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ADAPTIVE FUZZY LOGIC BASED QoS MANAGEMENT IN WIRELESS SENSOR NETWORK

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***Abstract*—In this paper, the state of the art Quality of Service (QoS) support in Wireless Sensor Network (WSN) is analyzed. Unlike traditional end-to-end multimedia applications, many non-end- to-end mission critical applications visualized for WSN have brought forward new QoS requirements. As an attempt in this direction, an Adaptive Fuzzy logic control based QoS management scheme (AFLC-QM) scheme for WSN's with constrained resources and dynamic environment is proposed. This scheme deals with the impact of unpredictable changes in traffic load on the QoS of WSN's. Coverage, lifetime, node density and energy cost are chosen as input parameters. A bell shaped membership function is chosen to analyze the effect of these input parameters on the QoS of the system as it provides low rise and fall time. Then a Fuzzy Logic Rule Base (FLRB) is applied to take the desired decision to improve the QoS. The system results are studied and compared using MATLAB. It gives satisfactory performance and can be easily embedded in real-time system.**

Keywords—*wireless sensor network, quality of service (QoS), fuzzy logic control.*

I. Introduction

Wireless Sensor Network (WSN) is a collection of several thousands of low cost, low battery powered devices known as sensor nodes which are capable of sensing, actuating, andrelaying the collected information. Each sensor node integrates a processor, memory, and transceiver and power source in one small device and has the ability to observe process and send data about the observed phenomenon to its neighboring nodes destined to a central processing unit often called as sink. As the resources are limited so they are needed to be used efficiently.

A sensor node should be able to process as much information locally as possible instead of just disseminating raw data in order to save energy, because of the fact that radio frequency (RF) communication is the key energy consumer [1]. The arena of WSN expands from sensing, actuating and processing, to information gathering in harsh weather, climate monitoring and radio transmission-reception [2]. WSN finds many applications in various fields such as military surveillance, environmental monitoring, habitat monitoring, wildlife protection, industrial control, home automation and security, area monitoring, health monitoring and asset tracking.

Wireless sensor networks are most suitable for highly dynamic applications, and hostile environments with no human existence (unlike conventional data networks), and therefore, they must be tolerant to the failure and loss of connectivity of individual nodes. The sensor nodes must be intelligent enough to recover from failures with minimum human involvement. As WSN's are growing as the key area of research and investments some important aspects of WSN's such as architecture and protocol design, energy consumption and localization and Quality of Service (QoS) support in WSN's are still under investigation [5].

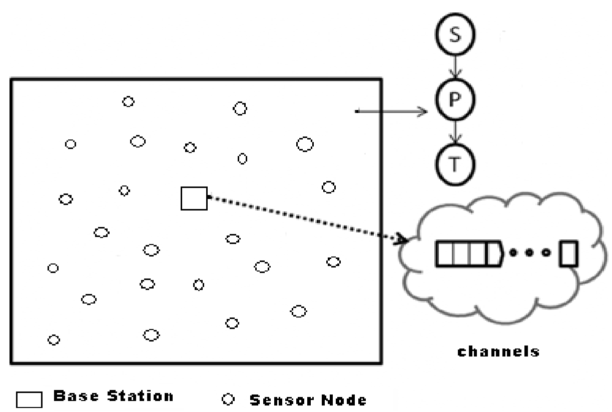

Figure 1: Simple WSN Model

II. QoS in WSN

Quality of Service aims at providing better networking services over current technologies like ATM, Ethernet and others. QoS requirements in traditional data networks arise from the rising demand of end-to-end bandwidth hungry multimedia applications. For example, in an end-end user application such as Internet, QoS refers to an assurance by the Internet to provide a set of measurable service attributes to the end users in terms of throughput, delay, available bandwidth and packet loss. For judging the quality of a networking protocol, QoS is referred to as the measure of the service quality that a network offers to the application users.

