International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 16 (2017) pp. 6055-6064

Fuzzy Logic and Trust Based Clustering Approach to Improve the WSN Performance

Manoj Challa[1], Dr. P.Venkata Subba Reddy[2] and Dr. M .Damodar Reddy[3]

[1]*Research Scholar, S.V.U college of Engineering, Tirupati, India.*

Orcid: 0000-0002-0706-4029

[2]*Professor, Dept of CSE, S.V.U college of Engineering, Tirupati, India.*

[3]*Professor, Dept of CSE, S.V.U college of Engineering, Tirupati, India.*

Abstract

Demand of wireless communication is increasing rapidly in real-time application scenario. In this field of wireless communication, wireless sensor networks play an important role to provide the communication in various real-time application scenarios such as atmosphere management, traffic localization etc. However, these networks suffer from various performance degradation issues such as network congestion, packet drop, routing and energy awareness during communication. Various techniques have been developed in this field to cater these issues but energy consumption still remains as an unsloved issue. To deal with this, here we present Fuzzy-Logic based scheme for routing in WSN. This work also uses clustering scheme where trust based routing is applied. Finally, Fuzzy rules are formulated and assigned to the network model. Experimental study is carried out and compared with other technique where simulation performance shows improved routing performance.

Keywords: Fuzzy Logic,WSN,Routing, Energy Effiency, Network System, Clustering

INTRODUCTION

The Wireless Sensor Networks (WSNs) has gained more popularity around the world, mainly due to latest developments in the field of wireless communication and microelectronics. The development sophisticated smart wireless sensor has strengthened the WSN, as the credit goes to enhancements in Micro-Electro-Mechanical Systems (MEMS) technology. The WSN is a large set of such sensor nodes which are interconnected together for communication purposes. The WSN is generally deployed to monitor and observe certain ecological or physical conditions, for example atmospheric pressure, humidity, noise, motion disturbance, wind force, rains, pollution, etc. The wireless sensor nodes possess the ability to detect, measure, accumulate and forward the data. Furthermore, the nodes can exchange information between themselves. The nodes will be equipped with particular sensors, and the information collected through these sensors will be sent to target or destination through conceivable multihop communication mechanism. WSNs have wide range of applications ,they are deployed in both domestic and industrial environments for example, home automation, hospitals, industrial monitoring, vehicle tracking, health monitoring, field survey, etc. [1][2].

Alternately, the Heterogeneous wireless sensor networks started to gain more popularity due to it several benefits. The HWSN can be used under various environments to fulfil the requirements of numerous applications and demands, as depicted in recent studies [3][4]. Nevertheless, energy efficiency is one of the critical difficulties in wireless sensor networks. The energy efficiency determines the stability and lifetime of the network. Conversely, the lifetime of the network might be degraded due to restricted memory, and processing power, and low energy levels. As the sensor nodes are deployed in harsh and remote environments, replacing a depleted battery is highly difficult, sometimes impossible. Due to limited battery backup and difficulty in replacing them, the energy aware mechanism and working must be instigated in WSNs, otherwise, the lifetime of the network will be degraded [5].

One of powerful and efficient techniques in WSN is the clustering, which can provide several benefits, including robust routing, energy efficiency, etc. Therefore, it can be inferred that the clustering can enhance the lifetime of the WSN. Clustering is a simple technique of grouping a bunch of sensor nodes, known as cluster. Each cluster will have a central cluster head. Each sensor nodes will forward data to their cluster head. As the data will be transferred to the base station by the cluster head, the energy consumption of the nodes will be lowered.

But, to ensure effective solution, the clustering must be done carefully and efficiently. Clustering based routing protocols are extremely useful in understanding the energy limitations of the sensor nodes, and helps in lowering the overall cost of data accumulation and transmission of the detected parameters, before forwarding it to target node or base station [6]. During the instigation of WSN, the clustering will be done based on the hierarchical division of the environment, which will be managed by the cluster heads.

Selection of cluster heads can be carried out under probability scheme, either through election or at random. Additionally, the cluster head selection is also possible through Centralized controlled methods. With the help of this, energy load can be well balanced in the network. Energy saving in the sensor networks without affecting the performance, can be achieved with the help of heterogeneity. The clustering mechanism is segregated into two layers. The first layer is in charge of choosing the cluster and the second layer is responsible for routing in WSN. Heterogeneity in sensor nodes is segregated into three types; namely, computational heterogeneity, energy heterogeneity and link heterogeneity [7]. Various researchers have emphasized on clustering under numerous routing techniques, for example, evolutionary [8], grid [9] and geometric [10] routing schemes, for both homogenous [11], as well as heterogeneous [12] WSNs.The Sensors nodes are powered by batteries. Hence, after their installation, they are left unattended or un-serviced. Therefore, they are expected to operate for a longer time, typically for several months. Due to the scarcity of energy in WSNs, the efficient energy usage is of the top priority. A sensor node spend energy mostly on three important tasks, sensing data, processing the data, and communication. Several methodologies were proposed to optimize the energy utilization in WSNs. [13]. Most of these techniques involves physical-level design decisions, i.e., voltage scaling, modulation scaling, and so on. There are also energy-aware MAC protocols and energy aware routing mechanisms [14].

