AN ENERGY-EFFICIENT CLUSTERING BASED COMMUNICATION PROTOCOL WITH DIVIDING THE OVERALL NETWORK AREA FOR WIRELESS SENSOR NETWORKS

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AN ENERGY-EFFICIENT CLUSTERING BASED COMMUNICATION PROTOCOL WITH DIVIDING THE OVERALL NETWORK AREA FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

AN ENERGY-EFFICIENT CLUSTERING BASED COMMUNICATION PROTOCOL WITH DIVIDING THE OVERALL NETWORK AREA FOR WIRELESS SENSOR NETWORKS

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In this thesis, the energy efficient and connectivity problem in wireless sensor networks (WSNs) is presented. There are more difference between energy levels of near nodes and far nodes of cluster heads. This problem compensated by dividing the entire network (sensor field) into equal area and applies different clustering policies to each section. The results compared with results of LEACH (Low Energy Adaptive Clustering Hierarchy). The performance of proposal system overcomed the previous studies. Also this protocol guaranted transmitting data and transmission in high traffic networks to reduce energy consumption and packet failure.

Keywords: Wireless Sensor Network, Efficient Energy, Clustering Protocol, Dividing Area.

ÖZ

KABLOSUZ ALGILAYICI AĞ ALANININ BÖLÜTLENMESİ YOLUYLA KÜMELEME TABANLI ENERGİ VERİMLİ BİR İLETİŞİM PROTOKOLÜ

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Bu tezde, kablosuz algılayıcı ağların enerji verimli ve bağlantı sorunu incelenmektedir. Küme başlarının yakın düğümleri ve uzak düğümleri arasında enerji düzeyleri açısından büyük farklar bulunmaktadır. Tüm ağ alanını eşit alana bölerek bu sorun telafi edilecek ve her bölüm için farklı kümelenme politikaları uygulanmaktadır. Sonra DEUKH (Düşük Enerji Uyarlamalı Kümeleme Hiyerarşi) ile protokol performansının karşılaştırması yapılmıştır. Önerilen sistemin performansının önceki çalışmalardan daha iyi olduğu gözlemlenmiştir. Gerçekleştirilen protokolde yoğun trafik olan ağlarda veri iletiminde enerji tüketim miktarının ve paket kaybının indirgenmesi garantilenmektedir.

Anahtar Kelimeler: Kablosuz Algılayıcı Ağ, Enerji Verimi, Kümeleme Protokolü, Bölünme Alanı.

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TABLE OF CONTENTS

LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLES

LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
AODV	Ad-Hoc On Demand Distance Vector
CH	Cluster Head node
MN	Member Node
LEACH	Low Energy Adaptive Clustering Hierarchy
MANET	Mobile Ad-Hoc Network
DSR	Dynamic Source Routing
MER	Minimum Energy Routing
HEED	Hybrid Energy Efficient Distributed
ACE	Algorithm for Cluster Establishment
TDMA	Time Division Multiple Access
SHC	Simple Hierarchical Clustering
HHC	Hierarchical Hop-ahead Clustering
AODV	Ad hoc On-Demand Distance Vector
GTS	Guaranteed Time Slots
CFP	Contention Free Period
DWEHC	Distributed Weighted Energy-Efficient Hierarchical Clustering
CFL	Clustering For Localization
IWCA	Improved Weighted Clustering Algorithm
MACA	Multiple Access with Collision Abstinece
RTS	Request To Send
CTS	Clear to Send
BS	Base Station
MTE	Minimum Transmission Energy
GC	General Clustering
DCA	Distributed Clustering in Ad-hoc

WCA	Weighted Clustering Algorithm
EDGA	Efficient Data Gathering Algorithm
PRNET	Packet Radio Networks
COTE	Clustering Algorithm with Optimal Tires to Achieve Energy-Efficiency
HPEQ	Hierarchical Periodic, Event-Driven and Query-based
PEQ	Periodic, Event-Driven and Query-based
TTL	Time To Live
FFD	Full Function Device
RFD	Reduced Function Device
PAN	Personal Area Network
UAVs	Unmanned Aerial Vehicles
CSMA-CA	Carrier Sense Multiple Access with Collision Avoidance
CAP	Contentions Access Period
EEHC	Energy Efficient Hierarchical Clustering
QoS	Quality of Service
WCA-L	Weighted Clustering Algorithm Using Local

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless sensor networks are the networks containing intelligent sensors which have different properties such as sensing, processing or communicating. Due to this reason sensors are usually equipped with data processing and communication capabilities. The sensing circuit is used to measure the parameters in the environment and transform these measures to electrical signal. Each sensor has an onboard radio that can be used to send the collected data to interested parties [1, 2]. There are different applications based on wireless sensor networks related with the abilities of these sensors. These wireless sensor networks are mainly used for monitoring, data gathering and communicating. Due to the difference between these applications sensors in different networks may require different properties.

Wireless sensor networks are widely used and preferred for environmental monitoring, military applications, health care, industrial monitoring, etc. Wireless sensor networks consist of different kind of interoperable nodes distributed in an area and those nodes employ wireless communication. By using flexible communication and routing schemes it may also be possible to add/remove nodes into/from the network while it is operating. For example, in order to recover from node failures affecting monitoring quality/coverage, new nodes can be deployed on to the sensing region and after a negotiation phase, new nodes can start to contribute sensing process. This capability adds flexibility to enlarge sensing area and also it contributes to the extending network life time.

In case of monitoring, the sensor nodes usually need to collect and send the data of some predefined parameters. Since they need to communicate with each other or an administrator these sensors need the ability of communication and data gathering. For example in a habitat monitoring application, user needs to monitor some parameters such as temperature and humidity. Since this network probably will contain large number of sensors data gathering will become a bottleneck for the application. There are different approaches for the problem of data gathering mainly based on data aggregation.

The wireless sensors in the networks can have different properties according to the applications as given above. Most of the applications based on sensor networks require communication between nodes and in order to provide communication these sensors usually have a radio transmitter. Moreover communication between any nodes require energy consumption, therefore the energy of a single node in the network becomes so limited.

Recently energy consumption in wireless sensor networks has become a hot research area, there are different algorithms based on different approaches for the optimization of energy consumption.

In addition to the problem of energy consumption one major problem of wireless sensor networks is the difficulty of monitoring these networks. There are different researchs in literature for the monitoring of sensor networks. The structure of these protocols differs with their different aims; discover failed nodes [3], compute the coverage [4], determine the remaining energy level [5] or topological mapping of the network [6]. The authors in [7] provides a monitoring tool which continuously aggregates and computes different properties of the networks such as loss rates, energy levels or packet loss.

Wireless sensor networks are the networks that contain many sensors which have different type of abilities such as sensing, communicating or processing. In recent years there are many applications based on these kind of networks. Since most of the applications in wireless sensor networks require energy consumption, the energy level of any single node becomes important. There are different methods in literature which provides efficient energy consumption for wireless sensor networks. Wireless network clustering is one of the major methods which has been used in many applications for energy optimization. As there are many nodes in the networks it is aimed to provide an adaptive energy consumption with clustering methods. LEACH is one of the most popular algorithm for clustering which is based on random clustering method. In this algorithm there are two different type of nodes as cluster heads and cluster members. Communication is provided via these cluster heads. Therefore LEACH algorithm reaches its main purpose by providing dynamic clustering and adaptive energy consumption.

In wireless sensor networks, each sensor node mainly consists of a radio transceiver, a micro controller and an energy source generally a battery unit. Nodes usually have limited battery energy and the lifetime of the network is closely associated with the energy consumption rates of the nodes. Nodes consume most of their energies while sending and receiving messages. There are lots of studies focusing on extending the lifetime of wireless sensor networks. The primary method to extend lifetime is to decrease the number of messages produced/transmitted by each node. In conventional sensor networks, all nodes send their messages to the sink node whenever they detect an event. If they are not within the range of the sink, they depend on other nodes to relay their messages towards the sink node. This causes transmission of too many messages and therefore lifetime of the network decreases. One of the methods to decrease the number of messages exchanged is clustering. In clustering, one of the nodes among a set of sensor nodes is selected as the cluster head. In clustering case, nodes in the cluster do not send messages directly to the sink. They send their messages to the cluster head and cluster heads collect and aggregate received messages into one possibly larger message and send it towards to the sink node. Clustering provides tremendous decrease in total number of messages flowing in the network. There are many approaches proposed for proper clustering in wireless sensor networks. Some of those approaches are:

1. Dedicated cluster heads and cluster members: In this approach nodes are designated as cluster heads or cluster members before the deployment phase. In general, cluster head nodes are equipped with larger batteries compared to cluster members. Clusters are formed during the deployment and usually they are not reconfigured.
2. Dedicated cluster heads: In this approach some nodes are designated as cluster heads before the deployment. Cluster heads form clusters during

normal network operation by selecting cluster members according to application needs.

3. Randomly selected cluster heads: In this approach, each node has a chance to be a cluster head. Nodes are elected as cluster heads according to some sort of algorithms and each node has a chance to be cluster head according to conditions defined in algorithms. LEACH and C-LEACH are examples of algorithms that employ randomly selected cluster heads.
4. Selecting cluster heads using semantic definitions: Cluster heads are selected as semantic definitions carried in query messages. Nodes process messages and applies query in the message to their sensed data. That is, nodes decide becoming cluster head or not according to the definition in the received query message.

Clustering approach offers data aggregation and decreases total messaging needs compared to the flat topologies. Data aggregation is done at cluster head nodes and by means of data aggregation the number of messages transmitted and relayed to sink is considerably decreased. There are different cluster formation techniques, and selection of appropriate clustering technique depends on the purpose of clustering and the requirements of the application. Cluster head nodes can be located and elected before implementation phase and they can be stationary during the network life time, they can be selected randomly, they can be selected in a predefined order or they can be selected as using semantic definitions. Those clustering mechanisms can be classified as; static which provides local topology control, dynamic which results in forming clusters according to changing network parameters. Moreover, clustering mechanisms can also be classified according to communication mode such as single hop and multi hop and node type which are homogeneous and heterogeneous.

There are lots of clustering algorithms proposed in the literature. Beside application specific clustering schemes, the main aim of clustering is to reduce energy consumption of nodes in the network by means of removing unnecessary messaging between the nodes and the sink node. In flat WSN topologies, each node that detects an event immediately sends a message to the sink via one hop or multi hop communication. However, this approach produces a huge number of messages flowing in the network and heavy usage of communication medium results in collisions that further cause waste of network capacity. Moreover, collisions lead to retransmissions and therefore, node's energy is wasted.

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In a clustered network there are usually two kinds of nodes such as cluster heads and cluster members. Once the clusters and cluster heads are determined hierarchical routing can take place. In this routing scheme cluster members only need to communicate with their cluster heads, in some applications they also may need to communicate with the members within same cluster. On the other hand cluster heads need to be in communication both with other cluster heads and the members of their own cluster head, they do not need to know whole topology and this provides data aggregation and decrease in energy consumption. Cluster heads will need to do all other things left such as finding destination address, computing the shortest path and sending the message via the shortest path. In order to design a more efficient network and prolong the networks life time the selection of cluster heads becomes very important.

In multi hop communication mode, nodes send messages to the neighboring nodes that are in the range of their transmitter and intermediate nodes relay messages to their neighbors until message is delivered to the sink node. Since nodes transmit messages in a limited range, this sort of communication results in nodes to efficiently use their energy compared to the one hop communication mode. However, as opposed to one hop communication mode, in multi hop communication mode the same message is transmitted repeatedly by the neighboring nodes towards the sink node, therefore we have to take into account the additional energy spent by intermediate node while relaying messages. Since the energy consumption rate depends on the transmission power and required transmission power grows exponentially with the distance between the nodes, in some cases, this approach is expected to be more energy efficient than the single hop communication mode.

In clustering approaches, cluster head nodes transfer messages of child nodes to the sink node. Cluster head node collects messages that are sent from the child nodes, makes an aggregation operation, prepares an aggregate message and sends it to the sink node.

Cluster head nodes can also send their messages to the sink node through multi hop communication. In that case, cluster head nodes collect the messages of the child nodes in the cluster and apply an aggregation operator on those messages and send the resultant message to the sink via non-cluster head nodes in its sending range.

Semantic clustering is another method to form clusters according to the information carried in the query messages. Cluster formation is triggered by the query message created by the sink node and cluster formation starts when the first node that satisfies the condition in the query message. In this approach the node that assign itself as cluster head starts cluster formation with disseminating cluster formation messages in its range. However, such a cluster head selection method does not consider remaining energies of the nodes and the location of cluster heads during cluster formation.

