Intelligent Cluster Routing: An Energy Efficient Approach for Routing in Wireless Sensor Networks

Arun Kumar
Associate Professor
Department of Computer Engineering
Maharishi Markandeshwar University, India

Vijay Kumar Katiyar
Professor and Head,
Department Of Computer Engineering
Maharishi Markandeshwar University, India

ABSTRACT
In this paper, we describe the approaches for routing in Wireless Sensor Networks. Their characteristics are discussed. An efficient routing approach is then proposed using genetic algorithm which is based on energy equations and use of advanced nodes having high energy than normal nodes. This intelligent cluster routing is then compared with SEP routing.

General Terms
Energy efficiency in Wireless Sensor Networks

Keywords
Intelligent Cluster Routing, Energy efficient approach for WSN

1. INTRODUCTION
In recent years development and refinement in energy-efficient design and wireless technologies had made possible the development of new applications for wireless devices. These applications include remote monitoring using micro-sensors in networks and networking of everyday use home appliances. One shortcoming of these devices is that they have problem of resource limitations that wired devices don't have. In general, wireless devices have limited bandwidth available to applications and the nodes are battery powered limiting available energy.

Such resource constrained networks requires application specific protocol architecture to obtain the best possible performance. The solution to the energy limitation is the use of LEACH based (Low Energy Adaptive Clustering Hierarchy) protocol with advanced nodes having high power to get better system lifetime. Further node selection may be refined using genetic algorithm. This approach improves system lifetime significantly as compared to general purpose approaches. Application-specific protocol architecture helps in attaining energy and latency efficiency for wireless networks.

2. ROUTING PROTOCOLS
Routing protocols for wireless networks can be classified into two types: multi-hop routing protocols and cellular/clustering approaches.

Multi-Hop Routing

Routing protocols for wired networks fall into two classes: distance vector routing and link-state [35]. Distance vector gets route packets by having each node share distances with its neighbors, after that who chooses the shortest path to a given destination and store this information in a routing table. When packet comes to the node, it checks in its routing table to find the next hop node to send the packet to its destination.

In link-state protocol, nodes spread the entire topology map and the individual nodes use a shortest path algorithm (like Dijkstra's Algorithm) to find the best path to a given destination. These routing methods have been used in wireless networks with some modifications, resulting in destination-sequenced distance vector (DSDV) and ad hoc on-demand distance vector (AODV) routing protocols [36, 37].

But there are issues with using these routing approaches in wireless networks. The periodic messages needed to maintain valid routes may apart from increasing the traffic on the network, may also drain the limited battery power of a portable node. Dynamic source routing (DSR), takes care of this by creating routes on an on-demand basis [38]. This reduces the efforts required for creating routes, at the cost of latency in searching a route when it is required. These ad-hoc self-configuring protocols handles node failures effectively.

Work has been done on "minimum-energy" routing protocols to increase the lifetime of the wireless network. In [39] author discusses an approach for selecting multi-hop paths to reduce the power dissipated in the nodes along the path. In these techniques, an intermediate node is used as a hop only if it minimizes the total energy compared with without using this middle hop node. In one approach proposed in [40], the authors observed that in a wireless network, data communication amongst neighboring nodes causes interference, which can reduce performance. Hence, they selected paths to minimize energy dissipation subject to a minimum interference criterion. Data Aggregation is one such approach.

Now a days work is being carried out on power-aware routing protocols for wireless networks [41, 42, 43]. Here in these protocols, optimal routes are selected based on the energy at each node along the route. Routes that are longer but use nodes with more energy than the nodes along the shorter routes are given preference. This approach avoids hot-spots in the network, where a node is used frequently to route other node's data, and it helps in distributing energy dissipation evenly.

