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LOAD BALANCING OVER GEOGRAPHIC ADAPTIVE FIDELITY ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

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Abstract

The energy consumption is a great challenge in Wireless sensor networks that may affect the performance of the entire network. Even though many techniques are being still addressed to this issue, it is ongoing problem. One of the most energy efficient routing protocols is Geographic Adaptive Fidelity (GAF), which is the location based protocol. This reduces the use of energy by switching off some nodes that do not take part in routing. Load balancing reduces hot spots in sensor networks by spreading the workload across a sensor network there by increasing the life time of the sensor network. Here we use chebyshev sum metric for evaluation via simulation and this method is better compared to the routing based on Breadth first search(BFS) and shortest path obtained by Dijkstra's algorithm. By combining Geographic Adaptive Fidelity with load balancing, a considerable amount of energy can be saved that tends to extend the lifespan of the whole network.

Index Terms— wireless sensor networks; routing; energy efficient; load balancing.

I. INTRODUCTION

Wireless sensor networks (WSN) are a self organization wireless network system used to collect data from a machine equipped with sensor nodes, and forward data to the sink node [5]. This system is constituted by the spatially distributed autonomous energy-limited micro sensor nodes equipped with sensing, computing, and with communication abilities [1]. Networks of sensors are amenable to support a lot of real world applications that vary considerably in terms of requirements and characteristics [2].

As sensor networks scale-up in size, effectively managing the distribution of the networking load will be of great issue [3]. By spreading the workload across the sensor network, load balancing averages the energy consumption. This may lead to extend the expected life span of the entire network by extending the time until the first node is out of energy. Load balancing also be used for reducing congestion hot spots, thereby reducing wireless collisions. Another challenging issue is to save the energy of the node [6]. Once sensor deployment is over, it is impossible to replace or recharge the battery. The depletion of energy may lead to poor link quality, link failure even it tends to the failure of the application. To minimize the energy consumption of the nodes, some location based schemes demand that nodes should go to sleep if there is no activity. This saves a considerable amount of energy and increase the network life time. More energy savings can be obtained by having as many sleeping nodes in the network as possible.

The remainder of the paper is organized as follows. In section II, a brief description of related work in energy saving and load balancing methods is provided. In section III, a basic Geographic Adaptive Fidelity routing algorithm with its transition states is presented. Section IV describes the load balancing routing algorithm for wireless sensor networks. In section V, we present Load balancing over GAF (LB-GAF) algorithm. Section VI presents the simulation results and analysis; and finally, we draw our conclusions in section VII.

II. RELATED WORK

A variety of routing protocols have been proposed with different techniques to minimize the energy consumption and to increase the lifespan of the network. In [4], some of the techniques such as Data reduction, protocol overhead reduction, topology control, energy efficient protocols and Sleep/Active scheduling are focused. An example of single path load-balancing is Load-Balanced Ad hoc Routing (LBAR) algorithm proposed in [15] which uses traffic interference as a metric to distribute the network load and to avoid routing via heavily loaded paths. Multipath Routing Protocol (MSR) [16] is based on DSR and uses a Round Trip Time (RTT) to measure delays for different paths, which form the basis of its routing metric. In [6], GAF protocol and it's working are considered. It also reviews the variety of new versions based on GAF protocol to make it better. Hierarchical Geographic Adaptive Fidelity (HGAF) is proposed to save the power of the nodes which increases the lifetime of whole network in [6].

COordination-based data Dissemination protocol for wireless sensor networks (CODE) is proposed which is based on GAF protocol in [10]. In [11], TENT rule defines the method of finding the neighbor nodes with the angle and distance. HGAF uses a layered structure in which the entire area is divided into virtual grids. eHGAF extends the HGAF in which the place of the active sub cell is rotated. GAF & Co [12] maintain the connectivity of a network and avoids the routing tables. Some of the sensor network routing [17, 18] and QoS routing in Wireless ad hoc networks [19] ignore the load balancing issues. In many works, such as in [20, 21] consider the base station as a resource rich focal point hosting the services such as securing the sensor network against vulnerabilities [22], data aggregation or monitoring of WSNs. Another protocol Energy efficient and Collision Aware (EECA)[23] takes energy of the nodes into account and it tries to avoid collision by choosing distant route paths.

