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Reliability and Energy Efficient Cluster Based Routing Protocol for Wireless Sensor Networks

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***Abstract*— Due to the Recent development in wireless technology, sensor networks researchers' attention because of their applicability in many fields for effective collection of sensing data with low cost. Nodes in such applications are equipped with limited energy supply and need careful management in order to extend their lifetime. Inorder to conserve energy, many of the routing protocols proposed for wireless sensor networks reduce the number of transmitted packets by pursuing in-network data aggregation. Reliability and energy efficiency are critical problem in wireless sensor networks. In this work, Delay bounded Energy constrained Adaptive Routing (DEAR) problem with reliability, differential delay, and transmission data energy consumption constraints in wireless sensor networks and also discuss improvements to be made for future proposed clustering schemes. This paper provides the reader with a basis for research in clustering schemes for Wireless Sensor Networks. The paper will address this problem and solution. In the paper, a routing algorithm is proposed by introducing Energy Delay Index for Trade-off (EDIT) to optimize both objectives energy and delay. EDIT is used to select Cluster Heads (CHs) and "next hop" by considering energy and/or delay requirements of a given application. Proposed approach is using two different aspects of distances between a node and the sink named Euclidean distance and Hop count, and further proven using realistic parameters of radio to get data closest to the test bed implementation. The result aspires to give sufficient insights to others before doing test bed implementation.**

***Keywords*— *Wireless Sensor Network, Cluster Head Election, Energy Delay Trade-off, Multi-hop routing*.**

I. INTRODUCTION

Many wireless sensor network (WSN) applications have been emerging in recent years due to the commercially available low-cost and diverse wireless sensors. Rapid improvements in low-cost hardware have prompted the development of Wireless Multi-media Sensor Networks (WMSNs), in which the sensors can be equipped with audio and visual information with collection of modules, and collection of multimedia data such as video and audio data, images, and scalar data from environments [2]. This advances in technology has made it possible to have extremely very small, low powered devices equipped with programming computing, multiple parameter sensing and with wireless communication capability. Also, the wireless sensors are very low cost of sensors makes it possible to have a network of hundreds or thousands of these wireless sensors, thereby enhancing the reliability and accuracy of data and the area coverage as well[3]. Sensor nodes in general are extremely small, low cost, low energy that possesses sensing, signal processing and wireless communication capabilities. Sensors usually gather information about the physical world.

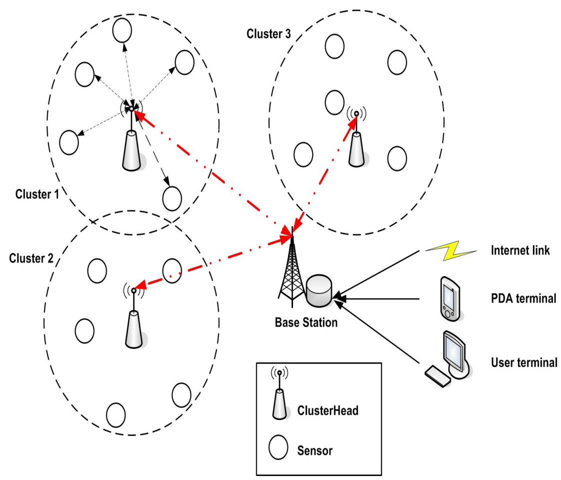

Fig. 1. General Sensor Network Architecture

By looking at Fig. 1, The architecture of a generic Wireless Sensor Network [5], it examine how the clustering phenomenon is an essential part of the organizational structure.

II. SYSTEM MODEL

The system architecture for the sensor network nodes are grouped into clusters controlled by a single command node. Every cluster has a gateway node that manages sensors in the cluster. Clusters are formed based on many criteria such as communication range, number and type of sensors and geographical location. In this model, the gateways collaboratively locate the deployed sensors and group them into clusters so that sensors transmission energy is minimized while balancing the load among the gateways. In this paper, let us assume that sensor and gateway nodes are stationary and the gateway node is located within the communication range of all the sensors of its cluster [11].

• Sensor Node: A sensor nodes is the main component of a wireless sensor network. Sensor nodes can play multiple roles in a network, such as sensing; data storage; routing; and data processing.