A holistic perspective on QoS in WSN deals with a number of factors such as mobility, reliability, heterogeneity, energy-efficiency, timeliness, scalability and cost-effectiveness. Heterogeneity refers to the ability to share same network infrastructure supporting several applications/services. This requires interoperability between sensor/actuator-level and higher-level protocols. Energy concern is always present in WSN as they are comprised of embedded devices at large-scale with most of them communicating through air (wirelessly). Therefore most of the devices must be self-sustainable (energetically) but this does not mean that all devices need to be autonomous in terms of energy. Timeliness is defined as the timing behaviour of a system and is reflected in properties such as network throughput, effective bit rate and message delays. Scalability refers to the capability of a system to easily/transparently adapt itself to variations in the number of nodes, nodes spatial density and geographical region under coverage. Computational and sensing power grows linearly with the number of sensor nodes. System cost usually includes issues such as system design/development, hardware cost, deployment and commissioning, exploration and maintenance. Reliability is the ability of a component or system to perform its required functions under stated conditions for a specified period of time. Mobility support can be very helpful in terms of improving network coverage, to adapt to dynamic stimulus changes (collect data upon event) and ultimately to increase user satisfaction.WSN differs dramatically from the traditional real-time systems due to its wireless nature, limited resources (power, processing and memory), low node reliability and dynamic network topology. Thus, QoS requirements generated by the application of WSN's are very different and cannot be satisfactorily defined by the traditional end-to-end QoS parameters. For applications involving event detection and target tracking, the failure to detect or extracting incorrect information regarding any physical event may arise due to various reasons These may include to fault in node deployment and network management which means that the area of occurrence of event may not be covered by sufficient no. of active sensors. Thus we can define 'Coverage' or the number of active sensors as a parameter to measure the QoS in WSN's [4][9].
Another challenging factor is the efficient use of available resources such as energy consumption of the sensor node and available bandwidth. In this paper, we have studied about the effect of some dependent parameters which directly or indirectly affects the QoS of WSN. These are Coverage, Lifetime, Node density and Energy cost [7].

III. Packet Loss probability in WSN

QoS in WSN can be found out in terms of throughput, probability of packet loss, latency etc. Here, a WSN consisting of 50 nodes deployed over an area of 500x500 sq. m is shown in Fig 2.

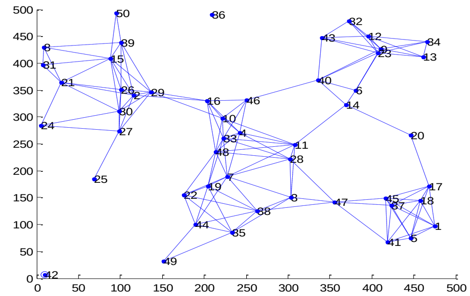

Figure 2: Nodes deployed over an area of 500x500 sq. m

In our work, we have assumed that all the nodes send data to the sink node. The probability of packet loss for different arrival rate of packets is plotted in Figure 3. The data rate is assumed to be 256 Kbps and the packet size 512 bits. So the packet arrival rate is 500 packets / sec. from figure 3, it is seen that for 500 packets/sec the probability of packet loss is 2%. So the throughput is 98% provided packets do not collide.

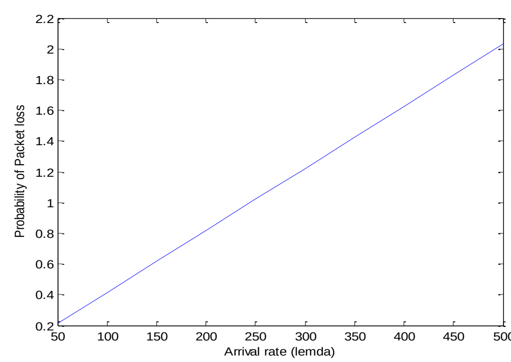

Figure 3: Probability of packet loss vs. arrival rate

Under real operating conditions, packets will collide and throughput will decrease. So, for increased throughput we have proposed a fuzzy logic based scheme where the decision will be based on various parameters.

IV. Fuzzy Logic Based QoS Management Model

Fuzzy logic is a multivalued logic which allows intermediate values to be defined between conventional evaluations like true/false, yes/no; high/low etc.Fuzzy logic provides an alternative way to represent linguistic and subjective attributes of the real world in computing.It is able to be applied to control systems and other applications in order to improve the efficiency and simplicity of the design process.The model of the fuzzy controlled system for QoS management is shown in Figure 4.

The linguistic variable is kept to be LOW, MEDIUM and HIGH for coverage, lifetime, node density and energy cost. Membership functions are shown in Figures 5, 6, 7 and 8 respectively. Bell shaped membership functions are used because it gives low rise time and lower number of fluctuations [7]. Based on the knowledge on the linguistic variable 27 IF THEN ELSE fuzzy rules are used to take decision for enhancing the QoS of WSN.

Linguistic rules used here are Mamdani because this type of fuzzy rule based system (FRBS) provides a natural framework to include expert knowledge. This knowledge describes the relation between system inputs and output, can be easily combined with rules. Mamdani type FRBS provides an easier way to select the most suitable fuzzification and defuzzification interface components as well as the interface method itself. Mamdani type FRBSs also provide a highly flexible means to formulate knowledge, while at the same they remain interpretable [3]. The proposed fuzzy Logic Rule Base is shown in Table 1.