The authors in [8] have proposed a different kind of clustering structure which aims to organize whole network into smaller clusters a sub clusters. In case of this clustering structure sensor nodes deployed in the wide area, will form many cluster groups for efficient network organization, where each cluster group contains sensor nodes in majority, one cluster head and one node leader. The main role of node leader is to gather and aggregate the sensor data from other sensor nodes in the same cluster group. The cluster head will then forward the aggregated data coming from the node leader, to the base station either directly or through other cluster heads. The authors also provide a fault tolerant clustering algorithm with this structure. In case of any fault in sensors, sensor data will be unreachable to calculate the critical threshold value, for predicting the event in the related application. Even if the sensor node fails, it is possible to give an approximately predicted sensor data from the same region, in the same sensor reading time interval. Thus the sensor information from the failed sensor node can be approximated from the geographically nearest sensor [8].

Recently there are many different approaches for clustering and cluster head selection. Different algorithms give rise to different improvements. Since wireless sensor networks become more and more important everyday clustering techniques seem to be improved in next years.

CHAPTER 2

OVERVIEW OF THE CLUSTERING ALGORITHMS

2.1 What is clustering?

Clustering is an approach to reduce communication between nodes and therefore minimize energy consumption. Researches show that clustering improves total performance of wireless sensor networks, such as communication overhead and network longevity etc.

Clustering hundreds of nodes into many controllable smaller groups may eventually increase the performance of the network. Partitioning a network into many clusters will reduce the amount of traffic and the amount of energy consumed in network [9]. Since energy efficiency is very important for network lifetime, clustering becomes crucial. If a sensor node needs to reduce its energy consumption, it should send its data packets to cluster heads firstly, instead of sending them directly to the sink [10,11].

As stated in [12] sensor nodes could be grouped together based on their energy levels, sensed data types, proximity to each other or many other parameters. There are many efficient proposed ways for selecting cluster heads. However, as a starting point of the selection process, there should be two basic criteria; (1) nodes should have a unique identifier and (2) these identifiers should be uniformly distributed among nodes [13]. Some of the methods used for cluster head selection are; choosing nodes which are closer to the base station, choosing nodes randomly, or choosing the nodes that have highest or lowest parameters than neighbors, in which parameters could be residual energy level, neighbor count, package count, sensed value, unique identifiers etc. However, using simple clustering algorithms is not always efficient. If simple clustering algorithms such as selecting nodes with lowest or highest identifiers are applied, same nodes will be selected as cluster head many times. This results in quick energy drain of these selected nodes. Therefore, selection of cluster heads is also crucial to distribute load evenly among other nodes in order to minimize energy consumption.

[14] Lists some of the reasons for using clustering in wireless networks such as; to perform data aggregation in order to reduce total energy consumption and reduce the total number of packets transmitted, to disseminate queries to members, or to form an effective routing algorithm for the network. Also, clustering can be performed in single-level, which is the mostly used approach, or multi-level clusters can be performed - which is creating clusters inside a cluster.

Data aggregation is collecting data from member nodes, and transmitting the final data in a single packet to sink node. Data aggregation is widely used in clustering approach, because data from member nodes are collected by cluster heads and sent to the sink in a single packet, in order to reduce network traffic. When a sensor node receives two packets from two different source nodes, it can process incoming data packets and calculate the average readings, in order to send the final value as a single data packet. Another choice for a sensor node to aggregate data is to merge two different readings into same packet and sending the final packet to its destination. Both methods will reduce the energy consumption and network data traffic [15].

Data aggregation models are necessary to avoid redundant data packets, which creates too much traffic, and to minimize energy consumption [16]. Besides, controlling all members in the network is easier when they are controlled as a group. In case of a query based approach, data aggregation algorithms work in the opposite direction to disseminate data query to members, in order to change event thresholds they store or in order to collect different data from network. Data propagation techniques are also very effective in controlling energy consumption. There are two ways of sending a packet to the sink node. Firstly, node can decide to send its packet directly to the sink, in a single hop fashion, which requires more energy. Secondly, a node can choose one of its neighbors to relay its packets to the sink, in a multi hop fashion. If the second solution is used, energy consumption will be smaller, because the distance is smaller between two nodes. Energy consumption increases incrementally when the distance between a node and sink is increased [17].

Data collection can be performed in a periodic fashion, where nodes send their sensed data in defined intervals, or event driven fashion, where nodes send their sensed data only when there is a significant event to sense and alert the sink. Centralized approach and distributed approach are the most commonly used approaches to form clusters. Distributed approach is more common in large scale networks, because centralized approaches require knowledge of the network topology and that is time and energy consuming [13].

Distributed approach [13] is more useful for our proposed algorithms, because our proposed algorithms are scalable to large scale networks. Also nodes decide whether they will become a cluster head of a group, or one of the members of a group, based on the information received from its neighbors and on many criteria coded in our proposed algorithms.

Two alternative ways to form clusters and cluster tree is top-down approach [18] and bottom up approach [19]. In top-down approach root selects its neighbors and they become cluster heads, then they form their own clusters. This approach provides more control in forming clusters and cluster tree. However bottom-up approach forms individual clusters and later try to gather them together. This increases the communication overhead between nodes.

2.2. Clustering Algorithms

In 1981, Baker et al. [20] proposed a linked clustering algorithm which is a self-starting and distributed clustering algorithm. Proposed algorithm has two phases, formation of clusters and linking clusters. There are three types of nodes; ordinary nodes, cluster head nodes, and gateway nodes which links two cluster heads, and also construct the backbone of the network. They performed simulations with different network sizes to collect performance results. In each run, according to the steps of the algorithm some nodes become cluster heads, while some remain ordinary nodes. Some cluster heads degraded to ordinary nodes as their coverage area is covered by another cluster head and overlapping occurs. This basic clustering protocol is the simplest step of clustering approach.

In 2000 Heinzelman et al. proposed “an application-specific” low energy consuming clustering scheme (LEACH) [21] [22] with the goal of increasing network lifetime.

In this algorithm, randomly selected nodes acts as “local base-stations” to a group of regular nodes. Main elements of the proposed algorithm can be stated as:

1) Load balancing via randomly selected nodes in each round to minimize energy consumption.

2) Local data processing in order to reduce communication load.

Simulation results showed that LEACH performs better than LEACH-C [22], minimum-energy routing (MTE) [23] and static clustering. Metrics used in the simulation are network lifetime and amount of data transferred. Results show that nodes can communicate longer until first node dies when using LEACH algorithm. Moreover, rotating the cluster head role will reduce the energy consumption when compared to fixed role. In [24], Lindsey et al. proposed an energy efficient communication protocol called PEGASIS.

Authors compared their near-optimal chain based protocol with LEACH protocol proposed in [21] [22]. Authors performed simulations to complete their study, and results showed that 100 to 200 percent improvement achieved as regards network lifetime.

In 2002, Handy et al. [25] extended Heinzelman’s LEACH protocol in [21] [22]. Aim of this extension was to reduce energy consumption of the network. Authors explained their simulation results according to two metrics, “First Node Dies” and “Half Node Dies”. Results showed that 30% and 21% improvements respectively against LEACH, with the proposed modifications.

Basagni in [26] described two approaches for the phases of clustering algorithm. First approach is, Distributed Clustering Algorithm, proposed for the set-up based and assumes that there is no mobility. Second approach is, Distributed Mobility Adaptive Clustering, proposed for set-up/maintenance phase and handles mobility of nodes. In both approaches, cluster head selection is based on a weight given to sensor nodes. The only requirement in the given algorithms is the knowledge of one-hop topology. As a result for the first approach, better cluster head selection is achieved and second approach adds mobility features to previously proposed algorithms.

In 2001, Banarjee et al. [27] proposed a multi hop clustering algorithm for large number of nodes, to maintain and organize these nodes into clusters. Authors listed their desired design goals as; all nodes are part of some cluster and all clusters are connected, all nodes should have similar transmission range, and all clusters should be same size, etc. The algorithm Works by finding a spanning tree, and has two phases, cluster creation and cluster maintenance.

Cluster creation consists of discovering tree and formatting clusters. Cluster maintenance is performed when cluster quality drops below a threshold, when new nodes join, or existing nodes die. Authors simulated their algorithm with 700 to 1100 nodes and presume that no RTS-CTS messages used. Therefore, they overcome package lost or collisions by soft-state timeouts. Results showed that connectivity is adversely proportional to diameter of a cluster. When node connectivity is increased cluster diameter will decrease.

Younis et al. [28] proposed an approach for energy-efficient clustering of nodes. Their approach is based on residual energy and an additional parameter of node, which can be node degree, node id or any other parameter. Their “Hybrid Energy-Efficient Distributed (HEED)” clustering algorithm does not make any assumptions about network. One important aspect of the proposed approach is every node can be both member and cluster head. Authors compared their algorithm with general clustering (GC) protocol (DCA [26] and WCA [29]), which uses only residual energy for cluster head election. Results showed that GC can guarantee that nodes with higher residual energy will become cluster heads, and cluster heads selected by HEED has lower average residual energies than nodes selected by GC. Besides this negative effect, HEED can produce more balanced clusters and cover most of the network. Authors simulated and compared their algorithm with an improved version of LEACH (gen-LEACH) algorithm in [21]. Simulation results showed that HEED uses less energy when clustering nodes than gen-LEACH, but original LEACH uses lesser energy than both with its assumptions. HEED prolongs network lifetime and propose desirable clustering characteristics such as balanced network, and higher non-single-node clusters.

In 2004, Chan et al. [14] proposed a new emergent node clustering algorithm called “Algorithm for Cluster Establishment (ACE)”, which has great efficiency in clustering nodes. Their algorithm does not use any localization information. The proposed algorithm has two main phases; cluster formation and mitigation. For the formation phase, each node can only chose one cluster head but it can follow multiple cluster heads until choosing one of them. Mitigation only occurs when two clusters overlap to minimize overlapping area. After the first iteration, clusters mitigate to non-overlapping spaces. Simulations are performed to compare the performance of ACE algorithm. The Node ID [20] and the Node Degree [30] algorithms are used for comparison. In Node ID algorithm, node with the highest ID among neighbors will become the next cluster head. In Node Degree algorithm, node with the highest degree (one of many parameters changing from algorithm to algorithm, which can be energy levels, neighbor count or distance to sink node etc.) will become the next cluster head. Simulations were performed in highly dense environment with 2500 nodes. Results showed that ACE has the lowest average cluster sizes. Even with some packet loss rate, ACE is still superior to Node ID and Node Degree algorithms. In three rounds ACE forms a highly efficient coverage over the network.

Lin et al. [30] proposed a new self-organizing multihop clustering algorithm based on node ID. Their algorithm uses code division multiple access to prevent collisions and supports mobility and topology changes. The main goal of the proposed algorithm is to cover the entire network. Their basic assumption is that every node has a unique ID and every node knows its neighbors IDs. They used transmitter-based code assignment, which means that every node using same transmitting code within a cluster, to prevent inter-cluster collisions. Added to that, they also implement TDMA schemes to prevent intra-cluster collisions, where each node has a different time slot to transmit. Simulations are performed to compare the performance of the proposed algorithm. Proposed Adaptive Clustering algorithm is compared with PRNET [31], MACA/PR [32] and Cluster TDMA [33] algorithms. Results showed that proposed algorithm has lower packet loss and has more packet transmission rate, but it performs similar to Cluster TDMA algorithm which has a difficult implementation.

Gupta et al. [34] proposed a load balanced clustering algorithm for sensor networks. They aim to distribute node balance among many clusters to minimize heavily loaded clusters. Network consists of sensors and gateway nodes, and they assume that all gateway nodes are within communication range with each other. As a first step, nodes send their packets according to TDMA schedule to prevent collisions.

Proposed algorithm has two phases. In the first phase, gateway nodes discover neighbor nodes, and in the second phase, gateways form clusters based on communication cost of each node. Simulations are performed on collision free and no-packet drop network. Results were compared with shortest distance clustering algorithm.

They showed that clusters are uniformly distributed when using the proposed algorithm. Also, performance of the proposed algorithm remains constant in high density networks. However, average energy consumption is higher than shortest distance algorithm when the number of clusters is small.

