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ENERGY EFFICIENT CLUSTERING USING EVOLUTION ALGORITHM IN WIRELESS SENSOR NETWORKS:A REVIEW

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Abstract: In designing of suitable and specific algorithms for minimizing energy dissipation applications, fulfilling the different performance demands has been considered as a critical issue in WSN. In this context many energy efficient algorithms have been proposed to improve earlier. In this paper we introduce the Evolution algorithm for improvised the existing research. Further this research compare to CBCR and LEACH. This algorithm includes the intercluster communication after employing Evolution algorithm. This research starts from deployment of nodes in communication area and calculate number of clique of all node present in deployment area of nodes in WSN. After this apply RSSI (Received Signal Strength Indication) for formation of cluster. RSSI facilitate the development of ranging and positioning technologies in wireless sensor networks (WSN). So, it becomes more and more important to find a mathematical model which can accurately describe the relationship between the RSSI values and distance. This should be able to adjust parameters according to the change of environment itself and it also able to reduce error farthest. Further Evolution algorithm for apply to activate cluster head shows as an optimization technique which is to improve the performance of cluster head election procedure. In particular, GAs is defined as search a algorithm which helps to use the mechanics of natural selection and Evolutions such as reproduction, gene crossover and the mutation as their problem-solving method which result as the results are not guaranteed to come up with a generation that has a best fitness value hut by the performing different Evolution operations. So, the probabilities of achieving the desired results are increased. Proposed work will simulate in MATLAB with all parameter considering the GA. Result come out in graph at the end of simulation which shows a comparative result of CBCR and LEACH.

Keywords: WS, Clustering, LEACH, CBCR, Clique, Evolution Algorithm

I. INTRODUCTION

1.1 Introduction to WSN

Most of the wireless sensor network contains sensor nodes, each node is connected to base station with limited power supply and it constrained the computational and transmission capability for various applications. Although the limited transmission and computational ability are high density of sensor nodes, forwarding of data packets takes place in multi-hop data transmission. Therefore they routing in wireless sensor networks it has been an important area of research in the past few years. The sensor nodes can use with non-rechargeable batteries, so along with efficient routing network should be energy efficient with utilization of resources. Hence this is an important research concern. An advance in wireless techniques and evolution of low cost sensor nodes is led to introduction of low power at wireless sensor networks. Due to multiple functions and ease of deployment of sensor nodes it can be use in various applications such as target tracking, environment monitoring , health care, forest fire detection, inventory control, energy management, surveillance and reconnaissance, and so on. The main responsibility of the sensor nodes in a network is to forward the collected information from the source to the sink for further operations, but the resource limitations, un reliable links between the sensor nodes in combination with the various application demands of different applications make it a difficult task to design an efficient routing algorithm in wireless sensor networks. In Designing of suitable and specific algorithms for routing different applications, fulfilling the different performance demands has been considered as a critical issue in WSN. In this context many routing algorithms have been proposed to improve the performance demands of various applications through the network layer of the wireless sensor networks protocol stack, but most of them are based on single routing technique. This technique approach basically source selects a single path which satisfies the performance demands of the application for transmitting the load towards the sink.

1.2 Introduction to Evolution algorithm

The Evolution algorithm (GA) is heuristic search technique that mimics the process of natural evolution. This heuristic are routinely used for generate useful solutions to optimization problems and search engines. Evolution algorithms belong to the evolutionary algorithms (EA) which is the solutions to optimization problems using techniques inspired by natural evolution for generating like inheritance, mutation, selection and crossover. In a Evolution algorithm to a population of strings developed, the candidate solutions (fitness value) to encode optimization problem to better solutions. Traditionally, the solutions are represented in binary operation as strings of 0s and 1s, but other encodings are also possible. The developments will usually starts from population of randomly generated individuals and happen in generations. In each generation, the fitness of individual in population are evaluated and multiple individuals are stochastically selected from the current population which is based on their fitness and other is modified (recombined and possibly randomly mutated) to form a new population. New populations are used in the next iteration of the algorithm.

