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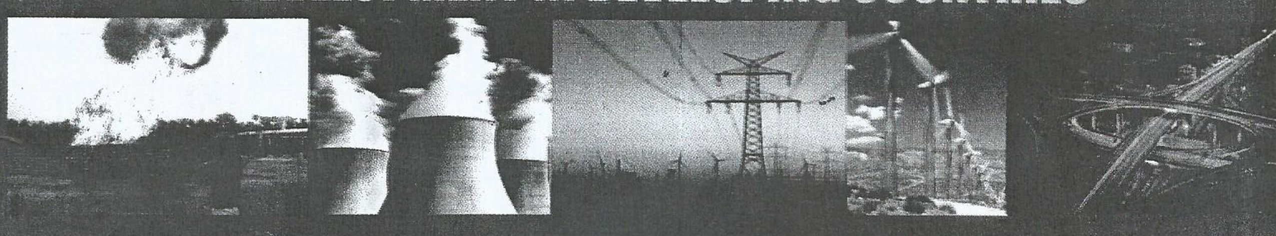
CHALLENGES IN ENERGY SUPPLY AND INFRASTRUCTURAL DEVELOPMENT IN DEVELOPING COUNTRIES



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Edited by:
Engr. Dr. A. S. Abdulkareem, Engr. Dr. A. A. Amadi
Engr. Dr. S. A. Abdulrahaman, Engr. Dr. M. Abdullahi

An Enhanced Cluster Based Routing Algorithm for Energy Conservation in Wireless Sensor Networks

S. Muslim [1], O. Ugweje [2], E.N. Onwuka [1] and A.M. Aibinu [1]
[1]Department of Telecommunication Engineering, Federal University of Technology, Minna Niger State, Nigeria
[2]Digital Bridge Institute, Abuja, Nigeria.

shehumuslimsaidu@yahoo.com, Phone number: +2348039719789

Abstract: It has been well established that the lifetime of a Wireless Sensor Network (WSN) depends on the energy of the sensor nodes which is limited by the battery of the nodes. This challenge has led to research efforts towards developing more efficient energy based routing algorithms and architectures. One of such popular algorithm is the Low-Energy Adaptive Clustering Hierarchy (LEACH). The LEACH approach adopts randomized rotation of local cluster base stations (or cluster-heads (CH)) to evenly distribute energy load amongst the sensors in the network. A variant of LEACH known as Vice-LEACH (V-LEACH) introduces the concept of a vice-CH that takes over the role of the main CH in the event of CH death. Both LEACH and V-LEACH ignores node's residual energy and the fact that optimal number of CH is not constant in all the rounds. This paper proposes an improved version of V-LEACH which selects the optimal number of CHs at network initialization, divides the network into optimal number of sectors, and then initializes the network with one node as a CH in each sector. This algorithm considers the node's residual energy while maintaining the optimal number of CHs throughout the network lifetime. It is envisaged that this approach will improve the performance of the network compared with LEACH and the typical V-LEACH.

Keywords: LEACH, Wireless Sensor Network, Vice-LEACH, Optimal Number, Network Lifetime

1. Introduction

A wireless Sensor Network (WSN) usually consists of a large number of battery operated *micro-sensor nodes* randomly and densely deployed over a geographical area to cooperatively monitor physical or environmental conditions at different locations (Ramesh & Somasundaram, 2011). WSN technology has attracted significant attention because of its large number of new applications in home automation, disasters and environmental monitoring, military operations, security surveillance, health services and other commercial purposes (Heinzelman, et.al 2000). A (WSN) has been described as an "exciting emerging domain of deeply networked system of lower-power wireless motes with a tiny amount of CPU and memory, and large federated networks for high-resolution sensing of the environment" (Kazem, .al, 2007). However, sensor nodes are resource constrained such as limited energy supply, low storage capacity, and weak computing ability. (Haosong & Younghwan, 2010). A WSN cannot operate effectively for long periods and this seems infeasible due to the aforementioned limitations. Therefore the lifetime of a WSN depends mainly on the energy consumption of the sensor nodes. Energy conservation is therefore the key issue in the design of systems based on wireless sensor networks. (Haosong & Younghwan, 2010)

Because of the above limitations, many different energy efficient clustering algorithms have been proposed in the literature. The Low-Energy

