USING FUZZY LOGIC AND SEARCH ALGORITHMS TO BALANCE CONSUMPTION POWER AND MAXIMUM LIFESPAN FOR WIRELESS SENSOR NETWORK

Phan Thi The*, Nguyen Quoc Thinh#, Nguyen Thanh Tuan#, Tran Cong Hung#
* Department of Information Technology, Thu Duc College, Ho Chi Minh, Viet Nam
# Department of Information Technology, Posts and Telecommunications Institute of Technology
Ho Chi Minh, Viet Nam

Abstract: *The most important issue for designing wireless sensor network routing protocols is energy efficiency. Our study uses a combination of both fuzzy logic and A-star algorithms that improve priority level in selecting node to form route. This algorithm is capable of selecting the best routing from the source node to the base station by prioritizing the highest remaining power, minimize number of hop, lowest traffic load. The performance of the proposed algorithm is evaluated and compared to the other three methods according to the same criterion. Simulation results show the effectiveness of the new approach for enhancing wireless sensor network lifetime with scattered random nodes*

Keywords: Wireless Sensor Network, energy efficiency, A-star algorithm, fuzzy logic, network lifespan.

I. INTRODUCTION

The Wireless Sensor Network can accommodate up to thousands of sensor nodes using wireless links (radio, infrared, or optical) to coordinate the data acquisition task with large scale dispersion in any geographical area, monitoring temperature, sound, vibration, pressure, motion or contaminants. The sensor node processes, stores and sends information collected to other nodes in the network, to the main location or transceiver where the data is being reviewed and analyzed. Due to the limitations of memory nodes, power and computing power, to transmit data the sensor nodes require a power source; if a node is insufficient power, it can not transmit data, In addition, irregular power dissipation can significantly reduce network lifetime

Unbalanced power consumption is a inherent problem in wireless sensor networks which characterized by multi-hop routing and multiple source traffic flows to one destination. And uneven energy consumption can significantly reduce network life. In general, in the routing algorithm, the best path is chosen to transfer data from source to destination. For a period of time if the same path is selected for all interfaces to achieve battery performance in terms of fast transmission time, the nodes on this route will suffer a rapid energy consumption [1], [2], [3]. In most applications of wireless sensor networks, sensor nodes are deployed in large-scale areas. When deploying nodes can not be reloaded or replaced. After the power is exhausted, nodes turn dead and stop working. Because the network can not perform the assigned tasks after the node dies. Longevity wireless sensor networks are an important parameter when evaluating the performance of routing protocols [1].

In traditional optimal path routing schemes in wireless sensor networks, each node selects specific nodes to move data according to a number of criteria to maximize network life. Due to this concept, the problem of wireless sensor life is always noticeable.

Our paper study on routing protocols and applications of fuzzy logic in wireless sensor networks. In this study, we first propose a fuzzy approach in conjunction with the A-Way path search algorithm in the route selection process for WSNs. It enables optimal data transfer from source to destination by considering three routing criteria: maximum residual energy, minimum number of hop and lowest traffic load. Next, the new approach introduces a priority variable in the selection of good sensor nodes (low power consumption at low transmissions) compared to randomly selecting algorithms for nodes and distributing data from the sensor node to the base station (BS) as fast as possible and save the most energy. To evaluate the effectiveness of our proposal, we analyzed simulation results comparing our approach with the fuzzy approach and the A-star algorithm using the same routing standard for data transmission costs. , average power consumption and life cycle of the network using the matlab network simulation. Simulation results demonstrate that network life is significantly increased when using the proposed routing method.

The structure of this article is composed of four parts: Part 1, Part 2 presents The Related Work, Part 3 Proposed Algorithms, Part 4 Simulation and Evaluation, and the final part is the conclusion.

II. RELATED WORKS

To provide proposal algorithm, We have studied some of the following related works:

Corresponding Author: Phan Thi The
Email: thept@tdc.edu.vn
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Yali Yuan and colleagues in the study "CAF: Clustering Algorithm and A-Star with Fuzzy Approach" [4] proposed a new routing method in the network Wireless sensors for extending network life use a combination of a clustering algorithm, a fuzzy approach, and an A-star method.