Usually, the algorithm terminates it when either a maximum number of generations has been produced has reached a sufficient condition for the population. If the algorithms are terminated by a maximum number of generations which is a satisfactory solution may or may not be achieved.
A typical Evolution algorithm steps:
1. A Evolution representation of the solution domain,
2. A fitness function to evaluate the solution domain.
Generally the solutions are represented as from an array of bits. Arrays of other types and structures can be used in essentially the same way. Main property which makes these Evolution representations convenient is that their parts are easily aligned due to their fixed size where facilitates simple crossover operations. Variable length representations can used but in this case of complicated crossover. Tree-like representations are explored in Evolution programming and graphic representations. The fitness function is defined over the Evolution representation and measures of the quality which represented solution. The fitness function is always problem dependent. Once there is Evolution representation and the fitness function can defined. GA is an order (usually random) initialize a population of solutions and then it can improve by repeated application of mutation, crossover, inversion and selection of contractors.

1.3 Introduction to CBCR
This Technique describes some tools that are necessary to derive thesis algorithm. A practical way of tackling the geocast problem would be to build a hierarchical structure above the network in order to simulate a sort of backbone made up of nodes which are more adapted than others. This is precisely the goal of clustering. This methodology has already proven its efficiency earlier. In sensor networks the sensor nodes can be partitioned into clusters by their physical proximity to achieve better efficiency, and each cluster may elect a cluster head to coordinate the nodes tasks in the cluster. Few references say that clustering with at most two hops is said to be node-centric, whereas clustering with over two hops is called cluster-centric.
In node-centric approach, cluster heads are first elected and a procedure indicates how to assign other nodes to different clusters. In Cluster-centric approaches, clusters are first formed, and each cluster then elects its cluster head. Such approaches require that all nodes in one cluster agree on the same membership before electing their cluster head. Now these summarize two clustering schemes that will be helpful to describe the geocast protocol.
1.3.1 Clustering Scheme in Cliques
The formulation uses one of the protocols from to partition network into clusters (cliques). The figure below illustrates the network in which each clique is a single hop sub network. Each clique is a single hop network. Each cluster head knows the partial IDS of its neighbors. Let G be the set of the cluster heads of cliques.
1.3.2 Clustering Procedure in Cliques
The sensors run one of the protocols in to create cliques like clusters. This thesis assume that this phase yields k cliques (clusters), hence the cluster heads named CH clique-I , $1 \leq i \leq k$, for the cluster head of clique i.

1.3.3 Analysis of the Energy Consumption
The energy model will use here are similar to that used by most existing energy-efficient clustering model

$$E = ET + ER = a \times (e_t + e_{amp} \times d^n) + a \times a_r$$

Where, ET and ER are energy consumptions of transmitting and receiving data items respectively. The energy dissipated at operating transmitter radio, transmitter amplifier and receiver radio are expressed by et, eamp and respectively. And d is the distance between of nodes and n is the parameter of the power attenuation with $2 \leq n \leq 4$.
1.3.4 Reducing Power Consumption during Clustering in Cliques
The aim to know how to consume less energy falls into the category of energy-efficient clustering algorithm in which the cluster head is located in the central area of the cluster. Here, since each cluster is a clique, each sensor is at one hop to the cluster head. These contribute less energy for transmission to and from the cluster head, comparatively to multi hop clustering.
1.4 Routing Challenges and Design issues in WSN
The main design goals of Wireless sensor network is carry out data communication while trying to prolong the lifetime in network and prevent connectivity degradation. Some of the challenges and design issues in WSNs are as given below.
Node deployment: Node deployment is application dependent in WSN
Energy consumption without losing accuracy: Sensor nodes can use supply of their limited energy performance when computations and transmitting information in a wireless environment. The malfunctioning of few sensor nodes due to power failure can cause significant topological changes and also require resending of packets and reorganization of the network.
Data Reporting Model: Data sensing and reporting in WSNs are dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as time-driven, query-driven, event-driven and hybrid.
Node/Link Heterogeneity: All sensor nodes present in wireless infrastructure were assumed to be homogeneous, i.e., having equal capacity in terms of computation and power etc. However, depending on the application a sensor node can have different role or capability. The existence of heterogeneous are set of sensors raises in technical issues.
Fault Tolerance: Some sensor nodes will may fail or blocked due to lack of power, physical damage, environmental condition like topological and energy constraints. The failure of sensor nodes should not affect the overall task of the sensor network.
Scalability: Sensor nodes were deployed in the sensing area may be in the order of hundreds or thousands, or more. WSN must be able to function with this large number of sensor nodes and more enough to respond to events in the environment. Until any specific event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.
Network Dynamics: Most of network architectures were assumed that sensor nodes are stationary. However, mobility

of both BS's and sensor nodes are sometimes necessary in many applications in addition to energy.