2.3. Semantic Clustering

In 2010 Liu et al. [35] proposed an energy efficient data gathering scheme for heterogeneous networks called EDGA, to achieve less energy consumption and therefore, to increase network lifetime. Authors defined their network model with several assumptions as follows: network is densely deployed and nodes do not move, all nodes should be time synchronized, there is only one base station to listen, nodes are not aware of their locations, nodes can change their transmission power, and lastly, all nodes have different starting energies. EDGA algorithm elects cluster heads according to a node's election probabilities, which is calculated by using remaining energy of a node. EDGA elects optimal number of cluster heads to maintain lowest energy consumption. Also, algorithm defines active members without compromising network coverage to reduce communication overhead. Simulation results showed that EDGA outperforms LEACH algorithm, in the meanings of network lifetime and active node counts. Nodes die slowly when deployed under EDGA algorithm.

Nam et al. [36] proposed an adaptive cluster head selection, which re-positions the cluster head node based on its position to its member nodes. This approach aims to use energy efficiently, by reducing energy spent on communication. LEACH-C uses the similar approach by adding GPS to determine positions, but this is not feasible due to high cost and energy consumption. The proposed algorithm works by first collecting distance values of the farthest sensor node and the closest cluster head, and then cluster head subtracts two values and if the results are negative cluster head repositions itself closer to its farthest member, otherwise positions itself closer to its nearest cluster head neighbor. Simulation results performed on 100 nodes showed that the optimal cluster size is 16-25 nodes and is achieved over 50% of the rounds by the proposed algorithm whereas in LEACH algorithm clusters often have less than ten or over thirty nodes. Distance results showed that proposed algorithm shows similar results to LEACH-C and the average distance between two cluster heads is 20.88m.

In 2006, Bouhafs et al. [37] proposed a new clustering scheme based on semantic information of the nodes. The goal of the proposed scheme is to reduce energy consumption and prolong network lifetime. In proposed approach base station starts the clustering scheme by advertising a query. Nodes that satisfy the query will start" cluster formation phase" and nodes which do not satisfy the query will only disseminate it to their neighbors. In this approach, member nodes can have more than one cluster head; in order to build a hyper-tree rather than simple tree and to overcome node failures and coverage problems. Different from LEACH algorithm, in this approach data aggregation is done at each level of the network tree to reduce energy consumption of the cluster head spent on data aggregation. Therefore, network lifetime is longer than when data aggregation is done only by cluster head. Simulation results showed that 95% percent of the total energy consumed when 90% of the nodes are alive in proposed algorithm and 35% of the nodes are alive in LEACH algorithm. Also, LEACH algorithm sends more data messages than the proposed algorithm which consumes more energy.

In 2010, Tan et al. [38] proposed a clustering algorithm with optimal tiers to achieve energy efficiency, named as COTE. Authors first examined the role of tiers in cluster formation and then proposed a multi-tier energy efficient clustering algorithm. In each tier, to elect CHs, candidate CHs broadcasts their energy levels to be elected as CH, and when selected, they manage member nodes in their cluster. Authors proposed an optimal tier calculation based on size of the network and compared simulation results based on this calculation. For 100 nodes, optimal network optimal tier number is 7 and for 800 nodes, optimal network tier number is 3 for the maximum energy consumption. Assumptions in these calculations are; the base station is in the center, there is unlimited data to send, every node can reach its cluster head directly, and sensing environment is contention free. According to the results, proposed algorithm performs slightly better than compared algorithms.

2.4. Query Based Clustering

Bandara et al. [18] proposed a top-down approach clustering algorithm, which does not require location, neighborhood information, time synchronization, or network topology. Authors perform cluster formation based on time to live values, where TTL exceeded a new cluster is formed. First algorithm with TTL=1 is Simple Hierarchical Clustering (SHC) and second algorithm with TTL=3 is Hierarchical Hop-ahead Clustering (HHC). Simulation results showed that in SHC, clusters are less circular and they form too many clusters with different sizes. However, in HHC, clusters are more circular and they form less clusters with high uniform sizes. With appropriate parameters desirable results can be achieved such as more circular clusters, uniform cluster sizes and depths.

Boukerche et al. [39] proposed an optimal energy dissipating and fault tolerant clustering algorithm. Proposed algorithm starts with the setup phase, in which nodes with highest energy will become cluster heads. Also, each cluster head discovers nearest cluster heads and stores the path through its one-hop members. Lastly, free node discovery is performed in setup phase when free nodes broadcast their existence to their neighbors. Energy efficiency is provided by the nearest node tables. Each cluster head stores two of its one-hop members to each neighbor cluster heads to minimize network path. Fault tolerance is provided by also this nearest node tables. If a cluster head needs to transmit a packet for the second time, it uses the alternate closest member to the destination cluster head to minimize the probability of using the same faulty nodes while transmitting. Authors did not perform any simulation or an experiment; therefore, they only provided proof of correctness of the proposed methods by formulas.

Zhang et al. [40] proposed a cluster based query protocol that aims to reduce energy consumption within the sensor network. The proposed algorithm provides solutions to locating sensor, fault tolerant network operations and energy efficient data processing. Authors' uses laser beams to stimulate sensors and their one hop neighbors. They also propose a sensor cluster location algorithm to locate and elect cluster heads. They assume that the nodes are not mobile and they are deployed on open-space area. Their cluster based query protocol aims to minimize energy spent on transmitting data packets, and perform data aggregation on cluster heads. They performed several simulations on NS2 [41] simulator, and they also compared simulation results with analytical results.

In 2004, Popovski et al. [42] proposed a design for clustered network and data aggregation. Proposed design includes random cluster head selection and conflict resolution algorithm. Simulation results showed that proposed algorithm runs faster and requires less messages and time to complete. This reduces the communication overhead and therefore reduces the energy spent. Authors stated that this achievement is accomplished by localized algorithms, which performs data aggregation and cluster formation. Therefore, we can understand that clustering and local data processing is very important and saves more energy.

In 2005, Boukerche et al. [16] proposed a hierarchical cluster based approach (HPEQ) that collects and transmits collected data to sink efficiently from group of nodes. Proposed algorithm selects nodes with more energy as aggregators in order to transmit data to sink. Aggregators advertise their ID to neighbor nodes and form a cluster. After a period of time, another node is selected as aggregator to minimize energy drain of certain nodes. Each aggregator has a time-to-live parameter which allows nodes to know how far they located from their aggregator. Aggregator-to-sink packets are performed in a multi-hop fashion, based on routing tables formed during cluster formation. Simulations are performed by using NS-2 [41] network simulator and HPEQ performance is evaluated with average event delay, average event delivery ratio, and average dissipated energy. Results are compared with Direct Diffusion [43] and PEQ [44] algorithms. Results showed that with a few source nodes HPEQ's performance is similar or worse than PEQ and DD, however when source number is increased, HPEQ outperforms both algorithms in terms of evaluated criteria. Intanagonwiwat et al. [43] proposed a data centric, energy efficient "directed diffusion" approach to collect data from network. Their proposed algorithm works by receiving interests from sink nodes and propagating interested data by using reverse path approach to sink. Intermediate nodes can also aggregate data if required. Key features of the proposed approach are; being data centric, neighbor to neighbor communication, therefore there is no need for routers and implementing reactive routing scheme which is on-demand routing similar to AODV described in [45]. Ns-2 simulator is used to compare direct diffusion with flooding and omniscient multicast. Flooding uses to much energy since it is always in broadcast mode. However since both direct diffusion and omniscient multicast using shortest path approach, direct diffusion also implements in network processing. Therefore, it minimizes its energy usage. As seen from all above proposed algorithms many researchers proposed clustering algorithms with very different approaches to select cluster heads. Some of the approaches are random selection, selection based on weight of various factors, or selection based on parameters like energy, node ID, communication cost, position of a node, or TTL value etc. Moreover, in these algorithms data aggregation can be completed on members, cluster heads, or only in sink node.

CHAPTER 3

WIRELESS SENSOR NETWORKS CHARACTERISTICS

3.1 Introduction

WSNs have some different characteristics compared to other type of wireless networks that affects network performance. These characteristics such as node density make protocols and algorithms unique for WSNs. Node deployment, energy constraints, node capabilities, node density are all specific features of WSNs that affect network design and performance. For instance, the number of sensor nodes in WSNs can be extremely higher than ad hoc networks and nodes are densely deployed. Besides node deaths occur frequently due to battery depletion or a failure and this leads to topology changes.

3.2. Node Deployment and Density

Node deployment can be either deterministic or self-organizing, depending on the application. In deterministic method, nodes are placed on pre-determined locations and data routing is executed over pre-determined paths. On the other hand, in self-organizing WSNs, nodes are scattered randomly over application area to form a network in an ad hoc manner [48]. It's also available to add some extra sensor nodes after the initial deployment in order to recover or support the network [46].

3.2.1. Network Topologies

IEEE 802.15.4 standard supports two types of topologies as shown in Figure 1 In star topology there must be at least one FFD as PAN coordinator to control devices in its respective PAN. The coordinator node is responsible for controlling the PAN and communicating to the other PAN coordinators. In peer-to-peer topology there must be at least one PAN coordinator and nodes have to be in communication ranges of one another to establish a link. This kind of topology is used in mesh networks which have complex topology. In such a network every node acts as a router and supports multi-hop routing.

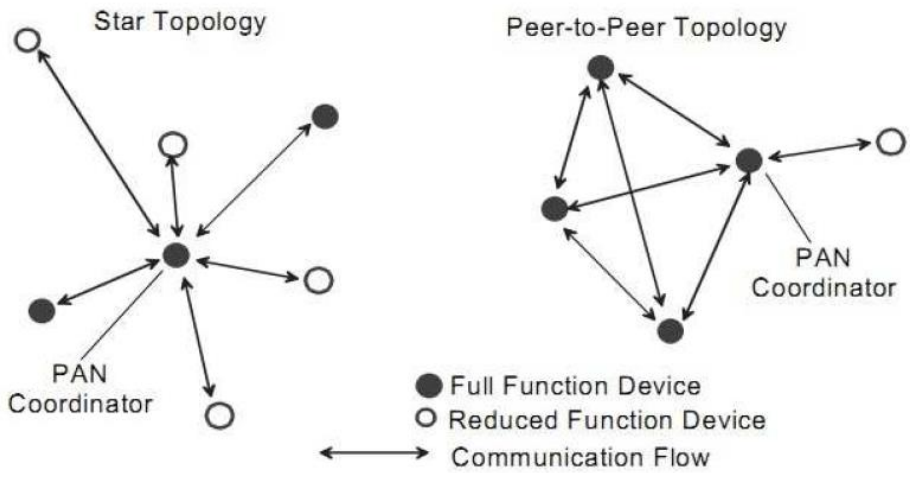

Figure 1 Star and peer-to-peer topologies and devices [47]

3.2.2. Heterogeneous Elements

IEEE 802.15.4 defines two different types of device with different capabilities. FFD nodes have ability to act as PAN coordinator as a router and communicate with other coordinators or a simple devices, on the other hand RFD nodes have very simple task as sensing and communicating with a coordinator as shown in Figure 1.
In addition to mobility, these nodes are embedded on vehicles such as UAVs, buses or robots and do not suffer from energy constraints. Compared to sensor nodes, these mobile nodes have rich system resources.

3.2.3. Power Consumptions

A sensor node is a micro-electronic device with limited battery capacity. For instance a Telos mote which has integrated CC2420 NIC is powered by two AA batteries (2.1 - 3.6V DC) [49]. Network lifetime depends on battery lifetime of the sensor node, because it's impractical to replace batteries of nodes that dispersed over inaccessible application areas. Thus energy-efficient power management is highly critical for sensor networks.

Dynamic power management capability is an important requirement for designing a sensor node. Thus, event-driven power consumption will extend sensor node lifetime. Sensor nodes have different level of power consumptions for their states such as idle, sleep, receive, transmit etc. [50] IEEE 802.15.4 compliant devices have sleep modes and spend most of its time with sleeping, unless they receive or transmit a packet. When we look at the TI CC2420 NIC datasheet, receive and transmit currents are extremely higher than idle current and sleep current (Table 1).

Table 1 Power Consumption of TI CC2420 NIC [60]

State	Value	Unit
Voltage Regulator Off	0.02	μA
Power Down	20	μA
Idle	426	μA
Receive	18.8	mA
Transmit	8.5 – 17.4	mA

3.3. WSNs Application Areas

WSNs have lots of application areas because of diversity of sensing devices used in the applications. These devices have ability to sense thermal, acoustic, infrared, pressure, humidity, temperature, noise etc. phenomenon in the environment.

Every wireless sensor node characteristics depend on the requirements of applications. The categorization of application areas for WSNs is given below;

· Military applications,

· Environmental applications,

· Health applications,

· Smart home applications,

· Industrial applications [51, 52, 46, 53].

