A Survey on Fuzzy Based Sensor Network and Its Applications

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ABSTRACT

Wireless Sensor Networks (WSNs) have been broadly applied in many fields such as industry, agriculture, event detection & monitoring, time critical applications and research to facilitate the gathering and distribution of information. The WSNs consist of many low cost sensor nodes. Each sensor node consists of a microprocessors and radio transceivers and can only be equipped with limited resources like power, bandwidth etc. Fuzzy logic is a recent approach to tackle few of the important decision making aspects of WSNs. Fuzzy sets provides a robust mathematical solutions for dealing with real-world problems and non-statistical uncertainty. The paper reviews few fuzzy set based solutions for WSNs applications.

Keywords— **Wireless Sensor Networks (WSNs), Fuzzy sets, Fuzzy Types, WSN applications**

I. INTRODUCTION

A. Wireless Sensor Network

Sensors are a type of transducer which is used to sense the sensory parameters like, temperature, greenhouse gases, motion etc. WSN is a network of such many sensory transducers that are used for processing the signal, machine to machine based computing, and interacting with the outer world. These smaller size and little cost sensors are having capabilities of self-adaptability and self-configurability. The work of sensing or to monitor a range of sensory environmental parameters/conditions are executed using different types of sensory transducers like chemical sensors, motion sensors, gas sensors, light and thermal sensors, biosensors etc [1-2]. The wireless channel and the multi-hop communication among nodes helps in collecting the sensed data and these data is sent to a central server point and used by user-defined applications [3]. The WSN promise the a high range of applications, for example, vachicle and wildlife monitoring, air and water quality monitoring, ozone layer monitoring, disaster monitoring, battlefield guidance, remote sensing applications, healthcare and bio- monitoring, industrial process monitoring, security and surveillance, event detection, petroleum products and mineral prediction and many - many more [2]. Thus, WSNs are becoming an integral part of the personal and professional life.

II. RESEARCH AREAS IN WIRELESS SENSOR NETWORKS

Although there are various applications of WSN, It faces to few common problems. The problem is basically due to the resource constraints in the network like, energy, bandwidth, channel conditions, reduced cost and size. Moreover, due to the distributed and ad hoc nature the network having different research areas/problems, as shown in fig 1, which are described in the following sections.

A. Energy:

A wireless sensor motes works on the battery power. There are many applications where the human intervention is not possible. For example, no man's land between two countries' borders, monitoring of lava movement inside the earth or monitoring of ozone layer above the earth etc. In these types of applications, it is not possible to change the batteries [4-5]. Therefore, sensor architecture and protocols must be designed to save the energy consumption as much as possible. Energy consumption can be optimized by power control [6], scheduling schemes [7], smart routing techniques [8] and data fusion algorithms [9].

B. Deployment

As per discussed in previous section, WSN can be used in many different applications like forest and wildlife monitoring, Intrusion detection, vehicular tracking etc. In many such applications, possibility of human intervention is very less. Therefore, the sensor nodes must be smart so that they can be deployed and start sending and receiving packets automatically. The WSN should be capable of self-configurable and self-adaptable to the environment and the situation [10-11].

C. Scheduling.

WSN is the very resource constrained network. The most important resource is the power as discussed. A sensor node should receive, send and collect the data periodically. The meaning is a sensor node is not always in working mode. Therefore, to reduce the power consumption, the nodes could be put into sleep mode. The issue is how to design the schedule for each node so that the overall WSN power consumption is minimized [12]. Moreover, the scheduling algorithm may interleave the

transmissions without or less error. The scheduling helps in reducing the collisions of the data packets [13].

D. Routing

Routing techniques are needed for sending and receiving data between different sensor nodes, coordinator nodes and the base stations or servers for communication. WSNs are usually ad-hoc in nature. A set of protocols are defined for the protocol used in Ad-hoc network of nodes. In WSN routing is quite challenging because of distributed and ad hoc nature [14].

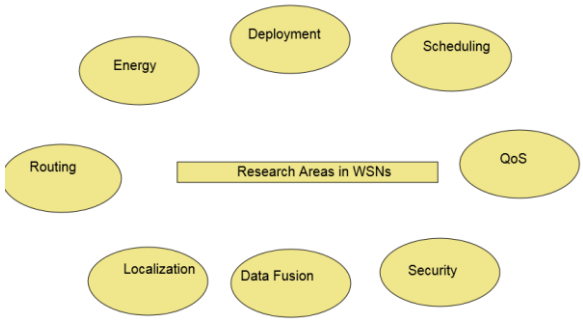

Fig 1: Research Areas in WSNs

E. Localization.

The localization techniques are used to find the spatial and temporal location of the node and event. The localization techniques are necessary because GPS cannot be installed in each sensor nodes. In many cases, the node location is part of the sensing information and is necessary for a location-aware application. There are various methods to make a sensor location-aware [15-16], but much research is needed to reduce the location error.

F. Data Aggregation

The large amount of sensors data are generated in the WSN in short span of time. If the whole data are transmitted directly, it requires high bandwidth and more power consumption. As a constrained resource, it is not affordable for a WSN. Therefore, a common design is to pre-process the aggregated data [17]. The goal is to obtain the condensed information and thus to optimized the transmission bandwidth and energy to the Sink.

G. Security

Wireless networks expose the signals to the open air. There is no dedicated path between source and destination. In addition of that, it works on multi-hopping concept. It is easy to attack the data. Depending on the application requirements, the security mechanism should be designed so that the WSN achieves adequate security level with optimal resource utilization [18].

H. **Quality of Service**.

The WSN based applications need QoS like, lesser delay, higher reliability, lesser packet – error, more secure communication. There are many QoS parameters require at each OSI layer [19]. It is common to include different QoS mechanisms in a WSN, and they should trade-off qualities among different aspects. Therefore, QoS is usually a multiobjective optimization problem [20].