Transmission Media: In a multi-hop typed sensor network, nodes are linked by a wireless medium. The older problems associated with a wireless channel may also affect the operation of the sensor network. In general, the required bandwidth of sensor data will be reduces.

Connectivity problems: High node density in sensor network is precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected. Connectivity depends on the, possibly random, distribution of nodes.

Coverage: In WSNs, each sensor node contains few specific area and coverage region. A given sensor's view of the environment is limited both in range and in accuracy; it may only cover a limited physical area of the environment. Hence, coverage covered is also an important design parameter in WSNs.

Quality of Service: For some applications, data should be delivered within a certain period of time from the moment it is sensed otherwise the data can be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications.

II. RELATED WORK

In [2] concept of distributed topology control algorithm to conserve energy is introduced. In this paper localized distributed Topology control algorithm is presented. It calculates optimal transmission power to active network connectivity. It reduces node transmission power to cover nearest neighbor. A node uses only the locally available information to determine nodes. Majority of work has been done on fault tolerant topology control algorithm to minimize the total power consumption. It provides k-vertex connectivity between two vertices. Michaela Cardei et al [7] propose new architecture to achieve minimum energy consumption by using k-approximation, centralized greedy, distributed and localized algorithm. It provides reliable data gathering infrastructure from sensors to super node. Andrew Ka-Ho Leung and Yu Kwong Kwok [15] have proposed a new localized Application driven Topology Control Protocol. This scheme is designed for a wireless P2P file sharing network. Their proposed scheme is based on enhancing the lifetime and effectiveness of file sharing among peers. Authors tried to achieve an efficient connectivity among mobile devices in order to better serve the file sharing application. Their designed protocol consists of two component 1) Adjancy set construction (ASC) 2) Community base Asynchronous wakeup (CAW). Waltenegu Dargie et al (2010) proposed topology Control protocol [1]. The developed protocol enables nodes to exhaust their energy fairly. This paper proposes algorithm based on eligibility and efficiency of nodes. In this paper, authors presented a shortest path and energy-efficient topology control algorithm[4].The algorithm tries to preserve shortest path connecting itself to nearby nodes and the minimum-energy paths. Research work carried out by [16] authors examines the price of ignorance in topology control in cognitive network with power and spectral efficiency objective. They proposed distributed algorithm that, if radio posses global knowledge, minimize both the maximum transmit power and spectral footprint of the network. They showed that while local knowledge has little effect on the maximum transmission power used by the network, it has the significant effect on the spectral performance. They have presented an approach for achieving end to end objective through learning and reasoning. For dynamic networks, as radios join the network, more knowledge provides better spectral performance. When radio leaves the network, some ignorance in the network results into better performance. Yunnai Liu et al [17] presented a paper on "Connectivity based Topology Control." Authors proposed that there are many intermittently connected wireless links called lossy links. Authors proposed CONREAP algorithm by exploring reliability theory. Experimental results showed that CONREAP is more appropriate for low density requirements. Algorithm can improve energy efficiency up to 6 times Antonio-Javier Garcia-Sanchez [18] proposed an integrated WSN based system for crop monitoring, video surveillance and process cultivation control. A node uses only local available information to determine the node that should be its logical neighbor at any given time. They developed locally distributed algorithm in a mobile environment. In this work the problem topology control in a hybrid WMN of heterogeneous wireless devices with varying maximum transmission ranges is considered. Hiroshi Nishiyama et al [20] proposed a dynamic method of effectively employing k-edge connected topology control algorithm in MANETs. This method automatically determines the appropriate value of k for each local graph based on local information. It ensures the required connectivity ratio of the whole network. The results show that dynamic method can enhance the practicality and scalability of existing k-edge connected topology control algorithm while guaranteeing the network connectivity. Azrina Abd Aziz et al [8] focused on energy efficiency issues and presented study of topology control techniques for extending the lifetime of battery powered WSNs. Authors considered that energy consumption and network lifetime are two commonly used evaluation metrics for measuring the impact of topology control algorithm on energy efficiency. They have identified number of open research issues for achieving energy efficiency through topology control. Topology control has been widely studied. CBTB (Cone based distributed topology control) is among the first algorithm that adjusts the transmission power to save energy consumption. In this algorithm it is ensured that in every cone of degree α around u can reach with power Up.