For the purpose of resolving such problems related to packet drop, energy consumption, and throughput, a soft-computing based technique is presented to optimize the performance of WSN. The proposed technique uses fuzzy logic, wherein, performance of the WSN is optimized by defined a predefined set of rules. These rules assist in achieving desired routing behavior for practical WSN conditions.

BACKGROUND INFORMATION

A few strategies have been proposed to enhance the lifetime in WSN. Among these techniques, clustering in one of the most effective, less-complex and broadly acknowledged mechanism. Apart from WSN, the clustering techniques are also used in Mobile Ad-Hoc Networks, Ad-Hoc Networks, etc. A few clustering mechanisms have been acquainted for dividing the nodes and allotting them with particular zones. In clustering, the sensor nodes are segregated and grouped. From the grouped cluster of node, only one node can communicate with the base station. This node is known as cluster head. The other nodes are known as cluster members. The role of cluster members is to sense and forward the data to the cluster head. The cluster heads accumulate all the data sent from the cluster members. This collective data will be forwarded to the target to base station, which completes the overall objective.

The location of Cluster heads is closer to the cluster members than target or sink node. The energy consumed to forward the data to cluster head is lower than the energy needed to forward the data to sink. Thus, the sensor nodes in clustering can conserve their energy. For Ad-Hoc Networks alone, there are numerous clustering techniques available at disposal, in any case, those techniques are not directly compatible with WSNs. The main reason being the stringent energy conservation rules in WSN. Therefore, additional efforts were made by numerous researchers to find suitable power-aware clustering schemes for WSNs. Since the WSN is dynamic nature, due to constant motion of wireless sensor nodes, the dynamic clustering techniques are more appropriate.

Few of the popular clustering techniques are: Distributed Clustering Algorithm (DCA) [15], Spanning Tree (or BFS Tree) based Clustering [16], Clustering with On-Demand Routing [17], Clustering based on Degree or Lowest Identifier Heuristics [18], Distributed and Energy-Efficient Clustering [19], Adaptive Power Aware Clustering [20], Power-Efficient Gathering in Sensor Information Systems (PEGASIS), Power Efficient and Adaptive Clustering Hierarchy (PEACH), Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network(LEACH)[28],Optimal Energy Aware Clustering Algorithm for Cluster establishment (ACE), Hybrid Energy-Efficient Distributed Clustering (HEED).

Lindsey et al [21] presented a near optimal chain-based protocol. In this technique, the node sends the data only to its closest neighboring nodes, which alternates transmitting that data to the base station. This considerably reduces the energy wastage. It is presumed that the constituent nodes are well aware of the underlying topology network, and hence the greedy algorithm is used.

PEGASIS is a type of greedy chain protocol, which is closely optimal to the information accumulation issue in sensors. Only the physical distance is considered in the greedy strategy. It neglects the capacity of a potential node on the chain. Thus, a selected node in the chain with low residual energy, but with shorter distance, may deplete and fail early. The Ref. [22] presents that a routing protocol have the capacity to work well under greedy environments. The procedure of sending a packet from the source node to destination node or base station in a particular region is carried out in two stages, as given below,

- Inter-cluster routing: In this mechanism, the greedy algorithm is use to send the data packets from the cluster heads to base station.

- Intra-cluster routing: In this mechanism, the flooding strategy is used to forward the packet to cluster head. Whenever there is a packet to forward, the cluster will be flooded with that packet, when the quantity of intra-cluster nodes are lower than certain threshold.

Furthermore, in Intra-cluster routing, recursive geographic forwarding methodology must be initiated to forward the data packet to target cluster. This required the cluster head to split the target cluster into number of sub regions. Then same number of identical query packet are created and forwarded to those regions.

PEACH [23] algorithm is based on the principle of overheard information from the sensor nodes. It was more leaned toward being a cluster formation strategy. As indicated by this strategy, if the cluster head turns into an intermediate node, it sets the target node as next hop, before commencing any other operation. After that, a timer is set for a pre-specified duration, to receive and accumulate data packets arriving from numerous other nodes. A comparison is made to determine the shorter distance among previously selected next hop node, and actual destination node. When the distance to destination is shorter, then the node joins to the cluster which contains the destination node. Accordingly, the next hop of this node will be replaced by destination node.

PEACH is a versatile dynamic clustering scheme for inter-cluster multi-hop communication. Nevertheless, the PEACH protocol also experiences nearly similar restrictions of PEGASIS because of the selection of physical proximity. On the other hand, the balanced k-clustering issue can be resolved using Optimal energy aware clustering [24]. The k corresponds to quantity of master nodes that are allowed to exist in the network. The working principle of this strategy is derived from the minimum weight matching. The sum of spatial distance present between the master nodes and member nodes are optimized in the given network. It adequately disseminates the load in the network to every master node, and lower the communication complexity and energy wastage. On the downside, this technique ignores the residual energy of the node while appointing the master nodes.

ACE [25] is another distributed clustering algorithm, which performs clustering operation in two stages, which are termed as spawning and migration. Each stage is composed of numerous iterations and the interval between the consecutive iteration are maintained uniform across all cycles.