Adaptive Clustering Hierarchy (LEACH) is one of the earliest major improvements on conventional clustering approaches in WSN. The LEACH approach adopts randomized rotation of local cluster base stations (or cluster-heads) to evenly distribute energy load among the sensors in the network. In this algorithm, the Cluster Head (CH) is chosen randomly and in each round the role of CH is assigned to another node in order to balance the energy consumption in the whole network. Many clustering algorithms proposed in the literature are improvements of the LEACH protocol and architecture. One of such improvements is the Vice-LEACH (V-LEACH) which introduces the concept of a Vice Cluster Head (V-CH) that takes over the role of the cluster head in the event of a cluster head death. Random selection of cluster head in both LEACH and V-LEACH ignore node's residual energy and the optimal number of cluster head is not constant in all the rounds.

In this paper, an improved energy efficient, WSN routing algorithm is presented. It is based on the V-LEACH algorithm. Our algorithm selects the optimal number of cluster heads at network initialization, divides the network into optimal number of sectors, and then initializes the network with one node as a CH in each sector. At each round each CH chooses the node with highest residual energy in the cluster as a vice CH, turns the vice CH to sleep for that round and the vice CH becomes the CH for the next round.

This algorithm considers the node's residual energy while maintaining the optimal number of CHs throughout the network lifetime.

In Section 2, a review of the hierarchical WSN routing algorithm is presented. We emphasize on the Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm. An improved cluster-based WSN routing algorithm is presented in Section 3. We conclude our preliminary findings in Section 4.

2. Review of Relevant Literature

The main goal of cluster-based (hierarchical-based) routing protocols is to improve energy efficiency in network nodes and increase network lifetime (Amir, al., 2012). In clustering, the whole sensor network is divided into small regions known as clusters. In each cluster, one node is elected as cluster head. Each CH is responsible for aggregating the sensed data from its cluster member node(s) and propagates it to base station or to the next CH. The phenomenon of CH selection is alternatively and periodically done in rounds. In each round, the methods of selecting a new CH could be:

- Selected randomly
- Selected based on the residual energy,
- Selected based on distance from base station,
- Selected based on connected nodes,
- Selected based on topology. etc.

This ensures energy balance and increase the overall lifetime of the network (Ramesh & Somasundaram, 2011).

Low-Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for WSN which partitions the nodes into clusters (Heinzelman. et. al.. 2000). LEACH is a distributed algorithm which periodically elects the cluster heads randomly. Each round consists of two phases:- a set-up phase and a steady-state phase. In the set-up phase the clusters are constructed and in the steady-state phase the data is acquired and transferred. Once the steady-state phase is finished, the next iteration begins. Fig. 1 illustrates this protocol. This algorithm saves energy due to data aggregation and fair cluster head selection, as a result of distributed clusters and nodes that make their decisions autonomously, without any central control. This is achieved by each node generating a random number between 0 and 1. If the number is smaller than the threshold value T(n), the node becomes the cluster head in this round. The threshold value is calculated by Equation

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(r \bmod \frac{1}{p}\right)}, & \forall n \in G \\ 0, & else \end{cases}$$

where

p	is the predetermined percentage of cluster heads (e.g., p =0.05),
r	is the current round; and
G	is the set of nodes that have not been cluster heads in the last 1/P rounds.

After l/p rounds, the process start again and all nodes will be in the set G for cluster head selection mechanism. Each node that has elected itself as cluster head for the current round will broadcasts an advertisement message to the rest of the nodes in the network. All the non-cluster head nodes, after receiving this advertisement message, decide on the cluster to which they will belong for this round. Once the cluster heads are decided, the steady-state phase begins the time when sensor nodes start sensing and transmitting data to their cluster-heads.

