Journal of Electrical Engineering, Electronics, Control and Computer Science – JEEECCS, Volume 8, Issue 30, pages 11-16, 2022

Fuzzy Logic based Technique for Distributed Wireless Sensor Network

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Abstract **– This paper, a fuzzy logic-based technique has been implemented to enhance the data delivery time and energy management capacity in a distributed wireless sensor network (WSN). A fuzzy logic system based on Mamdani model in the MATLAB simulation tool was implemented for distributed WSN using two input variables –status and message and one output variable – decision. The results of the simulation showed that by varying the packet size to be 1500 bits, 2500 bits, 5000 bits, 7500 bits and 10000 bits, the delivery time achieved were 1140 seconds, 1220 seconds, 3049 seconds, 3480 seconds and 4036 seconds. The total energy with respect to the packet size was 500 J, 661 J, 1948 J, 2272 J and 2380 J respectively. The use of fuzzy logic system ensures that not all the nodes transmit packet in accordance to logical condition required by a node to discard or continue to deliver data**

Keywords-delivery time; energy; fuzzy logic; sensor; wireless sensor network

I. INTRODUCTION

Today, attention has been largely given to WSNs because of their extensive usage in several fields of potential applications [1]. This can be attributed to the growth in wireless communication and the low power Radio Frequency (RF), which sensor nodes design widely employ. A communication link with several miniature sensor nodes designed to transmit and receive packets of data gives rise to wireless sensor network (WSN). That is in WSN various sensors are incorporated and are distributed around a given node to achieve the computational operations [2]. Sensor nodes are deployed to monitor target area and as a group transmits the information gathered or monitored to a sink node or base station (BS).

Sensors are characterised by their small physical structure, low powered, equipped with programmable computing, several parameter sensing and wireless communication potentials have in recent times increased due to advance in electronic technology. The miniature size and cost-effectiveness these sensors add to their being economically viable [3]. There has been increasingly trend of using WSNs in many fields including traffic monitoring, pollution control, flood detection, monitoring and measurement of environment conditions (such as humidity, temperature and others), target tracking, healthcare applications, military reconnaissance and surveillance, structure monitoring, and others.

Routing is a very critical task that should be carefully addressed in WSN. Communication is established in WSN uses routing algorithm which is required for transmitting information gathered by the sensor nodes and the BS. There are various routing techniques that have been developed to reduce the energy consumption and to optimize the lifetime of the WSN. The routing techniques can be categorized into three broad energy efficient protocols to include: data centric protocols, hierarchical or clustering-based protocols, and location based or geographical protocols. Three famous techniques have emerged from these three categories. Data centric routing techniques uses a model that is query driven to reduce the amount of transmitted data and are also capable of collecting data while conveying it to the sink. Directed Diffusion and Adaptive Protocols for Information Dissemination in WSNs (Sensor Protocol for Information via Negotiation known as SPIN) are the dominant data centric protocols [4]. Low Energy Adaptive Clustering Hierarchy (LEACH) is best among the hierarchical or clustering-based protocols. These three techniques have become common performance baselines, with most of energy efficient routing study focused on improving their performance. In WSN, energy consumption, scalability, node deployment, scalability, connectivity, security, and coverage are challenges in routing [5], [2].

In this paper, the objective is to develop a WSN to facilitate routing and packet delivery using fuzzy logic technique based on Mandani Fuzzy Inference System (FIS).