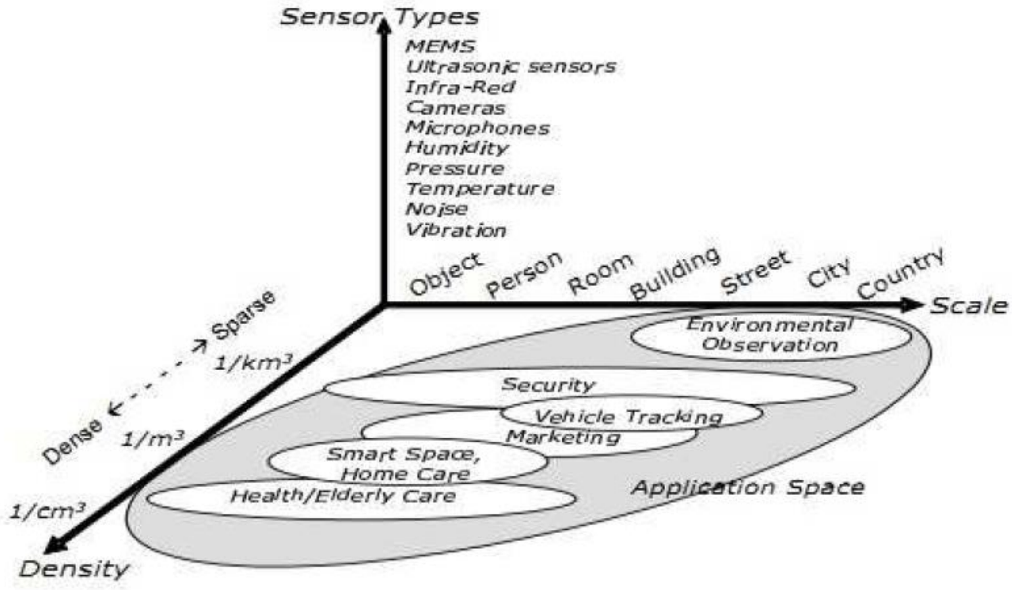

Figure 2 WSNs application spaces [46]

The application space of WSNs presented in Figure 2 [46] shows that node density, network scale and sensor types change in large scale interval depending on the type of application. For instance, in military and agriculture applications, nodes spread over large-scale geographical areas, on the other hand in human health applications nodes are placed on human body. Large-scale application areas sometimes require thousands of sensor nodes, but in some applications such as smart home devices, a few sensor nodes can be sufficient.

3.3.1. Military Applications

WSNs has important part of especially military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting (C4ISRT) systems. Easy of deployment, low-cost and disposable characteristics of sensor nodes make them very important for variety of military applications such as;

· Monitoring friendly forces, equipment and ammunition,

· Reconnaissance of opposing forces and terrain,

· Targeting,

· Battle damage assessment,

· Nuclear, biological, and chemical attack detection and reconnaissance

· Military situation awareness,
· Sensing intruders on bases, detection of enemy units movements on land/sea, and offering logistics in urban warfare,
· Command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems [51, 53]

3.3.2. Environmental Applications

WSNs are also convenient to environmental applications such as monitoring animal movements, flood detection, forest fire detection, air pollution monitoring etc. due to the characteristic of deployment into inaccessible areas. Some environmental applications such as forest fire detection, solar cell equipped sensor nodes are used in order to provide network longevity.

3.3.3. Home Applications

The sensor nodes are used to control home appliances such as refrigerators, microwave ovens, vacuum cleaners, furniture etc. Sensor nodes which are embedded on these appliances have connection to the Internet. Thus end user can control these appliances remotely over Internet connection [51].

3.3.4. Industrial Applications

Monitoring and control of industrial equipment, factory process control and industrial automation, monitoring material fatigue, monitoring product quality are some of the application areas in the industry.

3.3.5. Approaches for WSNs Communications

WSNs' peculiar characteristics require new communication methods apart from the other wireless communication methods. Limited energy source of WSNs require energy-efficient protocols and algorithms at the cost of lower data throughput and higher transmission delay [51]. Especially, energy constraints and high density of the network affect network organization and routing protocols applied to WSNs. Most common method is clustering method in order to reduce energy consumption and obtain scalability on such a dense network. Thus, in this section, we examine routing protocols, communication approaches for WSNs and focus on clustering methods.

3.3.6. Communication Patterns

In WSNs three types of communication is available;

· Member node to CH

· CH to CH

· CH to sink

The first one is called intra-cluster communication. In this type member node sends sensory data to CH or cluster head sends a beacon, query message to its members. The second one is called inter-cluster communication. CHs sends their aggregated data to sink via intermediate CHs with multi-hop communication. In the last type CHs sends aggregated data directly to the sink.

3.3.7. Beaconing

Sensor nodes use beacons in order to maintain neighborhood and maintain routing tables. This beaconing allows nodes to notice whether neighbor node is alive or died, thus network rapidly diagnose and solve the problems about node deaths. IEEE 802.15.4 standard defines super frame structure controlled by the PAN coordinator to synchronize the nodes in the PAN. These super frames are bounded by two beacons sent by the PAN coordinator. Any device in the PAN which wants to send data during the contention access period (CAP) between two beacons competes with other devices using a slotted CSMA-CA mechanism. On the other hand, PAN coordinator may create contention free period (CFP) and allocate intervals for devices in order to provide guaranteed time slots (GTSs) for devices. This CFP is suitable for applications for low latency that requires specific bandwidth.

3.3.8. Data Aggregation Method

WSNs have large number of sensor nodes to form a network, thus there can be a lot of neighbor node in a small area. This leads to sensing same phenomena by many neighbor nodes. Summarization of data in such conditions is a requirement in order to reduce communication load of the network. Data aggregation is performed by coordinators such as cluster heads [46].

There are several kinds of data aggregation method such as clustering-based approach, tree-based approach, centralized approach, In-network aggregation etc [54]. In cluster-based approach, nodes send their sensor data to CH, and then CH aggregates data and sends to remote sink [55, 28, 59]. In centralized approach, each node sends data remote leader node via shortest path with using multi-hop communication, then the leader node aggregates sensor data. In-network aggregation method executes aggregation by intermediate nodes of the multi-hop network for reducing resource consumption. In addition to combine data from different neighbors into a single packet, this method combines data with applying compression. Tree based approach forms an aggregation tree and all leaf nodes send data to parent node, then parent nodes send aggregated data to sink.

3.3.9. Clustering in WSNs

Grouping sensor nodes into clusters has been widely used in WSNs in order to obtain objectives such as scalability, energy efficiency, load balancing and maintaining connectivity etc. Sensor network is separated into groups called clusters and every cluster has a coordinator node called cluster head. In MANETs clustering method is used to generate stable clusters in environments with mobile nodes to maintain node reachability and route stability. On the other hand, clustering methods on WSNs focus on network longevity and coverage as in shown in Figure 3

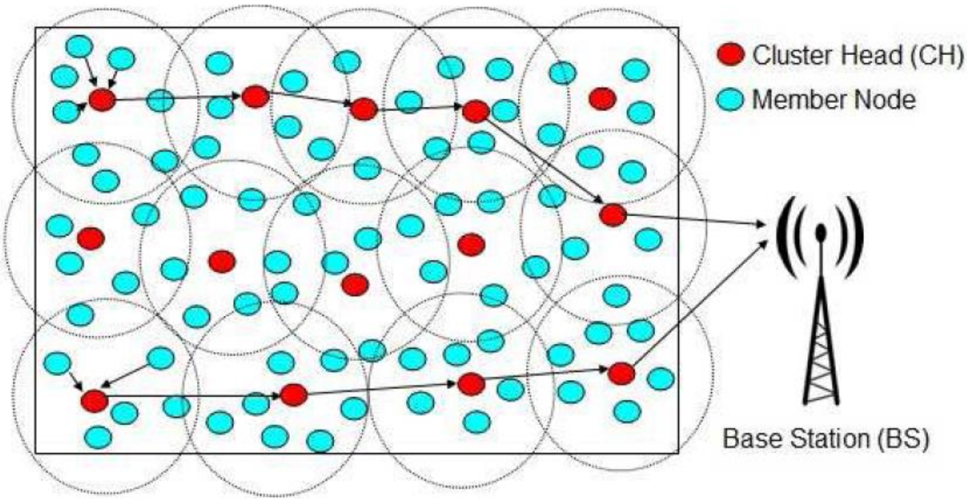

Figure 3 Cluster topology

In a clustered WSN, intra-cluster communication is executed between cluster members and CH either in a single-hop or multi-hop manner. Inter-cluster communication is performed among CHs or CH to sink. As shown in Figure 3 cluster heads have high energy load due to inter-cluster communication. On the other hand member nodes consume low power for intra-cluster. In this part of the thesis we examined and categorized clustering algorithms proposed in the literature for WSNs that have consider energy efficiency**.**

3.3.10. Energy-Efficient Clustering Protocols

Clustering protocols are proposed for different purposes, but main goal of the protocols focus on extending network lifetime. In addition to energy considerations of these algorithms, load balancing, fault tolerance, increasing connectivity and reducing delay and optimization of cluster count are the considerations required by applications. In this section, we explained energy-efficient clustering protocols in the literature.

3.4. Low Energy Adaptive Clustering Hierarchy (LEACH)

In LEACH algorithm [55] nodes select their respective CHs according to the RSSI value from the node that announces itself as CH. Data aggregation and fusion and

TDMA schedule is executed by CH, thus CH nodes consumes relatively much more energy than member nodes. In every round of the clustering process CH role have to be rotated among all nodes in order to obtain load balancing. LEACH algorithm runs in distributed manner, every node decides autonomously to become a CH without any centralized control. Every nodes determines a random value between 0 and 1, and compares this random value with the threshold T(i);

$$T(i) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \left(\frac{1}{p} \right) \right)} & \text{if} \quad i \in G \\ 0 & \text{otherwise} \end{cases} \tag{3.1}$$

where r is the current round number, p is the percentage of cluster head which determined for whole network before and G is the set of sensor nodes which are not become CH in the last 1/p round. If random value is less than threshold T(i) node becomes a cluster head for the current round.

This method is probabilistic and nodes in the network have to be CH without looking their energy level. Thus in the data gathering phase if node dies, whole cluster connectivity is affected until new clustering round would start. In order to obtain load balancing and select node with high energy level as CH, BS computes average energy of the network. The data gathering phase of LEACH-C is identical to that of LEACH. LEACH-C performs better than LEACH on energy consumption but needs node position information and centralized control.

3.5. Energy Efficient Hierarchical Clustering (EEHC)

EEHC [19] algorithm is also distributed, randomized clustering algorithm for WSNs as previous LEACH algorithm. EEHC has two stages. In the initial phase of the algorithm, each node volunteers to become CH with probability p to the neighboring nodes within its communication range. Volunteer CHs announcements of the node are forwarded at the range of k-hops away. After the nodes that are not volunteers receive announcements, they decide to become a member of closest CH. If a node does not receive any announcement it becomes forced CH. All these CHs are first level CHs of the network and they select second level heads in order to obtain multi-tier clustering topology. Data sensed by nodes are transmitted to from lower layer

CHs to upper layer CHs in order. In every layer data aggregation is executed in this method. This algorithm has time complexity of O(n).

3.6. Hybrid Energy-Efficient Distributed Clustering (HEED)

HEED [28] algorithm is also distributed clustering method that aims to select CHs with more residual energy level and communication cost in a hybrid manner. HEED has four main goals; prolonging network life-time by distributing energy consumption, terminating the clustering process within a constant number of iterations/steps, minimizing control overhead and producing well-distributed cluster heads and compact clusters.

HEED algorithm has three phases. In the initialization phase each node sets initial percentage to become a CH. Each sensor sets its probability:

$$CH_{prob} = \max(C_{prob} \times \frac{E_{residual}}{E_{\max}}, P_{\min}) \qquad (3.2)$$

Where Cprop is the desired percentage of CH which is set to 0.05, Eresidual is the current battery level of the node and Emax is the maximum battery level of the node. During the iterations phase, each node determines a random value between 0 and 1, if the node is uncovered by a tentative CH. If this value less than CHprob, sensor node announce itself as tentative CH, then checks neighborhood nodes whether there is tentative CH or not. If there is a tentative CH neighbor, nodes control neighbors node degree or communication cost. If the tentative node has the least cost among tentative CHs, it elects itself as final CH at the end of the iterations.

In every iteration, CH_{prob} is doubled and nodes check their neighbors cost until CH_{prob} is equal to or higher than 1 to compete to be tentative CH. P_{min} value limits the iteration count because in each iteration CH_{prob} value is doubled. Thus minimum iteration number is 6 and the maximum is 12 when P_{min} is set to 0.005.

