A Hybrid Reliable Routing Technique (HRR) for Wireless Sensor Network

Kavitha.C and **Dr.K.V.Viswanatha**,

Visvesvaraya Technological University, Karnataka, India.

Summary
The life span of the sensor network is limited to its residual power. In order to increase the normal life span of the network it is necessary to implement energy aware algorithm. While there are many ways to achieve energy efficiency during routing, organizing the entire network into clusters and henceforth performing routing is one such approach. Current work is focused on two issues : Organizing the network into clusters, changing the Cluster Head at the appropriate time and perform routing through the cluster heads to the sink consuming least energy.

Key words:
Broadcast, Routing, Multi-hop, Scalability.

1. Introduction

Wireless sensor network is an emerging technology consisting of small low power and low cost devices that integrate limited computation, sensing and radio capabilities. The advancement in technological improvements has lead to the use of small, inexpensive, low-power, distributed devices for local processing and wireless communication [1]. These devices are called as sensor nodes. Each sensor node when coordinated with the information from other nodes can assist to measure a given physical environment in great deal, regardless of its own limited processing capability. The collection of many such sensor nodes, which co-ordinate to perform some specific action are described as sensor network.

Formerly, one single central processing station was considered as a focal point to which small number of sensor nodes were wired to form a complete sensor network. But at present, focus is more on the wireless, distributed, sensing nodes, which permits for closer placement of the sensor node to a particular phenomenon even when the exact location is not known. Multiple sensor nodes are also given vital importance, which is required to overcome environmental obstacles like obstructions, line of sight constraints etc. These parameters result in the sensor nodes to endure on small, finite sources of energy and communicate through wireless communication channel. Taking all this into consideration, existing infrastructure should be monitored for both energy and communication.

Manuscript received March 5, 2009
Manuscript revised March 20, 2009

Communication between nodes consume a lot of energy in sensor networks, which makes distributed processing capability to be an important constraint for sensor network. A centralized system leads to more energy depletion, as some of the sensors need to communicate over long distances and it also includes more number of bits to be transmitted. Processing as much information as achievable in the neighborhood would be an excellent thought as this reduces the total quantity of bits broadcast.

Sensor networks are employed in various domains. Depending on the type of physical parameter to be monitored in the physical system, one or more appropriate type of sensors are considered. Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared and radar, which are able to monitor a wide variety of ambient conditions [2].

The routing protocols which have been proposed for sensor networks can be broadly classified as flat and hierarchical protocols. Flat routing protocols are similar to the conventional multi-hop ad-hoc routing protocols. Hierarchical protocols organize the network nodes into several logical levels. This is typically implemented by a process called **cluster formation**. A cluster consists of a set of geographically proximal sensor nodes. Selected nodes serve as a cluster heads. The cluster heads can be organized into further hierarchical levels. The key advantage of hierarchical routing protocols is that the cluster heads can perform efficient in-network data aggregation. Routing proceeds by forwarding packets up the hierarchy until the sink node is reached. Flat routing protocols, on the other hand, attempt to find good quality routes from source nodes to sink nodes using some strategy. **[3]**

The category of routing algorithms that facilitate organizing the network into groups and identifying Cluster heads and there by establish one or more path between the source and destination are known as hierarchical routing protocols. There are two reasons behind the hierarchical routing being explored. One, the sensor networks are dense and a lot of redundancy is involved in communication. Second, in order to increase the scalability of the network keeping in mind the security aspects of communication. Cluster based routing holds great promise for many-to-one and one-to-many communication paradigms that are prevalent in sensor networks.

This paper presents a novel frame work of a Hybrid Reliable Routing Technique **(HRR)** in wireless sensor networks. This protocol is intended to provide a hierarchical transmission environment by efficiently organizing, randomly placed sensor nodes into clusters and identifying a Cluster Head (CH) for each such cluster. The remaining nodes should enquire the energy availability factor of the neighboring CHs and join that cluster which promises to have more energy than other CHs, thereby ensuring service for a longer period of time. Once the CHs are identified, they form a Dominating Set (DS). The members of the DS find A multi-hop, least energy consuming path to the sink. There are several hierarchical routing techniques, and these offer rather different performance characteristics. *Section 2* describes some of the popular works in hierarchical routing. *Section 3* deals with organizing the WSN into clusters, identification of cluster heads, routing from a node to the sink through its CH.

