ENERGY EFFICIENT ROUTING IN WIRELESS SENSOR NETWORK

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Abstract— Energy conservation has a main priority in all technology and engineering field. Most current applications that consume energy can be customized or optimized in a process resulting less energy consumption. During the rise of wireless sensors field applications, and also, the critical situation of energy consumption, the optimization of energy dispatch becomes a critical and important field of research. Hence, the wireless sensor depends on its internal battery to work its total life time, extending the life time by minimizing the consumption of power is also very important field in current researches. This research aims to optimize the energy consumption of wide scale wireless sensor networks by deploying a novel and adaptive improvement and modification on the traditional clustering of the cells of the network. In this thesis we work on load balancing of each cell in the network, introduce the "Potential" concept which is a measurement of node and cells overall availability and it is related to energy, distance and data transfer, deal with the nodes in between two clusters and finally make all nodes die almost at the same time by using an adaptive system for solving these problems. This research improves the energy conservation with 93% regards to the original LEACH Algorithm.

Keywords**:** *Wireless Sensor Networks, LEACH Protocol.*

I. INTRODUCTION

Wireless Sensor Networks consists of very small sensors that are characterized by limited processing power and energy resources. All sensor nodes have limited power supply, limited memory and have the capabilities of information sensing, data processing and wireless communication. In a WSN, if one node dies, it could lead to a separation of the sensor network [1]. Thus, every sensor node should live as long as possible to maximize the lifetime of the wireless sensor network. Sensor nodes are scattered in a sensor field (figure1) .Each of these scattered nodes has the abilities to aggregate data and route to the base station (sink) and then to the end users. Data are routed to end user by using multihop techniques. It is a matter of coordination between sensor nodes to provide high quality information that supervised physical environment. Wireless sensor network will be widely deployed in the future because they greatly extend our ability to monitor and control the physical environment from remote areas. The area of wireless sensor networks is one of the emerging and fast growing fields in the scientific world .Current trend of research in this area mainly focuses on routing algorithm designed for better performance and prolong the lifetime of network. One of the main constraints in wireless sensor network is limited battery power which plays a great influence on the lifetime and the quality of the network. Several routing protocols have been designed for Wireless Sensor Network to satisfy energy utilization and efficiency requirement. Therefore, efficiency, scalability and lifetime of wireless sensor network can be enhanced using hierarchical routing .The design of routing protocol [2] is dependent on the nature of application requirements. The wireless sensor networks are an emerging field that performs a comprehensive process of sensing and measurements, measurement logging, data transfer and management via a wireless data network. The wireless sensor is a tiny small device that combines all functions in special measurements and computation. A bulk or set of sensors connected though network in mesh form perfuming a networking protocol. The hopping data of the sensors from one sensor to another is a major protocol and technique, the sensors that hopping data from one to each other is so called "NODE". The connection and cooperation of large number of nodes makes a rigid network with high capabilities and specifications [1]. The prospective and ability of any wireless sensor networks to deploy a connectivity of large number of nodes, which represents a very small "tiny" devices, represents the power of that network. This networks type is currently deployed to be used in wide range of applications with a suitable cost with respect to its prospective [2]. The wireless sensor networks major rule is to measure specific field and logging its measurements to a host, and this is the most application that known and directly used. But also, it can be used to control some applications or actuators in that field. It also, reduces the cost of hardware installation and cabling, coming from the fact that, it doesn't need large hardware installation. From the other hand, cancellation of large hardware installations and cabling, reduces significantly the cost of maintenance, neither emergency maintenance nor proactive maintenance. Over that, the outdoor installations,