III. PROCESS AND TECHNIQUE

3.1 Initializing Cluster

Cluster based approaches in appropriate monitoring applications that can require a continuous stream of sensor data. Routing protocols are applied to lower cost of delivering a data packet on time. For instance, they study the LEACH protocol, where the hierarchical and self-organized cluster-based approach. The area under the monitoring are randomly subdivided into several clusters where CHs collect data from the associated member nodes in their clusters which based on Time Division Multiple Access (TDMA) are scheduling. Then, redundant data is removed, and the outcome is transmitted to the Base Station or sink as a data packet. After a predetermined period of time, CHs are selected through a BS message.

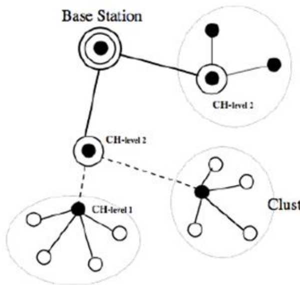

Figure 1: A sample of cluster based WSN.

Figure 1 shows the sample of WSN with a series in red circles surrounded by gray circles. The red circles represent a sensor and the surrounding green circle is the sensor detection range. There are several clusters that transmit aggregated data to the BS just through the CHs were surrounded by gray circles. In this paper it optimizes the network lifetime and energy consumption is in WSN and finally propose a new clustering protocol by using Evolution algorithm.

3.2 Initialization of GA to WSN

The Evolution algorithm can starts with an elementary population comprised of random chromosomes which includes genes with number of only 0 s or 1 s. Afterward, the algorithm leads individuals to achieve an optimum solution in the way of repetitive processes which includes the crossover and selection operators. There are two new way for development technique for population steady-state and generational Evolution algorithm. In earlier case, one or two members in the population are replaced and at the same time, the generational Evolution algorithm replaces all the generated individuals of a generation.

3.3 Apply Fitness Function

Under the Evolution algorithm, the fitness function is a process for scoring each chromosome based on their qualification. The assigned score will trait for continuation of further reproduction. Dependence to problem by fitness function which is considerable. So, that in case of some problems, it is not possible to define the problem. Naturally, individually they are permitted to go in new generation based on their fitness score. Therefore, the score dictates the fate of individuals.

3.4 Selection process

During every successive generation, there is new generation which is developed through adopting members of the current generation on the basis of their fitness. The individuals with higher fitness score have higher chance for being selected which process the results in preferential adoption of the best solution. Majority of the functions include a stochastically designed in element for adopting the small number of fit individuals for sake of keeping diversity in the population. Among the many selection methods the Roulette-Wheel were adopted differentiate proper individuals with the probability where the "i" and "n" are the fitness of chromosome and size of population respectively. According to the Roulette-Wheel, each individual is assigned a value between 0 and 1.

3.5 Crossover process

Crossover or reproduction process can constitute the major step of production. Indeed, sexual reproduction by which inherited the characteristics which are transferred from one generation to the next generation is simulated. In the reproduction process or crossover process which adopts a couple of individuals as the parents through breeding selection process. The process continues till the reach the desired size in the new population. Several crossover operations take place, each of which with different aims and direction. The easiest way is single point, where a random point is adopted to divide the role of the patents.

3.6 Fitness Parameters

The fitness of chromosome that determines the extent to where the consumption of energy are minimized and coverage are maximized. In what follows, there are some important fitness parameters in WSN are discussed.

3.7 Simulation Parameters

PARAMETER	VALUE
NETWORK SIZE	[100 100];
NUMBER OF SENSOR NODES	100
SENSOR NODE DEPLOYMENT	Uniform Random
PERCENTAGE OF CLUSTER HEAD	5
data_packet_size	=128
energy_th	10e-3
Eelec	=50e-9
Efs	=10e-12
Eda	=5e-9
MOBILITY MODEL	RANDOM WAY POINT MODEL
DATA_PACKET_SIZE	=128
broadcast_packet_size	=24
Transimission_range	=20
zoom	=10
COMMUNICATION RADIUS	d0=87.71