Vuyyuru. Lalitha. V et al. [5] proposed a new routing method for wireless sensor networks for the use of minimal energy using a combination of fuzzy logic and the A-star algorithm with the Leach protocol. The proposed method for high throughput, reduced packet loss rate and minimal power consumption of sensor nodes.

Chandra Prakash Yadav and others [6] in the paper "An Efficient Routing Method for Lifetime Enhancement in a Wireless Sensor Network", also proposed a combination of fuzzy logic and the A-star algorithm How to choose the optimal route from source to destination based on the highest remaining battery power, minimum hop number, and lowest traffic load.

Haifeng Jiang et al. [7] based on the energy consumption analysis for data transceivers, single-hop forwarding mechanisms have been shown to consume more energy than multi-hop transmissions within the transmission range Source sensor or transceiver current. The authors predicted the residual energy of the neighboring node after selecting the next node. Based on the energy imbalance, the method is designed to calculate the energy balance. Parameters such as the proximity of the node to the shortest path, the proximity of the node to the transceiver and the level of energy balance are fed into the fuzzy logic system. The optimized routing algorithm is based on the fuzzy logic proposed to achieve multiple parameters, deciding the fuzzy routing.

Author Tran Cong Hung and Phan Thi The [8] (2015) study to select clusters (CH) and use the Dijkstra algorithm to find the shortest path to the clusters and base stations (BS) This algorithm presents the shortest path between cluster and adjacent node, ensuring that this algorithm provides low cost power transmission and consumption. To optimize power consumption and maximize the WSNs network life span, the deployment of sensor balances as well as low path costs is found by Dijkstra's algorithm. Dijkstra's algorithm will find the lowest cost route based on the route distance, while the authors propose to apply the energy model to Dijkstra's algorithm to select the optimal route to the host cluster. Therefore, that is the reason for equal energy consumption. In this study, the author studied cluster cluster classification and used Dijkstra's algorithm to reduce energy consumption.

III. PROPOSED ALGORITHM

The main goal is to design an algorithm to extend the life of wireless sensor networks by limiting energy costs as well as distributing energy consumption evenly. Our proposal introduces a new approach by combining a fuzzy and A-Star algorithm to select the optimal routing route from source to destination by considering three routing criteria (Power combined with variable α (normal node and good node) to select the optimal node relative to the algorithm to randomly select nodes and balance them to extend the life of the sensor network. The process consists of two parts:

A.Set up Fuzzy logic

Fuzzy logic refers to analyzing information using fuzzy sets, each of which can represent a linguistic term such as "Low", "High" ... Fuzzy sets are described by the actual range of values. the mapped set, called domain, and membership function. A membership function assigns an authentication value between 0 and 1 to each point in the domain of the fuzzy set. Depending on the shape of the jaw function, different types of fuzzy sets can be used such as triangles, beta, PI, curves, sigma ...

Fuzzy values are handled by deductive mechanisms, including a rule base and various methods to deduce rules. The simple rule base is a series of If-Then rules involving input fuzzy variables with output fuzzy variables using linguistic variables, each of which is described by a fuzzy set and the fuzzy operation "And", "Or". All rules in the rule base are handled in a parallel method by inference structure.

The objective of the fuzzy program of the proposed protocol is to determine the optimal cost value for a link between two sensor nodes so that the network life is maximized. The lifespan of wireless sensor networks is usually defined as the time when the power level of the first sensor node becomes zero. The fuzzy rule base has been adjusted to not only prolong the life of the sensing network. but also to efficiently balance the load between the sensor nodes so that the maximum number of nodes has enough power to continue performing their own sensor tasks.

A number of different indicators are used to extend the life of sensor networks. These indicators are as follows [6]:

Remaining Energy (RE), Minimum Hop (MH), Traffic Load (TL).

The proposal protocol determines the optimal value of NC (n) of node n depending on the remaining energy RE (n) and load TL (n), using the five associated functions for each of the nodes. (RE, TL) and an output variable (NC) as shown in Figures 1, 2, 3, 4.