2. Related Work

Heinzelman et al have proposed a Low-Energy Adaptive Clustering Hierarchy **(LEACH) [4**]. LEACH is based on a simple clustering mechanism by which energy can be conserved since cluster heads are selected for data transmission instead of other nodes in the network (Algorithm 2). By the received signal strengths, local cluster heads are selected to serve as the routers to the data sinks. A sensor node sends its data to the local cluster head in turn transmitted to the nearest cluster head on the way to the sink. Since the cluster heads are only responsible for bulk of the data transfer, the overhead is minimized; however, if the cluster heads are chosen beforehand and remain fixed throughout the network lifetime, they will easily die out, thereby ending the lifetime of the member nodes of the particular cluster as well. To solve this problem, LEACH performs a periodic randomized rotation of the cluster head to enable all the nodes within the cluster to take on a collective responsibility in order not to drain the battery of a single node. The optimal number of cluster heads is considered 5 percent of the total number of nodes. LEACH also performs local data fusion and aggregation to compress the data received from each cluster. Sensor nodes are selected as cluster heads by the node choosing a random number between zero and one. The node is selected as a cluster head for the current round if the number is less than the following threshold values:

$$T(n) = \frac{p}{1 - p * (r \bmod 1\, p)} \quad \text{if } n \in G$$

where p is the desired percentage of cluster heads, r is the current round, and G is the set of nodes that have not been cluster heads in the last 1 p rounds.

Once all the nodes are organized into clusters, the cluster head will create a schedule for the nodes in its cluster which enables the radio components of each cluster node to be turned off for most of the time. Each node transmits its data to the cluster head according to its schedule. On completion, the cluster head aggregates and sends all the data to the sink.

LEACH achieves a significant reduction in energy dissipation when compared with direct communication and other minimum energy routing protocols. Properties of EACH includes (i) dynamic clustering to increase network lifetime; (ii) single hop routing from node to cluster head, hence saving energy; (iii) distributiveness; (iv) additional overhead due to cluster head changes and calculations leading to energy inefficiency for dynamic clustering in large networks.

Lindsey et al describe Power-Efficient Gathering in Sensor Information Systems **(PEGASIS)** [5]. PEGASIS forms chains of the sensor nodes instead of forming multiple clusters as performed in LEACH protocol. Each node in the chain can transmit and receive data from its neighbors. In the entire chain, one node is selected to transmit all the data received to the sink or base station. The chain construction follows a greedy approach. The problem of building a chain to minimize the total length is similar to the traveling salesman problem. The elected local leader in the chain waits for data from its closest neighbors. These neighbors first receive data from their own respective closest neighbors and aggregate the data before transmitting to the leader. The leader then sends the data received from its closest neighbors to the sink. Even though PEGASIS is similar to LEACH, it differs in the following ways. It uses multi-hop routing while only one node is selected to transmit to the base station. The reduction in overhead due to dynamic clustering as in LEACH leads to a performance gain of almost 100 to 300 percent in PEGASIS. This overhead is reduced when the following occur: (i) Transmission distances of non-leader nodes are minimized. (ii) One transmission is made to the sink per round by aggregating all the data. This reduces local energy consumption but introduces a large delay for nodes farther away from the leader node of that chain. It also results in a single point of failure by the bottleneck created at the chain leader. (iii) The number of transmission among the nodes are reduced leading to overall energy efficiency.

Manjeshwar et al have proposed Threshold-Sensitive Energy-Efficient Sensor Network Protocol **(TEEN)** [6]. The TEEN protocol is designed to respond to sudden changes in the sensed attributes and uses a hierarchical model along with a data-centric mechanism. Clusters are formed in a hierarchical fashion at different levels with elected cluster heads serving as communication links between each other and the data sink. Initially, the clusters are formed after which each cluster head broadcasts two threshold values to all the nodes. These are hard and soft thresholds for the sensed attributes. The hard threshold is the minimum possible value of an attribute based on which the sensor will be transmitting data to the sink. When the sensed value of the attribute is greater than this threshold, the data are sent to the cluster head. This enables the nodes to transmit only relevant data. Once a value above the hard threshold is sensed, the node checks if the difference in the current and earlier values is greater than the soft threshold; if so, the new data are transmitted. Hard and soft threshold values can be adjusted per requirements allowing to control the packet transmissions. This protocol is succeeded by the adaptive threshold-sensitive energy efficient sensor network protocol (APTEEN) [7], which aims at capturing periodic data collections and respond to time-critical events. While the architecture remains the same as TEEN, APTEEN supports three types of data query: (1) historical, to analyze and monitor past data values and take decisions based on these recorded values; (2) one-time, to take a snap view of the current network situation and visualize it at a particular time instant; (3) persistent, to monitor the network over a continuous time interval especially during an event taking place.

Sajid et al [8] describe hierarchical Clustering Routing **(HCR)** as an extension of LEACH. In HCR, each cluster is managed by a set of associates and the energy efficient clusters are retained for a longer period of time. The energy efficient clusters are identified using heuristics based approach. In a variation of HCR, the base station determines the cluster formation. Genetic Algorithm(GA) is used to generate energy-efficient hierarchical clusters. The base station broadcasts the GA- based clusters configuration, which is received by the sensor nodes and the network is configured accordingly. For continuous monitoring applications, the simulated results show that HCR is more energy efficient than the traditional cluster based routing techniques.