IV. GENERAL SETUP OF WSN NODES AND MODE

4.1 Direct distance to base station (DDBS): it refers to the sum of direct distance between all sensor nodes and the BS represented by di as

$$\text{DDBS} = \sum_{i=1}^{m} d_i,$$

Where, "m" stands for the number of nodes. Clearly, consumption of energy is reasonably subjected to the number of nodes and for large WSN the energy is extreme. Moreover, DDBS is acceptable for smaller networks where number of close nodes is not considerable.

$$\text{CD} = \left(\sum_{i=1}^{n} \left(\sum_{j=1}^{m} d_{ij} \right) + D_{is} \right),$$

Where "m" and "n" stand for the number of clusters and related members, respectively; "d ij" represents the distance between node and CH and "D is" stand for distance between the CH and the BS. The solution suits a networks with a large number of spaced nodes. Higher cluster distance leads to higher energy consumption. For minimization of energy consumption, the CD must not be too large. The density of the clusters is controlled by adopting this measurement, while density is the count of nodes in each cluster.

4.2 Cluster-based distance-standard CDSD: instead of an average cluster distance, standard derivation measures the changes of distances of the cluster. CDSD is a function of the placement of sensor nodes (random or deterministic). There are clusters with different sizes in random placement so that a SD within a specified variation in the cluster distance is acceptable. If so, the differences in cluster distance is not zero, while the variation must be adopted based on the deployment of information. At any rate, under deterministic placement with uniform distribution of node positions, cluster distance change must be minimized. Generally, changes of uniform cluster-based distances show that the network is poor, which is not the case when the nodes are placed randomly:

$$\mu = \frac{\sum_{i=1}^{n} d_c}{n},$$

$$\mathrm{SD} = \sqrt{\sum_{i=1}^{n} (\mu - d_c)^2},$$

Where, "ejm" stands for the required energy to transfer data from a node to the corresponding CH. Thus, the first term in the summation of "i" stands for the total consumption of energy for transfer of aggregated data to CHs. Moreover, the second term in the summation "i" pictures the total required energy to collect data from members, and finally, "ei" stands for the required energy for transmission from the cluster head to the BS.

4.3 Number of transmissions (T): In general, the BS dictates the number of transmissions that occurs at every monitoring period. This measure is obtained based on the conditions and the energy level of the network; therefore, "T" stands for a long time stage for which the superior optimum solution for maximizing and an inferior solution for minimization are acceptable. The quality of the best solution or chromosome determines the performance of previous GA-based solutions.

In what follows, using Evolution algorithm, a fitness function formula to improve each main operational aspects of WSNs (e.g., node placement, network coverage, clustering, and data aggregation) is introduced and discussed. In other words, fitness functions are mainly used to improve energy consumption and lifetime parameters. Simulation results confirmed improvement of the protocols.

4.4 Node Placement in Wireless Sensor Network

The placement of sensor nodes on a monitored field may influence the general performance of the network. Taking into account the placement of nodes in the field, there are three main categories of placement of nodes in a network including the deterministic node placement (grid), the semi-deterministic node placement (e.g., Biased Random), and the nondeterministic (stochastic) node placement (e.g., Simple Diffusion and Random). Long range transmission by sensor nodes is not energy efficient as it needs more energy than a linear function of transmission distance does. Clearly, node density is just one element in network topology as the placement of the node is another key factor. The placement of nodes influences the capacity of a network to correctly sense an event as well as the number of possible disjoint paths towards the sink(s). Under the deterministic node placement, the nodes are placed on exact, preset points on a grid or in specific parts of the grid. Commonly, deterministic or controlled node placement dictates the type of nodes, the environment that nodes will be placed, and the application. Thus, in Sensor Indoor Surveillance Systems or Building Monitoring application nodes must be placed manually.

V. RESULTS AND DISCUSSIONS

This research will shows after applying the Evolution algorithm, less energy dissipation in network appears after increasing number of rounds. Proposed work uses Evolution algorithm to improve the network lifetime (dead node) and energy dissipation value of the wireless sensor networks by finding the optimum number of cluster heads and their locations based on minimizing the energy consumption of the sensor nodes. MATLAB simulation results showed that the proposed work is less energy dissipation, less number of dead nodes.

REFERENCES

[1] Waltenegus Dargiea, Rami Mochaourabb, AlexanderSchill a and LinGuanc. 2010. A topology control protocol based on eligibility and efficiency metrics. The Journal of Systems and Software.