In the finalization phase if a node is not a final CH, it looks for CH among its neighbors and join as cluster member. If a node has no CH in its communication range, then it becomes a final CH. Extended HEED [28] algorithm which uses HEED algorithm is proposed for the purpose of selecting less CHs than previous method in order to minimize high cost energy consumption of the CHs, reduce routing table size. In this approach, a set of node is selected as core nodes with core extraction algorithm [58] where each node will check if its cost is the least among its neighbors (include itself). If it is the node with the lowest cost, it will set itself as core head; otherwise, it will set the least cost neighbor as core.

Only core heads execute repetition phase of the HEED algorithm, then in the finalization phase non-CH nodes select their final CH. Uncovered nodes do not become directly CH as in HEED, and all uncovered nodes run the core extraction algorithm to elect some extra CHs. Each uncovered node selects a node with the least cost in its neighborhood (including itself) as a CH.

3.7. Weighted Clustering Algorithm Using Local Cluster-heads Election for QoS in MANETs

Weighted Clustering Algorithm Using Local Cluster-heads Election (WCA-L) aims at turning isolated nodes into cluster-heads and forms their clusters by invoking an election immediately at the moment when two cluster-heads are one-hop neighbors. Therefore, as the figures below show, the ordinary nodes attempt to affiliate to another cluster and only the gateway nodes that lie within the transmission ranges of two different cluster-heads are successful. Lastly, the remaining nodes and the cluster-heads keep electing clustering process, which is the same as the one defined in WCA.

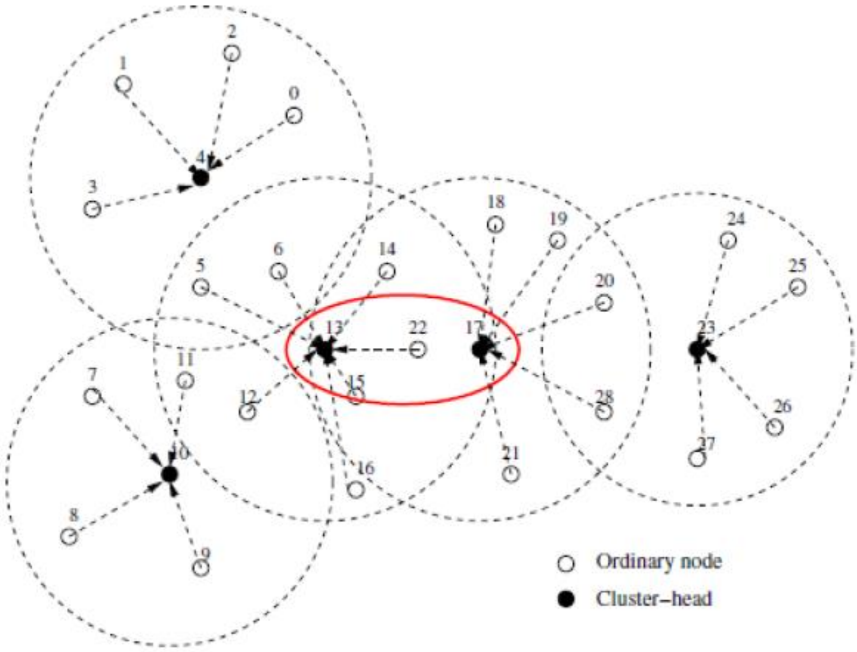

Figure 4 - A

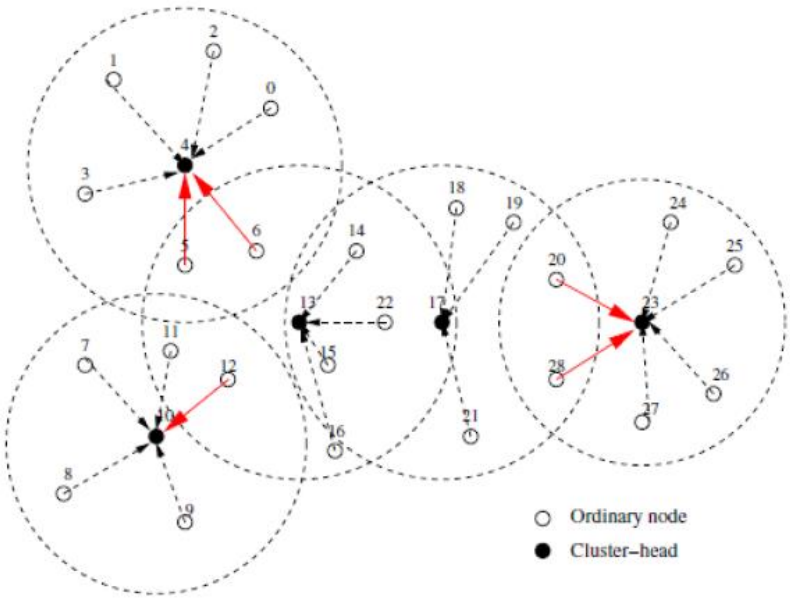

Figure 4 -B

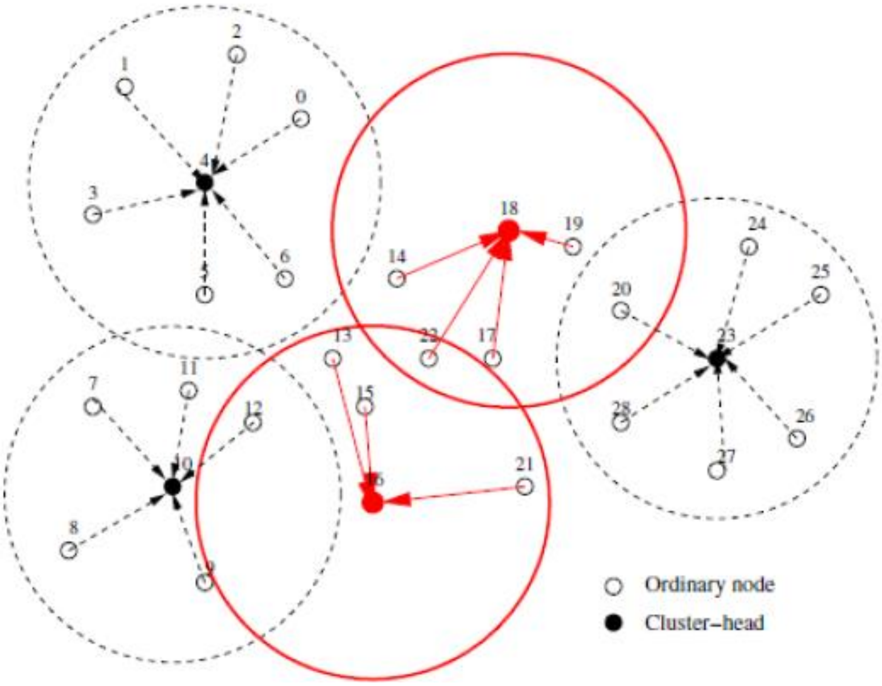

Figure 4 - C

Figure 4 A weighted clustering algorithm using local cluster-heads election for QoS in MANETs

3.8. Weighted Clustering Algorithm for WSN

It is necessary to mention that since MANET and WSN are relatively similar networks, some of the aforementioned weighted clustering algorithms for MANET are applicable to WSN as well. However Table 2 defines the weighted clustering algorithms, which are built specifically for WSN.

Table 2 Weighted Clustering Algorithms for WSN

Published Year	Name	Weighted Algorithms Full Name
2005	DWEHC	Distributed Energy-Efficient Hierarchical Clustering for Wireless Sensor Networks
2008	CFL	A Clustering Algorithm For Localization in Wireless Sensor Networks
2010	IWCA(2)	An Improved Weighted Clustering Algorithm for Determination of Application Nodes in Heterogeneous Sensor Networks

3.9. Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC)

DWEHC algorithm [55] is proposed to obtain more balanced clusters than HEED algorithm and to optimize the intra-cluster topology. Every node in the WSN calculates a weight value;

$$W_{weigth}(s) = (\sum_{u \in Na,c(s)} \frac{(R-d)}{6R}) \times \frac{E_{residual}(s)}{E_{initial}(s)} \tag{3.3}$$

Where R is the cluster range and d is the distance from node s to neighboring node, $E_{residual}$ residual is the residual energy in node s, and $E_{initial}$ initial is the initial energy in node s which is identical for all nodes. The weight is a function of the sensor's energy level and the proximity to the neighbors. Nodes decide to be cluster head if their weight is the largest among the nodes in the communication range. Nodes that have direct link to CH called as first-level member. These first level members are benefited by CH as relay node of multi-level members if multi-hop transmission to CH is more energy efficient than direct transmission. Sensor nodes have to know their own position information in order to calculate transmission costs according to distance. DWEHC generates well-balanced clusters than HEED and also achieves lower energy consumption than HEED.

CHAPTER 4

PROPOSED ALGORITHM

4.1 The proposed clustering hierarchy

Major activities in simulation are performed in the order defined by the main structure. These activities are initialization of objects, interest propagation, cluster formation and cluster maintenance. In the first part, constants of the simulation are declared and initialized. Those constants are round time, round count and node count. Round time is a constant that represents a round time which is used in inter cluster communication. Cluster Head node assigns TDMA schedules to child nodes considering the round time. Round count describes how many counts will occur in query lifetime. A query is processed up to round time x round count total time. After this time period, clusters are destroyed and nodes set their types to normal. In addition to the constants variables, arrays and array lists that will be used in the simulation are declared. Node count constant, time line array list, node list array list, round log array list are declared.

In figure 5 nodes A, B, and C requisite to select the cluster heads that have greater distance from the base station than the nodes themselves. So they send their data to the any habitation and at that point their information travels back a long distance to realize the base station. These sorts of broadcasts dissipation the energy resources of the network. Whereas the nodes D and E send their data in effect tracks, and don't send their data to the exterior place.

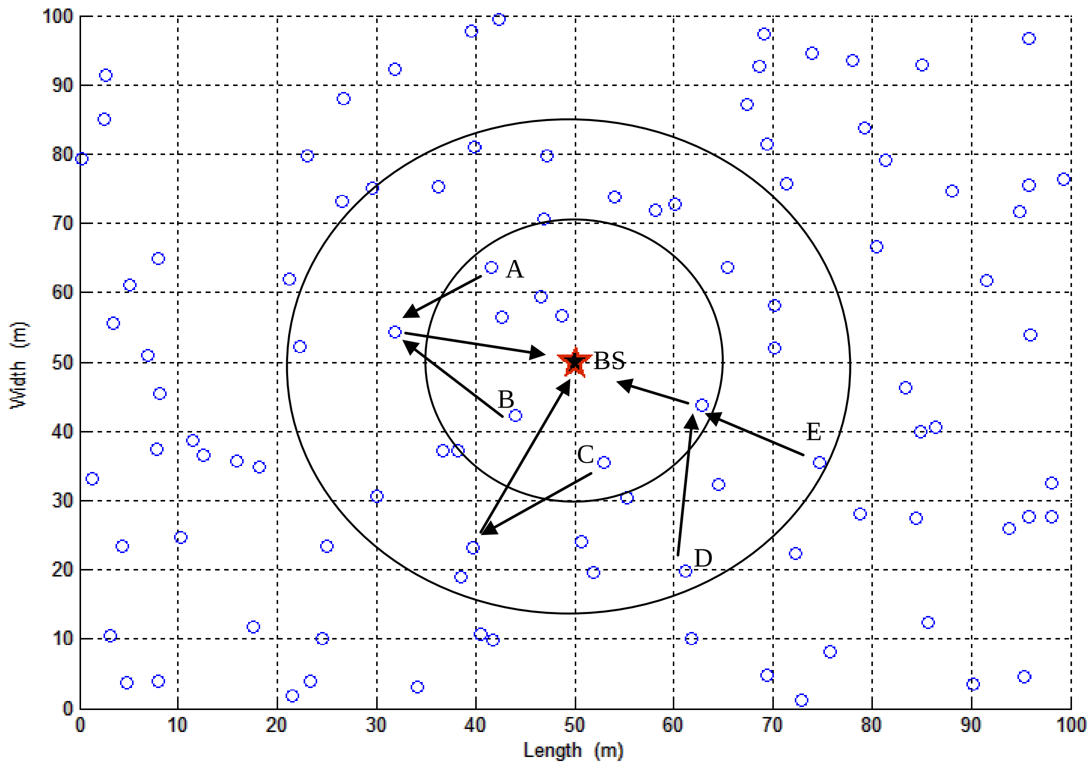

Figure 5 Data transmission in LEACH algorithm

4.2. Selecting new cluster head

Clustering protocols are proposed for different purposes, but main goal of the protocols focus on extending network lifetime. In addition to energy considerations of these algorithms, load balancing, fault tolerance, increasing connectivity and reducing delay and optimization of cluster count are the considerations required by applications.

