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Predicting and Extending of Sensor Lifetime in Wireless Sensor Networks using Fuzzy Logic

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Abstract: ***Wireless sensor networks are specially distributed autonomous sensor, WSN communicates with signals, the lifetime of a sensor mainly depends on the energy or battery of a sensor nodes. Cluster is a set of sensor nodes which communicates with each other in a range. Cluster formation and cluster head selection are important problems in Wireless Sensor Networks (WSNs). They can drastically affect the network's communication energy dissipation and performance of a network. In WSNs, energy shortens the operation time of sensors, lifetime of sensors and network lifetime. So to increase the network lifetime and operation time for sensors we proposed Fuzzy logic scheme. . In this work, we propose a fuzzy-based simulation system for WSNs, in order to calculate the lifetime of a sensor by considering the remaining battery power, sleep time rate and transmission time rate. Battery power of a node is depends on the range of transmission, if it is transmitting at a high range then it has more power else less power. Sleep time is when nodes are not transmitting any data to the nodes. We are also extending the life time of sensor nodes. We evaluate the system by NS2 simulations and show that it has a good behavior for measuring sensor lifetime.***

Keywords: Wireless sensor networks, cluster, performance, lifetime, energy.

1. Introduction

Recent developments in technologies such as wireless communication and microelectronics have enabled Wireless Sensor Network (WSN) applications to be deployed for many applications such as battlefield surveillance and environment monitoring. An important aspect of such networks is that the nodes are unattended, resource-constrained, their energy cannot be replenished and network topology is unknown. The resource-constrained limitations make it essential for these sensor nodes to conserve energy to increase lifetime of the WSN in Fig 1.

Recently, there are lot of research efforts towards the optimization of standard communication paradigms for such networks. In fact, the traditional Wireless Network (WN) design has never paid attention to constraints such as the limited or scarce energy of nodes and their computational power. Also, in WSN paths can change over time, because of time-varying characteristics of links, local contention level and nodes reliability. These problems are important especially in a multi-hop scenario, where nodes accomplish also the

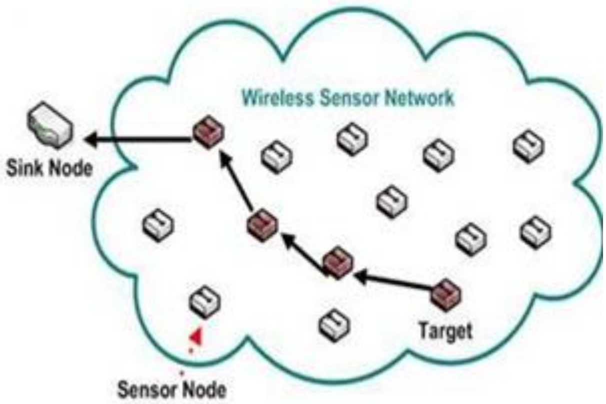

Figure 1: Wireless sensor network.

Figure 2 shows the schematic diagram of sensor node components. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer). The same figure shows the communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station. A base-station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user Challenges and Design Issues in WSNs .

Despite the innumerable applications of WSNs, these networks have several restrictions, e.g., limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in WSNs. In the following, we summarize some of the routing challenges and design issues that affect routing process in WSNs.

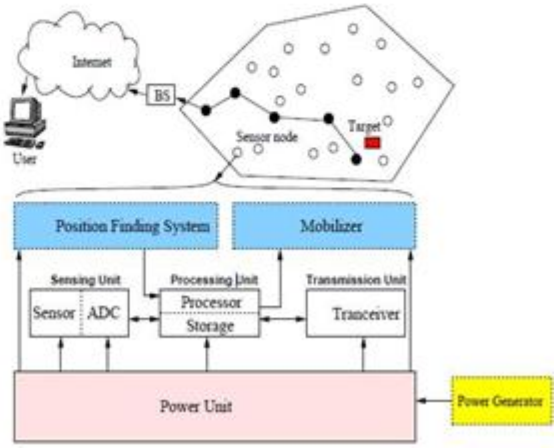

Figure 2: Sensor node

Node Deployments: Node deployment in WSNs is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized.

Energy consumption without losing accuracy: Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment.

Data Reporting Model: Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as either time-driven (continuous), event-driven, query-driven, and hybrid.

Node/Link Heterogeneity: In many studies, all sensor nodes were assumed to be homogeneous, i.e., having equal capacity in terms of computation, communication, and power. However, depending on the application a sensor node can have different role or capability.

Scalability: The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes.