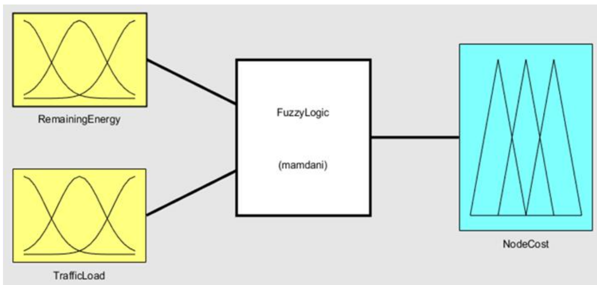


Figure 1: Fuzzy logic with 2 input variables (RE, TL) and NC output variable

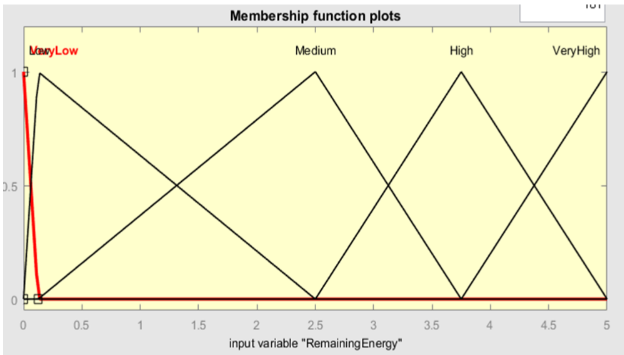


Figure 2: Linked graph for input variable Energy remaining (RE)

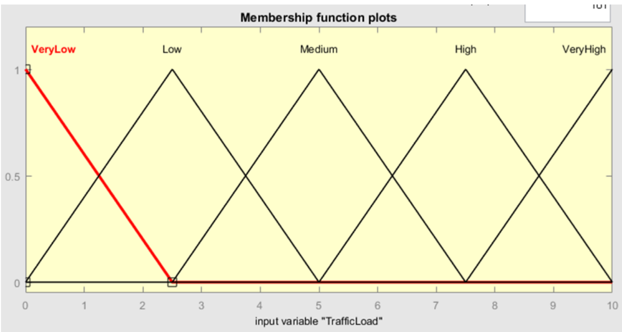


Figure 3: Link graph for input variables Load (TL)

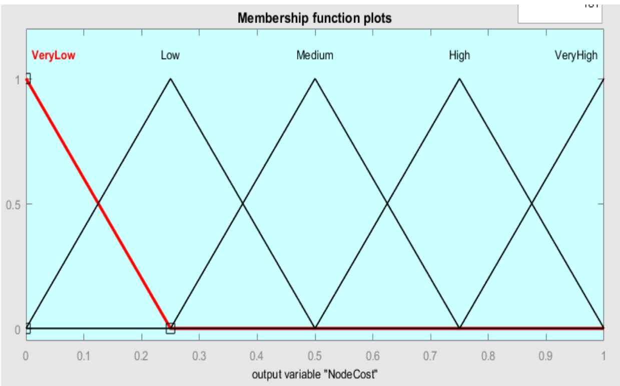


Figure 4: Link graph for output variable Cost node (NC)

For the fuzzy approach, fuzzy values are handled by the inference mechanism, including a rule base and various methods for inferring the rules. Table 1 shows the if-then rules used in the proposed method for a total of 52 = 25 basis fuzzy rules. For example, if RE (n) is very high and TL (n) is very low then NC (n) is very high. All of these rules are treated in parallel with a fuzzy reasoning mechanism.

Table 1: If-Then Rules

RE(n) **TL(n)**	Very Low	Low	Medium	High	Very high
Very Low	Low	Medium	High	Very high	Very high
Low	Very Low	Medium	Medium	High	Very high
Medium	Very Low	Low	Medium	High	Very high
High	Very Low	Low	Low	Medium	High
Very high	Very Low	Very Low	Low	Medium	High

Finally, the defuzzy will find a unique output value from the fuzzy solution. This value represents the cost of the node. Defuzzy is calculated by the below formular

$$\textbf{Node\_Cost}= \frac{\sum_{n}^{i=1} U_i * C}{\sum_{i=1}^{n} U_i} \qquad (1)$$

Where Ui is the output of the rule base i, Ci is the center output of the function

B. Set up A-Star algorithm

Energy Consumption Models: The energy consumption of each sensor node consists of three components: sensor energy, transmission energy, and data processing power. Sensors and data processing require less power than transmitting. This proposal uses the same energy consumption model as Heinzelman used for wireless transmission hardware [9], [10], [11].