especially cables, almost are subjected to be stableman. This topology of wireless sensors reduces the probability of stalling the equipment and hardware, because of no use of cables [3]. In addition to low installation cost, cheap devices, smaller sensing transducers, longer lasting, it is also, adaptive and can be reconfigured to work in different areas. For example, in a big farm, the same network that measure temperature, pressure, and humidity, also, can be configured to measure the wind speed, also, few configurations can enable that network to sense existence of specific materials in atmosphere. The single device of wireless sensor networks costs less than $1 in most applications [3]. The wireless sensor nodes also, don't require communicating directly with the nearest control tower which is high power or even don't require directly communicating to the base station. But it communicates with the nodes local peers only. Thus, this connection will be a pear-to-pear connection making a mesh network. The mesh architecture implies a flexible networking of hopping branches. And the system is very adaptive for node failure substitution and compensation [4]. Each sensor node in the wireless sensors networking can perform communication over a range of 50 meters. Thus, to communicate between sensors and transfer the data, no repeaters are needed and no huge number of sensors is required. Figure 1.1 shows an example of wireless sensor networks applied to a farm. It has a big important in agriculture fields, and such fields are active area for researchers and developers. It's clear that, large number of nodes are distributed throughout the field and connected together. That is establishing what so called "Routing Topology" or "Network Topology". The mount of sensors can be extended from tenth or hundreds to thousands in some cases [5].

A. Leach Protocol and Energy Optimization

The wireless sensor consumes energy from a battery depends on. The battery is internal structured in the sensors node, and has a specific power consumption period. Whoever, this period depends on the nature of the sensor and the running conditions. The running conditions represents the environmental conditions, data transfer packet, the sequence of transfer, measurement issues, etc. [3].

Figure 1.1: sample wireless sensor networks topology

Hence, the wireless sensor depends on its internal battery; the sensors node life time is limited to battery energy and energy consumption scheme, what so called Power Dispatch or Power Consumption Flow. The computational limitations and also, storage limitations are main bounds of the wireless sensor networks and such systems. Unlike the cell phones or PDA's, the power of the wireless sensor cannot be recharge during its running life. So, the sensor is almost being replaced after its battery died [6]. The communication of wireless sensors via a network is needs specified network to control, and manage the communication, data transfer, and also, measurement logging. Hence, such networks have wide range of applications, that makes developing universal or single protocol is difficult. Such network topology should provide a complete or enough support of application-specific protocols, that is proving the demands of the sensors and network, specially, power consumption and life time [7]. This thesis, concerns on energy optimization protocol for a large scale wireless sensors network. This protocol enables to cluster and distribute sensor nodes in optimal topology and communication specs in order to get maximum energy conservation and better communication management scheme [8].

B. Problem Statement and Motivation

The wireless sensor depends on its battery to run along its life time, thus, the life time depends on the consumption of the power. This is related to many variables, including the distance between the sensor and the head of cluster, the transfer packet size, the energy slope of that sensor which is related to its physical measuring structure, and other effects. In the wireless sensors network, once the first sensors battery consumed, the sensor is considered to be died. Not all sensors in the wireless network are being died in the same moment. So, once the first one died, the network and/or the cell will be unbalanced. In this case, if the network continues to running – collecting data, logging, and transferring the data to base station – the overall data will have a shortage. The dead sensor(s) couldn't send any data, so, the data is missing. Whereas, if the network stopped and replacement process is manipulated, this will comprise replacing batteries that not been died yet. Replacing non-empty batteries is the enemy of battery and energy saving. It causes to lose an interested amount of energy, that – if could to save – can save a non-negligible amount of energy, maintenance cost and time, wasted running time, chemical material, and sensors / battery cost. The maintenance cost is an issue in any engineered system, so, it is important to make the period between each replacement of the sensors to be longest. During the replacement time, the wireless network will be malfunctioned, and cannot collect data or transfer, thus, all measurements will be disabled in this time. The chemical materials that are the building components of the batteries and sensors are in most cases dangerous to the environment and human. From these points, it's important to minimize the use of those

materials. The energy optimization, of course, minimized the use of that material by minimizing the amount of batteries and other materials that used in wireless sensor networks over the time. Also, the cost of sensors, power and batteries represent a big problem for all users and manufacturers [1]. From that, the problem of energy optimization in wireless sensor networks is important case for the modern researchers, and taken into place for all manufacturers and developers of such systems. Whereas, the main issue of this problem - from computer systems and information technology side – is the clustering of the wireless sensors network. By developing a good new adaptive clustering algorithm of the network, it can be save energy by 93% or more in large scale wireless sensors network related to the original LEACH Protocol.

