Fuzzy Analysis for Nodes Deployment Strategies in Wireless Sensor Network

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Abstract:- The objective of a best sensor deployment policy is to have a fully connected network while optimizing coverage area at the same time. By optimizing the different parameters like distance, energy level, transmission loss and density of sensor nodes. the deployment plan would guarantee the optimum connectivity of sensor nodes, as required by the essential applications. By making sure that the network is connected, it is also ensured that the sensed data is transmitted to other nodes and perhaps to a centralized base station that can make important decisions for the application. This paper investigates the fundamental parameters of a wireless sensor network: that is optimization of node density, transmission range, transmission loss, residual energy and connectivity.

Keywords: *sensor networks, connectivity, node degree, isolated nodes; analytical methods, modeling, RSSI ,fuzzy inference system ,geometric random graphs.*

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1. Introduction

A wireless sensor network is a topological ordering of hundreds to thousands of sensor nodes that is deployed either randomly or in accordance with some predefined distribution orders, over a geographic region of importance. A sensor node by itself has severe limitations, like low power, limited processing capabilities, low communication range, and a few byte of memory capacity; hence it can operate only in a limited region of interest. However, when a collection of sensor nodes work in partnership with each other, they can achieve higher capabilities efficiently. One of the most important advantages of deploying a wireless sensor network is its capability to operate in harsh conditions. In present era every device needs to be connected wirelessly like washing machine, Air conditioner, microwave oven etc. more or less all devices are working on principle of wireless sensor network. Wireless sensor network works on ad hoc basis, that is there is no fixed infrastructure and each node can communicate with each other. Sensor nodes are sprinkled in a sensing field with variation in node densities. Typical node densities may ranges from 3 meter apart to as high as 20 nodes/m^3. Each node with in a WSN has a sensing radius in which it can sense data and a communication radius with in which it can transmit the data to another node [1]. One important condition for being able to implement an efficient sensor network is to find best possible node deployment strategies. Deploying nodes in large area needs best topology control methods [2]. The energy dissipated by radio transceivers is a major factor limiting the life span of wireless sensor networks. To increase energy efficiency there is a need for innovative method in node deployment and in protocol for data transmission. The physical dimensions and node density greatly influence the transmission range in wireless sensor network.

In this paper, we discuss mainly the node deployment issues that are related to area coverage, energy and transmission loss, node density with respect to node connectivity in wireless sensor networks.

2. Path loss with respect to inter sensor distance

In certain applications, it is possible to know in advance the probability distribution of distance in between neighboring sensors. Sensor network localization techniques can estimate the location of sensors with unknown location information by using inference of inter-sensor measurements of known locations. The inter-sensor measurement techniques can be classified in to three categories: received signal strength measurement (RSS), angle of arrival (AOA) and propagation times based measurement. Received signal strength indicator (RSSI) has become a standard in most of wireless applications because of their simplicity due to no additional hardware required in such measurements. In field experiments, it is found that the signal strength is affected by three factors: path-loss, fading and shadowing. Where path loss is directly proportional to decrease in power of an electromagnetic wave[3]. This attenuation is represented by the path-loss exponent[10]. Whose value generally lies in between 2 to 6.whereas fading is the deviation in attenuation. Shadowing is loss of signal due to obstacle in between a transmitter and receiver [4].The received signal power loss is given by equation

$$PL(d) = PL(d_0) - 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma \qquad (1)$$

Where $PL(d)$ the received signal power loss generally expressed in decibel-mill watts (dBm). d is the distance in between transmitter and receiver. d_0 is the reference distance. n is the path loss exponent varies in between 2 to 6. $PL(d_0)$ is the path loss expressed in decibel-mill watts at the reference distance. X_σ replicate the random variation in the path loss due to multipath and shadow fading. In general equation (1) is simplified as shown

$$RSSI = A - 10n\log_{10}(d) + X_\sigma \qquad (2)$$

Where A denotes the received signal strength on reference range.

3. Node Connectivity Vs Node Density

Geometrical representation of sensor network is modeled as a graph with sensor nodes as vertices and the communication link as edge. the graph is said to be connected if there exist a communication link in between two nodes may be it is direct known as single hop or indirect known as multi-hop communication. a sensor node is said to be fully connected if there is a communication link in between every node within the sensor network. The degree of a node is said to be k connective if removal of k-1 edge does not make the sensor disconnected [1]. Single node connectivity is not desirable for many sensor network applications because single node failure can lead entire sensor network functioning to halt .the robustness and throughput of sensor network are directly related to connectivity. So ultimate goal of an optimal sensor deployment is to achieve the globally connected network while covering the sensing region. Each sensor node has a communication radius r that forms an effective area of communication As. For non overlapping sensor nodes.

$$K.As \cong A \qquad (3)$$

$$K\pi r^2 = \pi R^2 \qquad \Rightarrow \qquad r = \frac{R}{\sqrt{K}}$$

i.e. $$r \propto \frac{1}{\sqrt{K}} \qquad (4)$$

From equation (4) we infer that as sensor density increase by a factor of k, then the communication radius of each sensor node get reduced by a factor of $\frac{1}{\sqrt{K}}$

The introduction of new nodes minimizes the distance of signal transmission by sensor nodes. Also it leads to creation of alternative routes for relay.