III. GEOGRAPHIC ADAPTIVE FIDELITY (GAF)

Geographic Adaptive Fidelity or GAF [6, 7] is energy aware location-based routing algorithm. It is initially designed for mobile ad hoc networks, but nowadays used in sensor networks as well. Nodes use location information through any system like GPS, received radio signal strength etc to locate itself along with its nearest neighbors. In GAF protocol, each node associates itself with a virtual grid so that the entire area is divided into several square grids, and the node with the highest residual energy within each grid becomes the master of the grid. Selection of proper size plays a vital role as it directly affects the connectivity of the network. If the grid size is large, then it is difficult to connect the whole network by activating just one node per grid. The size of grid (r) is based on the concept that any node can communicate with any other node present in the neighboring grid. The grid size r is

$$r \leq R/\sqrt{5}$$

Where R is the radio range. Two nodes are considered to be equivalent when they maintain the same set of neighbor nodes and they can belong to the same communication routes. Source and destination in the application are excluded from this characterization.

A. Routing over GAF

Figure 1 shows a virtual grid. Considering that there are five nodes 1 through 5. Node 1 can communicate with Node 5 with the help of sending the data to any of the intermediate nodes namely 2, 3 and 4. To minimize the energy consumption two nodes (3 and 4) from the same grid go to sleep mode. Still it is possible to send the data from 1 to 5 through 2. This is called as routing fidelity where the source and destination nodes are communicating using only one efficient node as their routing partner and other intermediate nodes go into sleep mode.

B. Transition states in GAF

Any sensor node can be in three different states namely sleeping, Discovery and Active state as shown in fig.2. Only one node per grid can be in active state and others go to sleeping mode to conserve the energy. A node to be in an active state is decided based on its residual energy and this active node is responsible for monitoring, routing and reporting data from and to the sink. The sleeping neighbors adjust their sleeping time

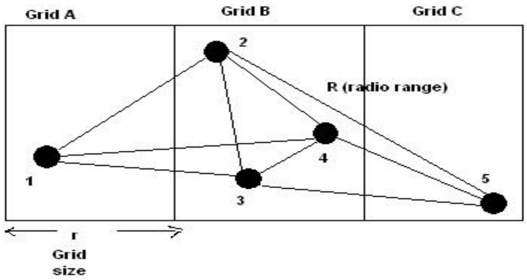

Fig.1.Vitrual grid in GAF

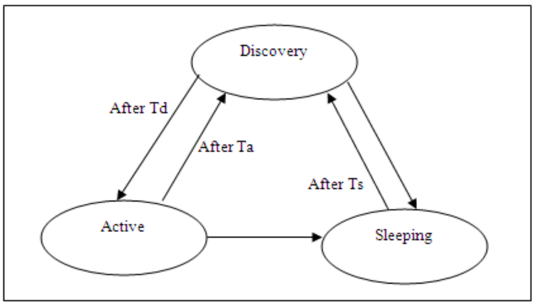

Fig.2.Transition states in GAF protocol

accordingly, in order to keep the routing fidelity. Before the leaving time of the active node expires, sleeping nodes wake up and one of them becomes active. Initially every node starts with the discovery state and then enters in active or sleep state.

- State Transition from Discovery to Active

In the discovery state, if node receives any other discovery message from another node having higher energy level than a node enters in the sleep state. To keep the routing fidelity; sleeping neighbors adjust their sleeping time (T_s) accordingly. One of the sleeping nodes becomes active much before the leaving time of the active node expires.

- State Transition from Active to Sleeping

T_a is an active time of the sensor node which shows that for how long a node will stay in an active state. After T_a, if another node having high energy is present in the grid then current active node will enters in a sleep state.

- State Transition from Sleeping to Discovery

To enter in the discovery phase, the node must complete the sleep time T_s. After T_s node again enters in a discovery phase and if it has highest energy level then enters active state else re-enters into sleep state.

- State Transition from Active to Discovery

After a predefined time, T_a, a node enters in the discovery phase and rebroadcasts the discovery message for time T_d. If it receives a message from another node having higher residual energy, then it enter into sleep state else re-enters into active state.

