Relay Node Selection in Wireless Sensor Network Using Fuzzy Inference System

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Abstract —Wireless Sensor Network (WSN) is continuously evolved with the advancement of wireless technologies. The dominating targets that control the WSN are energy and throughput of the network. Aiming to balance these targets, this paper proposed new relay node selection scheme based on Fuzzy Inference algorithms (RNSFIA) that give preference to communication distance between nodes, the degree of communication regarding intermediate nodes and priority on residual energy with the nodes. This included numerous level and various target improvement while selecting a relay node on every round of transmission. Further the results are compared with the Modified Low Energy Adaptive Clustering Hierarchy (MLEACH) algorithm. The performance of proposed RNSFIA is not only improving the network throughput from 35-40 percent but also increase the lifetime of the network from 50-60 percent. We recommend further to add more levels and targets that includes communicating bandwidth to tune the optimal utilization of network resources.

Index Terms—Wireless sensor network, throughput, fuzzy inference system, network life lime, relay node, RNSFIA

I. INTRODUCTION

The wireless sensor network consists of some small sensor node used in much application of military, hospital and environment monitoring [1]. The wireless sensor network is evolved to fulfill multiple objectives of network stability and reliability of the network. That being with optimizing of energy so that network lifetime would be extended. For efficient energy utilization, there were multiple objective algorithms were developed that includes measurement of energy utilize for specific communication, the distance between the sensor (node) and the Base Station (BS), and the minimal path to be followed by communication network between intermediate nodes and Relay Nodes (RN). Cooperative communication is a method that allows the use of a single antenna mobile to create an impact of the multiple-antenna system, this help to facilitate hop communication between the source, and receiver nodes. The basic concept is a collection of data through an intermediate node and forwards the same data toward the destination node. Here intermediate node called as Relay Node. The Cooperative relaying enhances multiuser communication through spatial multiplexing and increases the range of communication through distributed antenna array. The Cooperative Communication uses a signaling scheme that involves amplifying received signal and forward to next receiver. Here the Relay Node aggregates its data with the received data. Further, the relay node needs to measure the power of the received signal, check its power constraints, and retransmit to the cooperative network.

The problem arises when the set constraints do not allow relay node to operate as per scheme, or the relay has insufficient power to communicate with the network. As a result, the relay node becomes dead. Another major problem is of noise addition, by the wireless channel. From each relay node, noise may be added up and get amplified within cooperative communication. To counteract this problem, the receiver has to make decisions on the transmitted bits before combining the two-independent received faded signals [2].

A. Related Work

In LEACH method (Low-Energy Adaptive Clustering Hierarchy) and a clustering-based protocol [3] that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network. Further extending in [4] proposed modified LEACH (MODLEACH) method in WSN by using efficient cluster head replacement scheme and dual transmitting power levels and offers high lifetime and throughput for WSN.

In [5] jointly consider both relay-selection and resource-allocation for a cooperative network in a multi-user scenario and proposed a Neuro-Fuzzy (NF) based optimal relay selection algorithm that select best relay link concerning Signal-to-Noise Ratio (SNR), propagation delay and degree of mobility. In [6] form of spatial diversity using cooperative communication and discuss implementation challenges. Further, measure the performance of the network. The author shows that in the presence of noisy channel, cooperative communication improves the capacity for user and system and less susceptible toward channel variations. In [7] presented Low-complexity cooperative diversity protocols that mitigate the fading effect that caused by multipath propagation in wireless networks. The authors explored the fixed and adaptive relaying scheme and measured the performance regarding outage events and probabilities in

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[8] the authors proposed an optimized method that reduces energy consumption for the un-coded system by optimizing transmission time and modulation parameters. For the coded system, energy consumption varies with the function of distance and different modulation scheme. In [9] proposed a new relay selection algorithm using fuzzy logic aiming at both network lifetime and end-to-end throughput. In [10], [11] implement an opportunistic relaying method using a single relay selection to reduce outages. Here the selection of relay is based on the best instantaneous relay-destination channel and throughput. In [12] proposed new metric using circuit energy consumption and applied in clustered multi-hop sensor networks and transmit data to an appropriate next relay cluster far away from the former cluster. In [13] a fuzzy-logic-based clustering approach with an extension of prediction of the energy and prolongs the lifetime of WSNs by evenly distributing the workload. In [14] proposed a new energy-efficient metric for relay node selection in multi-hop random Wireless Sensor Networks (WSN) where the sensor nodes are distributed randomly and the node circuit energy consumption is also taken into consideration. In [15] proposed a new cooperative framework called the Three-Stage Relaying (TSR) scheme. The relays are divided into two groups based on Signal to noise ratio and constraint number-of-relay, and a virtual Multiple-Input-Multiple-Output (MIMO) antenna array between the two relay groups. The authors proposed an algorithm for the optimal selection of relay by groups.