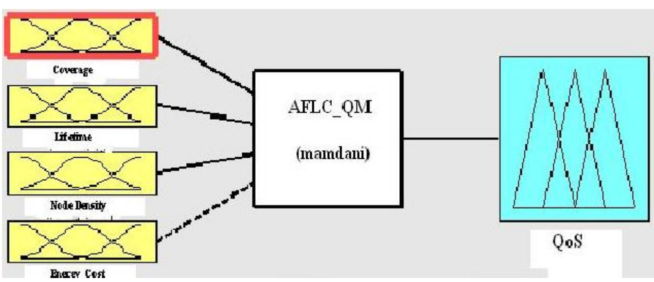

Figure 4: Proposed Adaptive Fuzzy Controlled WSN Model

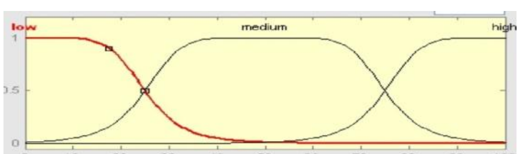

Figure 5: Membership function for Coverage

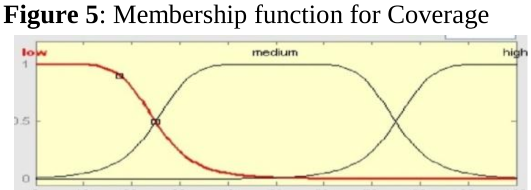

Figure 6: Membership function for Lifetime

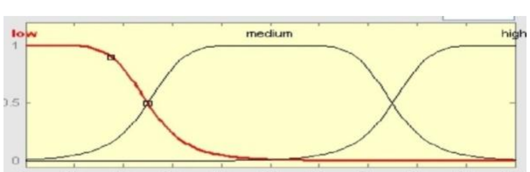

Figure 7: Membership function for Node Density

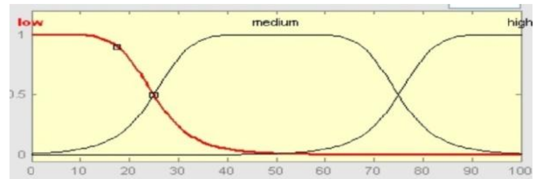

Figure 8: Membership function for Energy Cost

Table 1: Proposed Fuzzy Logic Rule Base

Rule no.	*Coverage*	*Lifetime*	*Node Density*	*Energy Cost*	*Output QoS*
1.	Low	Low	Low	Low	Poor
2.	Low	Low	Low	Medium	Poor
3.	Low	Low	Low	High	Poor
4.	Low	Low	Medium	Low	Medium
5.	Low	Low	Medium	Medium	Medium
6.	Low	Low	Medium	High	Poor
7.	Low	Low	High	Low	Medium
8.	Low	Low	High	Medium	Medium
9.	Low	Low	High	High	Poor
10.	Low	Medium	Low	Low	Medium
11.	Low	Medium	Low	Medium	Medium
12.	Low	Medium	Low	High	Poor
13.	Low	Medium	Medium	Low	Medium
14.	Low	Medium	Medium	Medium	Medium
15.	Low	Medium	Medium	High	Poor
16.	Low	Medium	High	Low	Good
17.	Low	Medium	High	Medium	Good
18.	Low	Medium	High	High	Poor
19.	Low	High	Low	Low	Medium
20.	Low	High	Low	Medium	Medium
21.	Low	High	Low	High	Poor
22.	Low	High	Medium	Low	Medium
23.	Low	High	Medium	Medium	Medium
24.	Low	High	Medium	High	Poor
25.	Low	High	High	Low	Good
26.	Low	High	High	Medium	Good

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27.	Low	High	High	High	Medium
28.	Medium	Low	Low	Low	Medium
29.	Medium	Low	Low	Medium	Poor
30.	Medium	Low	Low	High	Poor
31.	Medium	Low	Medium	Low	Medium
32.	Medium	Low	Medium	Medium	Medium
33.	Medium	Low	Medium	High	Poor
34.	Medium	Low	High	Low	Good
35.	Medium	Low	High	Medium	Medium
36.	Medium	Low	High	High	Poor
37.	Medium	Medium	Low	Low	Medium
38.	Medium	Medium	Low	Medium	Medium
39.	Medium	Medium	Low	High	Poor
40.	Medium	Medium	Medium	Low	Good
41.	Medium	Medium	Medium	Medium	Medium
42.	Medium	Medium	Medium	High	Poor
43.	Medium	Medium	High	Low	Good
44.	Medium	Medium	High	Medium	Medium
45.	Medium	Medium	High	High	Poor
46.	Medium	High	Low	Low	Medium
47.	Medium	High	Low	Medium	Medium
48.	Medium	High	Low	High	Poor
49.	Medium	High	Medium	Low	Medium
50.	Medium	High	Medium	Medium	Medium
51.	Medium	High	Medium	High	Poor
52.	Medium	High	High	Low	Good
53.	Medium	High	High	Medium	Medium
54.	Medium	High	High	High	Poor
55.	High	Low	Low	Low	Poor
56.	High	Low	Low	Medium	Poor
57.	High	Low	Low	High	Poor
58.	High	Low	Medium	Low	Medium
59.	High	Low	Medium	Medium	Medium
60.	High	Low	Medium	High	Poor
61.	High	Low	High	Low	Medium
62.	High	Low	High	Medium	Medium
63.	High	Low	High	High	Poor
64.	High	Medium	Low	Low	Medium
65.	High	Medium	Low	Medium	Medium
66.	High	Medium	Low	High	Poor
67.	High	Medium	Medium	Low	Medium
68.	High	Medium	Medium	Medium	Medium
69.	High	Medium	Medium	High	Poor
70.	High	Medium	High	Low	Good
71.	High	Medium	High	Medium	Medium
72.	High	Medium	High	High	Poor
73.	High	High	Low	Low	Good
74.	High	High	Low	Medium	Medium
75.	High	High	Low	High	Poor
76.	High	High	Medium	Low	Good
77.	High	High	Medium	Medium	Medium
78.	High	High	Medium	High	Poor
79.	High	High	High	Low	Good
80.	High	High	High	Medium	Good
81.	High	High	High	High	Good

