Original Article

International Journal of Fundamental Research

Volume 1 Issue 1 (June - 2026) ISSN – xxxx-xxxx

Application of Fuzzy Logic in Wireless Sensor Network for Energy Efficient Protocol.

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ARTICLE INFO

Keywords:
Fuzzy Logic
Wireless Sensor Network
Complete bipartite graph

ABSTRACT

In the last three decades, fuzzy logic has become one of the most important research tools in the application field of computer science and other areas. Fuzzy logic provides a way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, or missing input information. Fuzzy logic has proven capable of modelling highly nonlinear and multidimensional processes. Energy efficiency is the foremost criteria in the field of wireless sensor networks. This paper deals with the application of fuzzy logic in wireless sensor networks for an energy-efficient protocol.

1. INTRODUCTION

Wireless sensor networks are typically used for information gathering in applications like habitat monitoring, military surveillance, agriculture and environmental sensing, and health monitoring. The primary functionality of a wireless sensor network is to sense and monitor the state of the physical world. In most cases, they are unable to affect the physical environment. However, in many applications, observing the state of the physical system is not sufficient, it is also expected to respond to the sensed events/data by performing corresponding actions on the system. Featuring coexistence of sensors, wireless sensor networks enable the application systems to sense, interact, and change the physical world. They can be deployed in lots of applications such as disaster relief, planet exploration, intelligent building, home automation, industrial control, smart spaces, pervasive computing systems, and cyber-physical systems. In all application sensor is main component of wireless sensor networks that perform the basic operations. But a single sensor node has limited capability in sensing and is not sufficient for gathering useful information from a specific domain. This data gathering process can be accomplished by the collective work of a number of sensor nodes.

2. FUZZY LOGIC AND WIRELESS SENSOR NETWORKS

In the literature, there exist several techniques oriented to improve the performance of routing approaches for wireless sensor networks. Most of these techniques are focused on changing the metric used to optimize parameters in order to determine the best path between source and destination, reduce the number of packets used, or reduce the end-to-end delay, among others [8].

The use of fuzzy logic to optimize the metric used in routing approaches for wireless sensor network is a promising technique since it allows combine and evaluate diverse parameters in an efficient manner. Moreover, several proposals have shown that the use of fuzzy logic in this kind of networks is a good choice due to the execution requirements can be easily supported by sensor nodes,

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View Online: https://pub.aietr.ac.in/IJFR/view-article?pii=S0000000026961273
Received 02 Feb 2026; Revised 04 Mar 2026; Accepted 09 Apr 2026; Available online 12 Apr 2026
Published 15 June 2026.
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while it is able to improve the overall network performance.

Fuzzy logic is used in [1] to perform link quality estimation. The system takes as input the information about link capacity to transport information, asymmetry, and stability and channel quality. The experiments in a network in which all nodes are reachable from the base station show improvements in terms of reliability and stability.

In [2] is presented a method based on fuzzy logic and implemented in ZigBee nodes, with the aim of reducing the on/off frequency of an air conditioner system. To do that, they use as input variables the temperature, humidity, fan speed, and engine speed [9, 12]. The experiments show good results compared to a traditional control system based on discrete temperature values.

An example of the use of fuzzy logic in routing for wireless sensor network is LEACH-FL [3], where the selection of cluster-heads is based on several variables: node battery level, node density and distance to the base station. The experiments show that the use of fuzzy logic helps to reduce the energy consumption, so extending the overall network lifetime. Another example of fuzzy logic in wireless sensor network routing is [4-7] where the metric of the Tree Routing protocol used in ZigBee is replaced with the output of a fuzzy-logic based mechanism that allows a reduction in the path length, in the network discovery time and in the number of forwarding nodes.

3. Complete Bipartite Graph

In the mathematical field of graph theory, a complete bipartite graph or biclique is a special kind of bipartite graph where every vertex of the first set is connected to every vertex of the second set.

A complete bipartite graph, $G:=(V_1+V_2,E)$, is a bipartite graph such that for any two vertices, $v_1 \in V_1$ and $v_2 \in V_2, v_1v_2$ is an edge in G. The complete bipartite graph with partitions of size $|V_1|=m$ and $|V_2|=n$, is denoted $K_{m,n}$.