• Clusters: Clusters are the organizational unit for Wireless Sensor Networks. The nature of these networks require the need for them to be broken down into clusters to simplify tasks such a communication.

• Cluster heads: Cluster heads are the organizational leader of a cluster. They often are required to organize an activity in the cluster. These tasks are included but they are not limited to data-aggregation and organizing the communication schedule of a cluster.

• Base Station: The base station is at the upper layer level of the hierarchical Wireless Sensor Network. It provides the communication link between the sensor network and an end-user.

• End User: The data in a sensor network can be used for a wide-range of applications. Therefore, a particular application may use of the network over the internet, using a PDA, or even in desktop computer. In a queried sensor network the query is generated by the end user. The clustering phenomenon can play an important role not just only in an organization of the network, but can dramatically affect network performance.

An example of actor nodes are robots able of sensing, communicating and performing actions. Actor nodes in general are equipped with larger energy sources than sensors. Heterogeneous ad-hoc wireless networks of large numbers of such inexpensive but less reliable and accurate sensors combined with few actors can be used in a wide variety of commercial and military applications such as target tracking, security, environmental monitoring and system control[4]. Direct transmission provides minimal delay but increases energy consumption of WSN nodes. On the other hand, multi hop communication is energy efficient as nodes have to transmit over a shorter distance; and energy consumption is directly proportional to the distance [6], [7] but it increases delay. Also, we should select direct transmission or multi-hop transmission between CH and member nodes, and between CH and other CHs or BS to balance between the energy consumption of a node and delay encountered by the data. If a multi-hop communication is used then selection of the “next hop” is also a challenging issue. If same node is selected as a “next hop” then it runs out of energy within a short period. Hence, there is a need to design a CH election process which takes care of trade-off between energy and delay by selecting direct transmission or multi-hop transmission for intra-cluster and inter-cluster communication. If multi-hop transmission is used then selection of “next hop” to balance between the energy and delay is also a challenging task. In this paper, we have proposed Energy Delay Index for Trade-off (EDIT) for WSN by considering two different types of distances: i) Euclidean Distance and ii) Hop-count. As per our knowledge, this paper is the first attempt to find the energy delay trade-off using two different kind of distances for delay constrained applications. The proposed protocol along with the results are presented and discussed in the following sections. Major contributions It can summarize our contributions as follows:

• This paper has proposed a Cluster Head Election approach EDIT, to optimize two conflicting objectives named “Energy” and “Delay”.

• In this paper [1], the trade-off between Energy and Delay are considered by two different types of distances between the CH and its member nodes: i) Euclidean distance and ii) Hop-count.

• Also, this paper describes that how selection of “next hop” in a multi-hop communication affects the Energy and/or Delay requirements of the underlying application.

III. RELATED WORK

In [1], authors made research on sensor networking which is mostly focused on solutions that try to maximize the lifetime of the network and are scalable to large networks. In [3], authors have analyzed the problem of energy efficient routing in sensor and ad-hoc networks is a well-known and multifaceted problem. This problem and has different solutions in synchronous and asynchronous networks. A nice solution for a synchronous network with one gateway is proposed by the protocol. In [4], A cluster based routing protocol (CBRP) has been proposed by Jiang et. al for mobile ad-hoc networks. It divides the network nodes into a number of overlapping or disjoint two-hop-diameter clusters in a distributed manner. In [5], the fundamental advantage of WSNs is the ability to deploy them in an ad hoc manner, as it is not feasible to organize these nodes into groups pre-deployment. For this reason, there has been a large amount of research into ways of creating these organizational structures. In [8], a novel approach for energy-aware management of sensor networks that maximizes the lifetime of the sensors while achieving acceptable performance for sensed data delivery. The approach is dynamically to set routes and arbitrate medium access in order to minimize energy consumption and maximize sensor life. The approach calls for network clustering and assigns a less-energy constrained gateway node that acts as a cluster manager. In [7], paper surveys recent routing protocols for sensor networks and presents a classification for the various approaches pursued. The three main categories explored in this paper are data-centric, hierarchical and location-based. Each routing protocol is described and discussed under the appropriate category. Moreover, protocols using contemporary methodologies such as network flow and quality of service modelling.