II. EMPIRICAL REVIEW OF RELATED STUDIES

In this section, some studies involving the use of fuzzy logic and other intelligent aided algorithms for routing, energy-efficient, packet delivery and other performance parameters of WSN are presented. The use of fuzzy logic for cluster head selection to maximize the lifetime of WSN was presented by [6]. Fuzzy logic technique was used to increase the lifetime of the network by reducing the energy consumption in the nodes. [7] used fuzzy logic-based energy efficient clustering hierarchy (FLECH) to prolong the lifetime of a non-uniform WSN. The increase in lifetime of WSN was achieved by FLECH due to the fact that various critical parameters that affect the energy consumption by the sensor nodes were taken into account. The fuzzy logic-based algorithm integrated probabilistic and metric-based cluster head (CH) election in non-uniform WSN. The issues of performance degradation such as packet drop, network congestion, routing and energy consumption during communication was addressed using fuzzy logic-based technique including trust-based clustering algorithm [8]. An algorithm that employs hybrid scheme involving using neural network and fuzzy logic called ANFIS was implemented to improve performance parameters of WSN such as packet delivery ratio, packet loss and throughput [9]. The trust of each sensor node in the network is evaluated by ANFIS and the node that creates highest trust node was chosen as the intermediate node for data transfer. [10] used fuzzy logic and bloom filter to improve Depth Based Routing (DBR) protocol to improve routing in underwater WSNs. The fuzzy logic and the Bloom filters were used to choose parameter for the optimum route and to increase the rate of routing respectively. Considering energies of nodes, degree of nodes, and energies residual of neighboring nodes as input parameters, energy efficient distributed clustering protocol using fuzzy logic with non-uniform distribution (EEDCF). A cluster head selection algorithm that allocates a weight function to each node based on a fuzzy membership function and communication cost of intra-cluster in a cluster was proposed by [3]. The system also implemented Dijkstra’s algorithm for minimum weight path selection for improving the energy efficient of WSN. With most of the energy consumption in WSNs occurring during data communication and the need to improve packet delivery ratio which is a critical factor for achieving quality of service (QoS), an Energy Efficient Unequal Clustering Routing (EEUCR) algorithm was developed by [11]. The technique involves the division of the network into a number of rings with unequal size and with each further split into a number of clusters such that rings closer to the BS has smaller area than those farther. Nodes with closer proximity to the BS have more energy than nodes more distant from BS. Static clustering, but with non-fixed cluster heads (CHs) that are chosen based on residual energy was used. In[12], multifactor strategies that consisted of routing, flows differentiation, redundant packet coding and flow-based congestion control with retransmission to improve packet delivery ratio in zone-based WSN was implemented. The system uses geographic routing relay selection on the basis of a preference score. Similarly, geographic routing that depends on a weighted centroid localization technique using fuzzy logic algorithm that takes into account flow measurement through wireless path to compute the distance of separation between the anchor and the nodes was proposed by [13]. In [14], Temporally-Ordered Routing Algorithm (TORA), INtrusion-tolerant routing protocol for wireless SEnsor Networks (INSENs) and Low Energy Adaptive Cluster Hierarchy (LEACH) was used to carry out performance analysis of hierarchical and flat network routing protocols in WSN using Ns-2 (software). According to the research conducted by [15], the topology and routing algorithm of heterogeneous WSN was examined through the simulation conducted in MATLAB. The study observed that the overall energy consumed by the WSN topology was less than the initial energy of each node, and the energy variation consumed per traffic volume increases in the network but decreases in capacity of transmission.

III. DESIGN OF FUZZY LOGIC SYSTEM

The uncertainty and vagueness that may arise due to lack of information about certain parameters can be handled by fuzzy logic system (FLS). As to the deployment of distributed sensor nodes in a WSN, the distance and the direction of each node are distributed and with uncertainty that can hardly be depicted by some random distribution [16]. Fuzzy logic can be easily implemented on a standard computer [17], [18]. As a branch of machine intelligence [19], fuzzy logic helps the computer to be able understand and respond to vague human thought such as low, medium, high, and so on [18]. A Fuzzy logic system is generally described by at least two inputs and one output. The Membership Functions (MFs) of the fuzzy sets are used by Mamdani Fuzzy Inference System (FIS) to perform inputs to output mapping. The way by which each point in the input crisp value is linked to a degree of fuzzy value is shown by a shape that represents a MF [18].

In this paper, a fuzzy logic system is proposed for a distributed sensor deployed for wireless network application. A complete distributed decision is made by each sensor on its movement on the basis of FLS. The design of the FLS is performed using the Mamdani model and employed the method of deffuzification is centroid. The inputs are “status” and “message”, while the output is “decision.” The rule base comprises linguistic variables, which represent the human thought. Thus, in this paper, the linguistic variables used are: Low, Medium, and High for the inputs while the output linguistic variables are: Reject, Single, Multiple, and Flood. The fuzzy logic designer based on Mamdani model in MATLAB is shown in Figure 1.

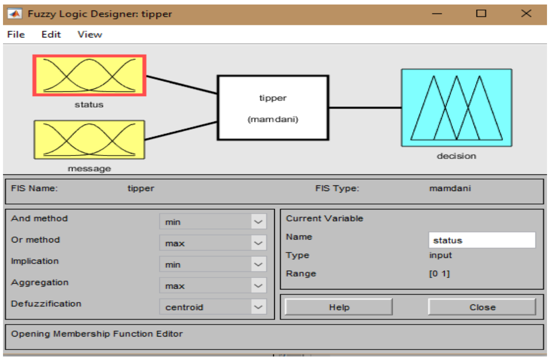

Figure 1: Fuzzy rule

In the modelling of the inputs, two trapezoidal MFs and one triangular MF were used, while the output used two trapezoidal and two triangular MFs respectively as shown in Figures 2a, 2b and 2c. The rule editor showing the IF-THEN mapping of the inputs to the output is shown in Figure 3. The display of the 9 rules in graphical form called rule viewer is shown in Figure 4. A plot of the mapping of the inputs to the output in three-dimension (3-D) called the surface viewer is shown in Figure 5.