- The spawning stage witnesses the creation of new clusters, independently. If a node intends to become a cluster head, a message will be broadcasted to other nodes, inviting them to become its members.
- In the migration stage, the established clusters are managed and organized. The cluster head also controls the migration of an existing cluster.

Occasionally, the cluster head will conduct polls among its members to determine the next cluster head, after it steps down. Based on the polling results, the current cluster head will promoter the chosen node as the new cluster head. With ACE protocol, uniform formation of cluster can be achieved. On the contrary, the residual energy of the nodes is ignored in ACE, which turns out to be a major disadvantage.

HEED [26] is a distributed algorithm, which considers the residual energy of the nodes. This helps in establishing the clusters by distributing the cluster heads uniformly across the network. Based on a hybrid parameter, the algorithm chooses a cluster heads, periodically. The hybrid parameter consists of primary parameter and secondary parameter. The primary parameter is the residual energy of a node, and secondary parameter is proximity of node and neighboring nodes.

HEED converges at 0 (1) cycles utilizing low message overhead and distributes the cluster head, uniformly across the network. Still, an initial percentage is chosen at random. This turns out to be a major constraint of the algorithm. Several studies were conducted to enhance the stability of the network, though modified scheduling, routing, data aggregation, and other. Nonetheless, this paper emphasizes on enhancing the network stability period through clustering technique. The reason behind choosing the clustering technique, is its beneficial functionality with respect to broadcasting, aggregation etc. The proposed ESRPSDC technique uses the operating principle of Energy-Efficient Level Based Clustering Routing Protocol [27]. In wireless sensor networks, the power resource of each sensor node is limited.Minimizing energy dissipation and maximizing network lifetime are important issue in the design of routing protocols for sensor networks.A new improved cluster algorithm of LEACH [28]protocol which is intended to balance the energy consumption of the entire network and extend the lifetime of the network . LEACH protocol is a typically representation of hierarchical routing protocol . It is a self adaptive and self oragnised . Leach protocol uses round as unit ,each round is made up of cluster set-up stage and steady state storage for the purpose of reducing unnecessary energy costs.The steady-state phase duration is usually much longer than set-up phase duration. However, the first phase is more important, in which sensor nodes are allowed to elect themselves as cluster-heads randomly, and then divided into clusters.

PROPOSED MODEL

In this section, we have discussed proposed fuzzy logic based approach to improve the performance of wireless sensor network by improving the network lifetime and optimizing energy consumption.

A. System design

In a WSN, a neighborhood table is generated, which contains details about energy cost, trust and distance. These table values are used to identify and judge the neighbors. For effective investigation of these qualities, three parameters are run on every node, which are, Trust Manager, Energy Watcher and Distance Estimator. The Energy Watcher observes and records the energy cost of each known neighbours. This depends on the scrutiny of the node N, conducted during its one hop transmission to send the data to its neighbors, and the energy cost report from these neighboring nodes. In certain situation, a malicious node may incorrectly report its energy cost as very low, so that the neighboring nodes will choose it as their next hop.

In any case, with the help of fuzzification, can effectively identify such malicious nodes and remove its entry from the next hop. This decision will be based on the trust parameter of a node, as determined by the Trust Manager. The role of the Trust Manager is to track the trust level of the adjacent nodes, on the basis of the network loop discovery and broadcast messages from the base station regarding delivery of the data. After the selection of next hop neighbours for a node N, which is based on the neighborhood table, the node N forwards it energy report message. For transmitting the data packet from the node to target, the energy cost will be forwarded to all the neighboring nodes. Various techniques are used by Energy Watcher for energy cost computation. Theses energy cost reports also contributes to Energy Watcher of the receiver. The distance between node and cluster head will be calculated by the Distance Estimator.

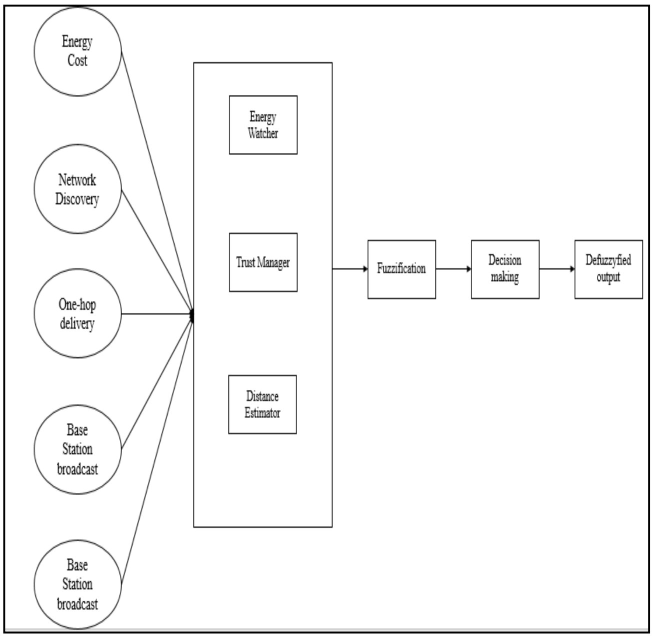

Figure 1: System architecture

B. Trust Based Clustering

With respect to link connectivity among the nodes, cluster head is selected by the sensor nodes in the WSN. Generally, the nodes which have greater link connectivity than its two-hop neighbours, will be chosen as a cluster head. Afterwards, the cluster head advertises itself to neighboring nodes. The other nodes will receive and unpack the advertisement message, which consists of ID and location information of the cluster head.

