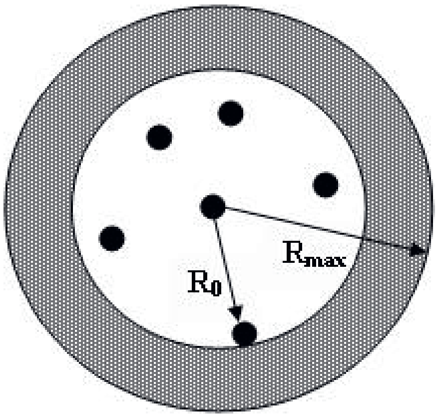

Figure 1. Transmission Radius Selection.

The distance between two nodes, x and y, is denoted by dist(x,y). R_{max} is the maximum transmission radius. R_0 is the initial transmission radius after adjusting the maximum transmission radius. N(u) is the neighbor set of node u.

3.2 Algorithm ITRS // Initiate Transmission Radius Selection

i. The collection of N(u)'s information
Sensor node u broadcasts HELLO packet containing it's and geographical information with the maximum transmission radius. All neighbors are chosen into N(u). Node u collects every neighbor's information after a round of communication and computes the distance to all other neighbors.

ii. The computation of R_0
Initial transmission radius R_0 equals to the distance to the farthest neighbor.

$$R_0=\max (\mathrm{dist}\,(u,v)|\ v \in N(u)) \qquad (1)$$

After the selection of initial transmission radius, node can still communicate with the farthest neighbor. Accordingly, network topology and routing information don't change, and no maintenance is needed. The schema for the ITRS algorithm is shown below.

Algorithm ITRS // Initiate Transmission Radius Selection
1 .Node u broadcasts HELLO packet 2. Set N(u) = NULL. 3. While each neighbor s receives the HELLO packet N(u) = N(u) U {s} 4. Compute Distance from u to s 5. End while 6. Compute R0=max (dist (u,v)| v Є N(u)) 7. For all sensors s in N(u) 8. If Energy of S≤0 9. N(u)=N(u) U {s} 10. GOTO 5 11. End for

3.3 Route Discovery

The routing selection used in this approach is multipath Ant Colony System. According to the characteristic of routing in WSN, this paper proposes the improved Ant Colony Optimization induce the ants with new characteristic and searching method. This paper nominates two kinds of ants, forward ant and backward ant. Forward ants have lifetime, can avoid consuming energy in bad path, and collect the nodes information in lifetime, update the local pheromone among the nodes, bring information to the backward ants. The backward ants return by original path, and update global pheromone of optimum path according to information. The ants possess memory function to save the information of visited nodes. This paper makes the ants search paths in a parallel way. M ants search paths respectively at the same time in sources. This method makes ants search optimum path in quick, and updates global pheromone as for suboptimum paths that searched by improved algorithm. The whole process is as follows.

i. When searching paths beginning, m forward ants distribute in sources.
ii. Each ant select next node to build a tour by repeatedly applying a probabilistic nearest neighbor heuristic V_i.
iii. When arriving at midway node V_i the ant firstly examines that it whether has visited this node or not. If having visited, the ant terminates search. If not having visited, the ant go on examines node V_i whether is close to the sink and farther from the source than former node V_j or not. If it is true, the ant updates pheromone level on the visited edges by applying a local updating rule. The identifier of every visited node is saved onto

a memory M_k and carried by the forward ant when building up the tour from the sources to the sink.

iv. Backward ants update pheromone level on the visited edges by applying a global updating rule when returning source with searched tour and information that transferred by forward ants.

v. Setup the number of times that forward ants and backward ants iteration to get optimum tour.

3.4 Readjustment of Transmission Radius

When node energy is low, energy will be exhausted rapidly if the node still uses the initial transmission radius. In order to decrease the speed of energy consumption and prolong the lifetime of node and network, node must reduce its transmission radius and the amount of neighbors and communication. In EERP, node readjusts it transmission radius based on coverage ratio CR when node's remaining energy reaches the threshold ET.

The ratio of the amount of neighbors after readjust transmission radius to the amount of neighbors before readjustment. RCR is the transmission radius after the readjustment based on coverage ratio CR. NCR(u) is the neighbor set of node u after readjustment. N_0 denotes the amount of nodes in N(u) when using the initial transmission radius.

3.4.1 Algorithm TRR // Transmission Radius Readjustment

i. The collection of N(u)'s information
Node u broadcasts Radius Readjustment Notification packet RRNT when remnant energy reaches ET, and every neighbor replies a Radius Readjustment Acknowledgment packet RRACK piggybacking its geographical position information. Node u collects every neighbor's information after a round of communication and computes N_0.

ii. Deciding which node in N(u) belongs to NCR(u) Node u computes the distance to every node in N(u) and sorts the nodes by the distance. The Coverage Ratio of □N_0 nodes with the minimum distance will be put into NCR(u).

iii. The computation of RCR. The transmission radius RCR based on the coverage ratio CR equals to the distance to the farthest neighbor in NCR (u).

$$RCR=\min(dist(u, v)| \text{ for all } v \in NCR(u)) \quad (2)$$

iv. The confirmation of RCR. Node u broadcasts Radius Readjustment Confirmation packet RRCN, informing the neighbors in NCR (u) that radius readjustment has finished and it will send packets with RCR.

If two nodes communicate by symmetric link, asymmetric link may come into being and the connectivity of graph will be influenced when node readjusts its transmission radius. Owing to the support of asymmetric link, EERP can minimize the impact. If the next hop to destination is unreachable and route is broken after readjustment, EERP can initiate a new route discovery to fix the route to the destination. Because destination uses another route to send packets to source, radius readjustment will not influence this route. The schema for the TRR algorithm is shown below.