In the proposed algorithm, new cluster head selection algorithm is developed by considering the locations of the nodes. The node which is closer to the average of X and Y values of the base station in the cluster is assigned as new cluster head.

In the re-clustering phase, all nodes in the simulation are tracked until a node with cluster head type is found. The node is added in a temporary list and child of the cluster head nodes are found. At the end of finding nodes in the cluster, all nodes total X and Y values are calculated. Calculated values are divided by the cluster node count and the average X and Y values are found. Node types of the nodes in the new temporary node list are set as normal type. The node that has the shortest

Euclidean distance to the average X and Y values has been highest probability to choose the cluster head and then select as new cluster head. That node's type is changed to cluster head and its joined node table is deleted. Advertisement message is created and this message is added to a send entry. Entry is added to the time line and the controlling process creates new receive type entries containing the nodes that are in range of the new cluster head.

In the development of the proposed algorithms, the algorithm which was used in LEACH algorithm is taken as the base algorithm. Proposed algorithms make changes in cluster formation phases of the base algorithm. It offers new cluster formation with selecting new cluster head by considering two conditions. Those conditions are selecting the node which has the highest probability value and selecting the node which is closer to the average coordinates of the cluster. The main flow of the simulation is coded in the main method of the simulation. The algorithm consists of main structure, interest propagation, cluster formation, generating schedules and cluster maintenance.

The probability value for each node is choose as below:

$$p_{i,j} = \begin{cases} \dfrac{k_{section_j}}{\dfrac{N}{m} - k_{section_j} \times \left(r \bmod \dfrac{N/m}{k_{section_j}} \right)} & if \quad C_{i,j}(t) = 1 \\ 0 & if \quad C_{i,j}(t) = 0 \end{cases}$$

$$= \begin{cases} \dfrac{p_{section_j}}{1 - p_{section_j} \times \left(r \bmod \dfrac{1}{p_{section_j}} \right)} & if \quad C_{i,j}(t) = 1 \\ 0 & if \quad C_{i,j}(t) = 0 \end{cases} \qquad (4.1)$$

In this equation, the indicator *Ci,j(t)* is one if node *i* in section *j* is qualified to be a cluster head at time t (i.e., it's not been a cluster head within the most up-to-date (r mod (1/ $p_{section_j}$) rounds.) and nil otherwise. If the amount of section is odd, $p_{section_j}$ is calculated as:

$$p_{\text{section}_j} = \begin{cases} p_{LEACH} & \text{if } j = \dfrac{m+1}{2} \\ p_{LEACH} + \left(\dfrac{m+1}{2} - j\right) \times \delta_P & \text{otherwise} \end{cases} \quad (4.2)$$

Where p_{LEACH} represents k_{opt}/N, with k_{opt} be the optimum amount of clusters in LEACH program that should be calculated before and δ_P is the distinction of 2 adjacent section's possibilities. It's easy to indicate that in every round of proposed method the expected amount of cluster heads is that the same as LEACH by noting that the regions of all section are a similar and also the possibilities are spread fairly around p_{LEACH}:

$$E[\#CH] = \sum_{i=1}^{N} p_i(t) \times 1 = \sum_{j=1}^{m} P_{i,j}(t) \times \frac{N}{m}$$

$$= \sum_{j=1}^{m} \left[\left[\frac{N}{m} - k_{\text{section}} \times \left(r \bmod \frac{N/m}{k_{\text{section}\,j}} \right) \right] \times \frac{k_{\text{section}\,j}}{\dfrac{N}{m} - k_{\text{section}} \times \left(r \bmod \dfrac{N/m}{k_{\text{section}\,j}} \right)} \right] \quad (4.3)$$

Therefore, proposed method doesn't have an effect on the quality of information, since each protocols hand over a similar amount of information per unit time. Hence, we are able to justly compare these method with one another. Simulation results check that exploitation a similar amount of energy by the network, proposed method hand over a lot of packets than LEACH. Consequently, proposed method yields a lot of information per unit energy.

In proposed method, exploitation MACA (Multiple Access with Collision abstinence [65]) method at the level of cluster not solely significantly decreases the amount of collisions among information packets however conjointly lowers the on top of point out delays since the nodes that understand the channel busy, understand specifically once the channel are released (via RTS and CTS frames [65]). However in nonpersistent model, the nodes expect a random amount of your time so repeat sensing the channel that leads to longer set-up part (overhead).

4.3. Simulation results

In this section the efficiency of proposed method is evaluated. Figure 6 shows the schematic of our proposed method and random sensors and cluster heads.

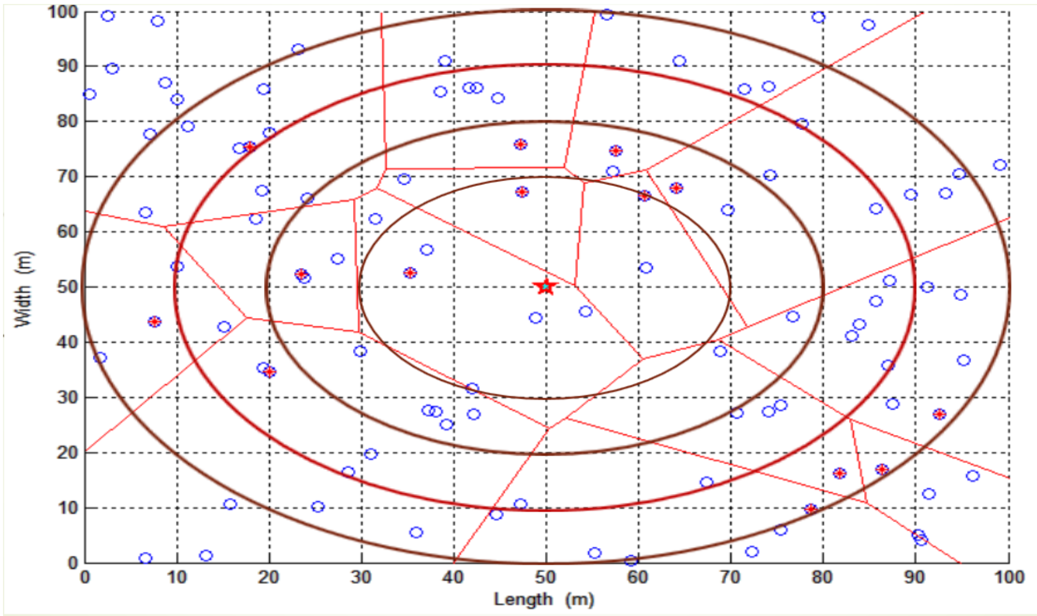

Figure 6 Schematic of our proposed method and random sensors and cluster heads

The simulation parameters exploited in every experience are accessible in table 3.

Table 3 Values of Parameters

Parameter	Value
Base station position	(50, 50)
X	[0 100] ^{m}
Y	[0 100] ^{m}
N (number of nodes)	100
E_0	0.5 J
E_{elec}	5 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
E_{da}	5 pJ/bit
Message Size	4000 Bit

Figure 7 demonstrations the whole of sensors that remain alive over simulation time of 1500 rounds. It is seen that sensors remain alive for a prolonged time in proposed method than LEACH.

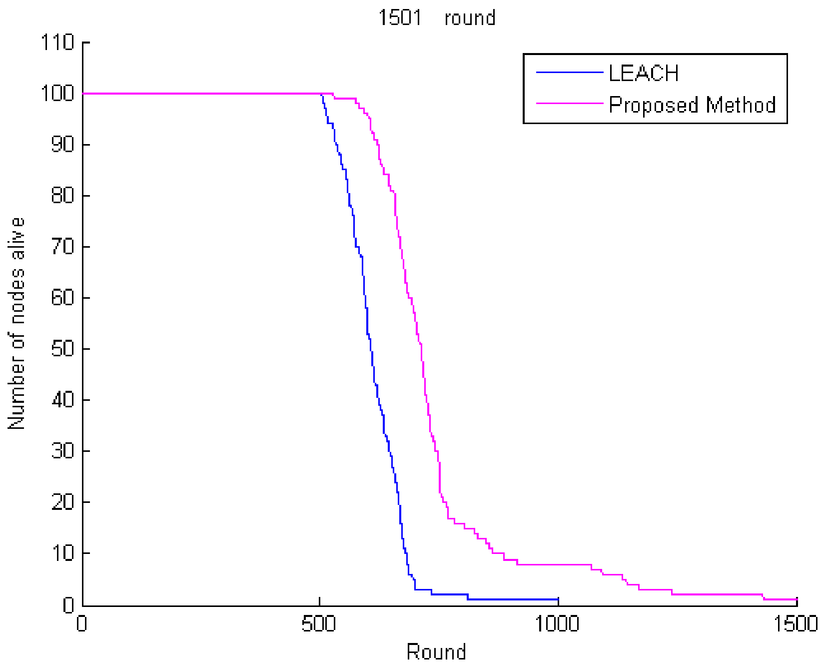

Figure 7 Result of simulation, number of nodes alive vs round

Figure 8 illustrations the whole energy consumption of the network over simulation time.

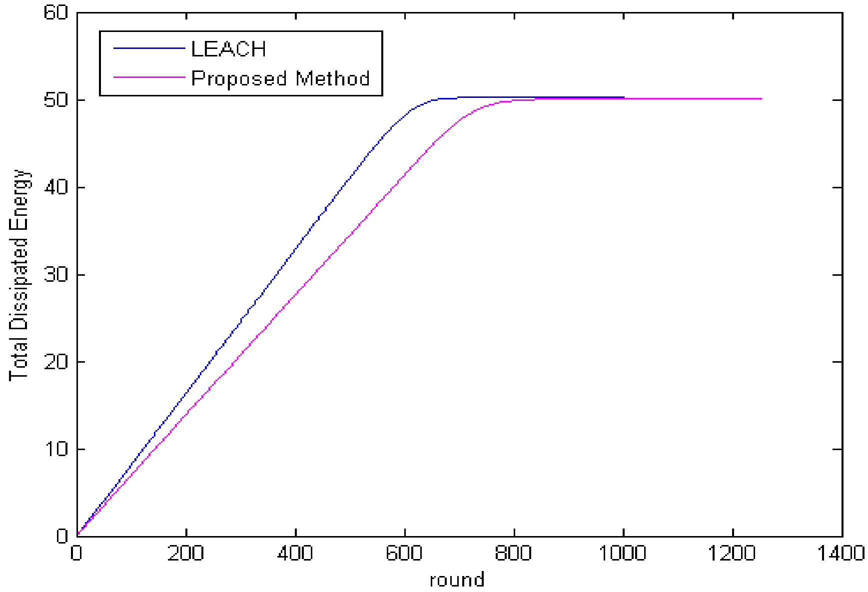

Figure 8 Total dissipated energy in proposed method and LEACH

Figure 9 shows the number of packers received at base station vs round. As this figure the proposed method is very good for sending data for base station as LEACH algorithm.