The normal nodes can receive this information when they lie in the radio range. Communication link must be formed between the normal nodes and cluster head. Therefore, the node selects any one cluster head through its advertisement messages based on its strong signal strength, which is termed as Received Signal Strength (RSS). After the decision is made, the node can join the cluster by sending membership message to the cluster head. The details about energy cost and its cooperative ability will also be appended to the message. The message also contains details about reliable sensing count, unreliable sensing count, and fuzzy trust value, which are all connected to the reliability of the node. For determination of closest neighbor cluster head, consider two cluster heads, denoted as, x and y. If an advertisement message of cluster head y is picked up by cluster head x, and the RSS value of y is higher, then the cluster head y will become the neighboring cluster head. The ID of cluster head y will be recorded.

C. Energy Cost

There are two types of models used in wireless communications, namely, the multi-path fading model and the free space channel model. The free Space channel model will be utilized when the communication distance d does not exceed the threshold distance, d_0. In any other case, multi-path fading will be used [29]. The total energy required to broadcast a k-bit message over a distance d, is estimated using the radio model.

$$E_{trans} = E_{amp}(k,d) + E_{elec}(k,d)$$
$$= k * E_{elec} + k * \varepsilon_{fs}(d \geq d_0)$$
$$= k * E_{elec} + k * \varepsilon_{fs}(d < d_0)$$

Where,

k = The total amount of forwarded bits over a distance d,

t = The transmit amplifier dissipation per bit.

E_{elec} = The transmitter circuitry dissipation per bit,

For computation of receiving cost, the equation is given as

$$E_{rec} = k * E_{elec}$$

The lifetime of the WSN can be increased by lowering the network energy consumption, which is represented analytically as:

$$E_{total} = E_{rec} + E_{trans} + E_{process} + E_{sense}$$

Where:

E_{total} = Total energy cost of the network

E_{rec} = The receiving cost

E_{trans}= The transmission cost

$E_{process}$ = The energy cost of processing

E_{sense} = The energy cost of sensing

With the help of minimum energy cost required for a transmission distance, the overall energy cost can be easily estimated. The minimum distance ($Min\ (E_{total})$)of separation between a node and cluster head is estimated.

D. Packet Delivery Rate Calculation

This parameter suggests the significance of communication ratio. The selfish behavior and the regularity of the sensor nodes can be regulated as,

$$PDR_i = \frac{STR_i - PFR_i}{STR_i + PFR}$$

Where:

STR_i= The success count of the packet delivery rate of the node i

PDR_i= The packet delivery rate of the sensing count node I is $1 \leq i \leq k$

PFR_i = The failure count of the packet delivery rate of the node i

E. Residual Energy Calculation

This parameter suggests the residual energy present in the sensor node. The complete depletion of weak battery will result in node failure, which can be avoided by carefully assessing the residual energy of the nodes. It additionally reduces the supplementary mechanisms to process the power aware strategies. For a given node i, the residual energy is denoted as R_i. Where $1 \leq i \leq k$. For the same node *i,* the Total Trust Value (TTV) is estimated using:

$$TTV = W_1 R_i + W_2\ PDR_i + W_3 \frac{RV_i}{W_1} + W_2 + W_3$$

F. Power Consumption

The power in the nodes will be determined by residual value of their batteries. Each sensor node broadcasts its own quantification value, P_i:

$$P_i: -1 \leq P \leq 1.$$

The rank of the node will be evaluated by the cluster head to choose the optimal nodes for data aggregation. This task is accomplished using fuzzy logic.

G. Fuzzy logic integration for wireless sensor network

The challenges concerned with the QoS can be ascertained with the pro-active strategy of the fuzzy logic. The operating phenomena of a highly dynamic nonlinear scheme like a WSN, not demanding the numerical model can be taken care of, skillfully with fuzzy logic.

Applications and functionalities like decision making, control systems, pattern recognition and system modeling, etc., can exploit if-then rules of the fuzzy logic. In a typical fuzzy rule based inference algorithm, there are three stages involved.

- **Fuzzy corresponding:** In this stage, the state of the fuzzy logic and the degree to the input fundamental steps are determined.
- **Conclusion**: Based on the degree of competition, the conclusion of the rule shall be estimated.
- **Grouping**: The obtained outcomes of every fuzzy rules are merged together into a solitary piece of total general results.

H. Rule Description

A fuzzy set An in X will be portrayed by a membership function. In general, these functions can be easily actualized by the conditional statements of fuzzy logic. On account of fuzzy statement, when the predecessor is true with some level of membership, then the subsequent outcomes are also true with the identical level.