IV. LOAD BALANCING IN ROUTING PROBLEM

Load balanced algorithms are initially employed to solve network congestion problem to improve packet delivery ratio and to reduce packet delivery. But nowadays these algorithms are also being used for energy conservation. Actually, there are two classes of load balanced routing algorithms name single path and multipath load balanced routing algorithms. In single path, it discovers multiple paths from a source to destination but will only use the best path for routing Eg. Load Balanced Ad-hoc routing (LBAR). On the other hand, in multipath load balanced routing, it distributes the data packets over multiple paths for a single flow Eg. Energy Balanced Dynamic source routing (EB-DSR)[13].

The WSN routing tree is rooted in the base station and the sensor nodes adds its upstream parent in the tree. Thus, the sensor nodes nearest to the base station will be the most heavily loaded. The goal of load balancing is to evenly distribute the packet traffic generated by the sensor nodes across the different branches of the routing tree. A shortest path routing algorithm executed on a sensor network may result in a shortest path tree that can minimizes the hop counts but yielding a highly-unbalanced tree [3]. This is because the selection of shortest path does not guarantee for the load aggregation on upstream nodes. In load, balanced tree, the base station at the root of the tree assumes the uniform grid, generating the equal amount of load on each of the branches emanating from the root. Figure 3 shows the unbalanced shortest path tree and top level balanced tree.

Load balanced trees may be classified into three different categories such as fully balanced, top-level balanced or hierarchy balanced. A fully load-balanced tree is a backbone tree for a set of loads such that, for each tree node with multiple branches, all the branches carry the same total amount of loads. A top load-balanced tree is a backbone tree for a set of loads such that, for the tree node that has multiple branches and is closest to the root, all the branches carry the same total amount of loads. A hierarchy balanced tree is a tree in which the branches in certain levels carry the same amount of load.

V. Load Balancing Algorithm over GAF (LB-GAF)

Load Balanced over Geographic adaptive fidelity works in three stages

Step 1. Applying the load balanced algorithm to convert the graph of sensor network into balanced tree structure.

Step 2: Applying the adjustment algorithm to rebalance the tree by moving the edges from the heavily loaded branches into lightly loaded branches.

Step 3: Implementing GAF routing over the tree where the nodes take part in routing alone switched on.

This part deals with the construction and adjustment of the top-level balanced tree for WSN considering Chebyshev sum inequality as load balancing metric.

The basic algorithm for load balancing iteratively grows a load balanced tree outwards from the base station or sink. This algorithm observes the nodes generating the greatest load to the lightest branches to achieve balance. Observing the heaviest nodes at the earlier maintains the greatest flexibility for future balance whereas observing them at the end of the algorithm could lead to highly unbalanced trees. This algorithm selects the unmarked border node with the greatest growth space when

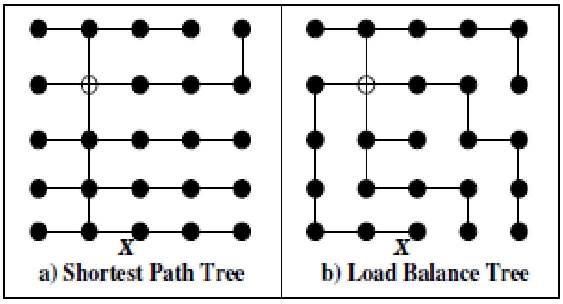

Fig.3.a) Unbalanced shortest path tree Vs Top-level balanced tree

there are multiple heaviest border nodes .

The Pseudo code for the algorithm is shown below.

```
M<= All nodes;
While (M ≠ Empty) do
//Select the lightest branch
B=B [0];
For each B[i] do
if (weight (B)> weight (B[i])
B<=B[i];
else
B<=minFreedom (B[i], B);
//Select the heaviest border node with most growth space
n1=no<=N, where N is B's border node list for each
ni<=N   if Weight (n1) ≠ Weight (ni)
n1<=heavier (n1, ni);
else
n1<=maxFreedom (n1, ni)
//graft nodes and update metrics
T=T+ { n1}
N=N-{ n1}
M=M-{ n1}
For each unmarked border node i of n1
N=N+{i};
done.
```

The base station or sink identifies the initial topology and load information about the sensor nodes and sensor network and computes the backbone tree from graph G. T is the current tree; B[i] represents the branches array; B is the selected branch, N [ ] refers to the list of the border nodes for each branch and M is the set of unmarked nodes.