Further authors demonstrated that the proposed algorithm was better than the existing approach regarding throughput and symbol error rate. In [16] presented fault detection strategy for wireless sensor networks using fuzzy inference system and similar work is proposed in [17]. The authors model a node that approximates the measurement error of neighbor sensor node and compares with the real network. Each node in the network has own fuzzy model that is trained to measure the input from neighboring sensors and output of its actual measurement. Faulty sensors are identified by limiting error measurement.

In [11], [18] the authors discussed the problem of designing the sensing duration for the node to maximize the achievable throughput for the secondary network. Further, the authors have formulated the sensing-throughput tradeoff problem and use energy detection sensing scheme. In [12], [19]-[21] proposed different relay selection algorithms based on residual energy, fuzzy rules, outage and power control at the nodes. Further, they have compared the performance with the existing algorithm and concluded the performance of the proposed method is better regarding the lifetime.

B. *Problem Statement*

The authors in [5]-[7] and [9] have proposed different tradeoff algorithms using energy, channel quality factors such as SNR, diversity, outage, and throughput to improve the performance of WSN. In clustered wireless networks, using the conventional dual-hope cooperation techniques [3]-[4] are inefficient because of imbalance transmission distance between relays to source and relay to the destination that becomes the bottleneck problem for the overall transmission within WSN.

C. *Major Contribution*

Through MATLAB we simulate the network and measured the performance of typical WSN channel and compared the performance of Existing and Proposed RNSFIA in terms of Packets delivery to Base Station (BS) and Relay Node RN with respect to rounds of iterations, Number of Relay Node RN with respect to rounds of iterations, and Alive and Dead Nodes with respect to rounds of iterations. Our significant contributions of this paper are listed below:

- Wireless sensor network and its performance parameters.
- Comparative analysis on the performance of WSN between MODLEACH and RNSFIA, in term of packet delivery from Relay Nodes (RN), Base Station (BS) and the lifetime of the nodes concerning rounds of iterations.

D. *Outline*

Section II presents the system model used in the Wireless Sensor Network (WSN) and working on the existing and proposed method of relay selection. Section III describes the experimental setup, Fuzzy optimal decision rules for the proposed method. Section IV describes the comparative results between the existing and proposed method that includes the Network Graph, Packet delivery at Base Station and Relay Nodes, Relay Nodes working with rounds of iterations, Alive and Dead Nodes with rounds of iterations and Cost regarding distance and level of optimization for WSN. The paper concluded in the last section.

II. System Model and Existing Method for Cooperative Communication Network

Wireless sensor nodes consist of sensors node that is connected to the wireless channel to the Base Station as shown in Fig. 1. The Relay nodes are same as sensor node however for a time act as an intermediate node to connect the sensor node to the Base Station. We assume that the wireless sensor node consists of n sensor nodes and a destination node, in which n sensor nodes act as a source node.

Other than source nodes, remaining nodes in the network are playing a function of relay node which collects the signal from the source node or intermediate network node and forwards toward the destination node or another intermediate node named as relay node as shown in Fig. 1.

In the system, the channel between the source node (S) and the destination node (D) exist, with the channel between the source node and each relay node (R) and further relay node (R) and destination nodes. In our work, we assume a simple model where the radio dissipates E_{elec}=50nJ/bit to run the transmitter or receiver circuitry and ε_{amp}=10pJ/bit/m^2 for the transmit amplifier to achieve an acceptable E_b/No (see Fig. 2 and Table I). We also assume an r^2 energy loss due to channel transmission and to transmit k- bits message at a distance d, radio energy expands as

TABLE I: LIST OF PARAMETERS USED IN EXPERIMENTAL SETUP

Number of Nodes	100
Width of Network	200 m
Length of Network	200 m
Radio Range (meter)	65m
Initial Energy of Sensor Nodes	0.5 J
Packet Size	4000 bits
Transceiver idle state energy Consumption	50 nJ/bit
Data Aggregation /Fusion Energy Consumption	5nJ/bit/report
Amplification Energy (Cluster to BS) $d \geq d_o$ *Efs*	10pJ/bit/m^2
Amplification Energy (Cluster to BS) $d \leq d_o$ *Emp*	0.0013pJ/bit/m^2
Amplification Energy (Intra Cluster Communication) $d \geq d_1$ *Efs/10*	Efs/10=Efs_1
Amplification Energy (Intra Cluster Communication) $d \leq d_1$ *Emp/10*	Emp/10=Emp_1

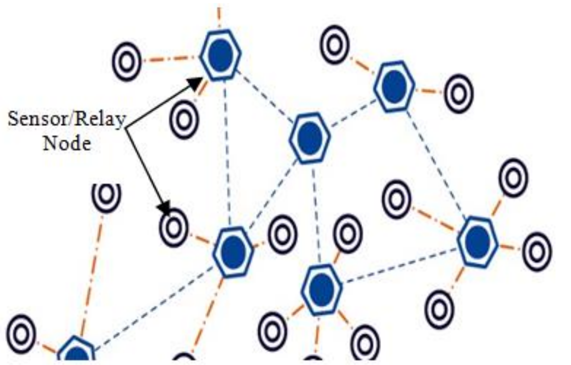

Fig. 1. Illustration of wireless sensor network consists of the sensor and relay node.