V. Experimental Results

The proposed model is simulated using MATLAB [8]. The results are shown in Figures 9, 10, 11, 12 and 13.

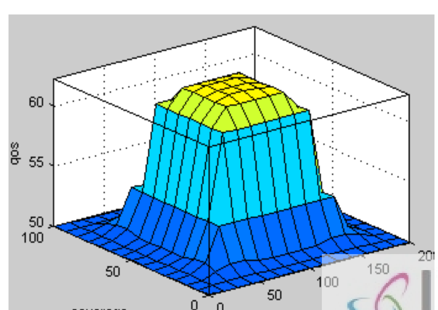

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Figure 9: Output QoS vs. Coverage & Lifetime

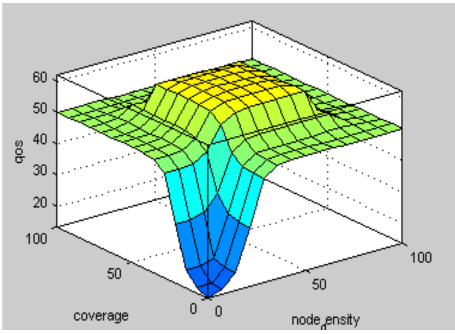

Figure 10: Output QoS vs Coverage & Node Density

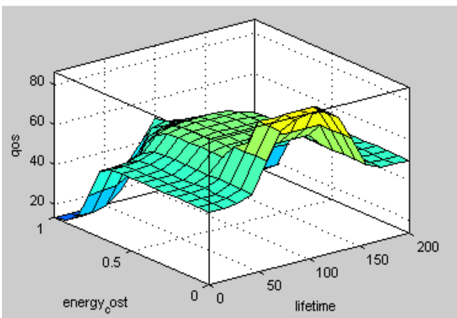

Figure 11: Output QoS vs. Energy Cost& Node Density

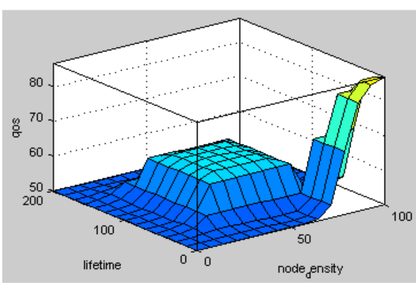

Figure 12: Output QoS vs. Node Density & Lifetime

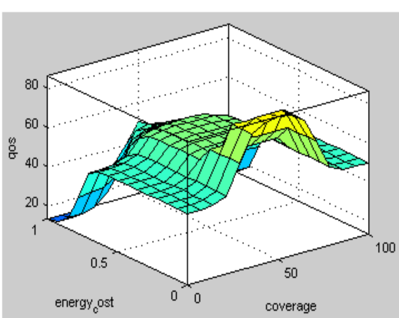

Figure 13: Output QoS vs. Energy Cost & Coverage

VI. Conclusion and Future Work

In this paper, a fuzzy logic based approach for QoS Management in WSN. Packet loss is estimated for a randomly deployed network. Simulation results show that our implementation particularly works well with increased network traffic, that is, with increased packet generation rate .The response of the fuzzy model is then found out and it seems to be satisfactory. The program is not complex and can be easily embedded in real system. Our algorithm works especially well, ensuring the efficient delivery of prioritized event-driven packets.

The future work includes application of the model in a WSN scenario and performance study of the same. Other future work includes improvement of AFLC-QM scheme for large-scale WSN's and practical implementation of AFLC-QM scheme in a real-time scenario.

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