II. RELATED WORKS

A. Sensor Nodes

Sensors nodes are typically built of few sensors and a mote unit as. A Sensor is a device which senses the information and passes it on to mote. Sensors are typically used to measure the changes in physical environmental parameters like temperature, pressure, humidity, sound, vibration and changes in the health parameter of person e.g. blood pressure and heartbeat. MEMS based sensor has found good use in sensor nodes. A mote consists of processor, memory, battery, A/D converter for connecting to a sensor and a radio transceiver for forming an ad hoc network. A mote and sensor together form a Sensor Node. Sensors nodes are typically built of few sensors and a mote unit as. A Sensor is a device which senses the information and passes it on to mote. Sensors are typically used to measure the changes in physical environmental parameters like temperature, pressure, humidity, sound, vibration and changes in the health parameter of person e.g. blood pressure and heartbeat. MEMS based sensor has found good use in sensor nodes. A mote consists of processor, memory, battery, A/D converter for connecting to a sensor and a radio transceiver for forming an ad hoc network. A mote and sensor together form a Sensor Node.

B. Base Station

A base station links the sensor network to another network. It consists of a processor, radio board, antenna and USB interface board. It is preprogrammed with low-power mesh networking software for communication with wireless sensor nodes. Deployment of the base station in a wireless sensor network is very important as all the sensor nodes handover their data to the base station for processing and decision making. Energy conservation, coverage of sensor nodes and reliability issues are taken care of during deployment of base station in sensor network. Generally base stations are assumed static in nature but in some scenarios they are assumed to be mobile to collect the data from sensor nodes.

C. Energy-efficient Routing Algorithms

Energy efficient routing algorithm can be categorized as follows: data centric routing algorithm, location based routing algorithm and hierarchical routing algorithm. Data centric routing algorithm uses Meta data to find the route from source to destination before any actual data transmission to eliminate redundant data transmission Location based routing algorithm requires actual location information for every sensor node. Hierarchical routing algorithm divides the network into clusters. Cluster head (CH) is elected in each cluster. CH collects data from its members, aggregates the data and sends to sink. This approach is energy efficient but relatively complex than other approaches [9].

D. LEACH

LEACH is acronym regards “Low Energy Adaptive Clustering Hierarchy”. The hierarchal clustering was introduced by Heinzelman. It clusters all nodes of the network into clusters (cells) where each cell has center called “head of cluster”. In such protocol, each node transmit its information to the head of cluster, and it collects the data from all cluster’s nodes, then, it compress and format the data before sending it to the base mobile station [2]. The cluster’s head consumes more power than other sensors, because of the load on it. The load is subjected to collecting data from all nodes, formatting data, sending and receiving data from base station. This needs to make the CH to have max power or energy than other sensor nodes. The LEACH, uses random selection of the head of cluster, so, it may not be the maximum energy node. The LEACH protocol rotates the node that is selected as head of cluster when its energy becomes low after a threshold value. Heinzelman simulation results show that the nodes that can be considered the head of cluster is not exceed than 5% of the total wireless sensor networks nodes. Where the LEACH, uses a specified MAC protocol in order to minimize inter or intra cluster collision, such as DMAC. Also, this algorithm supposed the head of cluster to be centralized or semi-centralized node in the cluster. Figure 2.1 shows a sample hierarchically clustered network [17].

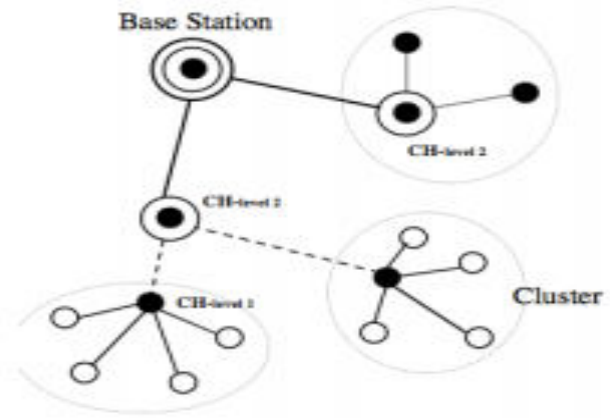

Figure 2.1: Sample Hierarchically Clustered Wireless Network

The operation of LEACH consists of two stages; step stage and steady running phase. In the first stage, the networks are being clustered and select the cluster-head (CH) for each cluster. In the next stage, the sensing and measurement data transfer is being done. The data is transferred to the base station. The first stage is the configuration phase, while the steady running is the normal run phase.