In the new approach, the base station prepares the routing schedule and broadcasts it to each node. The A-Star algorithm finds the optimal route from the node to the base station and applies to each node. The A-star algorithm creates a tree structure to find the optimal route from a given node to the base station, the tree node is found based on the algorithm's evaluation function as follows:

$$f(n) = [NC(n) + (1/MH(n))] * \alpha \quad (2)$$

If f (n) is large, then the optimal node is chosen.

Where:

- NC (n) is the cost of node n, which has values [0 ... 1] and is computed by fuzzy logic. This value is calculated based on the remaining energy of node n (n) and the traffic load of n nodes (n).
- MH (n) shortest distance from node n to base station.
- Variable α: α = 1.5 if node is good and α = 1 if node is normal. Here we set a small percentage of good nodes to conduct experiments compared with the experimental results of the authors in [11] (authors use different energy levels between good and normal node, same level energy consumption for nodes), [12] (authors use the same energy level, the same power

consumption for nodes and randomly selected under the initial conditions) for comparison.

The proposed method will preferentially select the best node on the routing route instead of randomly selecting the neighboring node in function f (n) without priority weighting. Choosing this good node helps to get the idea that when designing a wireless sensor network, it inserts some sensor nodes with lower power consumption than normal nodes, thus improving the algorithm. In this case, it is recommended that in the case of good node selection algorithms, this will help in some cases (except in special cases). The amount of transmission and increase the life cycle.

Figure 5 depicts the flowchart of the proposed algorithm combining fuzzy logic and A-star algorithm in optimal routing (with priority consideration) to increase wireless sensor network life.

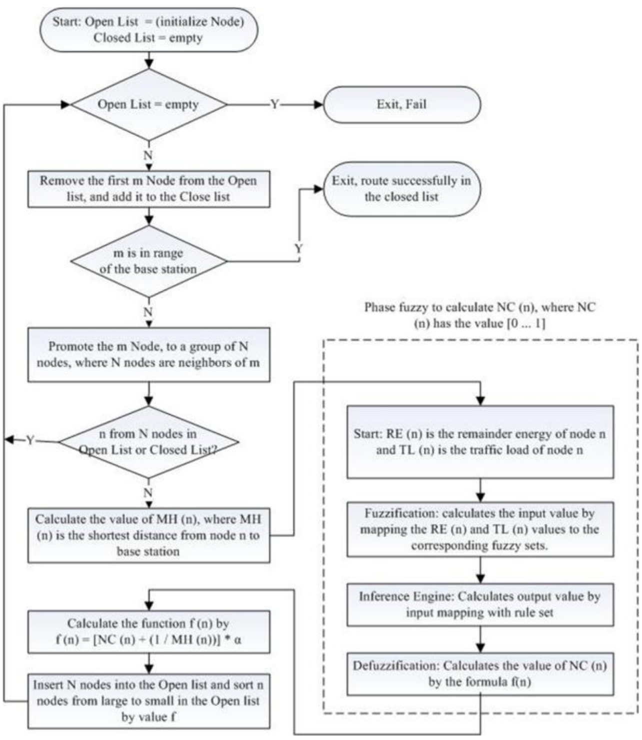


Figure 5: Flow chart of Proposal Algorithm

In wireless sensor networks, the node are limited by battery power, so the use of energy efficiency is very important. Another feature is that the lifespan of the network is related to route selection. Unbalance energy is a problem in the WSN network. Thus, the new proposal approach is to chose the optimal route from the source node to the point of acquisition based on the remaining energy, minimum hop, lowest traffic load using a combination of fuzzy approach and A-star algorithm to increase the lifespan of wireless sensor networks.