III. FUZZY SETS AND FUZZY LOGIC

WSNs are distributed, dynamic and ad hoc in nature. Therefore, there is a higher level of improbability linked with the data traffic and other resources. They are subjected to unexpected network & data overloads. The WSN is also subjected to error and failures. Fuzzy logic has been proved as a promising approach to address some of such important decision making aspects of WSNs [21]. It provides a mathematical framework and support to ad hoc and distributed network. The fuzzy based system provides the reliability and robustness to the imprecision and non-statistical uncertainty. The application of fuzzy logic in communication and wireless technology is very recent and less wide than in automatic control. A research in the area finds that current work on fuzzy logic in communication widens from queuing, buffer management, and load management to routing, bandwidth allocation, network management and quantitative performance evaluation of networks [22].Fuzzy systems permit the bring into play of fuzzy based sets to decide the path and to make conclusions. Fuzzy logics vary from traditional sets in that they permit an object to be partial members of a given set. Following are the few applications of WSN where fuzzy sets based approach proves the better reliable, robust and resource optimized solution than classical approach:

A. Agriculture

The authors in [23] have presented a WSN based monitoring system for the pesticides to increase the crop yields. Viani *el al.* has designed a fuzzy logic method with WSN to estimate of the optimal pesticide dosage and application time.

Patil *et al.* [35] proposed a Fuzzy Logic Based Irrigation Control System with WSN for Precision Agriculture. Irrigation controller had been used to control the moisture level of the soil. The proposed intelligent controller was using fuzzy logic approach for precision irrigation of agricultural fields.

B. Efficient Data Gathering

Ghosh *et al.* [24] has presented a data aggregation method which uses fuzzy c means. The fuzzy c means is used to cluster the sensor motes in the networks. The simulations results show that the proposed technique outperforms other techniques in battery lifetime and increased coverage percentage. The simulation results are shown to be statistically significant.

Data aggregation and cluster based energy efficient routing algorithm [26] has been presented using fuzzy temporal rules. The work discussed about the cluster based routing for large network. The result showed that the proposed fuzzy cluster based routing algorithm increase the network life the QoS by increasing the packet delivery with reduced latency.

C. Time Critical and Real-Time Applications

Jacob *et al.* [25] has proposed a fuzzy logic based system for time critical applications which helps in industry automation. The fuzzy logic method is proposed to set the arbitration threshold to make sure that the user with higher priority would access channel immediately with low latency.

The work in [32] improves the lifetime for real-time communications. A novel fuzzy logic model has been proposed provide real-time communication in a sure WSN lifetime. A fuzzy logic controller is proposed to accept the energy, instant and speed to determine each wireless node for real-time data which is a necessity of time critical applications.

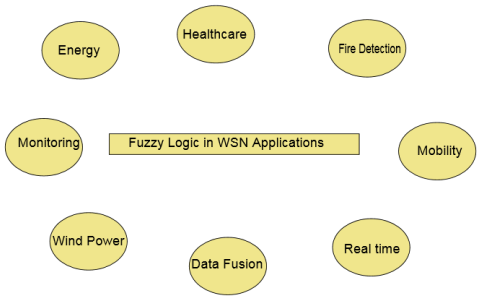

Fig 2: Fuzzy logic in WSN Applications

D. Residential fire and prediction system

Maksimovic *et al.* [27] has used two fuzzy logic approaches to monitor and determine the fire. The system optimized the number of decisions required to take the correct decisions. The system used the RESTful APIs for remote access of the sensor data. The system has given better lifetime and greater QoS like efficiency and reliability.

The work [31] has focused on wind power generation to meet the increase in power demand in future. The work has proposed a wind power prediction system with WSNs to enhance the prediction accuracy. A WSN has been used to sense air temperature, speed, pressure and density. The data has been clustered by modified Fuzzy C-Means (FCM) to decide the best number of fuzzy decision rules.

E. Fusion

Zhang *et al.* [28] has given a multi-attribute decision fusion model based on intuitionistic fuzzy set and WSN Data fusion technique. The results show the efficiency of intuitionistic fuzzification for the proposed algorithm is high compared with classical fuzzy fusion.

F. Event Detection

The work [29] has proved that fuzzy logic is a powerful and accurate mechanism to detect an event in WSNs. The empirical results had shown that the proposed rule-base reduction techniques are efficient and preserve both the accuracy and the efficiency of event detection.

Sharma *et al.* [34] has proposed two range free localization algorithms for 3D space in anisotropic environment using the application of bacterial foraging optimization (BFO) and invasive weed optimization (IWO). To reduce the calculation difficulty and to model the edge weights, the authors have used fuzzy logic system in work. The results show the better performance of the proposed localization than the others in term of accuracy and scalability.

G. Mobility Support

Mobility support layer, MoMoRo, has been proposed [30] to support mobility in WSN for data collection. It is based on fuzzy based estimator to take decision on link quality estimations. It works with IPv6 and gives better results than AODV protocol.

H. Healthcare

Chiang *et al. [*33] has introduced a fuzzy based computing model for healthcare applications. The body moves are measured by the body sensor. It combines with both acceleration based meter and gyroscope to make a sensing node submissive with a WSN. The fuzzy set progress was calculated to determine the sensor value that would require necessary features of static positions and active positions.

IV. CONCLUSION

Fuzzy logic is a recent approach to tackle few of the important decision making aspects of WSNs. Fuzzy sets provides a robust mathematical solutions for dealing with real-world problems and non-statistical uncertainty. The paper reviews few fuzzy set based solutions for WSNs applications

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