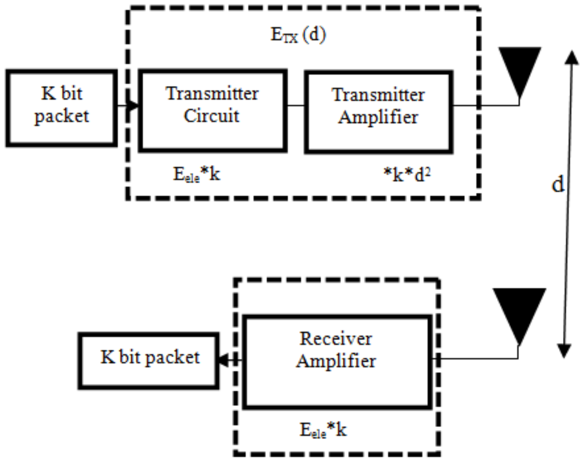

Fig. 2. Radio model for transmission [3]

$$E_{TX}(k,d) = E_{TX\text{-}elec(k)} + E_{TX\text{-}RL(k,d)}$$

$$E_{TX}(k,d) = E_{elec}{*}k + \varepsilon_{amp}{*}k{*}d^2 \qquad (1)$$

To receive message radio expands

$$E_{RX}(k) = E_{RX\text{-}elec(k)}$$

$$E_{RX}(k) = E_{elec}{*}k \qquad (2)$$

We assume that the best intermediate node gets selected within the network as per availability and network performance. Availability of node depends on the survival energy at the node and Performance of the network depends on the degree or hop of communication link allowed within the network. Another critical parameter is the priority of the network path prefer allocated for the selection of an intermediate node.

A. Leach and Mod Leach

Here optimization of the energy in the network is done. Algorithms were developed in such a way that the node would communicate over minimum threshold energy between nodes and intermediate nodes, i.e., nodes and relay nodes. Apart from these algorithms would support improvement in the network performance factor such as the throughput of the network and network lifetime.

0Working of LEACH [3] is

- Localized coordination and control for cluster set-up and operation.
- Randomized rotation of the cluster “base stations” or “cluster-heads” and the corresponding clusters.
- Local compression to reduce global communication.

MODLEACH [4] is the modified version of LEACH method that changes the cluster head at every round with specific threshold condition and probability. When the cluster head has less energy than the defined threshold the cluster head got replaced as per LEACH method otherwise it would continue to combine and propagate the signal in the network.

B. Proposed Realy Node Selection based on Fuzzy Inference Algorithm (RNSFIA)

Fig. 3 is block diagram representation of Proposed Relay Node Selection based on Fuzzy Inference algorithms (RNSFIA). That consists of Fuzzy Inference System (FIS) sections as Fuzzifier, Inference Engine, Fuzzy Rules, and De-fuzzifier. Here Fuzzifier had NoN, Degree, and Priority with numerous levels as input and applied over FIS to get an optimized path for WSN.

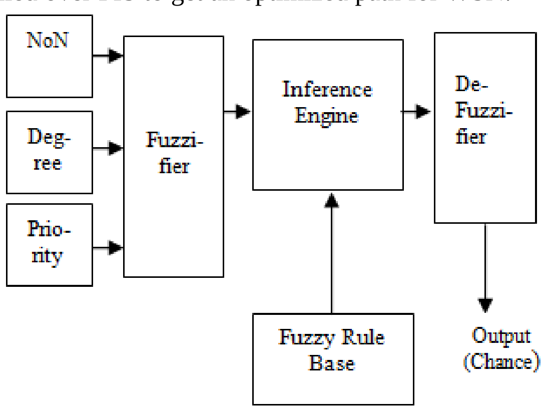

Fig. 3. Block diagram of proposed method of relay node selection (RNSFIA)