4. Proposed Method in Wireless Sensor Network

Transmission of information from node N_i to N_j carried out under best circumstances. The word best circumstance is not precisely defined. It is the node (at appropriate distance chosen by decision maker from destination) having enough power. These enough power and appropriate distance are linguistic variable assuming multiple values. The state of the node N_i is determined by the ratio of power and distance.

Let $P=$ set of different powers $=\{p_1,p_2,p_3,p_4,p_5\}$, where $p_1=$ very low, $p_2=$ low, $p_3=$ medium, $p_4=$ approximately medium, $p_5=$ very high.

Let $D=$ set of different types of distances $=\{d_1,d_2,d_3,d_4,d_5\}$,where $d_1=$ very short, $d_2=$ short, $d_3=$ middle, $d_4=$ approximately middle, $d_5=$ very long

So, the input variable at the source node and output variable at the sink node are linguistic variables. The complete bi-partite graph is given by fig 1.

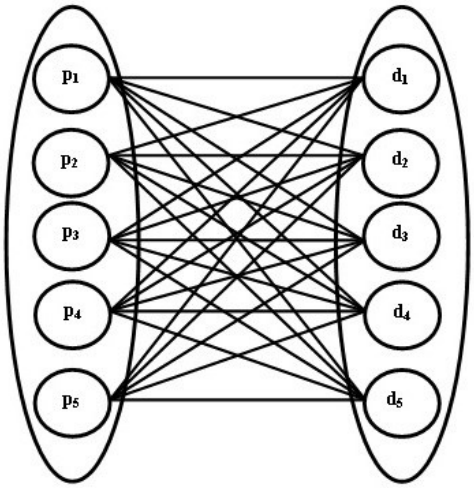


Fig 1.

$G=(V,E)$ where $V=\{p_1,p_2,p_3,p_4,p_5,d_1,d_2,d_3,d_4,d_5\}$ and $E=\{Sp_{11},Sp_{12},Sp_{13},Sp_{14},Sp_{15},Sp_{21},Sp_{22},Sp_{23},Sp_{24},Sp_{25},Sp_{31},Sp_{32},Sp_{33},Sp_{34},Sp_{35},Sp_{41},Sp_{42},Sp_{43},Sp_{44},Sp_{45},Sp_{51},Sp_{52},Sp_{53},Sp_{54},Sp_{55}\}$

Let S is the set of states as $S=\{S_{ij}: i=\text{power}, j=\text{distance}\}$, where $i=1,2,3,4,5$ stands for very low, low, medium, approximately medium, very high and $j=1,2,3,4,5$ stands for very short, short, middle, approximately middle, very long. S_{ij} is defined as the ratio of p_i and d_j. For finding reward r_{ij}, priorities of the states are compared by using formula $Sp_{ij}=\{\text{average of } p_i, \text{average of } d_j\}$. Each S_{ij} is a linguistic variable having different values, defined by $S_{ij}=\{\text{power } i, \text{distance } j\}$ which determines the reward of state of each node.

A reward $r_{ij},(i=1,2,\cdots,5;\ j=1,2,\cdots,5)$ may assume any value of very bad, bad, mild bad, very poor, poor, mild poor, medium, mild good, good, very good, less excellent, excellent, very excellent and so on. For instance: Let us consider a wireless network in which there is a sensor range of 500 meter for transmission information packages and 100-watt nodes. Some interval of parameters of power of distances is given as

Power: (0,10), (10,30), (30,60), (60,75), (75,100), and

Distance: (0,50), (50,100), (100,200), (200,350), (350,500)

Here we have following 25 states as shown below in the table

$$s_{11}=\frac{\text{very low}}{\text{very short}}=\frac{0-10}{0-50}=\frac{10}{50}=0.2$$