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

Data Aggregation: Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation is the combination of data from different sources according to a certain aggregation function, e.g., duplicate suppression, minima, maxima and average.

Quality of Service: In some applications, data should be delivered within a certain period of time from the moment it is sensed, otherwise the data will be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent.

1.1 Applications of Wireless Sensor Networks

- **Area Monitoring**

Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored.

- **Air Quality Monitoring**

The degree of pollution in the air has to be measured frequently in order to safeguard people and the environment from any kind of damages due to air pollution.

- **Forest Fire Detection**

A network of Sensor Nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fire in the trees or vegetation.

- **Natural Disaster Prevention**

Wireless sensor networks can effectively act to prevent the consequences of natural disasters, like floods.

- **Machine Health Monitoring**

Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionality. In wired systems, the installation of enough sensors is often limited by the cost of wiring.

- **Industrial sense and control applications**

In recent research a vast number of wireless sensor network communication protocols have been developed. While previous research was primarily focused on power awareness, more recent research have begun to consider a wider range of aspects, such as wireless link reliability, real-time capabilities, or quality-of-service.

- **Water/Waste Water Monitoring**

Monitoring the quality and level of water includes many activities such as checking the quality of underground or surface water and ensuring a country’s water infrastructure for the benefit of both human and animal. The cluster based algorithms could be used for partitioning the sensor nodes into subgroups for task subdivision or energy management. A survey on clustering algorithms for WSNs can be found in [2]. Cluster formation is one of the most important problems in WSN applications and can drastically affect the network’s communication energy dissipation. Clustering is performed by assigning each sensor node to a specific CH. All communication to (from) each sensor node is carried out through its corresponding CH node. Other approaches consider energy dissipation and energy consumption of nodes for different applications, where mobility is limited [3], routing decisions are based on supply power type [4] and so on. The heuristic approaches based on Fuzzy Logic (FL) and Genetic Algorithms (GA) can prove to be efficient for traffic control in wireless networks [5], [6].

In our recent works, we proposed a fuzzy-based cluster selection method for WSNs, which uses 3 parameters for CH selection: Distance of Cluster Centroid, Remaining Battery Power of Sensor and Number of Neighbor Nodes. We compared the performance with previous methods. The performance of our method was better than the previous methods. But, we found that for CH selection also sensor speed is very important. On the other hand, how to control the sensor speed was another issue in our system. We combined two Fuzzy Logic Controllers (FLCs), in order to control the sensor speed. In this work, we propose and implement a Fuzzy-based Lifetime Prediction (FLTP) system for measuring the lifetime of the sensors. The paper is organized as follows. In Section II, we show some related work. In Section III, we describe the proposed system. In Section IV, we discuss the simulation results Finally, conclusions are given in Section V.

2. Related Work

Njjj We review related work in WSNs. Several clustering methods such as weighted clustering [7], hierarchal clustering [8] and dynamic clustering [9] algorithms have been proposed to organize nodes as a cluster. Most algorithms elect CHs based on certain weights or iteratively optimize a cost function or use heuristic to generate minimum number of clusters. The Distributed Clustering Algorithm (DCA) [10] assumes quasi stationary nodes with real-valued weights. The Weighted Clustering Algorithm [7] elects a node based on the number of neighbors, transmission power and so on. The Max-Min d-Clustering Algorithm [11] generates d-hop clusters with a run time of O(d) rounds. This algorithm does not minimize the communicating complexity of sending information to the information center. The hierarchical clustering scheme [8] uses spanning tree based approach to produce cluster with certain properties. However, energy efficiency is not addressed in this work.

In [12], the authors have proposed an emergent algorithm that iteratively tries to achieve high packing efficiency, however negotiation among nodes to be CH and join cluster based on degree and proximity leads to high amount of communication overhead, thus wastage energy.

In [13], the authors propose a self-reconfiguring protocol for Wireless Personal Area Networks (WPAN) using an unsupervised clustering method. A fuzzy logic system is used to select the master/controller for each cluster. In our previous work [14], we had shown by simulation results that the selection surface of our system was better than the system in [13]. But, we found that for CH selection the number of neighbor nodes is very important. For this reason, we proposed and implemented a CH system using FL and number of neighbor nodes [15], [16].