Algorithm of RNSFIA

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Input:
    NoN: Number of Nodes in a network
    n: a node of  the network
    w: width of the network
    l: length of the network
    r: radio range
    x: the number of RN node
    N: the number of times to be RN
    B: {b | b is n's vicinity node which is an RN candidate}
    T_th: a threshold value to become an RN candidate
    chance(n): a suitability value of the node n to be an RN
    m: the number of the round for iteration.
Output:
    Relay Node(n): the relay node of the node n is Relay Node: true if
    RN(n): Optimum Cost @(tour) TourNoN
    (degree) Degree of Communication|
    (priority) Prioirty

Function:
    Distance (data, tour_distance);
    Send (data, destination);
    Length=@TourLength(tour,RNSFIA)
    h=PlotTour(model,tour)
    TourSelection=@(action)
    ActionList(nswap,nreversion,ninsertion);
    CostFunction = @(tour) TourLength(tour,model.RNSFIA);
Initialization:
    chance(n) ← fuzzy logic (NoN, Degree, Priority)
    isRelay Node(n) = false;
N← 0
Main:
/*For every round of iteration*/
    f(N==[NoN/x]   )
    is Relay Node(a) ← false;
    T_th← 1;
    else T_th←[x/NoN] ;
    end if ;
    if (rand(0,1) >Tth)
    RN(n) ← n;
    chance(n) ← fuzzy logic(Distance, NoN);
    (chance(n), B);//Candidate-Message
    On receiving Candidate-Messages from RN candidates;
    for each bϵ B
    if (chance(n) < chance(b) )
    RN(n) ← b;
    is RN(n) ← false;
       Distance(Quit, B)
    else is RN(n) ← true;
    N←N+1;
    end if
    end if
    if (is Relay Node(n) == true) Distance(RN-Message, B)
    On receiving JOIN-REQ messages;
    else
    On receiving RN-Message;
    Send JOIN-REQ messages to the closest RN;
    end if
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III. Implementation of Wireless Sensor Network

In this work, we consider WSN where the base station is fixed at the particular location (set at (x=100 m, y=100 m) and the sensors are distributed in the region of 200 by 200 m. All nodes in the network are homogeneous and energy- constrained.

Tabu Search: Tabu Search [22] is a search method developed through met heuristic procedure to optimize multiple variable problems. We used input variables are the number of Nodes, the degree of communication and priority under different weighting as fuzzy priorities as shown in Table II and Table III.

Number of Nodes (NoN) is the count of the working sensor node used to communicate within the wireless network. The degree is referred to as the number of intermediate communication working between the source sensor node to the base station, and priority is linked with the residual energy available with the sensor node. That reduces with increasing round of communication and classified into three categories as Low, Medium, and High. Fuzzy Inference inputs and output membership functions are shown in Fig. 4. Fig. 5 shows the impact of input membership function over the output membership function. Based on inputs and output membership function a surf graph was developed, as shown in Fig. 6.

Cost1 = Sum of all the path length between the nodes (3)

Cost2 = Sum of distance between the nodes to zero (4)

Cost3 = Sum of distance for each node to previous nodes (5)

Cost4 = Sum of the distance calculated through the fuzzy inference system algorithm (best cost as a function of distance and degree of communication under fuzzy inference rule) (6)

TABLE II: CLASSIFICATION OF CONTROLLING FACTORS ON FUZZY INFERENCE SYSTEM

Controlling Factor	Region of Classification	Where
NoN	Low: n/5 to 0 Medium: n/5 to n/2 High: n/5 to n	n is the total number of nodes
Degree	Low: D/6 - D/3 Medium: D/3 - D/2 -D*2/3 High: D*2/3- D*2.5/3- D	D is the maximum number of intermediate nodes
Priority	First: n/20 n/10 Second: n/5 n/2 Third: n/20 n-n/10	n is the total number of nodes

TABLE III: FUZZY RULES APPLIED TO THE FUZZY INFERENCE SYSTEM

Rules	Inputs		Output
	NoN	Degree	Priority
1	'Low'	'Low'	'First'
2	'Low'	'Medium'	'First'
3	'Low'	'High'	'Second'
4	'Medium'	'Low'	'First'
5	'Medium'	'Medium'	'Second'
6	'Medium'	'High'	'Third'
7	'High'	'Low'	'Second'
8	'High'	'Medium'	'Third'
9	'High'	'High'	'Third'

