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An Efficient Routing Method for Lifetime Enhancement in Wireless Sensor Network using Fuzzy Approach

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Abstract:

In recent years, many approaches and techniques have been explored for the optimization of energy usage in wireless sensor networks. Routing is one of these areas in which attempts for efficient utilization of energy have been made. These attempts use fixed (crisp) metrics for making energy-aware routing decisions. In this paper, we present a generalized fuzzy logic based approach for energy-aware routing in wireless sensor networks. This generalized approach is soft and tunable and hence it can accommodate sensor networks comprising of different types of sensor nodes having different energy metrics.

Keywords: Fuzzy logic, Routing, Wireless sensor networks.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) can be safely identified as one of the most important technologies of recent times. Developments in the areas of VLSI, WSNs storage and power management all have contributed to this exciting area. WSNs have become increasingly popular for both military and civil applications such as target tracking, space exploration, environmental control, habitat monitoring and patient care [5, 11]. A wireless sensor network consists of a large

number of unattended, usually self-organized micro sensors, of size of the order of a cubic centimeter, scattered in an area for a specific application. Each micro sensor is capable of sensing data from the environment, performing simple computations and transmitting this data over wireless medium either directly to command centre or through some cluster head, commonly known as gateway. WSNs although have some similarities with ad-hoc networks but they differ from ad-hoc networks mainly due to their more severe energy constraints, much larger density of sensor nodes, lower cost and usually static nature of nodes. Moreover, WSNs are designed for information gathering, rather than distributed computing. Sensors nodes are battery operated and once deployed are unattended and expected to operate for a long period of time, usually from a few months to years. Thus, energy is a scarce resource in a wireless sensor network and hence its efficient usage is crucial for extending the life of the whole sensor network. A sensor's energy is mainly consumed in the three main

activities: sensing, computing and communicating fuzzy approach using the same routing mechanism in terms of energy consumption.

In wireless Sensor network sensor nodes in the large-scale data-gathering networks are generally powered by small and inexpensive batteries in expectation of surviving for a long period [3]. Fig. 1 shows the schematic diagram of components inside a typical sensor node that comprises of sensing, processing, transmission, mobilizes, position finding system and power units. It also shows the communication architecture of a WSN. Each sensor node makes its decisions based on its mission, the information it currently has, knowledge of its computing, communication, and energy resources. The node must have capability to collect and route data either to other nodes or back to an external base station or stations that may be a fixed or a mobile node capable of connecting the sensor network to an existing communication infrastructure or to the internet.

Due to limitations in the range in wireless communication sensor nodes transmit their sensed data through multiple hops. Each sensor node acts as a routing element for other nodes for transmitting data. Energy is therefore of utmost importance in power-constrained data-gathering sensor networks. Energy consumption should be well managed to maximize the network lifetime. Unbalanced energy consumption is an inherent problem in WSNs characterized by the multi-hop routing and many-to-one traffic pattern. The problem with many routing algorithms is that they minimize the total energy consumption in the network at the expense of non-uniform energy drainage in the networks. Such approaches cause network partition because some nodes that are part of the efficient path are drained from their battery energy quicker. In many cases, the lifetime of a sensor network is over as soon as the battery power in critical nodes is depleted. Therefore, in this paper, the proposed method seeks to investigate the problems of balancing energy consumption and maximization of network lifetime for WSNs. In this paper we propose combining features Fuzzy logic has been successfully applied in various areas including communications and has shown promising results [4, 7]. However, the potentials of fuzzy logic in wireless sensor networks still need to be explored for applications having conflicting requirements. Moreover, in WSN, as the energy metrics vary widely with the type of sensor node implementation platform, using fuzzy logic has the advantage of being easily adaptable to such change we therefore, present our fuzzy logic based approach for energy-optimized routing in WSNs

2. Fuzzy Model

2.1. Overview of Fuzzy Logic

Fuzzy Logic [3] is used in this work as main implementation of perceptive reasoning. Fuzzy logic imitates the logic of human thought, which is much less rigid than the calculations computers generally perform. Fuzzy Logic offers several unique features that make it a particularly good alternative for many control problems. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely. The output control is a smooth control function despite a wide range of input variations. Since the FL controller processes user defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance.

In fuzzy systems, the dynamic behavior of a system is characterized by a set of linguistic fuzzy rules based on the knowledge of a human expert. These rules are of the general form IF *antecedent*(s) THEN *consequent*(s), where antecedents and consequents are propositions containing linguistic variables. Antecedents of a fuzzy rule form a combination of fuzzy sets through the use of logic operations. Thus, fuzzy sets and fuzzy rules together form the knowledge base of a rule-based inference system. Rules are the heart of a fuzzy system and may be provided by experts or can be extracted from numerical data. In either case, the rules that we are interested in can be expressed as a collection of IF THEN statements.