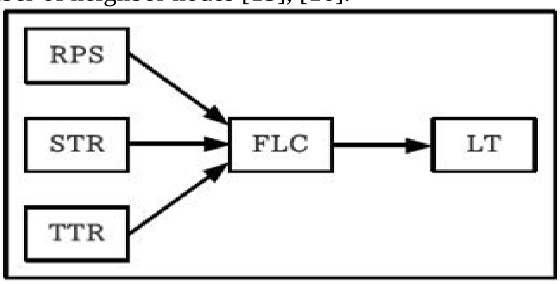

Figure 3: FLC structure

The existing system proposed an simulation system based on FL for prediction of sensor lifetime in WSNs. We implemented our system with one FLC and evaluated the performance by simulations. Existing system proposed a fuzzy-based cluster selection method for WSNs, which uses 3 parameters for CH selection: Distance of Cluster Centroid, Remaining Battery Power of Sensor and Number of Neighbour Nodes. The performance is compared with previous methods. The performance of existing system method was better than the previous methods. But, it has found that for CH selection also sensor speed is very important. On the other hand, how to control the sensor speed was another issue in our system

Disadvantages

- Existing cluster formation and Cluster head selection algorithms consume more energy since the existing system did not consider the energy drainage factor i.e. the number of times a node communicates.
- Existing system evaluates lifetime of WSN using only one FLC. Single FLC takes more time to estimate the lifetime in case of more number of CH. The speed cannot be controlled by single FLC.
- Existing system estimates the lifetime of sensor in WSN but no actions were taken to Extend or prolong the lifetime of WSN

3. Proposed System

System Architecture

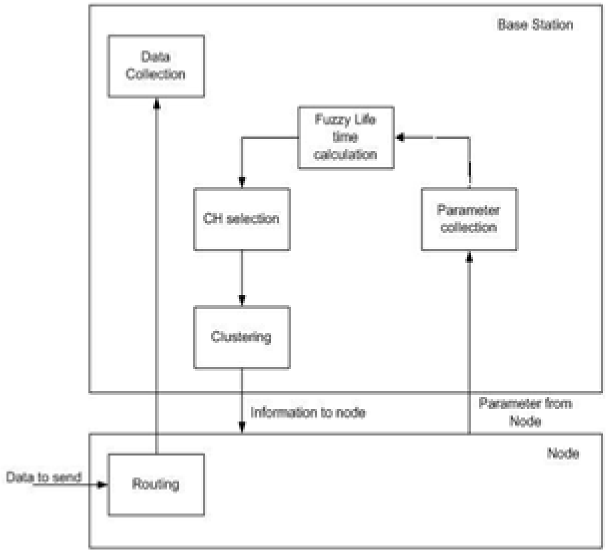

Figure 4: System Architecture

The main modules over which the interactions will takes place are given below:

Node: Is the front end application allowing user to deploy nodes and network architecture. It also allows user to enable data flow between nodes.

Parameter Collection: parameter values are collected from the nodes.

Fuzzy Logic Controller: calculates the life time of sensor nodes.

CH selection: cluster heads are selected based on the fuzzy logic.

Clustering: Separate group of nodes are created. The proposed system works in four modules

- Network Creation and Setting Parameters to nodes
- Cluster Head Selection and Life Time calculation
- Changing duty cycle of sensor node
- Performance Evolution

A. Network Creation and Setting Parameters to nodes

In Create Network the network is created according to the user specified number of nodes and communication range. The communication range specifies the range a node can communicate with other nodes. The nodes are randomly deployed in a simulated network environment. The NAM simulator will be used for that. For the simulator the number of nodes, base station location and initial parameters of each node will be set using this module and all node values and range of the nodes are set using this module Routing protocol is used in this method to transfer data through cluster heads. Time of simulation has been set in this method.

B. Cluster Head Selection and Life Time calculation

Based on the parameter values cluster head is selected using fuzzy logic controller and clusters are formed and the transmission of data is considered as one round and fuzzy logic controller will calculate at which round the very first node is died and which round half of the nodes has been died is calculated and displayed and that will be produced as output and accordingly it displays the change in the parameter values in the terminal.

Cluster Head Selection

The parameter values like STR, TTR AND RPS values are collected in the fuzzy logic controller jar file then based on those values life time is calculated for every node and the node which is having more energy that node is selected as cluster head. Here we have considered the energy value which is having more than 0.4 that will be considered as cluster head.

Life Time Calculation

The one transmission is considered as one cycle and tat value is stored in round flag as the number of cycles increases round flag count will be increased and finally it will be displayed in the terminal. Fuzzy logic controller will calculate energy dissipation in the nodes and remaining energy in the nodes at each round will be displayed in the terminal. Finally at which round the first node will dies is displayed as output in the terminal.