[2] F. O. Aron, T. O. Olwal, A. Kurien and M. O. Odhiambo. 2008. A Distributed Topology Control Algorithm to Conserve Energy in Heterogeneous Wireless Mesh Networks. World Academy of Science, Engineering and Technology. p. 40.

[3] Antonio-Javier Garcia-Sanchez, Felipe GarciaSanchez and Joan Garcia-Haro. 2011. Wireless sensor network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops. Computers and Electronics in Agriculture. 75: 288-303.

[4] Santi P. 2005. Topology control in wireless ad hoc and sensor networks. ACM Com- put. Surv. 37(2): 164-194.

[5] Zheng Yao and Guohuan Lou. 2010. Research and Development Precision irrigation control system in agricultural. International Conference on Computer and Communication Technologies in Agriculture Engineering.

[6] Raimo Nikkilä, Ilkka Seilonen and Kari Koskinen. 2010. Software architecture for farm management information systems in precision agriculture. Journal of Computers and Electronics in Agriculture. 70: 328- 336.

[7] Mihaela Cardei, Shuhui Yang and Jie Wu. 2008. Algorithms for Fault-Tolerant Topology in Heterogeneous Wireless Sensor Networks. IEEE Transactions on Parallel and Distributed Systems. 19(4).
[8] Azrina Abd Aziz, Y. Ahmet S¸ekercio˘glu, Paul Fitzpatrick and Milosh Ivanovich. A Survey on Distributed Topology Control Techniques for Extending the Lifetime of Battery Powered Wireless Sensor Networks. IEEE Communications Surveys and Tutorials, Accepted For Publication.
[9] Rami Mochaourab and Waltenegus Dargie. A Fair and Energy-Efficient Topology Control Protocol for Wireless Sensor Networks. Technical Report: MISTTR-2005-012.
[10] Bara'a A. Attea and Enan A. Khalil. 2011. A new evolutionary based routing protocol for clustered heterogeneous wireless sensor networks. journal of Applied Soft Computing. 432-441, (2011).
[11] Feng Wang, Yingshu Li, Xiuzhen Cheng and DingZhu Du. 2008. Fault-Tolerant Topology Control for All-to-One and One-to-All Communication in Wireless Networks. IEEE Transactions on Mobile Computing. 7(3).
[12] R. S. Komali, R. W. Thomas, L. A. DaSilva and A. B. MacKenzie. 2010. The Price of Ignorance: Distributed Topology Control in Cognitive Networks. IEEE Transactions on Wireless Communications. 9(4).
[13] Waltenegus Dargiea, RamiMochaourabb, AlexanderSchill a, LinGuanc. 2010. A topology control protocol based on eligibility and efficiency metrics. The Journal of Systems and Software.
[14] Andrew Ka-Ho Leung and Yu-Kwong Kwok. 2008. IEEE On Localized Application-Driven Topology Control for Energy-Efficient Wireless Peer-to-Peer File Sharing. IEEE Transactions On Mobile Computing. 7(1).
[15] R. S. Komali, R. W. Thomas, L. A. DaSilva and A. B. MacKenzie. 2010. The Price of Ignorance: Distributed Topology Control in Cognitive Networks. IEEE Transactions on Wireless Communications. 9(4).
[16] Yunhuai Liu, Qian Zhang and Lionel M. Ni. 2010. Opportunity Based Topology Control in wireless sensor network. IEEE Transactions on Parallel and Distributed Systems. 21(3).
[17] Antonio-Javier Garcia-Sanchez, Felipe GarciaSanchez and Joan Garcia-Haro. 2011. Wireless sensor network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops. Computers and Electronics in Agriculture. 75: 288-303.
[18] Tapiwa M. Chiwewe and Gerhard P. Hancke. 2012. A Distributed Topology Control Technique for Low Interference and Energy Efficiency in Wireless Sensor Networks. IEEE Transactions On Industrial Informatics. 8(1).
[19] [19]Hiroki Nishiyama, Thuan Ngo, Nirwan Ansari, Nei Kato. 2012. On Minimizing the Impact of Mobility on Topology Control in Mobile Ad Hoc Networks. IEEE Transactions On Wireless Communications. 11(3).
[20] Soledad Escolar Díaz, Jesús Carretero Pérez, Alejandro Calderón Mateos. 2011. A novel methodology for the monitoring of the agricultural production process based on wireless sensor networks. Journal of Computers and Electronics in Agriculture. 76: 252-265.