IV. SIMULATION AND EVALUATION OF RESULTS

A. Detailed hypothesis and initial setup for the simulation process:

The nodes in the network know the topology of the network. Know your location, proximity node location, and base station. The same transmission distance and two types (normal node and good node). All nodes in the network can transmit data directly to the base station (Sink).

Number of nodes in network N = 100 nodes (20 good nodes have power dissipation during transmission, lower than normal nodes). Network simulation range (100m x 100m). The base station is located at (0, 50). The transmission distance limit is 30m. The initial energy of all buttons iEnergy = 0.5J.

Energy consumes a bit: Eelec = 50nJ / bit (regular node), Eelec = 10nJ / bit (good node). Amplifier: Eamp = 100pJ / bit / m2 (regular node), Eamp = 20pJ / bit / m2 (good node).

The length of each packet k = 2000 bits. Packet numbers: 5000, 10000, 15000, 20000.

The maximum number of flows in a node's queue is 10.

Our simulation is installed on MATLAB R2017a. The nodes in the network are allocated randomly. The simulation process consists of the following steps:

Step 1: Find the neighbor node.

Step 2: Set up the optimal route.

Step 3: Transfer data to base station.

B. Simulation:

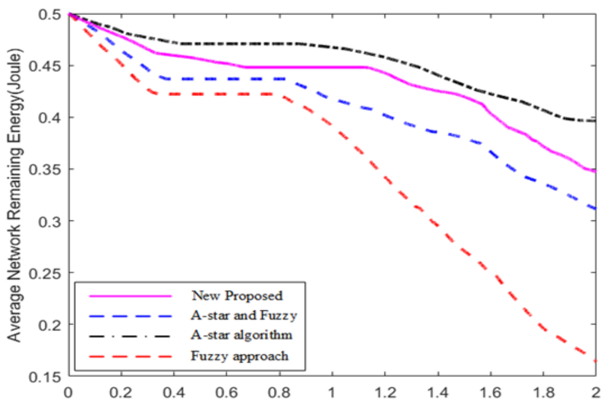


Figure 6: Average remaining energy after 20,000 rounds

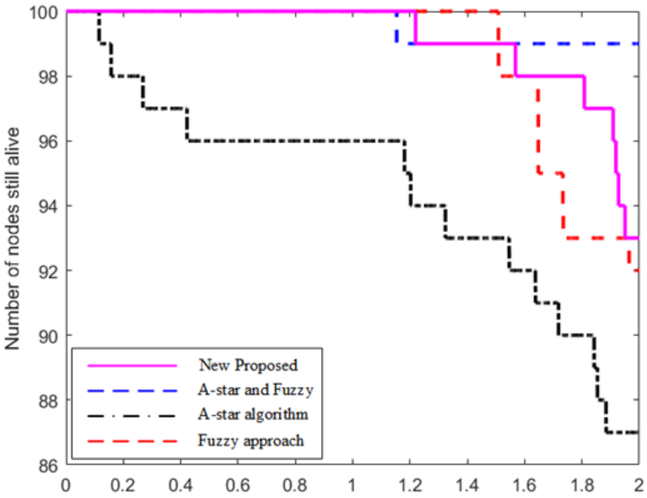
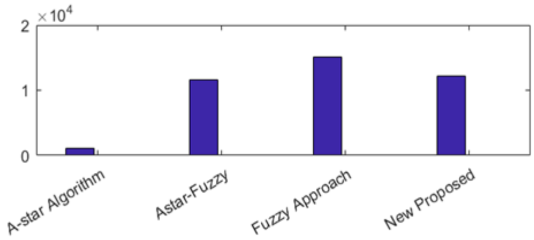


Figure 7: Number of live nodes after 20000 rounds



	1st	50th
Astar-Fuzzy	11537	0
New Proposed	12196	0
Fuzzy Approach	15088	0
A-star Algorithm	1153	0

Figure 8: Statistics of rounds when first node and fifty node died (4th time)

The result of Figure 6 shows that the remaining energy of the proposed method is lower than the A-star but higher than the other two modes. After 20000 rounds, the number of surviving nodes of the proposed method is 93 times lower than the A-star & Fuzzy with 99 nodes, higher than the A-star, the opaque approach is 92, 87 nodes, as shown in Figure 8. The new method has the first node dies at 12196 while the A-star is 1153, A-sao & Fuzzy is 11537, the fuzzy approach is 15088. The results show that the efficiency of the proposed method in balancing power consumption and maximizing network life.