I. The Rule Arrangement

The Rule:

When the trust is high, and the power consumption and separating distance is low, then the outcomes are gentle, in any other case, the output will be malicious. The technique used by the fuzzy Logic is mentioned as follows. In this research work, the if-then rules of the fuzzy logic accounts for these parameters for evaluating the nodes: energy consumed, distance, and trust. The aforementioned parameters determine the fuzzification analysis for a secure WSN in unknown environments under harsh conditions. For the given three inputs, energy utilization, distance and trust, the resulting probabilities are Worst Node (WN), Normal Node (NN) and Best Node (BN). The inputs are taken in terms of 2 values, High and Low. For three inputs with two possible values for each, the total combination of inputs will be $2^3 = 8$. The fundamental principle of selecting a node is based on the combination of input values, where the energy utilization and distance must be low, but trust should be high.

The energy consumption parameter, P, can be described under fuzzy set as,

$$P = Fuzzy\ Set[\{BN, s\}, \{NN, t\}, \{WN, u\}]$$

Where, s = The membership rank for Best Node in the estimation of energy consumption

t = The membership rank for Normal node in the estimation of energy consumption

u = The membership rank for Worst node in the estimation of energy consumption

The distance parameter D can be described under fuzzy set as:

$$Distance, D = Fuzz\_Set[\{BN, p\}, \{NN, q\}, \{WN, r\}] \quad (2)$$

Where: p = the membership rank for Best Node in Distance computation.

q = The membership rank for Normal node in Distance computation.

r = The membership rank for Worst node in Distance computation.

The trust parameter, T can be described under fuzzy set as:

$$,Trust, T = Fuzzy\ Set[\{BN, v\}, \{NN, w\}, \{WN, x\}]$$

Where: v = The membership rank for Best Node in trust computation

w = The membership rank for Normal node in trust computation

x = The membership rank for Worst node in trust computation

Based on the outcome of the combination of comparable members of the fuzzy sets of these parameters, the final decision can be made.

Table 1 describes the criteria for decision making process using fuzzy logic for a given combination of inputs and its respective outputs. The block diagram of the decision making system using the proposed fuzzy system is given in figure 1. Let the trust be denoted as T, and distance and consumed power be represented as D and P, respectively. Accordingly, depending on these parameters, the quality of node is determined, as given below,

Table 1 : Decision making process using fuzzy logic

Distance $dist$	**Trust T**	**Power Consumed Pwr**	**Result**
Low	Low	Low	Normal
Low	Low	High	Worst
Low	High	Low	Best
Low	High	High	Normal
High	High	High	Worst
High	Low	Low	Normal
High	Low	High	Worst
High	High	Low	Worst

The given node is best node, if $Dist$ and Pwr are low, and T is high.

The given node is normal node, if $Dist$ is low, Pwr is high, and T is high.

The given node is normal node, if $Dist$ is low, Pwr is low, and T is low.

The given node is normal node, if $Dist$ is high, Pwr is low, and T is low.

The given node is worst node, if $Dist$ is low, Pwr is high, and T is low.

The given node is worst node, if $Dist$ is high, Pwr is high, and T is high.

The given node is worst node, if $Dist$ is high, Pwr is low, and T is low.

The given node is worst node, if $Dist$ is high, Pwr is high, and T is low.

The following logic is simplified using if-then rules. The fuzzified values can undergo defuzzification using numerous strategies, for instance, max center scheme, centroid averagescheme, smallest of maximum and largest of maximum, mean of maxima, and many other. In our work, maximum scheme is used. The best nodes and normal nodes are chosen according to the decision made by the defuzzification mechanism. The selection is done by the cluster head, for data aggregation. On the other hand, the worst nodes will be discarded. With the help of selected nodes, the cluster head forwards the aggregated data to the designated target node. The communication is guaranteed to be secure as the path is free from malicious and faulty nodes.

RESULTS AND DISCUSSION

This section provides complete simulation study and comparative performance analysis using fuzzy logic technique. This technique is carried out by incorporating trust based routing and fuzzy logic based decision rule approach. Complete simulation is performed using MATLAB simulation tool with windows platform. Simulation parameters are given in table 2.

Complete simulation study is compared by considering various metrics such as: average packet delivery ratio, end-to-end throughput, packet drop rate and energy consumption

Table 2 : List of parameters with values

Parameter name	Considered value
No. of Nodes	25,50,75,100
Network area	1000mx 1000m
MAC protocol	802.11
General Routing	DSDV
Traffic Type	CBR
Packet Size	512 bytes
Transmission Power	0.400 W
Receiving Power	0.690 W
Initial Energy	5 joules

• Average Packet Delivery Ratio: provides the overall performance analysis in terms of successfully transmitted packets.

• End-to-end Throughput: it is the measurement of total successfully received packets by the sink node.

• Packet Drop Rate: it is the measurement of total number of dropped packets due to inefficiency of the network.