A growth space of a node is the measure of the freedom to grow the tree towards this node. The greater the growth space, the more open area to expand the load balanced routing tree through this node. The growth space of the node can be calculated as the sum of number of unmarked neighbors of all the node's unmarked neighbors minus common links.

Figure 4 shows the unmarked neighbors and the calculated growth spaces for each node. For example, in the figure node Z has two unmarked neighbors to its right and bottom. The growth space of Z can be calculated as 3+3-2(common links) =4. The growth space of a branch is defined as the sum of the growth spaces of all nodes within the branch.

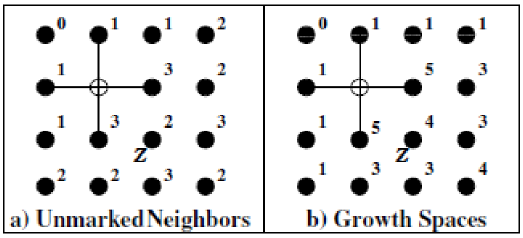

Fig.4.a) Number of unmarked neighbors of each node
b) Growth space of each node

As the basic algorithm generates a roughly load balanced tree at the top level, it requires an algorithm to achieve further balancing. There are several adjustment algorithms are available such as random adjustment [14] and spiral adjustment [3]. Former is blind to the topology information whereas the latter uses the topology information. After applying the basic algorithm, the adjustment algorithm is applied to iteratively rebalance the tree by moving the nodes from the heaviest loaded branches to more lightly loaded neighboring branches. The Spiral adjustment algorithm rotates through each of the tree's top-level branches. It either pushes the neighbors from heavily loaded to lightly loaded branches or pulls the neighbors to lightly load from heavily loaded branches.

Sleep Doze Co-ordination (SDC) [8,9] protocol over GAF increases the lifetime of the network by switching off the sensor nodes that do not take part in data transmission. There are 2 modes at each node namely "ON" period or "OFF" period. In ON period the sensor node remains in its Alert mode or Doze mode and in OFF period it is in sleep mode. Doze is an idle listening state and only one node per grid is in Doze state while the rest on the sensor nodes in the grid remains in sleep state. A node changes its state from doze to active once its buffer gets filled with data messages. Upon changing its state, the active node first sends the beacon message to activate the neighbor nodes and then sends its buffer content for further processing. Even though it increases the network lifetime by 20% over GAF protocol, it is an expensive method as it needs a buffer.

In our algorithm after the tree got balanced, a variation of the above protocol is implemented. There are some leaf nodes in the balanced tree only through the ingress and egress paths are set. The path may be either from the root to the leaves in the outward direction for data transmission or from the leaves to the base station or root for data gathering. All sensor nodes can be in any one of the three states namely doze, sleepy and interactive. Leaf nodes are always in a doze in other words idle listening state. It is enough to keep only one node in this doze state particularly the leaf node through which the data transmission starts. Remaining sensor nodes in the path up to the BS are in the sleep state. Once the leaf node identifies that its buffer is filled with data, it changes its state from doze state to interactive state. Leaf node alerts its neighbor by transferring its buffer content to its neighbor's buffer and enters in the doze state. Upon receiving the data content in the buffer, the neighbor node changes its state from sleepy to interactive, transfers its buffer content to its neighbor and enters sleepy state. Thus, the data is routed towards the base station. The sensor nodes on the path enters in to sleep state, once the data content leaves its buffer except leaf nodes that enters in doze state which again listens for data.

VI. EXPERIMENTAL RESULTS

In this section, we evaluate and compare various algorithms using the simulator ns-2. The performance measures of interest in this study are a) Balance factor; b) Network life time.

A. Balance factor

Initially we evaluate the load balancing performance of our algorithm with shortest path tree (SPT) and the tree created by BFS. Dijkstra's Algorithm using a link cost of 1 is accounted for every link to find the shortest path tree. The BFS algorithm grows the tree from the root in a rotational basis between branches. All the nodes in the N^{th} level are appended and marked visited before appending N+1 level from the root. Figure 5 assess the balance factor of the routing trees produced by the three algorithms. By considering uniform load distribution, for the square grid size as 20 X 20, the experiment is executed for 25 times. From fig.5, it is shown that the shortest path algorithm produces the most unbalanced trees whereas our LB-GAF outperforms both SPT and BFS.