V. CONCLUSION

The proposed algorithm uses a combination of both fuzzy approaches and the A-star algorithm to improve the priority in selecting the route-forming node. Evaluation results show that the proposed method outperforms the proposed protocols [12] when running simulated conditions, in the fourth round with the number of rounds reaching 20000 energy averages the rest was 0.35 higher than 0.25, the number of live nodes was 93 higher than 79 of the A-star & Fuzzy method [12]. Thus, this algorithm has the ability to select the optimal routing route from the source node to the base station by prioritizing the highest remaining power, minimum number of hop, lowest traffic load, and good node. The performance of the proposed method was evaluated and compared to the other three methods according to the same criteria. Simulation results show the effectiveness of the new approach in prolonging wireless sensor lifespan with scattered random nodes.

For future research, improvements may include the following: make improvements on other routing protocols, apply for heterogeneous sensor networks, We will use fuzzy logic combine with some other mobile sink algorithms.

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Tóm tắt: *Vấn đề quan trọng nhất để thiết kế các giao thức định tuyến mạng cảm biến là hiệu quả năng lượng*. *Nghiên cứu của chúng tôi sử dụng kết hợp cả hai phương pháp tiếp cận mờ và thuật toán A-sao có cải tiến độ ưu tiên trong việc lựa chọn nút hình thành tuyến đường. Thuật toán này có khả năng chọn tuyến đường định tuyến tối ưu từ nút nguồn đến trạm gốc bằng cách ưu tiên năng lượng còn lại cao nhất, số bước nhảy tối thiểu, tải lưu lượng thấp nhất và là nút tốt. Hiệu suất của thuật toán đề xuất được đánh giá và so sánh với ba phương pháp khác theo cùng tiêu chí. Kết quả mô phỏng cho thấy hiệu quả của phương thức tiếp cận mới trong việc tăng cường tuổi thọ mạng cảm biến không dây với các nút ngẫu nhiên phân tán.*

Từ khoá: mạng cảm biến, hiệu quả năng lượng, thuật toán A-sao, logic mờ, tuổi thọ mạng, định tuyến.

Phan Thi The was born in Vietnam in 1982.She received Master Data Transmission and NetWork in HOCHIMINH PTIT, Vietnam, 2012. She is currently a PhD.Candidate in Information System from Post & Telecommunications Institute of Technology, Vietnam in 2019.She is working as a lecture in Thu Duc College

Nguyen Quoc Thinh was born in Vietnam in 1989. He received Master in Post & Telecommunications Institute of Technology, Vietnam in 2019. He is working as a engineer in FPT Software Ho Chi Minh.

Nguyen Thanh Tuan was born in Vietnam in 1989. He received the Master of Management information system from Post & Telecommunications Institute of Technology, Vietnam, 2016. He is, currently, a PhD.Candidate in Information System from Post & Telecommunications Institute of Technology, Vietnam in 2020. He is working as a Teacher at Nha Trang Tourism College, Khanh Hoa, Vietnam.

Tran Cong Hung was born in Vietnam in 1961. He received the B.E in electronic and Telecommunication engineering with first class honors from HOCHIMINH University of technology in Vietnam, 1987. He received the B.E in informatics and computer engineering from HOCHIMINH University of technology in Vietnam, 1995. He received the master of engineering degree in telecommunications engineering course from postgraduate department Hanoi University of technology in Vietnam, 1998. He received Ph.D at Hanoi University of technology in Vietnam, 2004. His main research areas are B – ISDN performance parameters and measuring methods, QoS in high speed networks, MPLS. He is, currently, Associate Professor PhD. of Faculty of Information Technology II, Posts and Telecoms Institute of Technology in HOCHIMINH, Vietnam.