• Energy: It is the average energy consumed for the data transmission

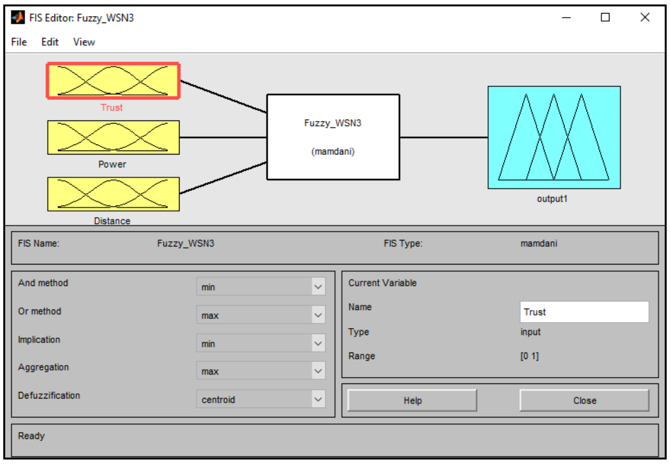

Figure 2: Fuzzy Logic formulation for WSN

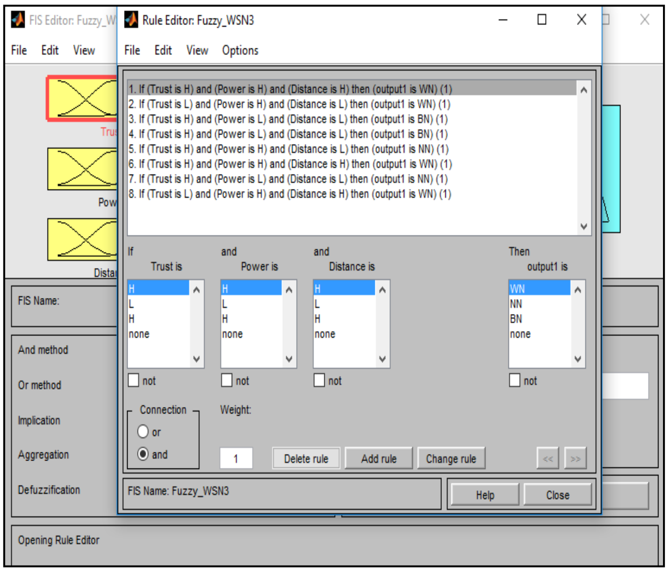

Figure 3: Fuzzy rules

Fuzzy logic formulation is depicted in figure 2 where a FIS file is created to obtain the desired output based on the fuzzy rules and membership functions. In order to construct this, trust, power and distance values are considered as input

Any fuzzy logic system requires fuzzy rules to obtain the output. Various membership functions are presented in the figure 3 which are used in this work.

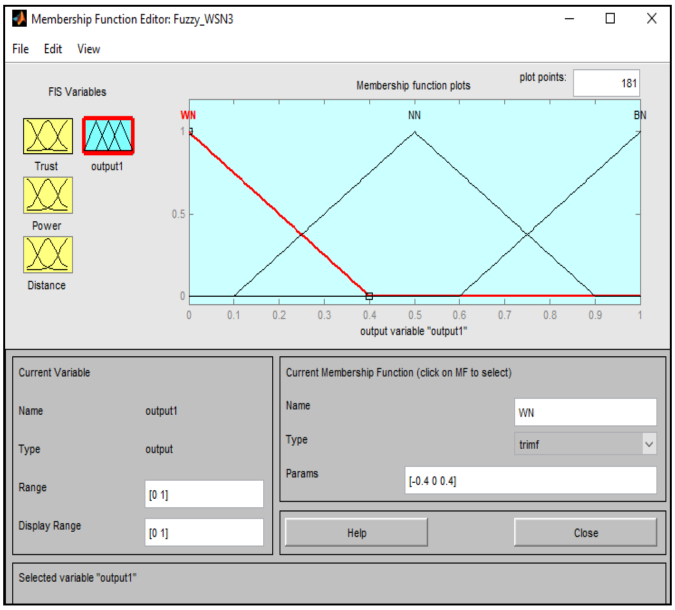

Figure 4: Output of the fuzzy system

Finally, a pictorial representation is given in the figure 4 which indicates the performance of nodes in terms of worst node, normal node and best node.

First of all, we evaluate the performance in terms of packet delivery rate. In order to evaluate this, we consider varied number of nodes. Performance obtained using fuzzy logic based scheme is compared with conventional LEACH routing protocol. During simulation, packet drop is analyzed at every 10 seconds of time duration. Comparative performance is depicted in figure 5.

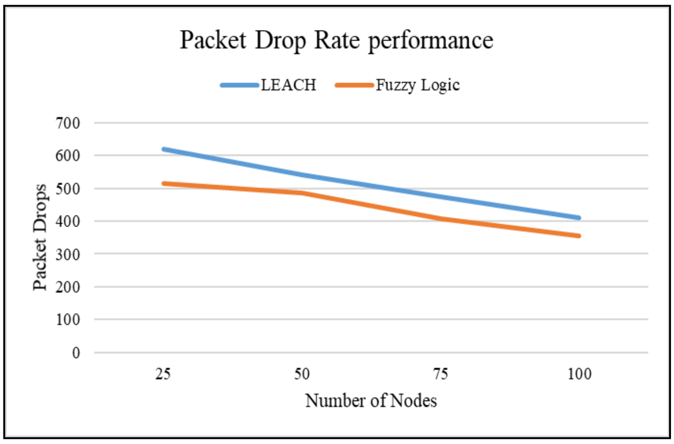

Figure 5: Packet drop performance

In next stage, we consider End-to-End throughput analysis for a given network configuration as presented in table 2. In this case also, we use varied number of nodes as previous simulation study. Previous case shows that more number of nodes helps to reduce the packet drop during simulation whereas this study shows that more number of nodes lead to the improving the packet delivery performance resulting in improving the throughput. This performance is depicted in figure 6.