Tubaishat et al. [9] propose an energy efficient level based hierarchical routing protocol. Additionally, it designs a Secure Routing Protocol for Sensor Networks **(SRPSN)** that provides protection against different kinds of attacks and guarantees that packets reach the sink from the source even in the presence of intermediate adversaries. The protocol organizes the sensor nodes hierarchically into levels. This classification into levels is based on the number of neighbors of each node. If a node has a larger number of neighbors, then it will be assigned higher level. A node discovers the identity and number of neighbors (NBR) by broadcasting a hello message. This is followed by a round of exchange of node IDs and NBRs to build connected groups or clusters. Nodes which have the highest number of NBRs become cluster heads. The cluster heads are responsible for aggregating and forwarding sensor data. The cluster heads filter and aggregate the sensor node data and forward the summary to the root nodes. Each sensor node shares a secret key with the sink node. The sink node maintains a table of (id, key) pairs for all nodes. The protocol runs in two phases: secure route discovery and secure data forwarding. The main draw back of this technique is formation of non-uniform clusters. Thus the nodes having the largest number of neighbors can burn out faster.

3. Hybrid Reliable Technique

A. Overview of the Protocol

One of the techniques used to create the clusters and represent the topology of the WSN involves the use of Graph Theory concepts to represent the topology of the sensors in the field. Graph theory can be used to create the sensor clusters and can help in identifying the cluster head. Sensor network can be represented by a graph $G = (V, E)$, where the vertices (V) represent the sensors and the set of links (E) represents the connections between vertices if the they are within the transmission range of each other.

The Sensor Nodes and the communication links between them can be represented by an undirected graph $G = (V, E)$, where each vertex $v \in V$ (the set of vertices in the graph) represents a sensor node with a unique ID. An edge (u, v) E (the set of edges in the graph) represents a communication link if the corresponding nodes u and v are within the transmission range of each other.

Considering the WSN as a graph $G = (V, E)$, the objective of routing can be achieved by a three step process as given below:

- The entire network has to be logically divided into various regions or clusters, with each cluster having a Cluster Head (CH).
- Considering the CHs, a Set C has to be formed, so that for any node request, the corresponding

CH can communicate to the sink in an effective way.

- If the current CH is loosing out too much of energy, it has to handover the job of CH to the next node in the race, thereby providing reliable transmission.

B. Cluster Head Election

The characteristics desired to identify a node as a Cluster Head (CH) are:

- Every node should be in exactly one cluster. The objective of this is to maximize. the average cluster sizes while maintaining full coverage.
- Guarantee the total coverage of the network.
- Minimize the number of CH to provide an efficient network coverage while minimizing the cluster overlap. A minimum cluster overlap reduces the amount of channel contention between clusters and improves the efficiency of algorithms that execute at the level of the CH.
- Create a highly uniform, balanced clustering.

Cluster Representation: There are many different graph concepts used for the creation of clusters in a WSN. Among them is the following definition for cluster:

Definition 1. Cluster. A cluster is any subset of nodes $C \subset V$. $y \in V$ is the cluster head and $G_c = (C, E_c)$ is the cluster graph.

$E_c = \{(u, v) | u, v \in C \wedge (u, v) \in E\}$

If G_c is connected, then the cluster is connected. $d_c(u, v)$ is the shortest path inside the cluster, and the cluster radius is the maximal distance between y and any other node $v \in C$. $\max_{v C} d_c(y, v)$

During the initialization phase, clusters are created using a threshold function T(n) defined as follows :

$$T(n) = [e^{-k_1 (T/CE)} - k_2]\, D$$

where,

C is the desired iterations,
E is the expected amount of energy to be spent for either receive/forward packets,
T is the time passed since the protocol began,
D is the estimated average number of neighbors,
k_1 and k_2 are constants
T(n) is an exponentially decreasing function.

- Initially when the clusters have to be formed, each node checks if the residual energy is greater than T(n). If so, the node will become a member of the set C.
- It may so happen that too many nodes constitute the set C. Keeping mind the desired characteristics stated earlier, and to minimize the number of clusters formed, and finally ensure total coverage, the set C is pruned. If the number of members in C is greater than 5% [10] of the total number of nodes deployed in the network, then eliminate some of the entries in the set C.
- Each member of C broadcasts a short range advertisement. The sensor nodes may receive advertisements from one or more CH's. Each sensor node chooses its CH on the basis of the energy strength entry in the received advertisements.
- The sensor node transmits short range acknowledgments to inform appropriate CH about their decision.
- The CT's are created at each cluster head. The Cluster tables will have all the details of each member in the corresponding cluster.
- Finally, at the end of the election phase, each member of the set C checks if it has sufficient energy for the next round. If the energy of any CH fall below the threshold value, it changes its role and gives control to the next promising node with respect to energy. Then a new cluster head is identified as a replacement for the CH in question. This fact must be updated by all other members of the cluster head set.