$s_{12} = \frac{\text{very low}}{\text{short}} = \frac{0-10}{50-100} = \frac{10}{50} = 0.2$
$s_{13} = \frac{\text{very low}}{\text{middle}} = \frac{0-10}{100-200} = \frac{10}{100} = 0.1$
$s_{14} = \frac{\text{very low}}{\text{approximately middle}} = \frac{0-10}{200-350} = \frac{10}{150} = 0.066667$
$s_{15} = \frac{\text{very low}}{\text{very long}} = \frac{0-10}{350-500} = \frac{10}{150} = 0.066667$
$s_{21} = \frac{\text{low}}{\text{very short}} = \frac{10-30}{0-50} = \frac{20}{50} = 0.4$
$s_{22} = \frac{\text{low}}{\text{short}} = \frac{10-30}{50-100} = \frac{20}{50} = 0.4$
$s_{23} = \frac{\text{low}}{\text{middle}} = \frac{10-30}{100-200} = \frac{20}{100} = 0.2$
$s_{24} = \frac{\text{low}}{\text{approximately middle}} = \frac{10-30}{200-350} = \frac{20}{150} = 0.133333$
$s_{25} = \frac{\text{low}}{\text{very long}} = \frac{10-30}{350-500} = \frac{20}{150} = 0.133333$
$s_{31} = \frac{\text{medium}}{\text{very short}} = \frac{30-60}{0-50} = \frac{30}{50} = 0.6$
$s_{32} = \frac{\text{medium}}{\text{short}} = \frac{30-60}{50-100} = \frac{30}{50} = 0.6$
$s_{33} = \frac{\text{medium}}{\text{middle}} = \frac{30-60}{100-200} = \frac{30}{100} = 0.3$
$s_{34} = \frac{\text{medium}}{\text{very long}} = \frac{30-60}{200-350} = \frac{30}{150} = 0.2$
$s_{35} = \frac{\text{medium}}{\text{very long}} = \frac{30-60}{350-500} = \frac{30}{150} = 0.2$
$s_{41} = \frac{\text{approximately medium}}{\text{very short}} = \frac{60-75}{0-50} = \frac{15}{50} = 0.3$
$s_{42} = \frac{\text{approximately medium}}{\text{short}} = \frac{60-75}{50-100} = \frac{15}{50} = 0.3$
$s_{43} = \frac{\text{approximately medium}}{\text{middle}} = \frac{60-75}{100-200} = \frac{15}{100} = 0.15$
$s_{44} = \frac{\text{approximately medium}}{\text{approximately middle}} = \frac{60-75}{200-350} = \frac{15}{150} = 0.1$
$s_{45} = \frac{\text{approximately medium}}{\text{very long}} = \frac{60-75}{350-500} = \frac{15}{150} = 0.1$
$s_{51} = \frac{\text{very high}}{\text{very short}} = \frac{75-100}{0-50} = \frac{25}{50} = 0.5$
$s_{52} = \frac{\text{very high}}{\text{short}} = \frac{75-100}{50-100} = \frac{25}{50} = 0.5$
$s_{53} = \frac{\text{very high}}{\text{middle}} = \frac{75-100}{100-200} = \frac{25}{100} = 0.25$
$s_{54} = \frac{\text{very high}}{\text{approximately middle}} = \frac{75-100}{200-350} = \frac{25}{150} = 0.166667$
$s_{55} = \frac{\text{very high}}{\text{very long}} = \frac{75-100}{350-500} = \frac{25}{150} = 0.166667$

Form the above table the least values of state is 0.066667 and the greatest value is 0.6. Therefore, states can be categorized as

$$c_1 = \{s_{14}, s_{15}\}, c_2 = \{s_{13}, s_{44}, s_{45}\}, c_3 = \{s_{24}, s_{25}\}, c_4 = \{s_{43}\}, c_5 = \{s_{54}. s_{55}\}, c_6 = \{s_{11}, s_{12}, s_{23}, s_{34}, s_{35}\}, c_7 = \{s_{53}\}, c_8 = \{s_{33}, s_{41}, s_{42}\}, c_9 = \{s_{21}, s_{22}\}, c_{10} = \{s_{51}, s_{52}\}, c_{11} = \{s_{31}, s_{32}\}.$$

We have the descending order of values of states is shown as $c_{11} > c_{10} > c_9 > c_8 > c_7 > c_6 > c_5 > c_4 > c_3 > c_2 > c_1$.