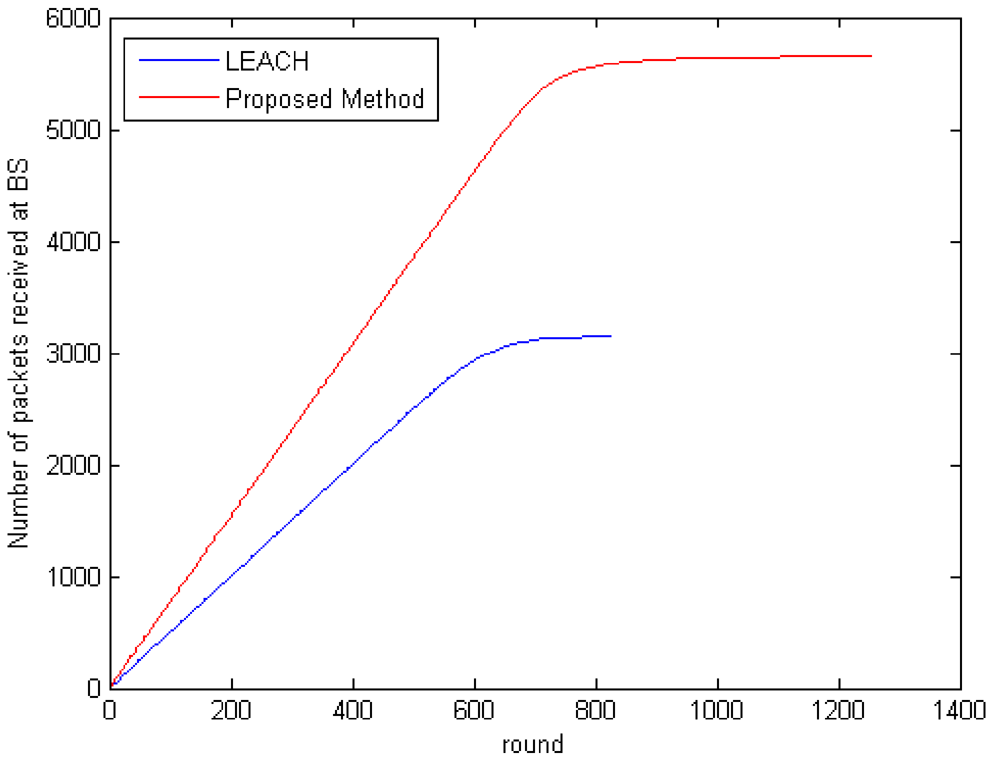

Figure 9 Number of packers received at base station vs round

Here we used some other scenario for our proposed. We changed the probability valuse of each sensor near and far from Base Station.

If the Base station is to be the other where the result is changed because the nearest sensor send directly communication sending data for BS, at now they have to send far a way. The result of scenario is illustrated in figure 10, 11 and 12.

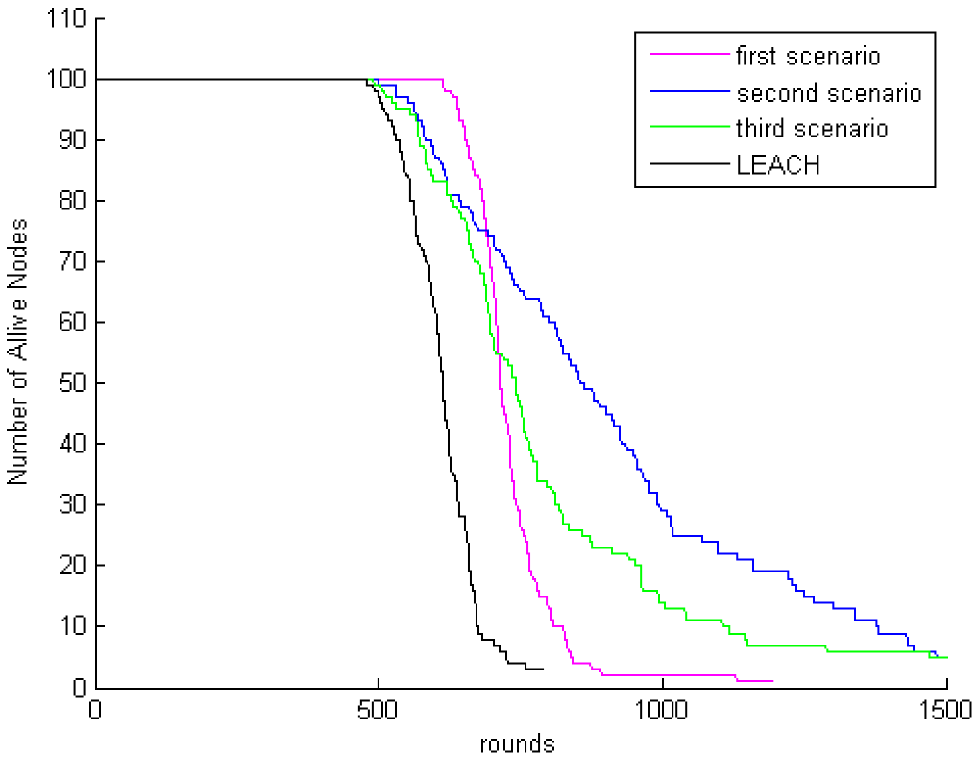

Figure 10 Result of simulation, number of nodes alive vs round

This figure shows if we choose the different probability valuse near to base station we can to save a lot of energy for sensors.

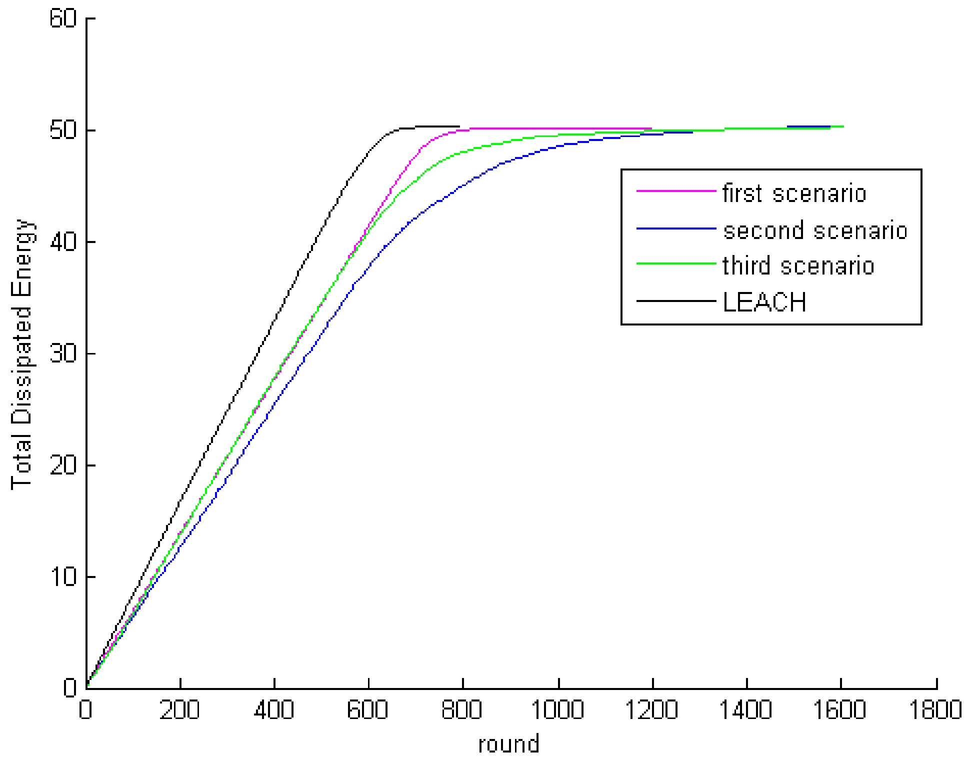

Figure 11 Different scenario: total dissipated energy in proposed method and LEACH

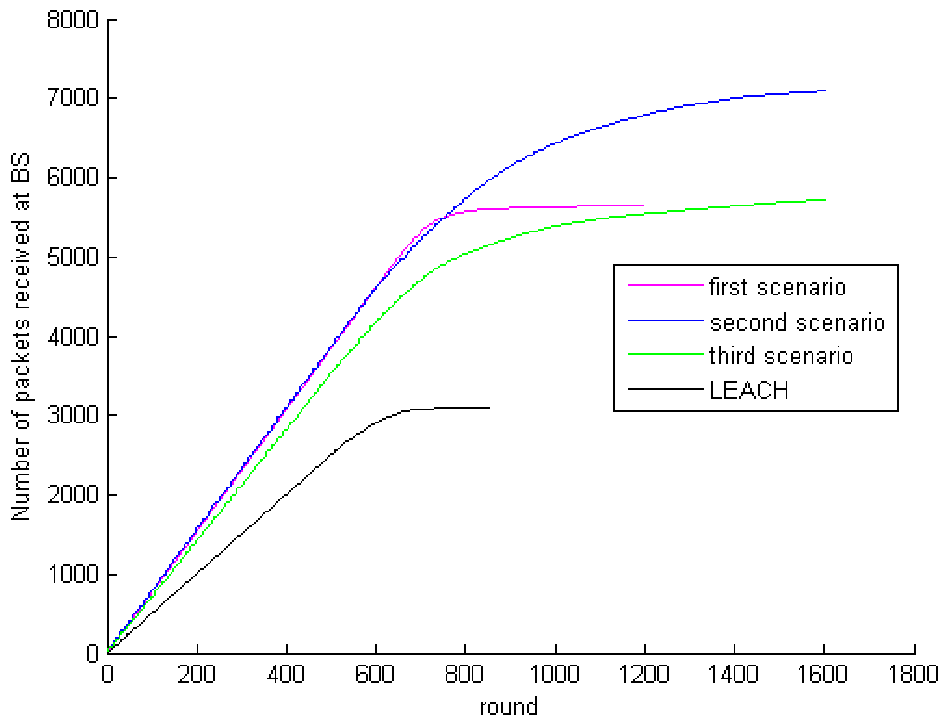

Figure 12 Different scenario: number of packers received at base station vs round.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this thesis, a reliable communication protocol for wireless sensor networks is presented that considers low energy consumption as well. This protocol is a cluster-based communication protocol that divides the entire network into equal area segments and applies different clustering policies to each segment. The first goal of this project is to reduce the total energy consumption of the wireless sensor network. The second goal is to increase the reliability of the protocol along with improving the network latency as compared with previous cluster-based protocols.

The CH is often a sensor node with richer resources such as energy. It may be elected by sensor nodes in a cluster or pre-assigned by the base station. Several clustering algorithms are proposed in order to reduce energy consumption in WSNs. Most of the improvements focus on CH selection. Cluster heads in clusters schedule nodes for sending and receiving messages. In this thesis, a clustering approach based on dividing the entire network for equal area is proposed.

Experimental results verify that concerning complete energy consumption, network time period and dependability, proposed method will outgo conservative cluster-based methods.

As results, the whole of sensors that remain alive over simulation time of 1500 rounds. It is seen that sensors remain alive for a prolonged time in proposed method than LEACH.

REFERENCES

1. **Chong C. Y., and Kumar S. P., (2003),** “Sensor Networks: Evolution, Opportunities, and Challenges”, *Proceedings of the IEEE Vol. 91, No. 8,* pp. 1247-1256.

2. **Pottie G. J., Kaiser W. J., (2000)**, “Wireless Integrated Network Sensors", *Communications of the ACM,* Vol. 43, No. 5, pp. 51-58.

3. **Staddon J., Balfanz D., and Durfee G., (2002)**, “Efficient Tracing of Failed Nodes in Sensor Networks", The First ACM International Workshop on Wireless Sensor Networks and Applications, Atlanta, USA, pp. 122-130.

4. **Meguerdichian S., Koushanfar F., Potkonjak M., and Srivastava M., (2001)**, “Coverage Problems in Wireless Ad-hoc Sensor Networks", Proceedings of the IEEE Infocom, Vol.3, pp. 1380-1387.

5. **Zhao Y., Govindan R., and Estrin D., (2002)**, “Residual Energy Scans for Monitoring Wireless Sensor Networks", Proceedings of the IEEE Wireless Communications and Net- working Conference, http://research.cens.ucla.edu/people/estrin/resources/conferences/2002mar-Zhao-Estrin-Residual.pdf, (Date Download Data: 19.10.2014).

6. **Deb B., Bhatangar S., and Nath B. I., (2002)**, “A Topology Discovery Algorithm for Sensor Networks with Applications to Network Management", IEEE CAS Workshop on Wireless Communications and Networking, Pasadena, USA, http://www.cs.huji.ac.il/labs/danss/sensor/sensors/deb_2002topology.pdf, (Date Download Data: 10.10.2014).

7. **Zhao J., Govindan R., (2003)**, “Computing Aggregates for Monitoring Wireless Sensor Networks", Proceedings of the International Workshop on Sensor Network Protocols and Applications, http://cens.ucla.edu/people/estrin/resources/conferences/2003may-Zhao-Estrin-Computing.pdf, (Date Download Data: 09.05.2014).

8. **Raj R., Ramesh M. V., and Kumar S., (2008)**, “Fault Tolerant Clustering Approaches in Wireless Sensor Network for Landslide Area Monitoring", Proceedings of the 2008 International Conference on Wireless Networks Vol. 1, pp. 107-113.

9. **Younis O., Krunz M., and Ramasubramanian S., (2006)**, “Node Clustering in Wireless Sensor Networks Recent Developments and Deployment Challenges. Network, IEEE, Vol. 20, No. 3, pp. 20 – 25.

10. **Wang L. and Xiao Y., (2006)**, “A Survey of Energy-efficient Scheduling Mechanisms in Sensor Networks. Mob. Netw. Appl., Vol. 11, No. 5, pp. 723–740.