In the setup / configuration stage, a predefined nodes part is being chosen as cluster heads. This is done according to a threshold value where this value deepens on the percentage that enables the node to be head of a cluster.

The node requests to become a cluster head by chosen a value between 0 and 1. The cluster head may be changed in rounds. Each new head of cluster will notify all cluster nodes to deal with it as head. The acknowledge message will be submitted from the non-head of cluster nodes. The LEACH protocol attack is very difficult in comparison with the conventional protocols of multi-hope networks.

The conventional protocols of multi-hop imply all nodes to be surrounding to the base station, so, this is attractive to compromise. But, in the LEACH protocol, the heads of clusters are communicates directly with the base station while the other nodes are not.

The head of cluster can be located anywhere in network irrespective of the mobile base station. Also, the heads of clusters (CH) can be changed randomly. This makes head cluster to be difficult to be spotted. Hence, the wireless sensor networks based on a negligible memory sensors and low computational power, thus, the security of the network is a key management of improving the networks.

LEACH protocol assumptions may cause a lot of real-time system's problems. The main assumptions are :

- If needed, all nodes can transmit to the base station with enough power.
- Each node can supports different MAC protocols, so it should have enough computational power.
- The nodes always have data that is waiting to be sent.
- The nodes that are located close to each other have data correlation.
- Since the first node dies, the system becomes unbalanced.

In each selection round, the rest of nodes have the same energy capacity amount, assuming that being a head of cluster will drain the same energy value that is for each node approximately.

III. METHODOLOGY

A. Proposed System

While Figure 3.1 illustrates the original LEACH algorithm flow. It is summarized as following; the process starts by data collection from the network. Then traditional clustering is applied at startup which means that the cluster head is going to be fixed forever. A normal running mode is entered, it consists of only data transfer and this is still running until the network becomes idle, either by nodes death or by the base station commands.

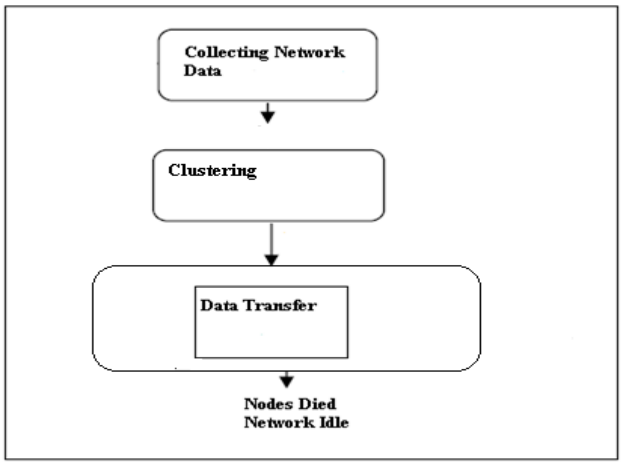

Figure 3.1: Basic Block Diagram of the Traditional LEACH Algorithm

B. Energy

The power consumption of any device can be represented in many ways. Actually, the energy is being measured in "Joules" and has the "J" abbreviation. The power consumption is measured in "Watts" and is abbreviated as "W". Watt is the energy consumed in one time unit. Usually, the system's power is represented by the manipulated variables – not direct variable – like voltage and current. The voltage is not changes depending on the load, the manipulated variable of batteries become the current and time. Batteries in general are being rated as "Amp-hour" or "mAH" regards to milliamp hour. Milliamphour means by theory that, i.e. if the battery is being rated as 50mAH, if the load consumes 50mAmp, then, the battery can run this load for one hour. If the load consumes 20mAH, then, the battery can be operated on this load for 2.5 hours. But from practical view, this is not completely true, due to the chemical structure of the battery. In wireless sensors network, the battery is fixed and wouldn't be replaced until the sensor is replaced. The sensors are designated for a long time operation of its internal battery. The life time of battery may extend to 5 or more years. This thesis aims to optimize the energy consumption of the wireless sensors nodes by optimizing the protocol of LEACH introducing a new terms and algorithms of nodes clustering in order to make the network to be adapted to the work conditions.