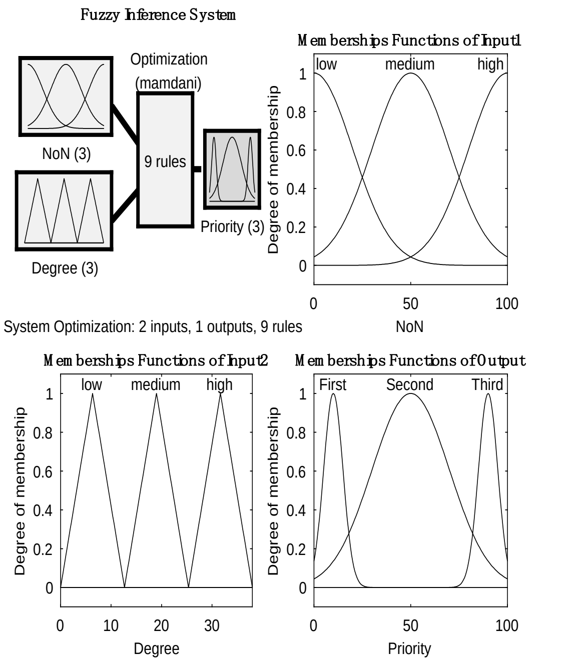

Fig. 4. Fuzzy Inference System with two input and output membership function

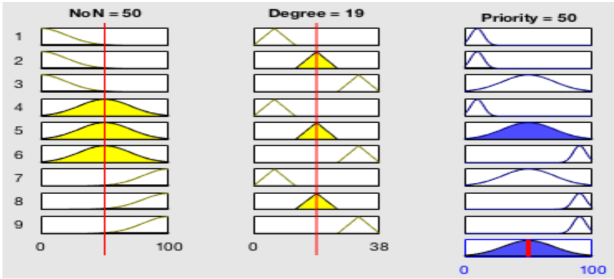

Fig. 5. Rule graph for fuzzy inference system (input as NoN, degree of communication and priority)

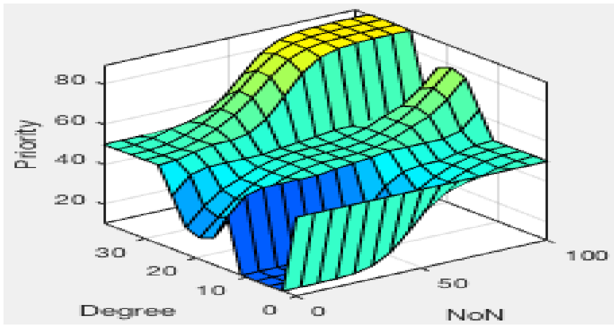

Fig. 6. Surf graph developed after applying rules on fuzzy inference system (NoN, degree, and priority).