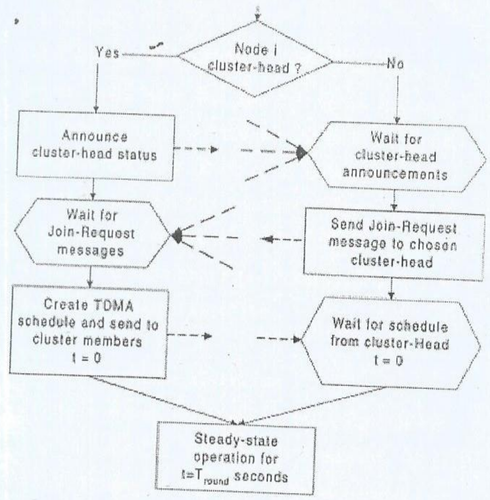

Fig.1. Flow chart of LEACH Algorithm (Wendi et al., 2002)

Another variant of LEACH algorithm is LEACH Centralized (LEACH-C) (Wendi B., al., 2002). This is identical to the LEACH protocol as far as formatting clusters at the beginning of each round. However, instead of nodes randomly self-selecting the CH, a centralized algorithm is performed by the sink in LEACH-C. In this case, the sink collects location information from the nodes, decides the CH and then broadcasts its decision to the nodes. The overall performance of LEACH-C is better than LEACH since it moves the duty of cluster formation to the sink. However, LEACH-C is sensitive to the sink location. Once the energy cost of communicating with the sink becomes higher than the energy cost for cluster formation, LEACH-C no longer provides good performance.

Dependence on the sink location is a major disadvantage of LEACH-C.

A technique known as Energy-LEACH (E-LEACH) protocol improves the CH selection procedure of LEACH by making the residual energy of nodes as the main metric that determines whether the nodes turn into CH or not after the first round (Fan & Song, 2007). In the first iteration, nodes are randomly selected as CH. Subsequently, nodes with more residual energy are selected as CH in the remaining round.

Another mechanism known as Multi-hop-LEACH protocol is presented (Fan & Song, 2007). It is almost the same as LEACH protocol, except that makes communication mode from single hop to multi-hop between cluster heads and sink. That is, multi-hop communication is adopted among CHs. Based on the selected optimal path; these CHs transmit data to the corresponding CH nearest to the sink. Finally, this CH sends data to the sink.

LEACH's stochastic CH selection algorithm is extended in (Ray & De, 2011) by adjusting the threshold T(n) denoted in the above equation . The threshold included; residual energy of the nodes, distance between the nodes and the base station and the number of consecutive rounds in which a node has not been a cluster head as metric for selecting cluster heads.

In (Anindita & De, 2012), the LEACH protocol is enhanced by improving the election strategy of the cluster-head nodes. The enhanced protocol considered the residual energy, distance from base station, number of consecutive rounds in which a node has not been a CH and also the factor that whether the nodes remaining energy is sufficient enough to send the aggregate data to the base station or not.

Finally, another variant known as the Vice-LEACH approach introduces the concept of an assistant which resumes duty as full cluster head in the event of the main CH death (Bani. et. al 2009). However, it was observed that this approach fails to account for the optimal number of CH selection as a function of the algorithm's performance. This is the focus of our proposed algorithm.

3. Description of the Algorithm

In this next section, an algorithm that enhances the existing V-LEACH concept is described. This algorithm intends to improve on certain limitation of the original V-LEACH algorithm (Bani, et. al., 2009). The objective is to address the limitation of the V-LEACH algorithm which includes the following:

1. Sub-optimal CH selection process
2. Inefficient energy conservation process.

The enhancement process is divided into the Network Initialization phase and Network Operation Phase. The solution to the problem of sub-optimal CH selection process is incorporated into the network initialization process. This will be achieved by hard-coding the original CH candidates before Sensor nodes are deployed. To obtain an efficient realization, the sensing area is identified and geometrically divided into N equally sized grids. Sensors are then carefully deployed into each grid box with an initialized CH node per batch. This introduces a simple solution to the challenge of optimal CH selection by ensuring that a single CH is deployed per grid. It is presumed that all sensing areas including irregularly shaped sensing areas are on rectangular coordinates (grids) as hypothetically depicted in Figure 2. This ensures a total of N initial CHs per total sensing area. Furthermore, designers can now ensure that only one CH is deployed per grid.