Algorithm TRR // Transmission Radius Readjustment
1. Node u broadcasts Radius Readjustment Notification RRNT packet.
2. For all sensors s in N(u)
3. if Energy of s < Energy Threshold
4. s replies a Radius Readjustment Acknowledgment RRACK packet
5. Node u computes NCR(u)
6. Node u computes the distance to every node in N(u)
7. And sorts the nodes by the distance.
8. RCR=min(dist(u, v)| for all v ∈ NCR (u))
9. Node u broadcasts Radius Readjustment Confirmation RRCN packet
10. Finished Radius readjustment
11. End if
12. End for

3.5 Route Maintenance

When originating or forwarding a packet, each node transmitting the packet is responsible for confirming that the packet has been received by the next hop; the packet is retransmitted (up to a maximum number of attempts) until this confirmation of receipt (ACK) is received. If the packet is retransmitted to the maximum number of times and no ACK is received, this node returns a route error message RERR to the source node of the packet, identifying the link over which the packet could not be forwarded. Source node then removes this broken link from its route table. If there is another route in its route table, source node will send packets through this route. If not, source will initiate a new route discovery and find a new route to the destination. Route failure caused by transmission radius readjustment can be solved by the method mentioned in transmission radius readjustment.

4 Simulation and Results

The proposed EERP protocol is simulated by NS2 and compared with energy efficient routing protocols LEACH, PEGASIS, ECR and TEEN. The main objective of our simulations is to show that EERP prolongs the network lifetime and has the balanced network load and routing traffic.

4.1 Simulation Environment

The following is the parameters used in the simulations. The network size is 100m×100m with the size of the sensor nodes varies from 50 to 400. Average node traffic is 5packets/s. Packet size is 256 bits. Transmission speed is 100kbps. Max transmission radius is 250m. The simulation uses IEEE 802.11 as MAC protocol. Each node's initial energy is 10J and Energy Threshold is 5J. Transmitting power is 600mW and receiving power is 300mW. Each simulation is run for 10 minutes.

4.2 Results and Discussion

Figure 2 shows the comparison of lifetime using EERP, LEACH, PEGASIS and ECR. Our first objective is to show that EERP can provide a balanced network load. Some observations are in order. First, allowing a small portion of the region up to 100 nodes can lead to significant improvement on the lifetime of the ECR compared with that of LEACH. But compared with the EERP the lifetime of the ECR is not good. Second, the number of nodes alive in the EERP is larger after the network size of 200 nodes. Finally, the EERP achieves 20-22% higher node living ratio for every round compared to that of other protocols.

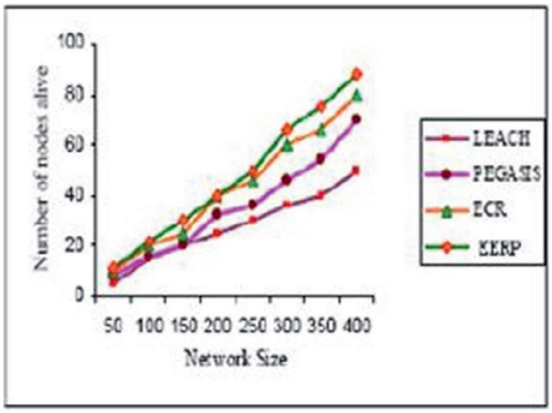

Figure 2 Energy Efficiency

In order to measure how much energy EERP saves, compute the mean energy consumption (mec) per node using the following equation

$$mec = (E_0 - E_t) / (n X t) \quad (3)$$

Where n is the total number of nodes with initial total energy of n nodes as E_0.After time t the remaining total energy of n nodes is E_t. Figure 3 shows the mean energy consumption of a node with different routing protocols. As expected, the EERP has a lower mean energy consumption compared to that of the other protocols. PEGASIS and ECR have very similar energy consumption with ECR being slightly higher from 200 to 300 seconds. From 150 to 200 seconds the energy consumption of the EERP lies between 50 and 75 milli Joules. It states that the energy consumption of the EERP is two times lesser than that of LEACH, due to the dynamic cluster head selection mechanism for 250 seconds. Also the energy consumption of the EERP is two times lesser than the energy consumption of ECR for 250 seconds.

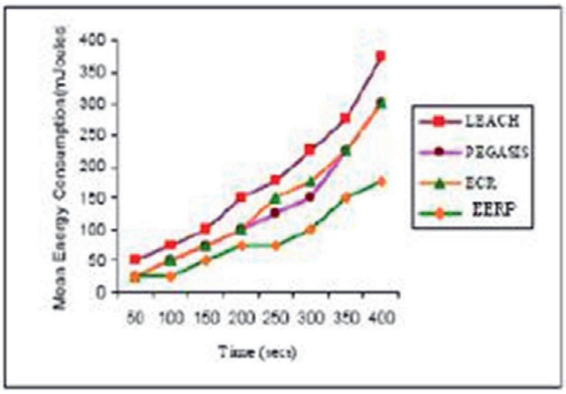

Figure 3 Lifetime Comparison

5 Conclusion

Great majority of node energy is consumed by wireless communication and the value of radius launches a direct impact on energy dissipation. In this paper, a transmission radius self-adjust energy-saving routing protocol EERP is proposed. Using EERP, node reduces its initial transmission radius to the farthest neighbor before it sends the first packet. The on demand route discovery process is initiated whenever a source sensor node needs to communicate with another node for which it has no routing information in its route table. When remnant energy reaches a certain threshold, node reduces its Transmission radius again in order to achieve less energy consumption under the premise of a coverage ratio. Simulation results demonstrate that EERP can prolong the network lifetime, energy consumption and has a balanced network load and routing traffic.

6. References

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