Here we find s_{11} has the very low power and the very short distance to destination, s_{15} has the very low power and the very long distance to the destination and s_{51} is has the very high power and the very short distance to the destination. Thus, in a node s_{51} is the best choice for the routing, and node s_{15} is the worst choice for the purpose. To compare among the priorities of the 25 states for the purpose of determining the rewards we use the formula given by

$$S_{\text{prioritiy}} = \frac{\text{mean of power}}{\text{means of the distance}}.$$

Thus, we find

$$s_{11} = \frac{\left(\frac{0+10}{2}\right)}{\left(\frac{0+50}{2}\right)} = \frac{5}{25} = 0.2.$$

$$s_{12} = \frac{\left(\frac{0+10}{2}\right)}{\left(\frac{50+100}{2}\right)} = \frac{5}{75} = 0.066667$$

$$s_{13} = \frac{\left(\frac{0+10}{2}\right)}{\left(\frac{100+200}{2}\right)} = \frac{5}{150} = 0.033333.$$

$$s_{14} = \frac{\left(\frac{0+10}{2}\right)}{\left(\frac{200+350}{2}\right)} = \frac{5}{275} = 0.018182.$$

$$s_{15} = \frac{\left(\frac{0+10}{2}\right)}{\left(\frac{350+500}{2}\right)} = \frac{5}{425} = 0.011765.$$

$$s_{21} = \frac{\left(\frac{10+30}{2}\right)}{\left(\frac{0+50}{2}\right)} = \frac{20}{25} = 0.8.$$

$$s_{22} = \frac{\frac{10+30}{2}}{\frac{50+100}{2}} = \frac{20}{75} = 0.266667$$

$$s_{22} = \frac{\frac{10+30}{2}}{\frac{100+200}{2}} = \frac{20}{150} = 0.133333$$

$$s_{24} = \frac{\frac{10+30}{2}}{\frac{200+350}{2}} = \frac{20}{275} = 0.072727.$$

$$s_{24} = \frac{\frac{10+30}{2}}{\frac{350+500}{2}} = \frac{20}{425} = 0.047059.$$

$$s_{31} = \frac{\frac{30+60}{2}}{\frac{0+50}{2}} = \frac{45}{25} = 1.8.$$

$$s_{32} = \frac{\frac{30+60}{2}}{\frac{50+100}{2}} = \frac{45}{75} = 0.6.$$

$$s_{33} = \frac{\frac{30+60}{2}}{\frac{100+200}{2}} = \frac{45}{150} = 0.3.$$

$$s_{34} = \frac{\frac{30+60}{2}}{\frac{200+350}{2}} = \frac{45}{275} = 0.163636.$$

$$s_{35} = \frac{\frac{30+60}{2}}{\frac{350+500}{2}} = \frac{45}{425} = 0.105882.$$

$$s_{41} = \frac{\frac{60+75}{2}}{\frac{0+50}{2}} = \frac{67.5}{25} = 2.7.$$

$$s_{42} = \frac{\frac{60+75}{2}}{\frac{50+100}{2}} = \frac{67.5}{75} = 0.9.$$

$$s_{43} = \frac{\frac{60+75}{2}}{\frac{100+200}{2}} = \frac{67.5}{150} = 0.45.$$

$$s_{44} = \frac{\frac{60+75}{2}}{\frac{200+350}{2}} = \frac{67.5}{275} = 0.245455.$$

$$s_{45} = \frac{\frac{60+75}{2}}{\frac{350+500}{2}} = \frac{67.5}{425} = 0.158824.$$

$$s_{51} = \frac{\frac{75+100}{2}}{\frac{0+50}{2}} = \frac{87.5}{25} = 3.5.$$

$$s_{52} = \frac{\frac{75+100}{2}}{\frac{50+100}{2}} = \frac{87.5}{75} = 1.166667.$$

$$s_{53} = \frac{\frac{75+100}{2}}{\frac{100+200}{2}} = \frac{87.5}{150} = 0.583333$$

$$s_{54} = \frac{\frac{75+100}{2}}{\frac{200+350}{2}} = \frac{87.5}{275} = 0.318182.$$

$$s_{54} = \frac{\frac{75+100}{2}}{\frac{200+350}{2}} = \frac{87.5}{275} = 0.205882.$$