B. Network life time

Network life time is the primary metric of interest. There are many definitions for network lifetime such as time to which the network is partitioned, time to which data delivery rate falls below a predefined value, or time to which a pre-defined number of nodes exhausted.

Here we consider the most common definition for network life time, which is the duration from the beginning of the network operation to first node failure. Figure 6 shows the life time of 25 nodes plotted against the time duration. It is apparent that LB-GAF is much more energy balanced that can be seen from the node life times. It also has the longest network life time compared with other algorithms.

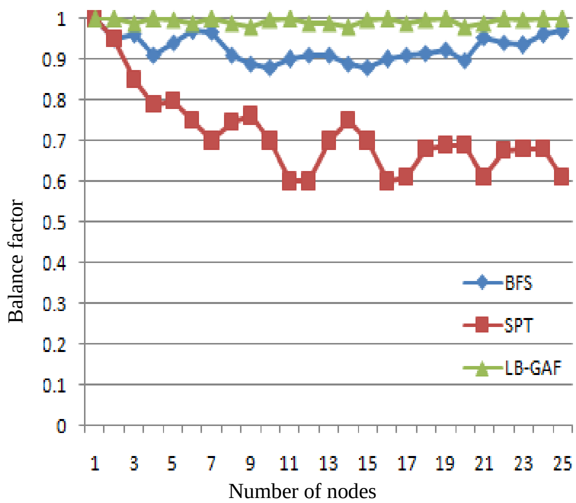

Fig.5. Comparison of balance factor.

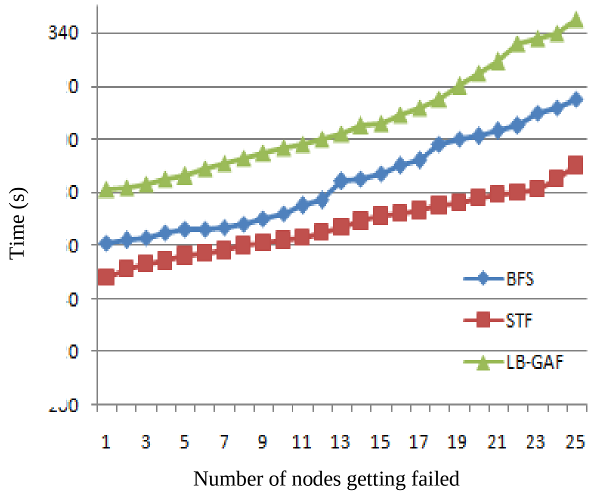

Fig.6. Number of nodes getting failed against time.

VII. Conclusion

In this paper, we provide a load balanced – Geographic Adaptive Fidelity routing protocol for wireless sensor networks. First, the unbalanced network is converted into a load- balanced tree structure. After establishing a load balanced tree, a variation of sleep-Doze coordination protocol of GAF is applied to conserve energy. Our algorithm achieves considerably better balanced trees than BFS and SPT. The results from simulations have shown that LB-GAF can effectively prolong the network lifetime by consuming less energy from the sensor nodes.

References

[1] Degan Zhang, Guang Li, Ke Zhang, Xuechao Ming and Zhaohua Pan, An Energy – Balanced Routing Method Based on Forward-Aware Factor for Wireless Sensor Networks. IEEE transactions on Industrial informatics 10(1): 766 - 773 (2014).

[2] Chiwewe, T.M. and G.P. Hancke, A Distributed Topology Control Technique for Low Interference and Energy Efficiency in Wireless Sensor Networks. IEEE Transactions on Industrial Informatics 8(1): 11-19 (2012).

[3] Hui Dai and R. Han, A node-centric load balancing algorithm for wireless sensor networks, IEEE Global tele communications Conference 1: 548-552 (2003).

[4] Ridha Soua and Pascale Minet, A Survey on Energy Efficient Techniques in Wireless Sensor Networks, IEEE Wireless and Mobile Networking Conference (WMNC), Pp. 1-9, October (2011).

[5] Junyoung Heo, Jiman Hong and Yookun Cho, EARQ: Energy Aware Routing for Real-Time and Reliable Communication in Wireless Sensor Networks. IEEE Transactions on Industrial Informatics 5(1): 3-11 (2009).