Let us consider the acoustic sensing device in 2D-plane communication for a distance r.

Where receiving signal power P_r is directly proportional to transmitted signal power and inversely proportional to square of distance in between transmitter and receiver.

$$P_r \propto \frac{P_r}{r\propto} = \frac{P_t}{r^2}$$

$$SNRr = 10\log\frac{P_r}{Pnoise} = 10\log P_t - 10\log P_{noise} \quad -20 \qquad (5)$$

$$SNR_{\frac{r}{\sqrt{K}}} = 10\log P_t - 10\log P_{noise} - 20\log\frac{r}{\sqrt{K}} \qquad (6)$$

SNR detection advantages can be derived by subtracting (5) from (6)

$$SNR_{\frac{r}{\sqrt{k}}} - SNR_r = 20\log\frac{r}{\frac{r}{\sqrt{k}}} = 10\log\log k \qquad (7)$$

From equation (7) it is found that by increasing the sensor density by a factor of k, improves the source to noise ratio (SNR) at a sensor node by 10log db.

4. Error in data transmission

Errors can occur in different patterns and quantity**.** There are many factors that contribute to error in data transmission with in wireless sensor network. Some of the major factors that cause the error are channel noise, interference, signal distortion, and bit synchronization. errors can occurs at random and independent intervals. Probability that a packet of size L bit received in error [6] is given by the equation :

$$P_p = 1-(1-P_e)^L \qquad (8)$$

Where P_e is the bit error rate (BER) and is defined by

$$BER = \frac{\text{incorrect error after decoding}}{\text{total number of bits decoded}} \qquad (9)$$

For very small packet error probability (Pe) :

$$P_p = P_e L \qquad (10)$$

5. Fuzzy Inference for optimum connectivity of Nodes

Fuzzy inference is the technique of formulation of analysis from a given input to an output using fuzzy logic .on the basis of this mapping decision can be made. The fuzzy inference system contains membership functions, fuzzy logic operators and if-then rules. Fuzzy inference system has been successfully applied in the fields of automatic control, data classification, decision making, and expert system as well as in computer vision. Fuzzy logic in fact a precise problem solving methodology. Fuzzy logic differs from classical logic in that statement is not black or white, true or false [5]. In traditional logic an object take on a value of zero or one. In fuzzy logic a statement can take any value in between 0 and 1.representing the degree to which an element belongs to a set. Fuzzy inference methods are classified in direct and indirect methods. Direct methods are Mamdani and Surgeon's are most commonly used. In this paper, there is use of fuzzy inference system to find out the optimum connectivity with in the sensor nodes by considering the various factors that affects the communication within the sensor network.

5.1 Fuzzy inference for distance and Energy with respect to node connectivity:

To achieve full connectivity it is made sure that large percentages of nodes are connected consequently increases the energy requirement. From the figure we can infer that we can achieve the full connectivity within the sensor nodes if the distance lies within a range of 0 to 5 meter apart and the energy of the sensor nodes is up to 70 to 100%.with increase in the distance between the sensor nodes with respect to decrease in energy level there is a drastic reduction in the connectivity. From figure 1.it is clear that the connectivity of sensor nodes is related to position of nodes, and these position are affected by deployment methods and energy levels of each node with in a sensor network.

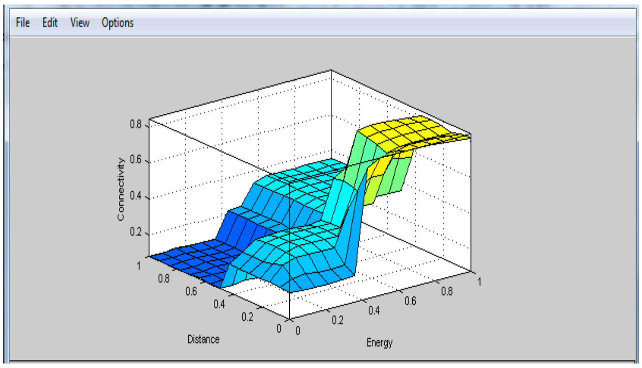

Figure1.variation of connectivity with respect to distance and energy level of sensor nodes.

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5.2 Fuzzy inference for distance of sink node and node density

The density of nodes is optimized based on the distance of nodes while ensuring the connectivity and coverage. in general ,the sensor that are in proximity of sink tend to consume more energy due to they are heavily involved in communication process and this disparity seriously affect the connectivity. From equation 4 it is already proved that transmission radius is inversely proportional to node density. If the node density is higher, as a result we can achieve the full connectivity within the sensor nodes.

