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A genetic fuzzy system based optimized zone based energy efficient routing protocol for mobile sensor networks (OZEEP)

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ABSTRACT

Wireless sensor networks have become increasingly popular because of their ability to cater to multifaceted applications without much human intervention. However, because of their distributed deployment, these networks face certain challenges, namely, network coverage, continuous connectivity and bandwidth utilization. All of these correlated issues impact the network performance because they define the energy consumption model of the network and have therefore become a crucial subject of study. Well-managed energy usage of nodes can lead to an extended network lifetime. One way to achieve this is through clustering. Clustering of nodes minimizes the amount of data transmission, routing delay and redundant data in the network, thereby conserving network energy. In addition to these advantages, clustering also makes the network scalable for real world applications. However, clustering algorithms require careful planning and design so that balanced and uniformly distributed clusters are created in a way that the network lifetime is enhanced. In this work, we extend our previous algorithm, titled the zone-based energy efficient routing protocol for mobile sensor networks (ZEEP). The algorithm we propose optimizes the clustering and cluster head selection of ZEEP by using a genetic fuzzy system. The two-step clustering process of our algorithm uses a fuzzy inference system in the first step to select optimal nodes that can be a cluster head based on parameters such as energy, distance, density and mobility. In the second step, we use a genetic algorithm to make a final choice of cluster heads from the nominated candidates proposed by the fuzzy system so that the optimal solution generated is a uniformly distributed balanced set of clusters that aim at an enhanced network lifetime. We also study the impact and dominance of mobility with regard to the variables. However, before we arrived at a GFS-based solution, we also studied fuzzy-based clustering using different membership functions, and we present our understanding on the same. Simulations were carried out in MATLAB and ns2. The results obtained are compared with ZEEP.

1. Introduction

Demand for 'Ambient Intelligent' devices has become very popular in our daily lives. Such devices are capable of sensing and controlling environmental or physical parameters such as temperature, humidity, pressure, and movement and allow remote human interactions with applications where direct intervention of humans is difficult or is impossible. Networking such embedded systems, called sensors, create a new and versatile network known as wireless sensor networks. Due to the low cost, easy integration and mass-scale production of MEMS technology, wireless sensor networks have garnered great deal of interest in a variety of applications such as the design of intelligent buildings, disaster relief, military, facility management, medicine and health care, and machine surveillance. However, such varied applications require very careful planning, design and implementation of such sensor networks so that they achieve complete coverage and connectivity for accurate detection or monitoring of events. After the sensor network deployment covering the physical space under observation, each node in a sensor network goes through multiple phases of operation. Every node starts by sensing a particular event, listening for the communication channel to be free to perform transmission of the sensed data, routing and sleeping. Fig. 1 shows these phases of operation.

The activities that are primarily responsible for energy consumption in the sensor networks are sensing events and data routing. Energy consumption by nodes varies during the sensing of events depending on whether the application requires continuous or periodic sensing of events. Accordingly, diverse studies have

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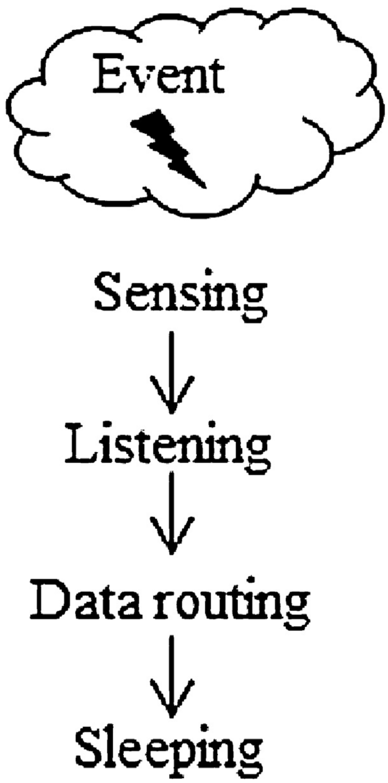

Fig. 1. Various phases of operation of a sensor node.

been performed in the literature that focus on the sleeping and sensing patterns of the nodes in the data link layer, in particular the Medium Access Control or MAC layer.

In the data routing phase, all of the sensors that are active transmit their sensed information to the sink or the base station. It is observed that in direct communication, nodes that are located close to the sink or the base station spend less energy during transmission than the nodes that are placed at greater distances from the base station or the sink node. This unequal energy consumption leads to a multi-hop routing choice and, therefore, a many-to-one traffic pattern in the network. Fig. 2 shows a diagrammatic representation of the data packet arriving from multiple sources.