Fuzzy Logic deals with the analysis of information by using fuzzy sets, each of which may represent linguistic term like “Warm”, “High” *etc*. Fuzzy sets are described by the range of real values over which the set is mapped, called domain, and the membership function. A membership function Assigns a truth value between 0 and 1 to each point in the fuzzy set’s domain. Depending upon the shape of the membership function, various types of fuzzy sets

can be used such as triangular, beta, PI, Gaussian, sigmoid *etc*. A Fuzzy system basically consists of three parts: fuzzifier, inference engine, and defuzzifier. The fuzzifier maps each crisp input value to the corresponding fuzzy sets and thus assigns it a truth value or degree of membership for each fuzzy set

The fuzzified values are processed by the inference engine, which consists of a rule base and various methods for inferring the rules. The rule base is simply a series of IF-THEN rules that relate the input fuzzy variables with the output fuzzy variables using linguistic variables, each of which is described by a fuzzy set, and fuzzy implication operators AND, OR *etc*. The part of a fuzzy rule before THEN is called predicate or antecedent, while the part following THEN is referred to as consequent. The combined truth of the predicate is determined by implication

rules such as MIN-MAX (Zadeh) and bounded arithmetic sums. All the rules in the rule-base are

processed in a parallel manner by the fuzzy inference engine. Any rule that fires contributes to the final fuzzy solution space. The inference rules govern the manner in which the consequent fuzzy sets are copied to the final fuzzy solution space. Example, techniques are MIN-MAX and fuzzy adaptive method. The defuzzifier performs defuzzification on

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the fuzzy solution space. That is, it finds a single crisp output value from the solution fuzzy space. Common defuzzification techniques are centroid, composite maximum, composite mass, *etc*. Details of the theoretical and practical aspects of fuzzy logic can be found in [6, 8].

Table 1. Fuzzy rule base.

S#	A	B	C	D	E	F	O
1	low	high	low	small	small	large	VL
2	low	high	medium	small	small	large	VL
3	low	high	medium	small	large	large	L
4	low	high	low	small	large	large	L
5	low	high	low	large	large	large	LM
6	low	medium	high	small	small	large	LM
7	low	medium	medium	large	small	small	HM
8	high	medium	low	small	small	small	HM
9	high	medium	medium	large	small	small	H
10	high	medium	medium	large	large	large	H
11	high	low	low	small	small	large	VH
12	high	low	medium	small	large	small	VH

3: PROPOSED METHOD

The topology of a WSN is design as a directed graph *G (N, A)*, where *N* is the set of nodes, and *A* is the set of direct links between the nodes. A sink node is responsible for collecting data from all other nodes within its transmission range[5].The routing schedule is computed by the base station. It calculates optimal routing schedule and broadcasts it. Every node follows this schedule. The process of ***finding*** the optimal path, and ***broadcasting*** it in the network and ***sending*** data from all nodes to the base station by following this routing schedule is repeated in every round. Computation of routing schedule is done dynamically with the consideration of current level of some criteria of each node. For this, normally it may require the nodes to report their criteria periodically to the base station. The base station can then determine the routing schedule based on this updated information.

The proposed method assumes that: 1) all sensor nodes are randomly distributed in the area and every sensor node is assumed to know its own position as well as that of its neighbors and the sink; 2) all sensor nodes have the same maximum transmission range and the same amount of initial energy; 3) each node has a certain amount of traffic pending in node's queue. The node's queue includes the application traffic and also the traffic that a node has already committed to forward. One of the important measures of WSN is the network lifetime. For the proposed model, whenever any sensor node runs out of energy, communication links between various sensor nodes and the base station will break. This is considered as the end of the network lifetime. Since the lifetime of each sensor node depends on energy consumption, it is important to preserve residual energy of these nodes in such a way that overall network lifetime is extended. The primary goal of this paper is to design a protocol that will prolong the lifetime of the WSNs through limiting energy cost as well as equal distribution of energy consumption. To achieve this, we make use of the Fuzzy approach.

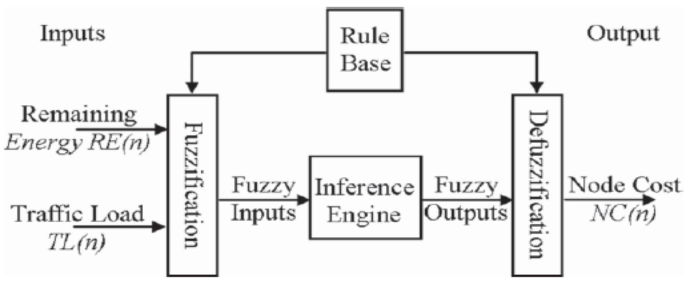
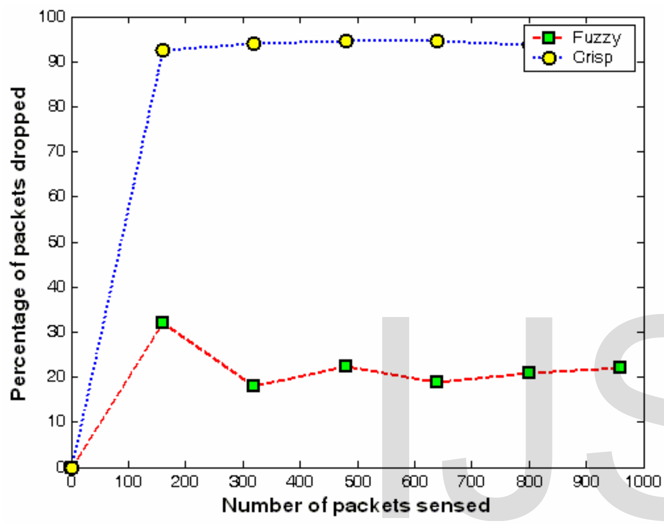