11. **Manjeshwar A. and Agarwal D. P., (2001)**, “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, pp. 2009 - 2015.

12. **Sevgi C., (2009)** “Network Dimensioning in Randomly Deployed Wireless Sensor”, PhD thesis, Middle East Technical University.

13. **Younis O., Krunz M., and Ramasubramanian S., (2006)**, “Node Clustering in Wireless Sensor Networks: Recent Developments and Deployment Challenges. Network, IEEE, Vol. 20, No. 3, pp. 20 –25.

14. **Haowen C. and Adrian P., (2004)**, “Ace: An Emergent Algorithm for Highly Uniform Cluster Formation”, In Proceedings of the First European Workshop on Sensor Network, EWSN, pp. 154–171.

15. **Fasolo E., Rossi M., Widmer J., and Zorzi M., (2007)**, “In-network Aggregation Techniques for Wireless Sensor Networks a Survey. Wireless Communications, IEEE, Vol. 14, No. 2, pp. 70 –87.

16. **Boukerche A., Pazzi R. W. N., and Araujo R. B., (2005)**, “Hpeq a Hierarchical Periodic, Eventdriven and Query-based Wireless Sensor Network Protocol”, Local Computer Networks, pp. 560 –567.

17. **Olivier P., Pierre L., and Rolim J., (2007)**, “Energy Optimal Data Propagation in Wireless Sensor Networks”, J. Parallel Distrib. Comput, Vol. 67, No. 3, pp. 302–317.

18. **Dilum B. H. and Jayasumana A. P., (2007)**, “An Enhanced Top-down Cluster and Cluster Tree Formation Algorithm for Wireless Sensor Networks”, Industrial and Information Systems, pp. 565 –570.

19. **Seema B. and Coyle E. J., (2003)**, “An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks”, INFOCOM, Vol. 3, pp. 1713 – 1723.

20. **Baker D. and Ephremides A., (1981)**, "The Architectural Organization of a Mobile Radio Network via a Distributed Algorithm", Communications, IEEE Transactions on, Vol. 29, No. 11, pp.1694 –1701.

21. **Heinzelman W. B., Anantha P. Ch, and Balakrishnan H., (2002)**, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transactions onWireless Communications, pp. 660–670.

22. **Heinzelman W. B., (2000),** "An Application-Specific Protocol Architecture for Wireless Networks. PhD thesis, Massachusetts Institute of Technology.

23. **Timothy J. S., (1996)**, "A Channel Access Scheme for Large Dense Packet Radio Networks", SIGCOMM Comput. Commun. Rev., Vol. 26, No. 4, pp. 219–230.

24. **Stephanie L., Cauligi R., and Krishna M. Sivalingam, (2002)**, "Data Gathering Algorithms in Sensor Networks using Energy Metrics. IEEE Trans. Parallel Distrib. Syst., Vol. 13, No. 9, pp. 924–935.

25. **Handy M. J., Haase M., and Timmermann D., (2002)**, "Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-head Selection", In Mobile and Wireless Communications Network, 2002. 4th International Workshop on, pp. 368 – 372.

26. **Basagni S., (1999)**, "In Fourth International Symposium on Parallel Architectures", Algorithms, and Networks, pp. 310 –315.

27. **Banerjee S. and Khuller S., (2001)**, "A Clustering Scheme for Hierarchical Control in Multi-hop Wireless Networks", In INFOCOM, Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, Proceedings. IEEE, Vol. 2, pp. 1028 –1037.

28. **Younis O. and Fahmy S., (2004)**, “Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-efficient Approach. In INFOCOM 2004. Twenty-third Annual Joint Conference of the IEEE Computer and Communications Societies, pp. 629-640.

29. **Sajal K. D., and Damla T., (2002)**, “WCA : A Weighted Clustering Algorithm for Mobile”, Ad Hoc Networks, Mainak Chatterjee, pp. 193–204.

30. **Lin C. R., and Gerla M., (1997)**, “Adaptive Clustering for Mobile Wireless Networks. Selected Areas in Communications, IEEE Journal on, Vol. 15, No. 7, pp. 1265 –1275.

31. **Shacham N., Craighill E., and Poggio A., (1983)**, “Speech Transport in Packet-radio Networks with Mobile Nodes”, Selected Areas in Communications, IEEE Journal on, Vol. 1, No. 6, pp. 1084 –1097.

32. **Lin C. R. and Gerla M., (1997)**, “Asynchronous Multimedia Multihop Wireless Networks. Vol. 1, pp. 118 –125.

33. **Mario G. and Jack T. T., (1995)**, “Multicluster, Mobile, Multimedia Radio Network Wirel. Netw, Vol. 1, No. 3, pp. 255–265.

34. **Gupta G. and Younis M., (2003)**, “Load Balanced Clustering of Wireless Sensor Networks. Vol. 3, pp. 1848 – 1852.

35. **Zhen L. and Chen Z., (2010)**, “Data Gathering in Wireless Sensor Networks. In Sixth International Conference on Semantics Knowledge and Grid, pp. 351 –354.

36. **Choon S. N., Jeong H. J., and Shin D. R, (2008)**, “The Adaptive Cluster Head Selection in Wireless Sensor Networks. In Semantic Computing and Applications, IWSCA ’08. IEEE International Workshop on, pp. 147 –149.

37. **Bouhafs F., Merabti M., and Mokhtar H., (2006),** “A Semantic Clustering Routing Protocol for Wireless Sensor Networks. In Consumer Communications and Networking Conference, CCNC 3rd IEEE, Vol. 1, pp. 351 – 355.

38. **Liansheng T., Yumei Y., and Wei L., (2010)**, “Cote: A Clustering Scheme with Optimal Tiers and Energy Efficiency in Wireless Sensor Networks. In Semantics Knowledge and Grid (SKG), Sixth International Conference on, pp. 164 –171.

39. **Boukerche A. and Martirosyan A., (2007)**, “An Energy-aware and Fault Tolerant Inter-cluster Communication based Protocol for Wireless Sensor Networks. In Global Telecommunications Conference, GLOBECOM, IEEE, pp. 1164 –1168.

40. **Zhanyang Z. and Guping Z., (2006)**, “A Cluster based Query Protocol for Wireless Sensor Networks”, Advanced Communication Technology, Vol. 1, pp. 140 –145.

41. The network simulator ns-2, http://www.isi.edu/nsnam/ns/.(Date Download Data: 11.7.2014).

42. **Popovski P., Fitzek F. H. P., Yomo H., Madsen T. K., Prasad R., and Vej N. J., (2004)**, “Mac-layer Approach for Cluster-based Aggregation in Sensor Networks”, Wireless Ad-Hoc Networks, 2004 International Workshop on, pp. 89 – 93.

43. **Intanagonwiwat C., Govindan R., Estrin D., Heidemann J., and F. Silva, (2003)**, “Directed Diffusion for Wireless Sensor Networking. Networking, IEEE/ACM Transactions on, Vol. 11, No. 1, pp. 2 – 16.

44. **Azzedine B., Richard We. N. P., and Regina B. A., (2004)**, “A Fast and Reliable Protocol for Wireless Sensor Networks in Critical Conditions Monitoring Applications. MSWiM, pp. 157–164

45. **Perkins C. E. and Royer E. M., (1999),** “Ad-hoc On-demand Distance Vector Routing”, In Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA, Second IEEE Workshop on, pp. 90 –100.

46. **Yoneki, E., Bacon, J. (2005)**, “A Survey of Wireless Sensor Network Technologies: Research Trends And Middleware’s Role”, Technical Report, Number 646, Computer Laboratory, UCAM-CL-TR-646, pp. 1-46.

47. **IEEE Computer Society, (2006)**, “IEEE Std.802.15.4-2006, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), pp. 1 - 320.

48. **Akkaya K., Younis M., (2005)**, “A Survey on Routing Protocols for Wireless Sensor Networks”, Ad Hoc Networks, Vol. 3, No. 3, pp. 325–349.

49. **Telos Ultra low power IEEE 802.15.4 compliant wireless sensor module, (2011)**, “Revision B : Humidity, Light, and Temperature sensors with USB Datasheet, pp. 1-28.

50. **Sinha A., Chandrakasan A., (2001)**, “Dynamic Power Management in Wireless Sensor Networks”, IEEE Design&Test of Computers, Vol. 18, No. 2, pp. 62 – 74.

51. **Akyildiz, I. F., Su W., Sankarasubramaniam, Y., Cayirci, E., (2002)**, “A Survey on Sensor Networks,” IEEE Communications Magazine, pp. 102–114.

52. **Estrin, D., Girod, L., Pottie, G., Srivastavay, M., (2001)**, “Instrumenting the World with Wireless Sensor Networks”, International Conference on Acoustics, Speech, and Signal Processing, pp. 2033-2036.

53. **García-Hernández, C. F., Ibargüengoytia-González, P. H., García-Hernández, J., Pérez-Díaz, J. A., (2007)**, “Wireless Sensor Networks and Applications: a Survey”, IJCSNS International Journal of Computer Science and Network Security, Vol. 7, No. 3, pp. 264-273.

54. **Patil, N. S., Patil, P. R., (2010)**, “Data Aggregation in Wireless Sensor Network”, IEEE International Conference on Computational Intelligence and Computing Research, pp. 1040 - 1052.

55. **Heinzelman, W. R., Chandrakasan, A., Balakrishnan, H., (2000)**, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks,” Proceedings of the 33rd International Conference on System Sciences, pp. 1-10.

56. **Ping D. , Joanne H. , Aslıhan Ç., (2005)**, “Distributed Energy-Efficient Hierarchical Clustering for Wireless Sensor Networks”, Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems, pp. 322-339.

57. **Huang, H., Wu, J., (2005)**, “A Probabilistic Clustering Algorithm in Wireless Sensor Networks”, Proceeding of IEEE 62nd Semiannual Vehicular Technology Conference (VTC), Vol. 3, pp. 1796–1798.

58. **Sinha, P., Sivakumar, R., Bharghavan, V., (1999)**, “CEDAR: a Core-Extraction Distributed Ad hoc Routing Algorithm”, IEEE Journal on Selected Areas in Communications, Vol. 17, No 8, pp. 1454 - 1465.

59. **Bricard-Vieu, V.; Nasser, N., (2006)**, "WSN16-1: A Weighted Clustering Algorithm Using Local Cluster-heads Election for QoS in MANETs," Global Telecommunications Conference, GLOBECOM, IEEE, pp.1-5.

60. **Texas Instruments TI** CC2420 2.4 GHz IEEE 802.15.4/ZigBee-ready RF Transceiver Datasheet, pp. 1-85.

61. **T. Rappaport, (1996)**, “Wireless Communications: Principles & Practice, Englewood Cliffs, NJ: Prentice-Hall.

62. **Heinzelman W. B., Chandrakasan A., Balakrishnan H., (2000)**, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks,” Proc. of the 33rd IEEE International Conference on System Sciences, pp. 1–10.

63. **Heinzelman W. B. , Chandrakasan A. P. , and Balakrishnan H., (2002)** “An Application-Specific Protocol Architecture for Wireless Microsensor Networks,” IEEE Transactions on Wireless Communications, Vol. 1, No. 4, pp. 660-670.

64. **Batalin M. A., Shukhatme G. S., and Hattig M., (2004)**, “Mobile Robot Navigation Using a Sensor Network,” Proc. of IEEE International Conference on Robotics and Automation, pp. 636-642.

65. **Karn P., (1990)**, “MACA - A New Channel Access Method for Packet Radio,” Proc. of the 9th Computer Networking Conference, pp. 134–140.

66. **Amini N., Miremadi S. G. and M. Fazeli, (2007)**, “A Hierarchical Routing Protocol for Energy Load Balancing in Wireless Sensor Networks,” Proc. of 20th IEEE Annual Canadian Conference on Electrical and Computer Engineering, Vancouver, Canada, pp.1086 - 1089.

67. **Ye W., Heidemann J., and Estrin D., (2002)**, “An Energy-Efficient MAC Protocol for Wireless Sensor Networks,” Proc. of the IEEE INFOCOM 2002, New York, NY, USA, pp. 1567-1576.

68. **Slijepcevic S. and Potkonjak M., (2001)**, “Power Efficient Organization of Wireless Sensor Networks,” Proc. of the IEEE International Conference on Communications, volume 2, Helsinki, Finland, Vol 2, pp. 472 - 476.

69. **Manjeshwar A. and Agarwal D. P., (2001)**, “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, pp. 2009 - 2015.

APPENDICES A

CURRICULUM VITAE

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