A.Definition1 (Energy consumption)

For a sensor node the total energy consumption is defined as the set of links from its neighbors on multipaths, and the packet size transmitted on link and the energy consumption of transmitting 1 bit [12].

B. Definition 2 (Latency/Delay).

Let s be the source node and BS the base station. When packets are transmitted from one node to another, it is known that the communication latency/delay consists of mainly three factors [12].

- *Queuing delay*: the time waiting at output link for transmission [12].
- *Transmission delay*: the amount of time required to push all of the packet bits into the transmission media [12].
- *Propagation delay:* the time takes for the head of the signal to travel from the sender to the receiver.
  The delay studied in this paper consists of the *transmission* delays on the nodes and the propagation delays on the links [12].

IV. MOTIVATION

In the current body of research done in the area of wireless sensor networks, we see that particular attention has not been given to the time criticality of the target applications. Most current protocols assume a sensor network collecting data periodically from its environment or responding to a particular query.

This method feels that there exists a need for networks geared towards responding immediately to changes in the sensed attributes. We also believe that sensor networks should provide the end user with the ability to control the trade-off between energy efficiency, accuracy and response times dynamically. So, in our research, it is focus on developing communication protocol which can fulfill these requirements [2].

Recently in [6] it was proposed an implicit prioritized access protocol for sensor networks that utilizes Earliest Deadline First scheduling algorithm to guarantee the delay for real time traffic. Table 1 shows the comparison of various techniques and what are the advantages and disadvantages of the each technique.

V. CLUSTER HEAD ELECTION WITH ENERGY DELAY TRADE-OFF IMLEMENTATION

The proposed algorithm [1] works in rounds and each of these rounds are divided into two phases: i) Cluster Setup Phase and ii) Steady State Phase. A neighbor discovery phase executed once before the commencement of the first round and it is explained below.

A. NEIGHBOUR DISCOVERY PHASE

Hop-count and Euclidean distance both are used to measure distance from the sink. Receiving nodes of Hello packet add sender as its neighbour and record information like Sender Id, Hop-count and location, and then send Hello Reply to the sender [1].

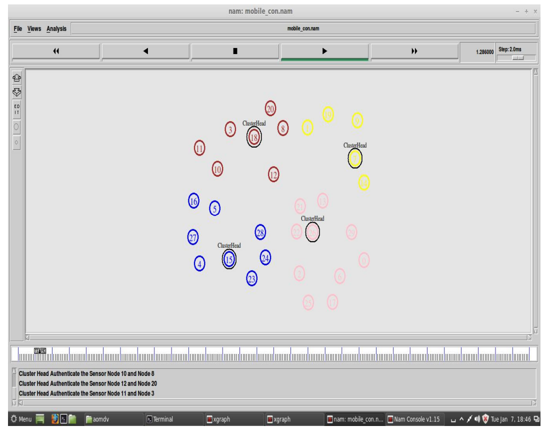

Fig. 2. Neighbour Discovery Phase

In Fig. 2. Shows the result of Neighbor Discovery Phase algorithm which begins with the sink by sending a Hello packet that consists of Sender Id, Hop-count and Euclidean distance to reach the sink and location of the sender.

Each receiving node also forwards the Hello Packet by setting its id as Sender Id, location parameter and both distances Hopcount and Euclidean distance, to reach the sink [9]. Whenever any node is having its energy less than threshold depending on application), it will broadcast itself as a dead node by sending Dead message. The receiving node updates their neighbor table on reception of Dead messages. Neighbor discovery phase should be done only once at the time of network deployment [1].

B. CLUSTER SETUP PHASE

At the end of Neighbor discovery phase, each node waits for Wait Time Energy, before it broadcasts its energy level. A node compares its energy level with the energy level of the nodes from which it has received Energy Messages[1].

$$WaitTime\ energy = \frac{1}{remaining\ energy}$$

If a node has less energy, then node will cancel its timer and decides to be a cluster member. The probable cluster heads are the set of nodes, which have sent Energy Messages and after that either they do not received any Energy Messages or their energy is higher than the energy received in Energy Messages. To break a tie in such cases,

[12] Energy Delay Index for Trade-off (EDIT) is used. Each probable cluster head will wait for 1 EDIT time before doing announcement that it is a final cluster head.