Fig 4 Fuzzy structures with (remaining energy and traffic load) and output (node cost).

4. SIMULATION RESULTS

We have simulated our fuzzy model using Matlab byrandomly deploying sensors in an area of 1000m x 1000m. The gateway was positioned at the center. Initial energy and buffer capacity of each sensor node have been taken as 5 joules and 5 packets respectively. Eighty percent of the sensor nodes have been taken to be initially in the sensing state. A node has been assumed to stop sensing when its energy level drops to zero. Simulation was run for 960 sensed packets, the size of each packet being 10k bits. For comparison with the crisp ap proach, the same scenario was simulated using non-fuzzy/crisp variables. The link cost is again determined on the basis of percentage of remaining energy of each node. Consequently, the routes are selected so as to avoid nodes with low remaining energy, thereby extending the lifetime of the sensor network. Figures 5, 6 and 7 show simulation results. We have considered a node to

be in critical state if its remaining energy becomes less than 40% of its initial energy. In Figure 5, it can be seen that fuzzy performs better than the crisp approach as the percentage of critical nodes is significantly Figure 6 compares the performance of fuzzy vs. crisp approach in terms of the minimum remaining energy at any sensor node against the total packets sensed by the network. Referring Figure 6, the lifetime of an individual node is slightly lesser in the fuzzy approach as compared to the crisp one. This decrease in an individual node's lifetime has been traded off with a much longer network lifetime as shown in Figure 5. Packet drop percentage is shown in Figure 7. Packets are dropped either due to insufficient buffer capacity at the receiver or because of the lack of energy needed to transmit the packet. Percentage of packets dropped is significantly lower for our fuzzy approach resulting in greater reliability



life-time.

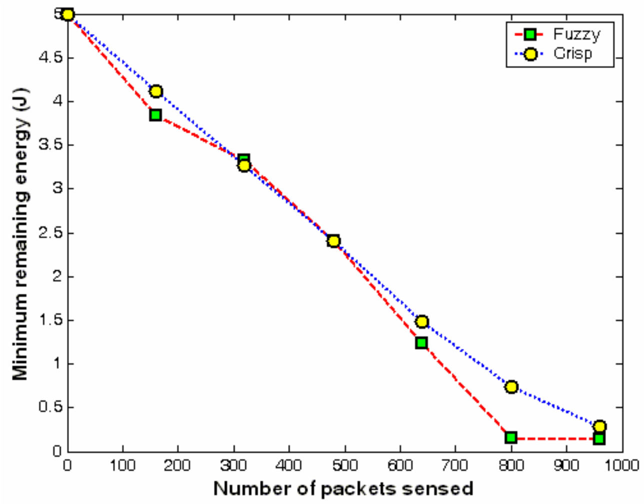


Fig 6. Sensor node lifetime.

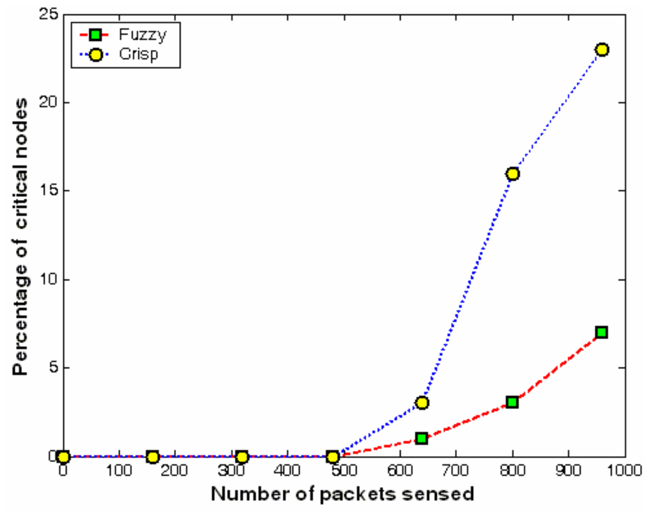


Fig7: Percentage of packets dropped.

5. CONCLUSIONS

We have presented a novel fuzzy model for energyoptimized routing in wireless sensor networks. Our simulation results have demonstrated the reliability and efficiency of this approach. Moreover, as fuzzy approach is soft it can be easily tuned for different network and node conditions simply by changing shapes of the fuzzy sets.

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