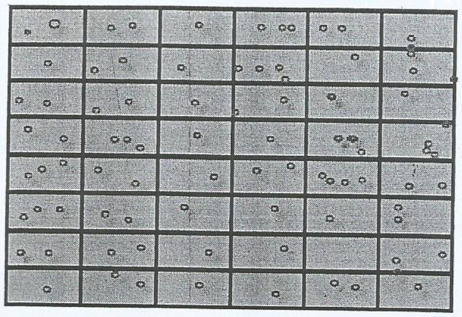

Fig. 2: A Grid of Sensors Nodes Deployed in a Hypothetical Testbed

The Network Operation Phase commences upon deployment of sensors. Figure 3 represents the flowchart of the enhanced V-LEACH algorithm. The operation begins with the initialization of the originally hard-coded CHs deployed in each grid of the sensing area along with other sensor nodes. The CH broadcasts its CH-status in a CH-advertisement packet to other nodes. Each node compares the Received Signal Strength (RSS) of all broadcasted CH-status messages, selects the CH with the highest RSS and sends a CH-bind request along with the residual energy status to the CH.

The CH receives the CH-bind request and residual energy status and selects node with the highest residual energy as the Vice-Cluster Head (V-CH). The CH sends V-CH results to the waiting nodes. The nominated V-CH accepts its new status, sends an acknowledgement to the CH and activates a sleep mode to conserve its energy for the period when it will assume CH status.

The CH then creates and sends the Time Division Multiple Access (TDMA) schedule to the cluster members. The nodes listen for this schedule and begin transmission on receipt. The CH continues to aggregate and transmit collected data for the first round.

At the expiration of the round, CH sends a V-CH awake request to the listening V-CH (currently in sleep mode) and upon receipt of a V-CH awake acknowledgement, the expiring CH relinquishes its CH-status to the V-CH. The V-CH assumes status as new CH and the algorithm re-runs for the second round of data transmission.

This algorithm possesses two key additions to the V-CH algorithm that will serve to improve its performance dramatically over the original V-CH algorithm in the V-LEACH protocol. It incorporates an initialization process that will clearly address the sub-optimal CH selection procedure and introduces a sleep mode period for the V-CH, thereby ensuring that V-CHs conserve sufficient energy to expend during the period as the CH. This ensures that the demanding activity of the CH does not run down the V-CH whenever it assumes its CH status.

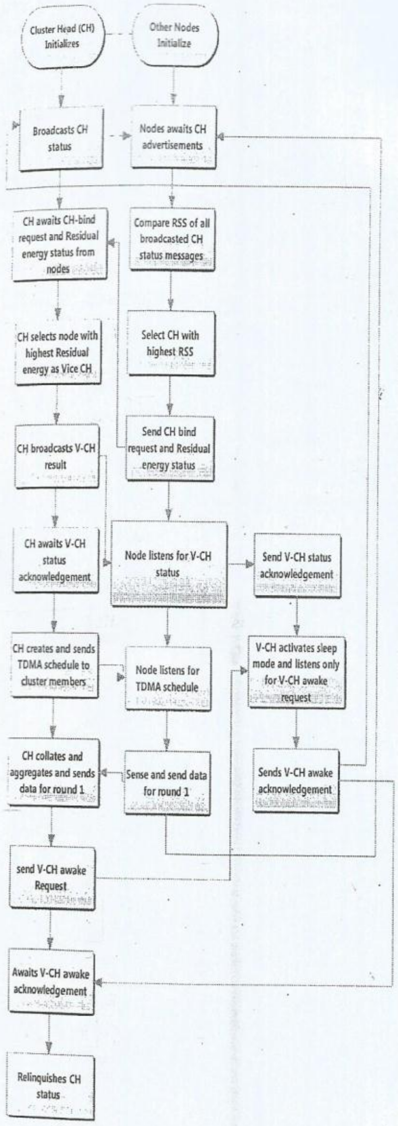

Fig.3: Flowchart of Enhanced V-LEACH algorithm

4. Conclusion

Energy conservation has remained the key desire of any WSN routing algorithm. Several algorithms have been proposed with the LEACH algorithm receiving utmost attention in literature. The Vice-LEACH suffices as a variant of the popular LEACH algorithm. However, two drawbacks of the V-LEACH were observed and this paper presents a proposed solution to address these identified downsides. In this paper, we have proposed an enhanced V-LEACH algorithm that addresses the challenge of sub-optimal CH selection and improves on the energy conservation of the WSN. Our ongoing and future works intend to implement this algorithm and analyze its output over existing techniques.

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