All probable cluster heads, which receives Final Cluster Head announcement becomes the member nodes for the current round provided that Final Cluster Head announcement is yet to be done by them. These member nodes cancel their EDIT timers and go to sleep state until the commencement of Steady State Phase [1].

In Fig.3, Selection of CH is based on minimum communication energy expenditure between non-CH node and selected CH node [1]. After selection of CH node, non-CH nodes will send Cluster Join message including their current energy level. Each final CH node prepares TDMA schedule for its own member nodes from which it has received CH JOIN messages [3].

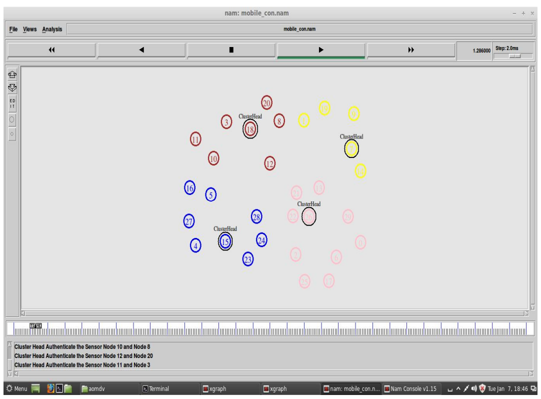

Fig. 3. Electing the Cluster Head

In Fig.3, Selection of CH is based on minimum communication energy expenditure between non-CH node and selected CH node [1]. After selection of CH node, non-CH nodes will send Cluster Join message including their current energy level. Each final CH node prepares TDMA schedule for its own member nodes from which it has received CH JOIN messages [3].

It also ensures that these highest energy nodes must also have more number of neighboring nodes. It also selects one of the member nodes as a gateway node if two CH nodes are not in a communication range of each other. Selection of a gateway node depends on the energy/delay requirements of the underlying application [1].

C. STEADY STATE PHASE

All nodes remain in sleep state except CHs nodes. Data transmission from non-CH nodes to CH node is done as per the TDMA schedule announced by the CH [3]. This scheme avoids collision of the data messages, and each member node remains in transmit state for a short duration. This helps to save energy of the member nodes [1].

In Fig. 4 shows the packet delivery from one node to another node with the help of Cluster Head using the trade-off "Energy and Delay". The data transmissions will be happened among the CH. Each CH is selected using EDIT (Energy Delay Index Trade-off).

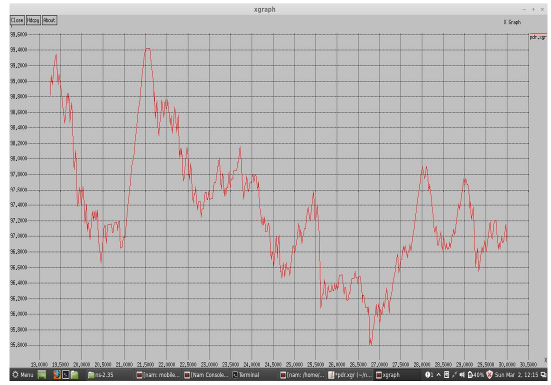

Fig. 4. Packet Deliver Ratio Graph

In Fig. 4 shows the packet delivery from one node to another node with the help of Cluster Head using the trade-off "Energy and Delay". The data transmissions will be happened among the CH. Each CH is selected using EDIT (Energy Delay Index Trade-off).

CONCLUSION

In proposed approach, it is examined and derived EDIT protocol to analyze energy-delay trade-off by doing extensive simulation. The future work has successfully demonstration of the effect of two types of distances to be used to elect cluster heads using EDIT protocol and their effect on delay and energy. In the course of research, the effect of controlling parameters for EDIT protocol was manifested. The simulation results presented by us will be useful to other researchers to analyze of two contradicting parameters namely energy and delay before implementing it on a real test bed.

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