C. Changing Duty Cycle of Sensor Node

Here Extended the lifetime by changing the duty cycle of each sensor node so that during the sleep time the energy will not be deducted from nodes thus the life time will be increased that has proved by displaying the round at which first node fails and at which node half of the nodes will dies. From the output total number of rounds is less in extended fuzzy logic compare to fuzzy logic.

D. Performance Evolution

Plot graph of all the results using gnuplot the module for this is shown below. The graphs will show the difference in Existing system and the proposed system.

Advantages of the Proposed System

The proposed FLTP protocol has the ability to find nodes and maintain the route while transmission of data which is better than other protocols.
The proposed FLTP protocol is highly energy efficient when compared to FLTP.
The proposed FLTP not only detects the life time it also extends the life time.
The proposed system uses two FLC's in order to From the above graph we can analyze that as the number of increase the speed of evaluation of life time and to get more accurate results. nodes increases energy will be deducted more in case of FUZZY logic and less in EFUZZY logic.

4. Simulation Results

Scenario 1:

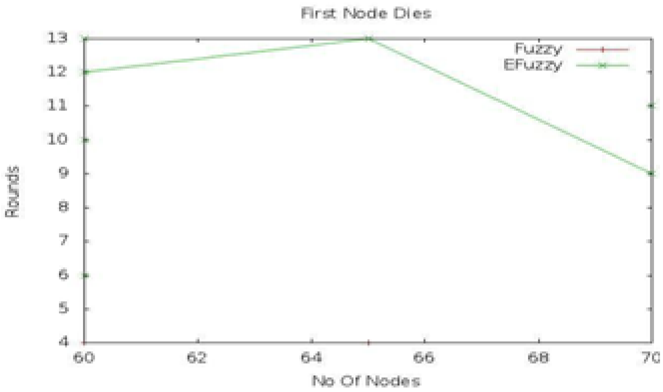

Figure 5: Graph shows No of Nodes vs Rounds

From the above graph we can analyze that first node die in less number of rounds in case of FUZZY and more number of rounds in case of EFUZZY.

Scenario 2:

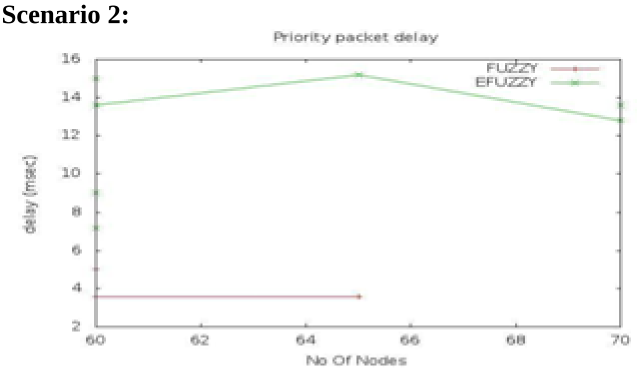

Figure 6: Graph shows No of Nodes vs. Delay for Priority Packets

Scenario 3:

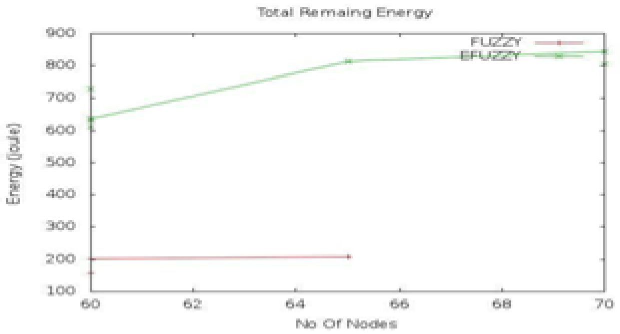

Figure 7: Graph shows No of Nodes vs. Energy

5. Conclusion and Future Work

As a result of these experiments, It has been conclude that FLTP is a stable and energy-efficient clustering algorithm for WSNs and it is a stable and energy-efficient controller for calculating the energy reduction of sensors in WSN.FLTP is used to extend the life time of sensors by changing the duty cycles of each sensors thus wastage of energy is reduced and life time is extended thus we can conclude that using this method we can predict the sensor life time and extend the lifetime of WSN. As a future work, the fuzzy clustering approach can be extended for handling mobile sensor nodes. Residual energy, distance to the base station and competition radius fuzzy sets can be adjusted in order to find optimal cluster-head radius values. In addition to this, the optimal maximum competition radius values for each scenario can be estimated by applying extensive tests. Some additional parameters such as node degree, density and local distance may also be employed to improve the performance of fuzzy clustering approach.

From the above graph we can analyze that as the number of nodes increases delay for priority packet will be more in case of FUZZY logic and less in EFUZZY logic

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