An energy analysis of routing data using direct transmission reveals that as the strength of the signal reduces by square of the distance (d_i) therefore, the nodes located far away from the base station (BS) have to expend more energy in transmitting their data to the sink. The amount of energy used in direct transmission can

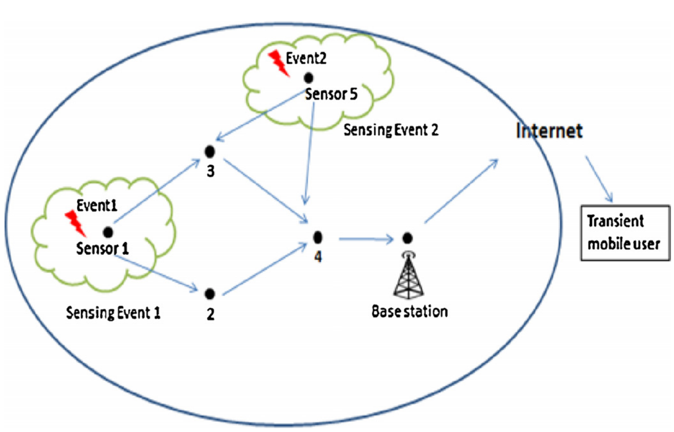

Fig. 2. Collaborative processing between multiple data sources and the base station.

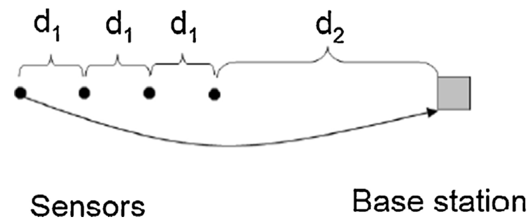

Fig. 3. Energy analysis of direct transmission.

be modeled as $\varepsilon_{\text{amp}}K\ (3d_1+d_2)^2$, where ε_{amp} is energy used by amplifier and K is constant. It is also evident that the nodes farthest from the BS die out quickly giving rise to network partitions and low network lifetime. However, in multi-hop communication, the data is carried to the sink via multiple hops through closely located nodes or neighbor nodes. The amount of energy used for data transmission in multi-hop communication is given by $\varepsilon_{\text{amp}}K(d_1^2+d_2^2)$ and is much is less due to smaller transmission distances involved when compared to direct transmission (Figs. 3 and 4 show the energy analysis).

The biggest challenge associated with these nodes is that they are extremely energy constrained and have variable channel capacity and limited bandwidth availability to perform data routing. Such networks also have redundant information and, because of best path routing, have cluttered loads on a single or a few paths compared to other available routes, giving rise to an increased unbalanced load and data losses in the network.

In such a highly resource-constrained scenario, delivering real time data and maintaining real time communication along with quality of service are very stimulating research topics, in particular when such networks exist in harsh environments with heterogeneous nodes trying to address mobility, dynamic network topology, node failures and communication failures. It is, therefore, very important for such networks to be self-configurable in nature and operate in an adhoc manner. Fig. 2 shows the collaborative processing performed by sensor nodes.

It has been observed that in reality, real world problems and applications require a network with variable size. In such networks, the number of nodes deployed grows generously, leading to an increased network size. Therefore, scalability demands a network architecture that can meet the reduced energy consumption requirement in addition to being fault tolerant, allowing load balancing, and performing efficient data routing. Clustering or grouping of sensors is a well-known two-tier architecture that has proved [1] to be a good solution for reducing network energy consumption as well as meeting the scalability requirements. Clustering of nodes allows efficient data aggregation and selection of optimal paths toward the sink. They help reduce generation of duplicate packets in the network and further save the network from message overheads for route creation every time a node has to send data. Clustering, which is a hierarchical model of data transmission, restricts participation of the nodes in dissipation of information and allows multi-hop data routing only between the cluster heads (CH). Hence, with a reduced number of nodes performing data transmission, the overall energy consumption of the network is reduced significantly, which results in an extended network lifetime. Figs. 5 and 6 represent this idea.

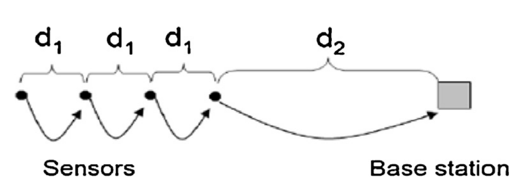

Fig. 4. Energy analysis of multi-hop transmission.