[6] Jitender Grover, Shikha and Mohit Sharma, A Study of Geographic Adaptive Fidelity Routing Protocol in Wireless Sensor Network. IOSR Journal of Computer Engineering 16(5): 88-96 (2014).

[7] Sinchan Roychowdhury and Chiranjib Patra, Geographic Adaptive Fidelity and Geographic Energy Aware Routing in Ad Hoc Routing, Special Issue for International Conference [ACCTA], 3-5 August 2010, IJCCT 1(2-4): 309-313 (2010).

[8] Arpan Roy, Adway Mitra, Arijit Khan and Debashis Saha, Buffering Techniques in Sleep Doze Coordination and Grid Based Clustering Protocols as Power Management Schemes for Wireless Sensor Networks, IEEE International Conference on Wireless, Mobile and Multimedia Networks Pp. 240-245 (2008).

[9] Arpan Roy, Adway Mitra, Arijit Khan, Mita Nasipuri and Debashis Saha, LSDC A Lossless Approach to Lifetime Maximization in Wireless Sensor Networks, IEEE Sensors Applications Symposium (SAS), Pp. 166-171 (2008)

[10] Hung Le Xuan, Dae Hong Seo, Sungyoung Lee and Young-Koo Lee, Minimum-Energy Data Dissemination in Coordination based Sensor Networks, IEEE International Conference on Embedded and Real-Time Computing Systems and Applications Pp. 381 - 386 (2005).

[11] Xiao-gang QI and QIU Chen-xi, An Improvement of GAF for Lifetime Elongation in Wireless Sensor Networks, IEEE International Conference on Wireless Communications, Networking and Mobile Computing, Pp. 1-4, September (2009).

[12] Jiaxi You, Dominik Lieckfeldt, Jakob Salzmann and Dirk Timmermann, GAF & Co., Connectivity Aware Topology Management for Sensor Network, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Pp. 2260 - 2264, September (2009).

[13] Kok-Poh Ng and Charalampos Tsimenidis, Energy-Balanced Dynamic Source Routing Protocol for Wireless Sensor Network, Research gate conference paper December (2013).

[14] Hsiao, P.H., A. Hwang, H. T. Kung and D. Vlah, Load-Balancing Routing for Wireless Access Networks, IEEE Infocom, April (2001).

[15] Hassanein, H. and A. Zhou, Routing with load balancing in wireless Ad hoc networks, in Proceedings of the 4th ACM international workshop on Modeling, analysis and simulation of wireless and mobilesystems, New York, NY, USA, Pp. 89–96 (2001).

[16] Wang, L., L. Zhang, Y. Shu and M. Dong, Multipath source routing in wireless ad hoc networks, Canadian Conference on Electrical and Computer Engineering 1: Pp. 479–483 (2000)

[17] Manjeshwar, A. and D. P. Agrawal. Teen: A routing protocol for enhanced efficiency in wireless sensor networks. 1st International Workshop on Parallel and Distributed Computing Issues in Wireless (2001).

[18] Li, Q., J. Aslam and D. Rus, Hierarchical power-aware routing in sensor networks. Proceedings of the DIMACS Workshop on Pervasive Networking, May (2001).

[19] Lee, S.S. and M. Gerla, Fault Tolerance and Load Balancing in QoS Provisioning with Multiple MPLS Paths, IWQoS Pp. 55-169 (2001).

[20] Madden, S., M. Franklin, J. Hellerstein, and W. Hong, TAG: a tiny aggregation service for ad hoc sensor networks, USENIX Symposium on Operating Systems Design and Implementation (2002).

[21] Madden, S.R., R. Szewczyk, M.J.Franklin and D. Culler, Supporting Aggregate Queries Over Ad-Hoc Wireless Sensor Networks, in Workshop on Mobile Computing Systems and Applications (2002).

[22] Deng, J., R. Han and S. Mishra, A Performance Evaluation of Intrusion-Tolerant Routing in Wireless Sensor Networks, IEEE 2nd International Workshop on Information Processing in Sensor Networks (IPSN '03), Palo Alto, California (2003).

[23] Xiang M., W.R. Shi, J.C. Jiang and Z.H. Ying, Energy Efficient Clustering Algorithm for Maximizing Lifetime of Wireless Sensor Networks. Int. J. Electron. Communication Pp 289-298 (2010).