ENERGY EFFICIENT WIRELESS SENSOR NETWORK CLUSTERING ALGORITHMS AND THEIR REAL LIFE PERFORMANCE EVALUATION

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Approval of the Graduate School of Informatics

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

ENERGY EFFICIENT WIRELESS SENSOR NETWORK CLUSTERING ALGORITHMS AND THEIR REAL LIFE PERFORMANCE EVALUATION

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Improvements in technology result in evolution of smart devices. One of such smart devices is wireless sensor nodes, which consist of a sensing board, a battery supply and a wireless antenna to transfer data. We can collect information from the environment by deploying thousands of these tiny smart devices. These devices can also be used to monitor natural habitats or used in giant machine parts for performance evolution. Energy efficient operation is an important issue for wireless sensor network design and clustering is one of the most widely used approaches for energy efficiency.

This thesis study aims to analyze the performance of clustering algorithms for wireless sensor networks. We propose five clustering algorithms and perform experiments by using real sensor hardware over different topologies to investigate energy efficiency of the clustering algorithms.

Keywords: Clustering, Wireless Sensor Network, Wireless Sensors

ÖZ

KABLOSUZ ALGILAYICILARIN ENERJİ TASARRUFLU GRUPLAMA ALGORİTMALARI VE BU ALGILAYICILARIN GERÇEK PERFORMANS DEĞERLENDİRMESİ

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Teknolojideki ilerlemeler akıllı cihazların ortaya çıkmasına neden olmaktadır. Ortaya çıkan bu akıllı cihazlardan bir tanesi algılayıcı kart, güç kaynağı ve veri aktarımı için kablosuz antenden oluşan kablosuz algılayıcılardır. Bu küçük akıllı cihazlardan binlercesini etrafımıza yayarak çevremizden bilgi toplayabiliriz. Bu kablosuz algılayıcı cihazlar aynı zamanda doğal yaşamı izlemek için ya da büyük cihazların performanslarını ölçmek amacı ile de kullanılabilirler. Enerji tasarruflu çalışma kablosuz algılayıcı cihazlar için önemli bir özelliktir ve gruplama da enerji tasarrufu sağlamak için kullanılan en yaygın yaklaşımlardan bir tanesidir.

Bu tez çalışmasının amacı, kablosuz algılayıcıların gruplama algoritmalarının performansını analiz etmektir. Bu bağlamda farklı yerleşim şemalarında gruplama algoritmalarının enerji tasarruflarını incelemek amacıyla beş gruplama algoritması önerdik ve bu algoritmaların performanslarını gerçek algılayıcı cihazlar kullanarak test ettik.

Anahtar Kelimeler: Gruplama, Kablosuz Sensör Ağlar, Kablosuz Algılayıcılar

to my family...

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-C	Low Energy Adaptive Clustering Hierarchy - Centralized
MTE	Minimum-Energy Routing
RTS	Request to send
CTS	Clear to send
GC	General Clustering
HEED	Hybrid Energy-Efficient Distributed
ACE	Algorithm for Cluster Establishment
GPS	Global Positioning System
CH	Cluster head
TTL	Time to live
SHC	Simple Hierarchical Clustering
HHC	Hierarchical Hop-ahead Clustering
DD	Direct Diffusion
PEQ	Periodic, Event-driven and Query-based
HPEQ	Hierarchical Periodic, Event-driven and Query-based
AODV	Ad hoc On-Demand Distance Vector Routing
DCA	Distributed Clustering Algorithm
WCA	Weighted Clustering Algorithm
PR	Power Register

CHAPTER 1

INTRODUCTION

Recent improvements in technology provide us cheap and tiny electronic devices with various sensors on it. These tiny devices are called 'sensor nodes' and they have great abilities. The aim of using sensor nodes is to sense the environment and process and/or transfer collected information to an analysis center. Sensor nodes are usually battery powered and their transmission range is very low. Therefore, these sensor nodes can establish a network to propagate their data to long distances.

Wireless sensor networks idea is envisioned and defined as self-deployed, error prone, long living inexpensive communication devices that are densely deployed to collect data from physical space [1]. Another definition of wireless sensor networks is "a large-scale, ad hoc, multihop, unpartitioned network of largely homogeneous, tiny, resource-constrained, mostly immobile sensor nodes that would be randomly deployed in the area of interest"[2].

Sensor nodes can be placed regularly or they can be randomly deployed with the help of a plane, simply throwing them from air to inaccessible areas like mountains or forests. These sensor nodes may not be very powerful but they are actually very smart devices. They can establish a sensor network by self-organizing themselves, and they can immediately start transferring data packets as soon as they sense data from their coverage area.

These sensing devices are capable of sensing temperature, humidity, visual, acoustic, location and many more. There are several fields benefiting from sensor networks [1], such as military applications for border control and surveillance, environmental applications [3] for forest fire detection [4, 5], health applications for patient monitoring [6, 7], home automation and smart homes, and many other fields like agriculture [8], vehicle tracking, inventory management,

seismic activity[9] etc.

Since wireless sensor network is a new field in the literature, there are many challenges of using them. Most important challenge is energy consumption. Since these devices are deployed on unattended wide areas, replacing their batteries is not very feasible. With a pair of AA batteries a sensor node can last for 100-120h [10]. Therefore designing an algorithm with a good energy consumption mechanism is very important.

There are several ways to reduce energy consumption in sensor networks. Clustering the network, using sleep/listen cycles, using data aggregation methods, and using data propagation methods are some of them. The objective of this thesis study is to develop energy efficient clustering algorithms to partition a network into several groups for energy efficient operation.

There are many proposed algorithms and approaches for clustering to achieve energy efficient communication. However, most of these proposed studies have been done with the help of simulations. In these simulations calculations are forming the basis, like energy consumption per data packet, idle listening power consumption, or transmission range etc. Also every possibility of events has a probability of occurrence, like data losses, collisions, etc. However in real life situations we cannot calculate every possibility. Therefore performing experiments with actual sensors becomes very important.

In this study we aim to experience how sensor nodes act in normal environment. We developed several clustering algorithms employing different cluster head selection mechanisms, such as energy level or neighbor count. We performed experiments on different network topologies to observe the effect of node placement on clustering algorithms' performance. We compare each algorithm with others in terms of total transmitted and received packet counts, total coverage percentage, total number of cluster heads and member nodes, and total energy consumption.

While conducting our experiments by using actual sensors, we have encountered several problems. First of all, we have to consider that each sensor nodes' quality may be different than others. Since these devices are prototypes, their radios might not work 100% efficiently all the time. Moreover, some nodes might have hardware failures or low performances. Also testing environment may include interference, like other radio frequencies stronger than our sensor nodes. Furthermore since these sensors are powered with two AA type batteries, we

should also consider that each battery pair might have a different energy level, which effects transmission range. In order to cope with these problems we repeated the experiments several times and we present the results free of such problems as much as possible.

Due to the changing battery levels, some sensor nodes can suppress other sensor nodes' transmission signals throughout the experiments. As a result some sensor nodes might not be a part of a cluster at all.

The remainder of the thesis is organized as follows;

Chapter 2 includes definitions and the literature review on the related study. We include clustering, semantic clustering and query based clustering approaches.

Chapter 3 presents the clustering approach and proposed clustering algorithms.

In Chapter 4, we state experiment setup and present the results of experiments performed. Then, we compare the performance of proposed clustering algorithms.

Chapter 5 summarizes results obtained in this thesis study and states potential future research topics.