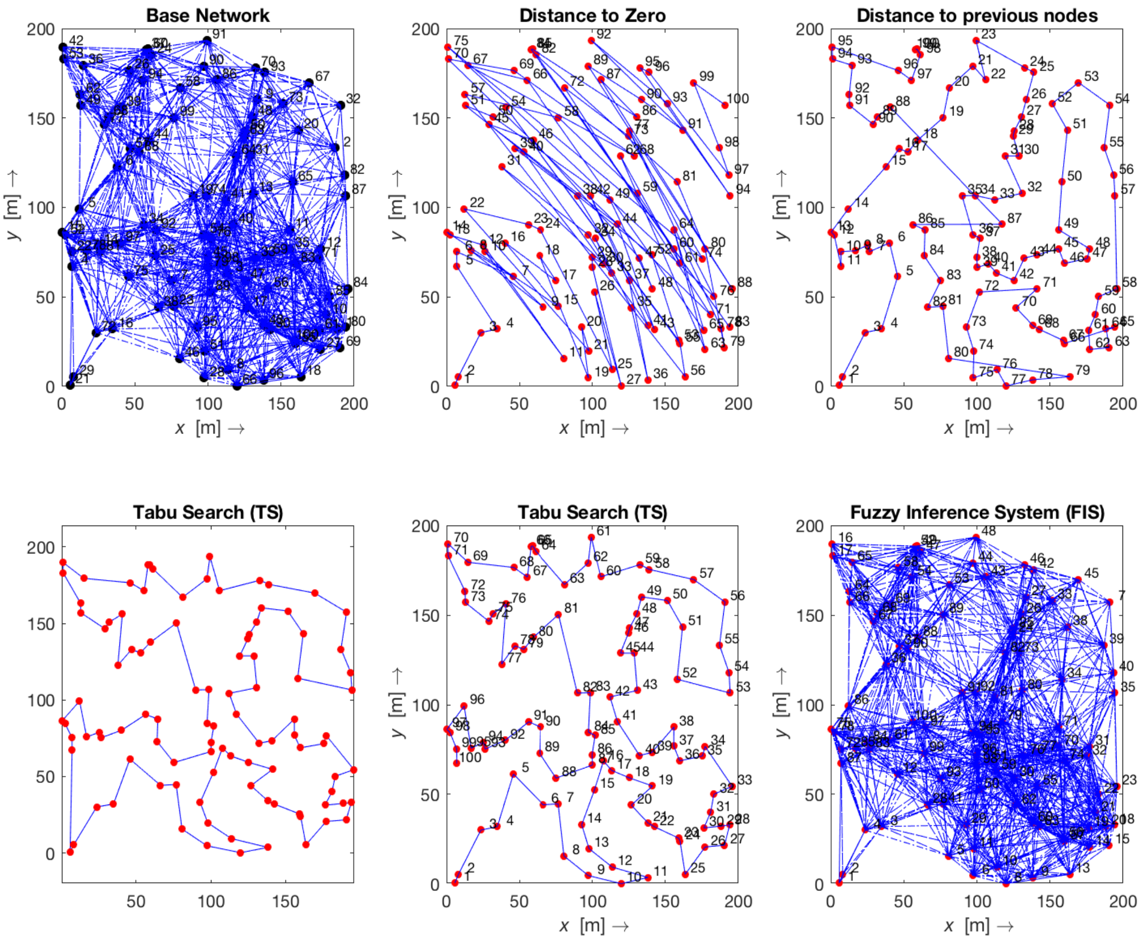

Fig. 7. Wireless sensor network route with four network path routes; Default network, distance to zero, distance to previous node and tabu search FIS network.

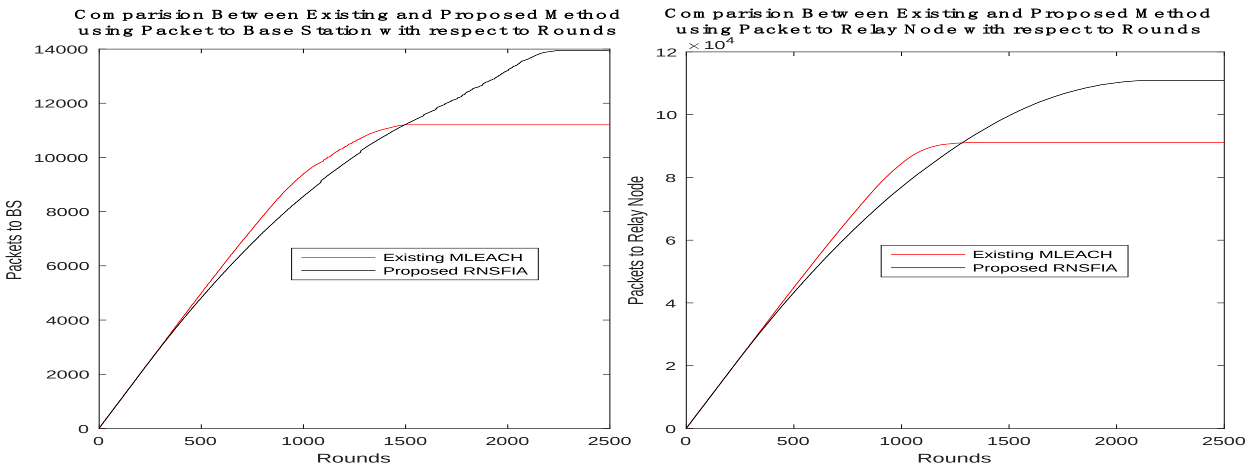

Fig. 8. Comparison between existing and proposed relay node selection based on fuzzy inference algorithms (RNSFIA) regarding packets delivery to Base Station (BS) and Relay Node RN concerning rounds of iterations.