One approach of choosing routes is to use minimum transmission energy (MTE) routing [44, 45]. In this approach, the intermediate nodes are chosen in such a way so that the sum of squared distances (and hence the total transmit energy, assuming a d^2 power loss) is minimized; thus for the network shown in Figure 1, node A would transmit to node C through node B if and only if:

$$E_{transmit}(d = d_{AB}) + E_{transmit}(d = d_{BC}) < E_{transmit}(d = d_{AC}) \quad (1)$$

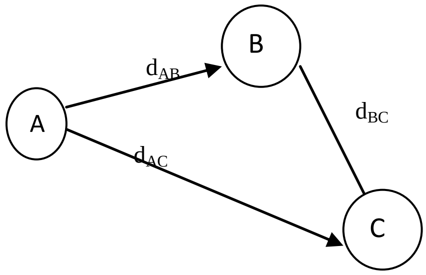

Figure 1 : Nodes for MTE

MTE runs a start-up routine to determine its next-hop neighbor. This approach of choosing routes minimizes the transmit energy required to feed the data to the base station. Data are passed to each node's next-hop neighbor until the data reaches the base station. When nodes run out of energy the routes are determined again to ensure connectivity with the base station.

In terms of cluster formation there are two different approaches. In one approach, each node broadcast in a certain region its properties (id, node degree, residual energy etc.), after which an election process is executed to choose the cluster head [34], [10]. This approach generally assures regular cluster size and full node coverage, but at the cost of high communication overhead. In another approach, the clustering algorithm is triggered at regular intervals to select new cluster heads. At each interval, the clustering process uses a certain number of iterations to finally get the desired cluster head. If the minimum probability of a node becoming a cluster head is *p*, it takes $N <= [\log_2 1/p]+1$ steps for the election algorithm to stop (N = 6-15 iterations for average scenarios). During each iteration, a designated cluster head generates broadcasting messages, resulting in a total message cost (for setting up the cluster) to be of order $N * n$, where n is the total number of nodes in the network. This results in significant energy consumption, given that the election process is called repeatedly to achieve load balancing.

Another approach, such as the one used in [11], is to specify a certain probability for each node to become a cluster head, and the node which turns out to be cluster head announces itself through flooding. This approach has lower message overhead, but cannot assure uniform cluster head distribution and complete coverage of all non-cluster nodes. Therefore, the nodes not covered by any cluster heads have to send their messages directly to the sink, significantly increasing the total message cost.

Since cluster heads require more energy for communication and computation, cluster head rotation is an important step of any clustering scheme. For most of the clustering schemes, rotation involves re-election of cluster heads, which requires a lot of efforts. With well designed rotation sequence, the role of cluster heads can be uniformly distributed to all sensors in the network.

3. PROTOCOL ARCHITECTURE

A protocol architecture for wireless micro-sensor networks is required to be developed which achieve low energy dissipation and latency. Mostly data are correlated and the end-user needs high-level details of the events happening in environment which the nodes are monitoring. The nodes can share information locally amongst themselves to reduce the data transmission to the end-user. Strong correlation exists between nodes that are near to each-other. That enables one to use a clustering infrastructure which allows neighboring nodes to share information. In suggested protocol, nodes in a local cluster can send their data to a local cluster-head. This node along with receiving data from nodes within the cluster may aggregate this data into smaller set of information that describes the events nodes are sensing. The cluster-head node, then send the processed information to the end-user.

One of the sensor node with high energy will act as a cluster head. If this position is fixed the cluster head energy will be quickly depleted, ending the communication for the rest of the nodes in the cluster. Suggested protocol implements a scheme in which the position of cluster head is rotated amongst all the nodes in the network to distribute the energy load uniformly. A cluster formation algorithm must ensure that minimum time and energy are used for rotation of cluster-head and associated clusters. In the proposed method nodes communicate their data to the cluster-head node uniformly to utilize available energy efficiently. Cluster formation should be random as well as adaptive for saving energy. The individual nodes must also contributes to decisions for good cluster formation. A protocol based on these techniques will reduce the overall latency considerably. As a result system lifetime is considerably improved.

Further genetic algorithm is applied to improve performance than SEP.

Moreover if TDMA is used, nodes may shut down some of their components and enter a sleep state in case of non transmission of data to the cluster-head. This also prevents collision of data within the cluster and saves energy. If low energy compression is employed, it further can reduce power consumption.

TDMA is used for real-time delivery of data and CSMA is used for asynchronous delivery.