C. Clustering

Nodes classification in clusters (cells) is the core of the LEACH protocol. In general, grouping a set of points (nodes) into cells or clusters is interested methodology in modern applications and researches, especially, in networking and scalability of the networks. The grouping a bulk of nodes into clusters is highly dependent on the deployment specifications, system's architecture, scheme of bootstrapping, cluster characteristics, etc. The center of the cluster is commonly known as Head of Cluster "CH". The head of cluster is one of the cluster's nodes. The

number of nodes in one cluster is almost differs from it in the other clusters. Where the head of cluster can form in some systems a second tier of the network and thus, another hieratical level can be formed, or it may be just the data to another point. The clustering in theory has many advantages in addition to the network scalability support. Also, it minimized the routing table's size that stored at individual nodes, and allows to safe the bandwidth of the communication because it limits the cluster interactions scope to the head of clusters, the redundancy avoiding would result and change among nodes is being enabled. Figure 3.2 shows a sample of bulk data clustering in the left, and that is being clustered in the right side. The Figure shows two dimensional distributed nodes, then, it classified into four clusters. Each cluster is colored with unique color. Different methodologies are being used in data clustering, some of them are numerical or analytical, and the most intelligent methodology is the fuzzy clustering method. The most common, efficient, and reliable fuzzy clustering method is the Fuzzy C-Mean "FCM" algorithm. In wireless sensors network, the clustering process isolates the nodes of changes at the tier of inter-cluster heads level, thus, reducing the maintenance topology overhead. Optimized techniques can be implemented by the head of cluster in order to enhance the operation of the network and extends the battery life of the nodes.

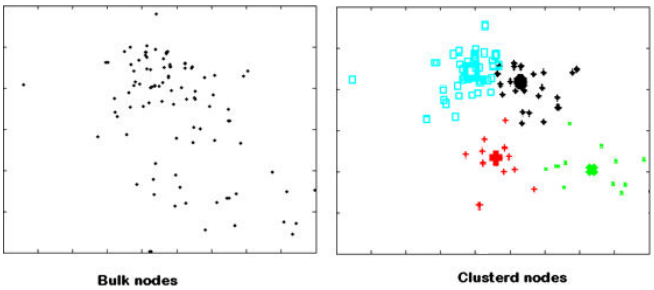

Figure 3.2: Sample of data clustering

So, the heads of clusters schedules the overall activity of the clusters, thus, the nodes switch the sleep modes at the most of the time. That reduces the consumption of energy. To minimize or even cancelation the redundancy of the data in the clusters, the use of data aggregation or similar techniques is being taken a place. In addition, the clustering increases the connectivity of nodes to the head of cluster and center all cluster nodes on the cluster head. This reduces the delay of measurement transfer and communicating to the base station. It comprises the maximum network longevity.

IV. RESULTS AND DISCUSSION

A. Performance Evaluation

This Thesis developed MATLAB program to experiment and simulate LEACH algorithm and getting the results. In such, two assumed areas are used for testing the protocol. The wireless sensor networks are distributed in the two scope areas individually and both are tested, and the parameters measured individually. The "round" concept represents a complete transmission process over running of the wireless sensors network. The first scope is 100 by 100 m, where the second is 80 by 80 m. Initial conditions and test conditions are illustrated. The test will consider almost on the energy optimization measurements with respect to a LEACH protocols. The assumed parameters that have been implemented in simulation for testing purpose. Those parameters are selected in order to make the comparison between the LEACH protocol and the other LEACH protocols more meaningful. Thus, the new modifications, improvements, and optimization – especially in energy – are clearer in the Figures. 4.3 The testing of LEACH is done in two topological scenes; the first is over 100 by 100 meters, while the other comprises 80 by 80 meters.

B. Experimental Result

The cycle across the total running time of the network of 100X120 m results are displayed in Figure 4.1, From the Figure, it's clear that, the nodes using the Leach algorithm are running for more number of cycles than the others and the death of the nodes is very balanced in the contributed Leach algorithm. While in comparison to other schemes, there is a larger interval. Again, that cause to save more power and energy by prolong the nodes running time.