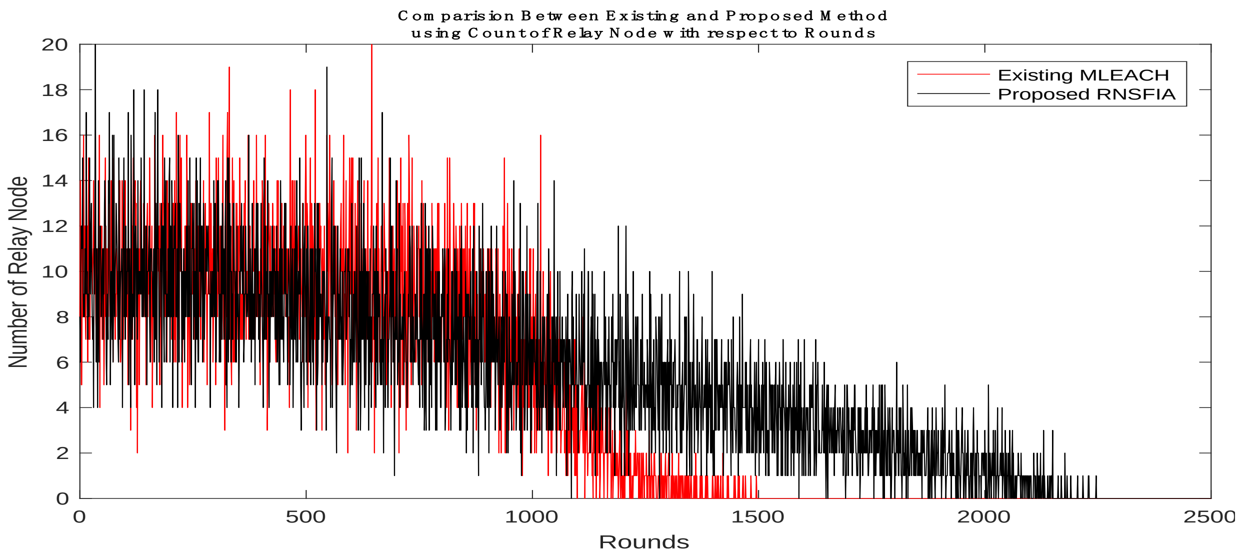

Fig. 9. Comparison between existing and proposed relay node selection based on fuzzy inference algorithms (RNSFIA) regarding number of Relay Node RN concerning rounds of iterations.

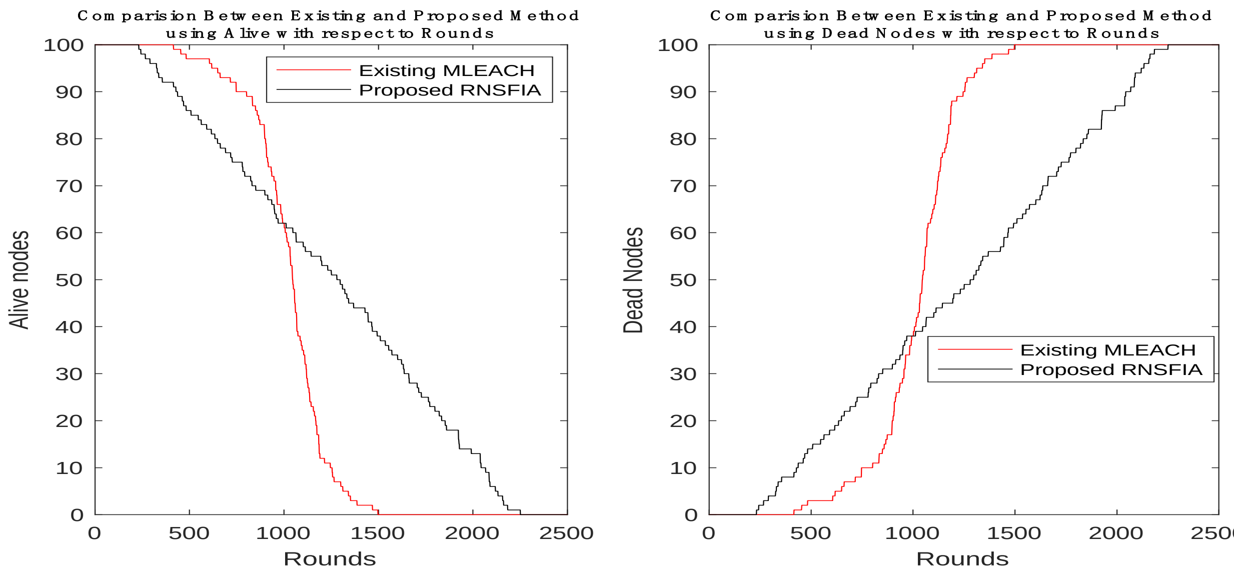

Fig. 10. Comparison between existing and proposed relay node selection based on fuzzy inference algorithms (RNSFIA) regarding alive nodes concerning rounds of iterations and dead nodes concerning rounds of iterations.