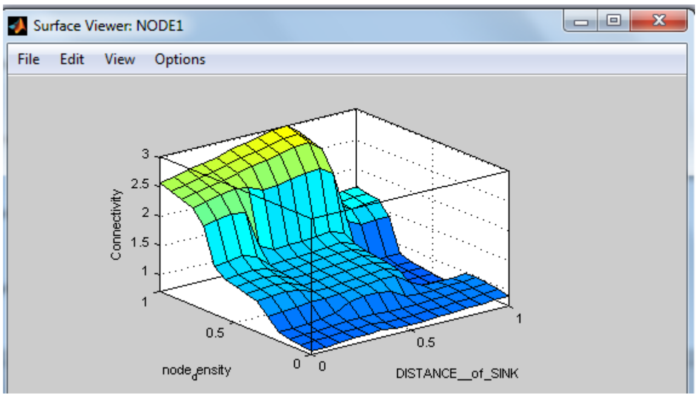

Figure 2.variation of connectivity with respect to distance and node density.

From fuzzy analysis of figure 2, it is found that the node density greatly effects the connectivity if the node density is higher, then we can achieve the full connectivity. But if the distance of sink node is larger than the data transmission is affected. We can achieve the full connectivity if the distance of sink node is half of node density.

5.3 Fuzzy inference for connectivity with respect to transmission loss and distance

The variation in transmission that is mainly caused by environmental factor such as surface activity for a particular sensor network scenario causes the interruption in the connectivity. The life of a sensor network depends on the data transmission until certain nodes depletes their energy below their threshold value. from fuzzy analysis in figure 3. It is found that connectivity within the sensor nodes is better till the transmission loss is up to 50 % from original value with respect to distance at optimal level[8]. As the inter nodal distance increases connectivity drastically reduced and reached zero level.

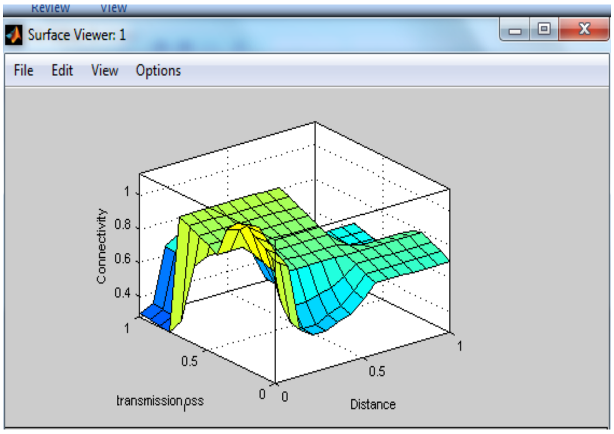

Figure3.variation of connectivity with respect to distance and transmission loss.

5.4 Fuzzy inference for connectivity with respect to energy and node density

In a dense network there is more processing for mutual authentication of nodes and are sometimes detrimental for energy loss, network performance and quality of service.inspite of these factors wireless sensor techniques encourages us to use dense network to obtain the better performance as it encourages the coordination between the nodes. Node density directly proportional to transmission range and energy of sensor nodes. From fuzzy analysis of figure 4 it is found that connectivity is directly proportional to node density and energy of sensor nodes.

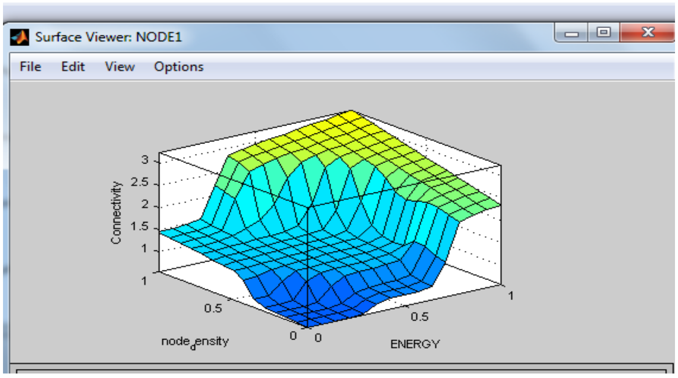

Figure 4.variation of connectivity with respect to energy and node density.

6. Conclusion

Fuzzy inference of various factors concluded that lifetime of a sensor network is a function of energy consumed; which in turn primarily a function of transmission radius, data transmission distances along with certain other factors like node density. All these factors directly influence the connectivity within the sensor network. Even it is impossible to minimize the environmental factors those hinder the connectivity but the optimum use of node deployment policies greatly influence the network life and maximize the data transmission rate. We investigated the node density impact on connectivity. We also investigated that as node density increase the energy level for data transmission which results in better connectivity. We also investigated that transmission loss up to certain level may not greatly affect the connectivity. We also investigated that the energy level is inversely proportional of distance in between the sensor nodes.

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