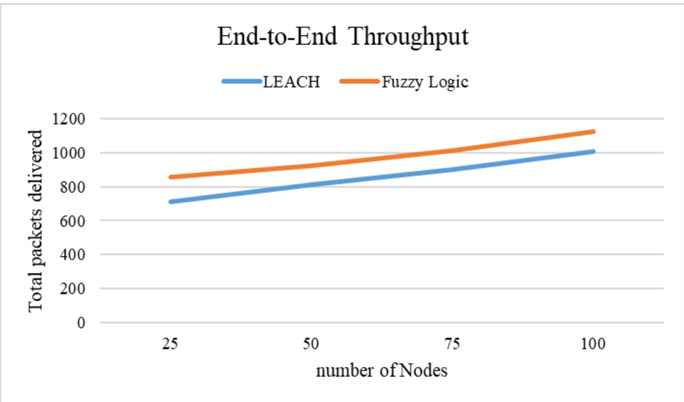

Figure 6: End-to-end throughput performance

Finally, we present a comparative study by considering energy consumption as performance constraint. However, more number of packets causes congestion on the network which increases energy consumption. In order to deal with this, fuzzy logic provides decision based rules which can improve the energy consumption by mitigating these issues. A comparative study is presented in figure 7.

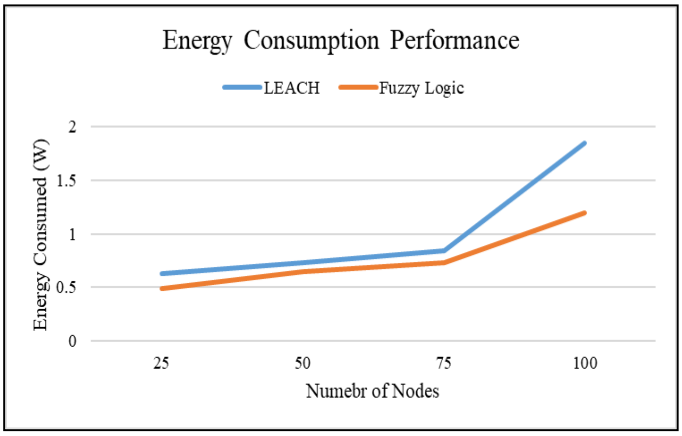

Figure 7: Energy consumption performance.

Complete study shows that fuzzy logic based scheme helps to obtain better performance when compared with other state-of-art techniques in wireless sensor networks.

CONCLUSION

This work discussed about wireless sensor networks and issues present in network during communication. various studies have been presented recently for improving the network performance but energy efficiency and network lifetime remains a challenging task due to routing issues. In this work, Fuzzy-Logic technique is applied for routing where various rue sets are defined to work according to the conditions. Fuzzy rules are constructed based on the distance from node, power consumption and trust values of clustering. Experimental study shows that the Fuzzy-Logic technique outperforms when compared with conventional energy aware routing protocols.

REFERENCES

[1] I.F. Akyildiz, W.Su, Y. Sankarasubmmaiam, E.Cayirci, “A Survey on Sensor Networks,” *IEEE* Comm. Magazine, pp.102-114, Aug 2002.

[2] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal. Computer Networks, *The International Journal of Computer and Telecommunications Networking*, Volume 2 Issue 12, August, 2008.

[3] R Kumar, V. Tsiatsis, M.B. Srivastava, Computation Hierarchy for In-Network Processing, Proceedings of 2nd ACM *International Workshop on Wireless Networks and Applications*, San Diego, CA, 68-77, 2003.

[4] D. Kumar, T. C. Aseri, R.B. Patel, HCEE:

Hierarchical clustered energy efficient protocol for heterogeneous wireless sensor networks, *International Journal of Electronics Engineering*, 1(1):123-126, 2009.

[5] Kemal Akkaya and Mohamed Younis, "A Survey on Routing Protocols for Wireless Sensor Networks," Ad Hoc Networks, Vol. 3, No. 3, pp. 325-349, May 2005.

[6] J. Al-Karaki, and A. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey," *IEEE Communications Magazine*, Vol. 11, no. 6, Dec. 2004, pp. 6 -28.

[7] M. Yarvis, N. Kushalnagar, H. Singh "Exploiting heterogeneity in sensor networks," *IEEE INFOCOM*, 2005.

[8] E. A. Khalil and B. A. Attea, "Energy-aware evolutionary routing protocol for dynamic clustering of wireless sensor networks," *Swarm and Evolutionary Computation,* vol. 1, no. 4, pp. 195–203, 2011.

[9] E. Kranakis, H. Singh, and J. Urrutia,"Compass Routing on Geometric Networks" Proc 11th *Canadian Conference on Computational Geometry, Vancouver, Canada*, August 1999, pp. 51-55.