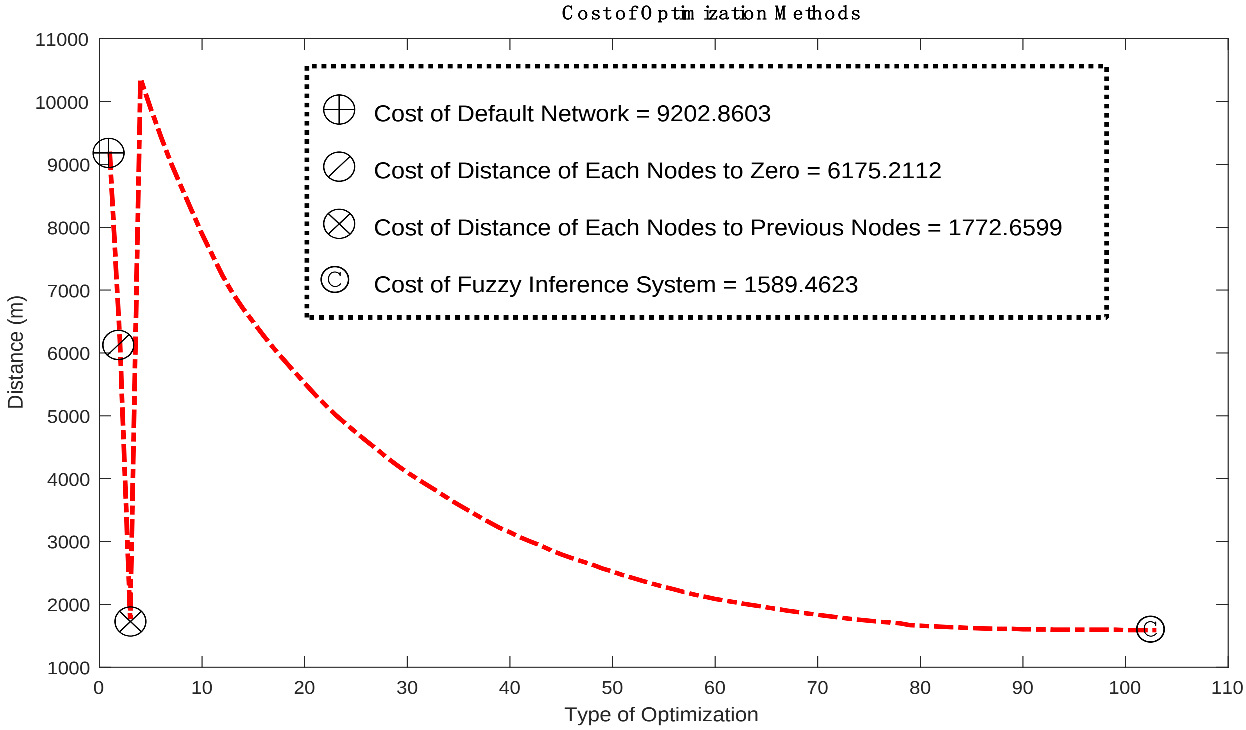

Fig. 11. Comparison of four wireless sensor network by the cost function using distance and types of optimizations as the factor

IV. Results

Fig. 7 shows the Base Wireless Network node where node connected with all other nodes, Distance to Zero Network where Network path was developed through a chain of nodes followed toward origin, Distance to Previous Node where a network path was developed on distance measurement between previous node and Tabu Search (TS) Optimized Network Path where network was developed on Fuzzy Inference System.

Fig. 8 shows the performance of Existing and Proposed RNSFIA regarding Packet delivery to the Base Station (BS) and Relay Node (RN) concerning rounds of iterations. We found that packets delivered to the Base Station increase with an increasing round of operations in both methods. The proposed RNSFIA offered a higher packet at Base Station, as shown in Fig. 8 Packet delivered at the base station using proposed RNSFIA is 40 percent higher than the existing method. Similarly, we found that in both methods, the packet forwarded through Relay Nodes is increased with an increasing round of operations. On comparing Packet forwarded from Relay Nodes using the proposed RNSFIA are 22 percent higher than the existing method.

Fig. 9 shows the performance of Existing and Proposed RNSFIA regarding Number of Relay Node RN concerning rounds of iterations. Further, we found that the Relay Node in existing method collapse near to 1550 rounds of operation while the proposed RNSFIA would be working till 2200 rounds of operation. Quantitatively, we noted that the proposed RNSFIA relay node would be available at 40 percent more rounds of operation than the existing method.

Fig. 10 shows the performance of Existing and Proposed RNSFIA regarding Alive Nodes concerning rounds of iterations and Dead Nodes concerning rounds of iterations. Here operation of both methods got validated concerning the round of operation. The existing method would be survived until 1550 rounds of operations, which was quite less (700 rounds) than the survival of the proposed RNSFIA. However, after 750 rounds of operation performance of existing method tremendously decay (30 percent of nodes), nodes in wireless network got dead.

To validate the network cost, we have calculated the communication cost for individual networks. Fig. 11 shows the comparative cost of default (Base) Network, Node to Zero Network, Node to Previous Node Network and Fuzzy Inference System (FIS) regarding distance and optimization level. Here RNSFIA belongs to cost of FIS which was quite less with other networks.

V. Conclusion

There are numerous level and various targets to improve the performance of WSN. The proposed relay node selection based on Fuzzy Inference algorithm (RNSFIA) give an efficient method to identify the relay node and provide an optimum path for transmission of data. The outcome of the method is based on the number of Nodes, the degree of communication, and the priority help to select an optimum relay node sequence that extends the lifetime and throughput of the sensor network. As a result of defuzzification, we got the network path for an operation which improves the network performance. On comparing the performance of the existing algorithm and proposed RNSFIA, we found that proposed RNSFIA not only improve the network throughput from 35-40 percent but also increase the lifetime of a network from 50-60 percent. We recommend further to add more levels and targets that includes communicating bandwidth to tune the optimal utilization of network resources.

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