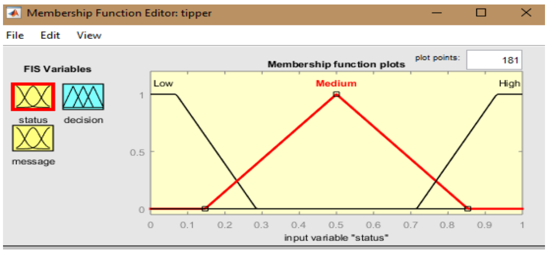

Figure 2a: Input variable status

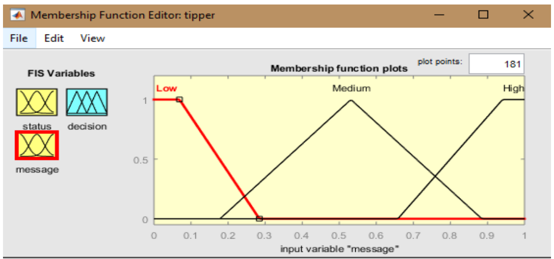

Figure 2b: Input variable message

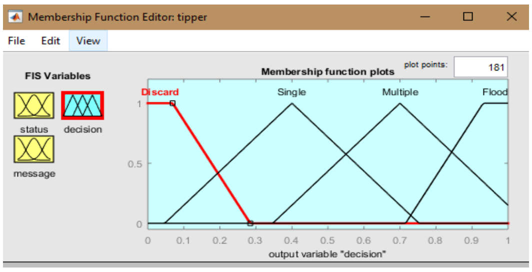

Figure 2c: Output variable decision

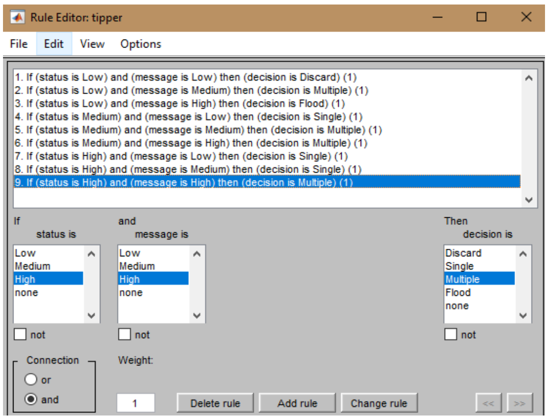

Figure 3: Rule editor showing IF-THEN mapping

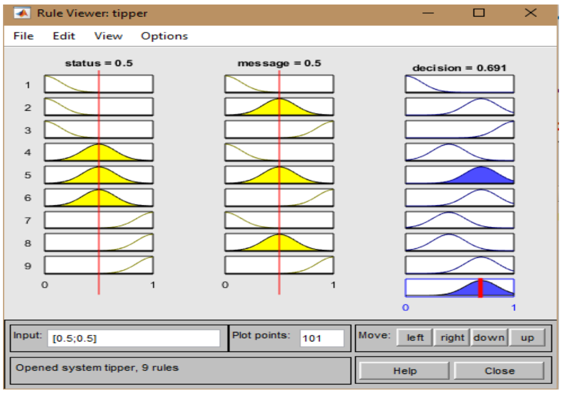

Figure 4: Fuzzy logic rule viewer

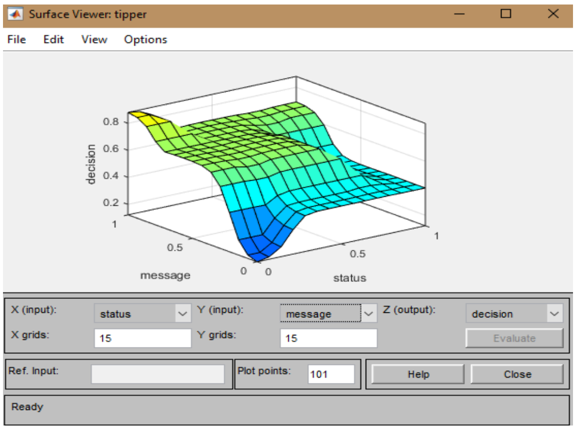

Figure 5: Fuzzy logic surface viewer

IV. SIMULATION RESULTS AND ANALYSIS

This section presents the results of the simulation conducted for the randomly distributed WSN in MATLAB. The parameters for configuration and simulation are set up such that the network size is (x = 100 m × y = 100 m), location of BS is (50, 50) m, number of nodes 100, and data packet size varied with respect to five iterations from 1500 bit to 10000 bit.

The simulation starts with the graphical display of the random deployment assuming a 2-dimensional sensor field (100 m, 100 m) representing a target area of surveillance as shown in Figure 6.