4. ALGORITHM

1. Randomly create wireless sensor network
2. Chose normal nodes
3. Chose advance nodes.
4. Randomly select the cluster head nodes, having optimal probability less than threshold value T (n) = p/ 1-p(r mod (1/p)), where ‘r’ is current round.
5. Count the number of dead nodes, initially all nodes are alive.
6. Calculate the energy dissipated in transmission:-

   E_DISP(r+1) = E_DISP(r+1) + ((ETX+EDA)*r +E_{fs}*r*d^2) when distance > d_0 ($d_o=\sqrt{E_{fs}/E_{mp}}$)
   E_DISP(r+1) = E_DISP(r+1) + ((ETX+EDA)*r +E_{mp}*r*d^4) when distance<= d_0(initial distance)

7. Calculate the energy dissipated by each cluster head:

   If (min_dis>do)
   E_DISP(r+1)=E_DISP(r+1)+(ETX*(4000)+Emp*4000*

   (min_dis)^4);

   if(min_dis<=do) then

   E_DISP(r+1)=E_DISP(r+1)+(ETX*(4000)+Efs*4000* (min_dis)^2);

8. Apply GA to position cluster heads precisely for efficient communication.

9. Repeat steps 4 to 8 for all rounds

5. RESULTS AND ANALYSIS

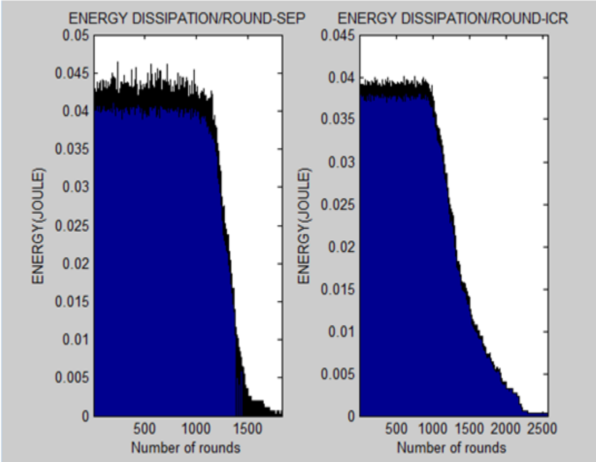

Figure 1: Energy dissipation per round

Energy dissipation is an important factor in getting the performances of SEP and ICR protocols. In SEP the energy dissipation takes place at a rate of near about 0.045Joule per round whereas ICR(Intelligent Cluster Routing) do not permit the energy dissipation at a higher rate and decrease this level to 0.04 per round.

Figure 2 is showing the Packets that are sent to Cluster head in SEP & ICR Protocols during the lifetime of the protocol. It shows the throughput from 0 rounds to 2000 rounds as 1800 is the overall lifetime of SEP in this experiment. Here Y axis shows the no. of packets sent during running time. It represents the benefits of the stability period of wireless sensor network. It also shows the progress in terms of network life time.

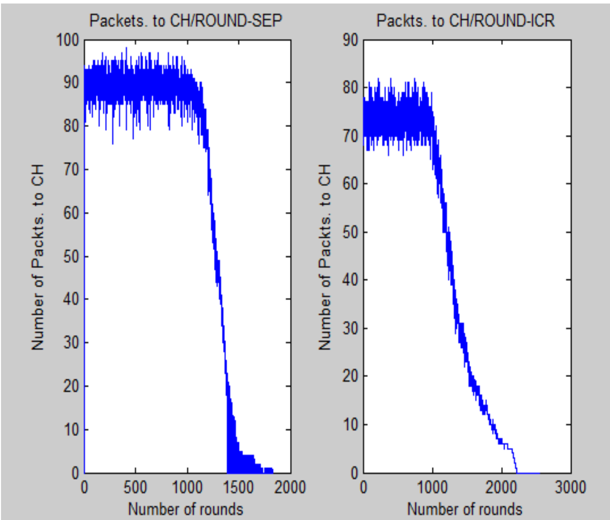

Figure 2 Packets transmitted in given rounds

Figure 3 shows the Packets that are sent to Base station in SEP & ICR Protocols during the network lifetime in the protocol. It shows the throughput from 0 to 3000 rounds. Here y axis represents the amount of packets transmitted to BS during running time. The number of packets per round varies initially 12 to 24 packets per round and in the last 500 rounds it lies in between 5 and 0 per round in case of SEP while this packet variation is from 34 packets per round to 1 packet per round in case of ICR.