C. Multi-hop Routing

The routing mechanism constructs a small number of alternate paths that are *node-disjoint* with the primary path, and with each other. These alternate paths are thus unaffected by failures on the primary path, but can potentially be less desirable (*e.g.,* have lesser energy) than the primary path. A constructive definition for a node-disjoint multipath is:

1. Construct the primary path *P* between source (CH) and sink.
2. The first alternate disjoint path *P*1 is the best path node-disjoint with *P*.
3. The second alternate disjoint path *P2* is the best path that is node disjoint with *P*and *P1* and so on.

After creating the clusters, HRR uses a Bellman Ford Technique by choosing the next hop node which promises to poses maximum energy. Routing table is maintained by each of the cluster head in addition to the cluster table. The routing table consists of the details of each of its neighboring node. This table is formed by periodic

"HELLO" message exchanges between the members of the Set C.

Conclusion

In this paper, a Hybrid Reliable Routing technique has been proposed. This protocol is intended to utilize best of the features of both flat routing and hierarchical routing in WSN. In order to provide scalability in WSN this paper proposes clustering of the network. The energy available in the Cluster heads form the bottle neck during routing. As a counter measure this paper suggests a method to identify a new cluster head. The routing is done by identifying the maximum energy possessing path links any other flat routing protocol. Hence, this strategy is a hybrid of hierarchical and flat routing providing a reliable service. The proposed technique is under implementation.

References

[1] I.F.Akyildiz, W.Su, Y. Shankarasubramaniam, and Cayirci, Wireless sensor networks: a survey, Computer Networks, 38(2002) 393-422.

[2] Kemal Akkaya and Mohamed Younis, A Survey on Routing Protocols for Wireless Sensor Networks, ,Elsevier Ad Hoc Network Journal 2005.

[3] N.Narasimha Datta, K.Gopinath, A survey of routing algorithms for wireless sensor networks, Journal of IISc, Nov-Dec 2006.

[4] Wendi Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan, Energy efficient communication protocol for wireless microsensor networks, Proc. 33rd Hawaii International Conference on System Sciences, 2000.

[5] S. Lindsey and C. Raghavendra. PEGASIS: Power-efficient gathering in sensor information systems. In Proceedings of IEEE Aerospace Conference, 2002, pp. 1125–1130.

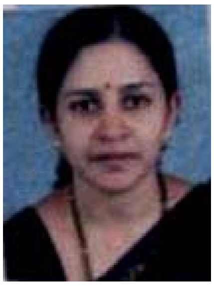
[6] A. Manjeshwar and D. P. Agrawal. TEEN: A routing protocol for enhanced efficiency in wireless sensor networks. In Proceedings of IPDPS, 2001, pp. 2009–2015.

[7] A. Manjeshwar and D. P. Agrawal. APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks. In Proceedings of IPDPS, 2002, pp. 195–202.

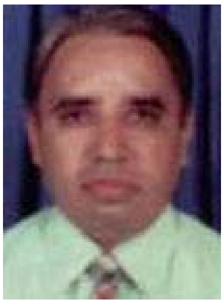
[8] Sajid Hussain, Abdul W. Martin, Hierarchical Cluster based Routing in Wireless Sensor Networks, Journal of networks,Academy Publisher, Vol 2, Number 5, Pages 87-97, 2007.

[9] Malik Tubaishat, Jain Yin, Biswajit Panja and Sanjay Madria, A secure hierarchical model for sensor network, ACM SIGMOD Record, 33, 7-13(2004)

[10 D. Ganesan, R. Govindan, S. Shenker, and D. Estrin. Highly- resilient, Energy-Efficient Multipath Routing in Wireless Sensor networks. Mobile Computing and Communications Review (MC2R), (2):28–36, 2002.



Kavitha.C received the B.E. and M.E. degrees in Computer Science & Engineering from Bangalore University in 1992 and 1997 respectively. She is working as an Asst.Professor in the Department Of CSE, RVCE, Bangalore. She is pursuing PhD in the area of routing in Wireless Sensor Networks. Her areas of interest are Computer Networks and Data Structures.



Dr.K.V.Viswanatha received his PhD from IISc, Bangalore in the year 1975. He has more than 30 years of experience together in industry as well as in academics. Currently he is working as a Professor in the Department Of CSE, RVCE, Bangalore. His areas if interest are Data Structures & Algorithms, Programming Languages, Computer networks.