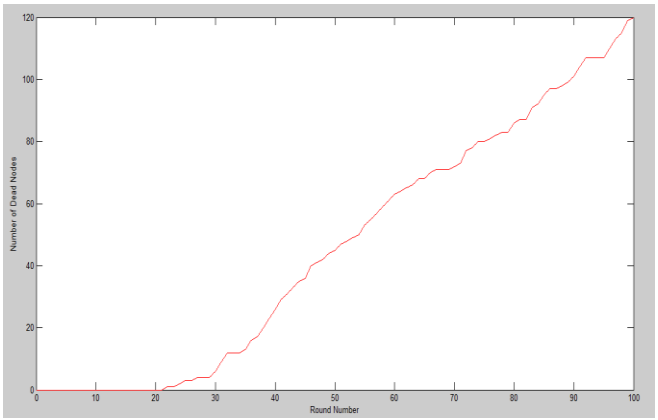

Figure 4.1: Nodes Death over 100 x 120 round in different protocols.

Whereas Figure 4.2 displays the nodes death scheme for an area of 80 by 80m. It can be shown that Leach algorithm has two benefits: The system is running for more number of rounds than using other protocols and the time death interval between the first and last node is the shorter than others. So Leach system can minimize the death nodes interval, reduce the power consumption, save more energy and prolong the lifetime of the nodes.

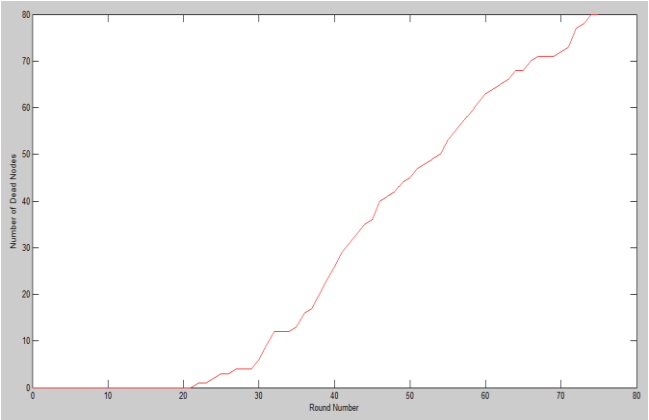

Figure 4.2: Dead Nodes over a round of 80 x 80 in different protocols

The next two Figures show the received packet number in time interval of all LEACH protocols in addition to the Leach protocol tested in 80x80m WSN space, and 80x80m WSN space respectively. The next two Figures show the direct relation between the power consumption with the number of cycles for an area of 100 by 100m and 100 by 100 m respectively. The power consumptions (energy drain) of different LEACH protocols are compared to the contributed LEACH protocol in the next two figures. Figure 4.3 represents a 100 by 80m space WSN space. In the same conditions, this figure shows the amount of energy consumptions over a time, the total sensor's energy value is adopted to keep the network running in long period of time. So, the capacity of the battery is enough to run the sensor in normal operation using LEACH algorithm rather than old methodology as in old protocol. The energy optimization efficiency that is achieved using the LEACH algorithm of variable clustering of the wireless sensor networks comparison with the different algorithms that is used.

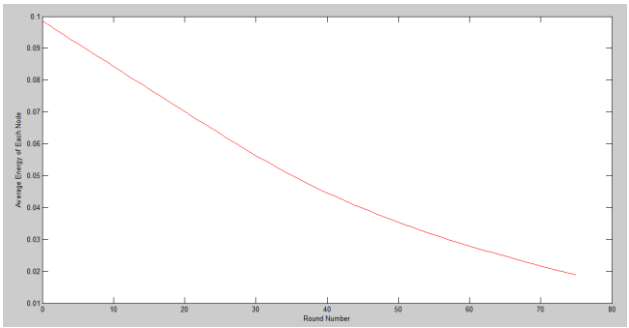

Figure4.3: Energy Consumption over round of 100 x 80 in different protocols

V. CONCLUSION

This research concerns to implement a new methodology for wireless sensors adaptive clustering in order to optimize energy and power consumption in the network. Many researches in past and current information systems world are concerning in the energy optimization. The optimization of wireless network energy researches either concerns on hardware modification and optimization or either software management. The past researches on clustering of wireless sensor networks got a result of saving an interesting amount of energy and sensor's life. This research added a value of saving more energy and power, and building adaptive algorithm. This algorithm as shown in chapter four, was been tested on different scopes of wireless sensors networks in different conditions.

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