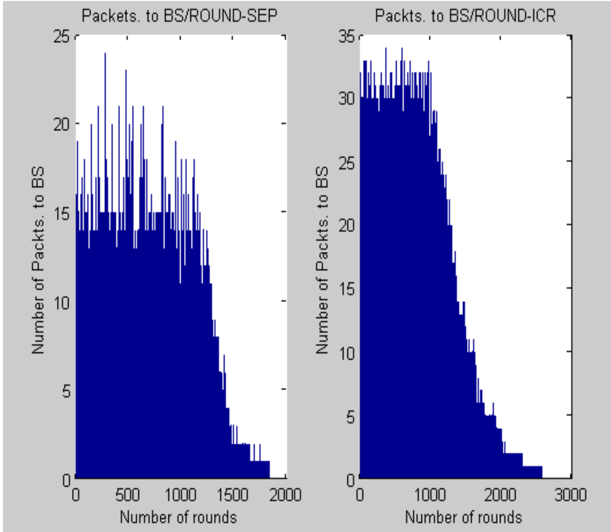

Figure 3: Packets sent to Base Station

Figure 4 provides the statistics of Dead node with same number of initial nodes. In our proposed algorithm all the 100 nodes are alive till 1000 rounds and start dying thereafter. All the nodes completely die at 2500th round. While in SEP all the 100 nodes are alive till 900 rounds and start dying thereafter. All the nodes completely die after 1800 rounds. It shows the improvement in lifetime of network by increase in number of rounds for which the network works, in our proposed algorithm.

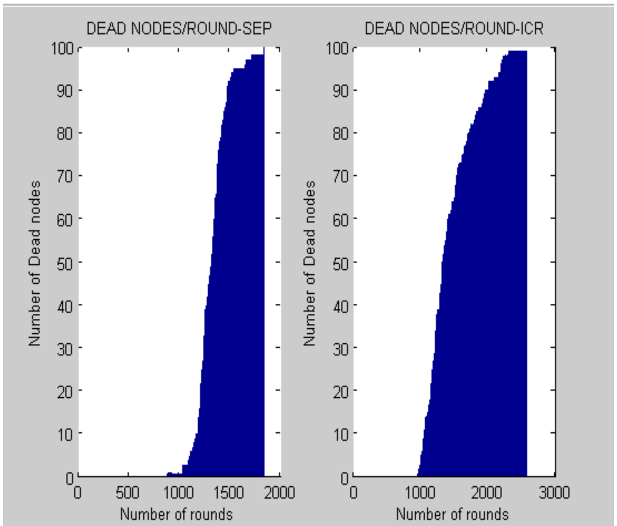

Figure 4: Total number of Dead nodes

6. CONCLUSION

Table 1 shows the results obtained for the two methods. The proposed algorithm has shown a significant improvement over SEP. The difference among existing protocols and proposed algorithm include proposed algorithm selects a node as cluster head after application of GA i.e the fittest node is chosen as cluster head where fitness is considered more only if it has maximum energy among other nodes in cluster during run time. Further GA is applied to select the fittest node as cluster-head amongst the cluster. The proposed algorithm seems to be justified as heterogeneity of WSN nodes is also considered by introducing the normal, advance and intermediate nodes.

Table 1: Performance comparison of SEP and ICR

Parameter	**SEP**	**ICR**
Energy Dissipation per round (in Joules)	0.045	0.04
Network Lifetime (in no. of rounds)	1800	2200
Packets sent to base station	12-24 to 5-0	28-34 to 1
Round where the last node died	1800	2600

More efficient method could be achieved by fine tuning the fitness function of the GA used in the above mentioned approach.

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