Thus, the following priorities of states

$$s_{51} > s_{41} > s_{11} > s_{31} > s_{52} > s_{42} > s_{21} > s_{32} > s_{53} > s_{43} > s_{54} > s_{33} > s_{22} > s_{44} > s_{55} > s_{34} > s_{45} > s_{23} > s_{35} > s_{24} > s_{12} > s_{25} > s_{13} > s_{14} > s_{15}$$

We find that each node has a specific state in the network. In routing between two nodes, let us go from state to another and going to a more suitable state must enjoy a greater reward. The states of sender and receiver nodes are taken as the input of fuzzy system and reward is as the output.

5. Conclusion

There are various issues available in wireless sensor networks. From the above issues energy saving is the most important concern in wireless sensor networks applications which should be consider in all aspects of real time communications. Fuzzy logic as intelligent tools shows great compatibility with wireless sensor networks representative and can be useful in different energy maintenance scheme of them. The real world required real-time energy saving in wireless sensor networks to accomplish real-time communication. So, with the increasing petition for real time facilities in wireless sensor networks this paper deals application of fuzzy logic in wireless sensor network for energy efficient protocol.

6. References:

[1] Bacour, N., Koubaa, A., Youssef, H., Jamaa, M. B., do Rosario, D., Alves, M. & Becker, L. B. (2010). F-LQE: A Fuzzy Link Quality Estimator for Wireless Sensor Networks, Proceedings of the European Conference on Wireless Sensor Networks (EWSN).

[2] Wang, T. M., Liao, I. J., Liao, J. C., Suen, T. W. & Lee, W. T. (2009). An Intelligent Fuzzy Controller for Air-Condition with ZigBee Sensors, International Journal in Smart Sensong and Intelligent Systems 2.

[3] Ran, G., Zhang, H. & Gong, S. (2010). Improving on LEACH Protocol of Wireless Sensor Networks Using Fuzzy-Logic, Journal of Information and Computational Science 7(3).

[4] Ortiz, A. M., Olivares, T. & Orozco-Barbosa, L. (2011). Smart Routing Mechanism for Green ZigBee-based Wireless Sensor Networks, Proceedings of the 16th IEEE Symposium on Computer and Communications (ISCC).

[5] Lotfi A. Zadeh (1994), “Fuzzy Logic, Neural Networks and Soft Computing”, Communication of the ACM, 37(3),77-84.

[6] Kalantari S. et al., (2011) “Routing in wireless sensor network based on soft computing technique”, Scientific Research and Essays 21(6) 4432-4441.

[7] Siddesh G.K et al., (2011) “Routing in Ad Hoc Wireless Networks using Soft Computing techniques and performance evaluation using Hypernet simulator”, International Journal of Soft Computing and Engineering (IJSCE),1,2231-2307.

[8] Nikravan M. et al., (2011) “An Intelligent Energy Efficient QoS-Routing Scheme for WSN”, (IJAEST) International journal of advance engineering sciences and technologies, 8(1),121 – 124.

[9] Nekooei S.M. et al., (2011) “Location Finding in Wireless Sensor Network Based on Soft Computing Methods”, Journal of Information Security Research, 2(4) 186-191.

[10] Neeraj Kumar et al., (2010) “Coverage and Connectivity Aware Neural Network Based Energy Efficient Routing in Wireless Sensor Networks”, International journal on application of graph theory in wireless ad hoc networks and sensor networks (Graph-Hoc), 2(1) 45-60.

[11] J. Barbancho et al., (2005) “an ad-hoc wireless sensor network simulator for public utilities applications”, In E. Cayircy, S. Baydere, and P. Havinga, editors, Proceedings of the Second Europen Workshop on Wireless Sensor Networks, 419-424. IEEE, IEEE Press.

[12] Averkin A et al., (2005).” Soft Computing in Wireless Sensors Networks”, International Conference on Soft Computing and Measurements SCM

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