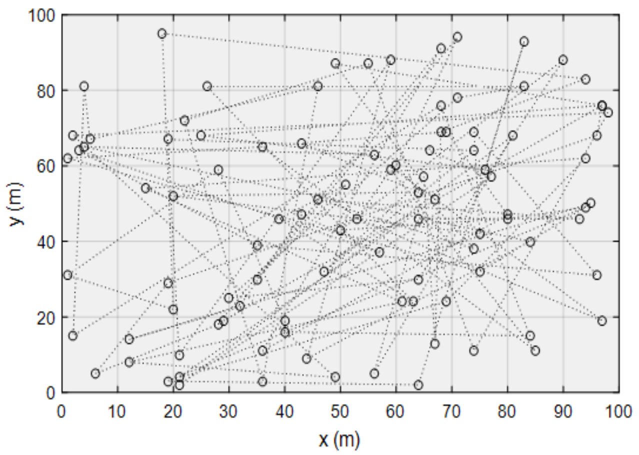

Figure 6: Randomly distributed sensor nodes

Figures 7, 8 and 9 show the relationship between the packet delivery time and packet size, total energy consumed with respect to packet size, and total energy against delivery time.

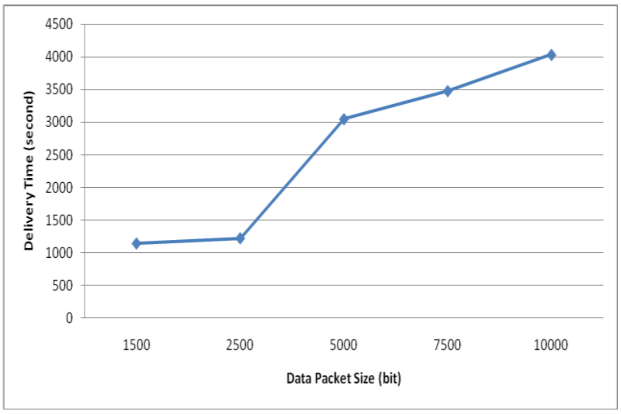

Figure 7: Delivery time with respect to packet size

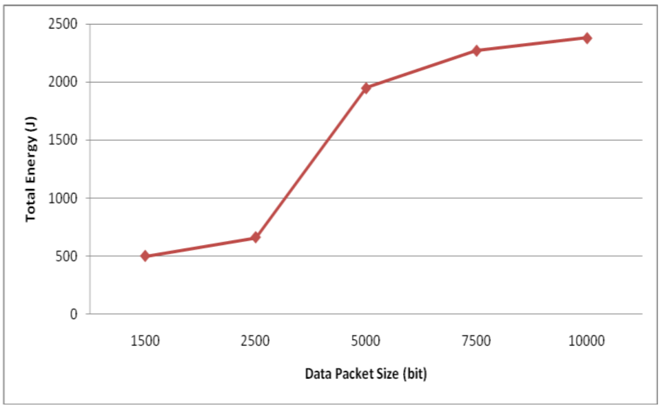

Figure 8: Total energy with respect to packet size

Figure 9: Total energy against delivery time

Simulation results for five different iterations conducted by regarding the packet size of 1500 bits, 2500 bits, 5000 bits, 7500 bits, and 10000 bits. If the status is low and the message is low then the decision of the network is to discard the time and energy. In any case, with a packet size of 1500 bit applied, the delivery time was 1140 seconds and the total energy consumption of the WSN was 500 J. For packet size of 2500 bits, 5000 bits, 7500 bits and 10000 bits the delivery time and the total energy were (1220 seconds, 661 J), (3049 seconds, 1948 J), (3480 seconds, 2272 J) and (4036 seconds, 2380 J). Figures 7 and 8 showed that increasing packet size resulted in increase in delivery time and total energy. In Figure 9, the total energy increases as with delivery time. Thus, it suffices to say that more energy is consumption and increased delivery time is associated with increasing packet size. However, energy and delivery time are logically conditioned. That is, these parameters depend on the logic decision of the fuzzy logic algorithm, and as such the sensors transmit or sent data to destination node based on fuzzy logic inspired algorithm such that when the resulting decision for delivering data is less than less 0.1, sensor node does not need to deliver data and as such nodes are only allowed to transmit data when certain criteria are logically reached. This way all nodes may not be participating in packet delivering and thereby reducing energy consumed in the network at a time and thus prolongs the network lifetime.

V. CONCLUSION

This paper has presented the use of fuzzy logic-based technology in WSN to enhance data delivery time and total energy used. A fuzzy logic algorithm was developed in MATLAB and implemented to facilitate the performance of a WSN. Simulations conducted considering varying packet size indicated that increasing the data packet size results in more delivery time and total energy consumed

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