[10] Y. Huang , L. Yang , and J. Lin, "An efficient energy data gathering based on grid-chain for wireless sensor networks," Proc. 2012 *4th International Conference on Awareness Science and Technology*, August 2012, pp.78- 82, DOI: 10.1109/iCAwST.2012.6469593.

[11] W. R. Heinzelman, A. Chandrakasan,and H.Balakrishnan,"Energy- Efficient Communication Protocol for Wireless Microsensor Networks," *IEEE Proc. Hawaii Int',l. Conf. Sys. Sci.,* pp. 1-10, 2000.

[12] G. Smaragdakis, I. Matta, A. Bestavros, "SEP: A Stable Election Protocol For Clustered Heterogeneous Wireless Sensor Networks," in proceedings of *2nd International Workshop on Sensor and Actor Network Protocols and Applications (SANPA'04), Boston, MA*, 2004, pp. 660 -670.

[13] Heinzelman R., "Energy Scalable Algorithms and Protocols for Wireless Sensor Networks," in Proceedings of the *International Conference on Acoustics, Speech, and Signal Processing* (ICASSP'00), Turkey, pp. 773-776, 2000.

[14] Shih E., "Physical Layer Driven Protocol and Algorithm Design for Energy-Efficient Wireless Sensor Networks," in the Proceedings of the *7th Annual ACM/IEEE International Conference on Mobile Computing and Networking (Mobicom'01), Italy,* pp. 272-287, 2001.

[15] S.Basagni, "Distributed Clustering Algorithm for AdHoc Networks," Proceedings of *International Symposium on Parallel Architectures, Algorithms, and Networks,* pp.310-315, December 1999.

[16] S.Banerjee and S.Khuller, "A Clustering Scheme for Hierarchical Control in Multi-Hop Wireless Networks," Proceedings of *IEEE INFOCOM*, Anchorage, pp. 1028-1037, April 2001.

[17] M.Gerla, T. J.Kwon and G. Pei, "On Demand Routing in Large Ad Hoc Wireless Networks with Passive Clustering,‖ Proceedings of *IEEE Wireless Communication and Networking Conference*, Vol. 1, pp.100-105,March 2000.

[18] C. R. Lin and M. Gerla, "Adaptive Clustering for Mobile Wireless Networks," *IEEE Journal on Selected Areas in Communications*, Vol.15, No.7, pp.1265-1275, April 1997.

[19] J.Kamimura, N.Wakamiya and M.Murata, "Energy-Efficient Clustering Method for Data Gathering in Sensor Networks," Proceedings of *Workshop on Broadband Advanced Sensor Networks,* Vol.103, pp. 31-36, April 2004.

[20] J. Leu, M. H.Tesai, T.C.Chiang and H. Y. M. Huang, "Adaptive Power Aware Clustering and Multicasting Protocol for Mobile Ad Hoc Networks," Lecture Notes in ComputerScience, Vol.4159, pp. 331340, June 2004.

[21] S.Lindsey and C.S.Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Information Systems," Proceedings of *IEEE Aerospace Conference*, Vol. 3, pp.1125-1130, June 2002.

[22] L.Li, S. Dong and X. Wen, "An Energy Efficient Clustering Routing Algorithm for Wireless Sensor Networks," *Journal of China Universities of Posts and Telecommunications*, Vol.3, No.13, pp.71-75, June 2006.

[23] Y. Sangho, H. Junyoung, C. Yookun and H.Jiman, "PEACH: Power-Efficient and adaptive Clustering Hierarchy Protocol for Wireless Sensor Networks," Computer Communications, Vol.30, No.14-15, pp. 2842-2852, April 2007.

[24] S.Ghiasi, A.Srivastava, X.Yang, M. Sarrafzadeh, "Optimal Energy Aware Clustering in Sensor Networks," *Sensors Journal*, Vol.2, No.7, pp.258-269, June 2002.

[25] H.Chan and A.Perrig, "ACE: An Emergent

Algorithm for Highly Uniform Cluster Formation," *Springer Lecture Notes in Computer Science*, Vol. 2920, pp.160-171, February.2004.

[26] O.Younis and S. Fahmy, "Distributed Clustering in Adhoc Sensor Networks: A Hybrid, Energy Efficient Approach," Proceedings of *IEEE INFOCOM*, Vol.1, pp.629-640, April 2004.

[27] M.Diwakar and S.Kumar , ― An Energy Efficient Level based Clustering routing protocol for WSN‖ *International Journal of Advanced Smart Sensor Network Systems*, Vol.2, issue 2, pp 55- 65, April 2012.

[28] Lalith Yadav, Ch.Sunitha- LEACH, *IJCSIT, Vol. 5 (3) , 2014, 4661-4664*

[29] Jun, W., Z. Xin, X. Junyuan and M. Zhengkun, 2010. A distance-based clustering routing protocol in wireless sensor networks. Proceedings of the 12th *IEEE International Conference on Communication Technology (ICCT),* Nov. 11- 14, IEEE Xplore Press, Nanjing, pp: 648-651.