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Fuzzy Based Particle Swarm Optimization Routing Technique for Load Balancing in Wireless Sensor Networks

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Abstract**—**Network lifetime improvement and uncertainty in multiple systems are the issues of wireless sensor network routing. This paper presents fuzzy based particle swarm optimization routing technique to improve the network scalability. Significantly, in the cluster formation procedure, fuzzy based system is used to solve the uncertainty and network balancing. Cluster heads play an important role to reduce the energy consumption using particle swarm optimization algorithm, the cluster head sends its information along data packets to the heads with link. The simulation results show that the presented routing protocol can perform load balancing effectively and reduce the energy consumption of cluster heads.

Keywords**—**Wireless sensor networks, fuzzy logic, PSO, LEACH.

I. Introduction

WIRELESS sensor network (WSN) is used to monitor wide coverage area [1]. Features manipulating sensor network intend are blunder forbearance, reachability, working atmosphere, sensor network hierarchy, broadcast medium and energy utilization [16]. Hence, the important challenge for WSN is load balancing in the network. Several routing protocols have been proposed to increase the WSN lifetime [5]. Clustering routing protocols are developed by using a large amount of neighboring nodes which consist of cluster nodes and cluster heads (CHs). Clustering routing protocols can have the improved scalability, reduced load, reduced power consumption [8]. CHs of high level network are the combination of all the cluster members of a top level network with the communication to the Base Station of the WSN [31]. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol has been proposed for clustering routing technique. The common path of LEACH is to improve the lifetime of a WSN by reducing the power consumption of the sensor nodes [6]. To solve the problem, the various levels of improved algorithms are implemented to increase the CH distribution [9].

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Multi-hop routing protocols are used to minimize the energy consumption for data communication [12]. In this initial phase, the node can generate a pseudo-random number from 0 to 1 [2]. LEACH-C is the centralized algorithm that means all CHs are formed by the base station [4]. An established Quality of Service scheme has been premeditated, where the neighbor assortment algorithm and the path assortment algorithm are used to choose a path by vehicles which are likely to move at comparable speeds and in the direction of comparable directions [13]. An innovative routing protocol is used to generate the channels with non-evaporation period for routing, and then it attempts to diminish packet failure. Due to evaporation reuse, the path with some protection strategies is used to enlarge the throughput in WSN [14].

Snooze and energetic of nodes will occasionally assist to preserve their power for more time. The occurrences happening in any ingredient of the network must be recognized by the nodes [15]. In I-LEACH, at the outset, the possibility based assortment criterion for a CH was substituted with conception of remaining energy [17]. Enhanced Cluster Based Key Management Algorithm is used to minimize the end-to-end delay by the way of increasing the throughput. The routing transparency is condensed and then it extends the network existence. Replication results demonstrated that the broadcasting technique is used to decrease the jitter by improving the Quality of Service [18]. In a clustering method, the nodes are separated into similar groups. They are frequently based on environmental properties. Each group has a CH and numerous regular nodes. A CH regularly provides the restricted controller for its adjacent cluster nodes [19]. CLENER algorithm [20] affords energy-efficiency by group arrangement using fuzzy logic and CH determination based on a possibility function. The disadvantage is that the foundation position has not been subjected to power limitations and is situated within the sensing meadow. Dominating set algorithm remains the initial node animated with larger amount of erstwhile protocols. Since the dominating set formations of every group of CHs are unswervingly associated to every node, the liveliness of the network is kept by eliminated transitional nodes in WSN [21]. Directional Flooding-based Routing (DFR) is used to increase the network connectivity [22]. The sink node is employed to acquire an invalidate path for the destination node and to transmit acknowledgement for the preceding demand. The generously proportioned maximum value will stay behind the route release [57].

Depth Based Routing protocol (DBR) [23] is used to choose the power, environmental or spatial data. In this technique, the sagacity data from the surroundings are routed to the regular descends [51].

A tree-based data fusion clustering routing algorithm (TBDFC) is proposed to minimize the consumed energy in WSNs [24]. Routing path is additionally recommended and calculated using meta-heuristic iteration based Bat algorithm [25]. The fundamental functioning attitude is based on hydraulic weight available along dissimilar strengths in the sea. Opportunistic routing has been performed to execute the adjacent paths for unappeasable procedure. For up-stream, broadcasting is another level of distributed systems; it is a controlled up-stream related to the planned time of every process of broadcasting that avoids divergence from creature source to the up-stream information, and improve the limited bandwidth utilization [26]. The new algorithm is used to improve Data Base Administrator with the relation of the Interleaved Polling with Adaptive Cycle Time (IPACT) methodology that involves a queue-based preparation scheme [28].

Tree Based Opportunistic Routing (TBOR) discovers a multipath routing scheme to achieve the threshold possibility of high throughput [27]. Geographical routing protocols afford extended detachment data forwarding and superior improvement across the destination [39]; direct to enlarge indicator reduction and packet failure problems in the system [29]. Assortment joining methods are used at the destination node to connect the data from assorted range of divisions [30]. Shifted assortment is the simplest diversity merging method amongst the channel position data of the route under reflection. In [32], the outage presentation is identified for the shifted assortment method in supportive DF communicating network over other related fading network channels. In [34], the supportive system uses switch-and-stay transmit assortment scheme for obtaining the outage possibility in a related fading network channel. In [35], the presentation of a solitary middle node supportive network is calculated using a harmonizing fault method [36].

A most favorable assortment joining method is scrutinized for the supportive system using complete network and an end to end symbol error possibility is calculated by shifting technique [37]. The consequence of association limitation (A_q) is glowing scrutinized for nakagami-m fading channel [38]. In [40], a bit fault possibility and outage possibility are calculated.

In [41], the Quality of Service is improved by using the cooperative system relays. The end to end delay is obtained with controlled and observe technique [43]. Virtual back bone path computation is based on the restrictions like message success rate, communication rate, and greatest connectivity [42], [66].

WSNs are susceptible to numerous hazards. Antagonists are accomplished of conciliating sensor nodes that snoop on information, insert fake information plus dissipate system supplies [33]. Consequently, cryptography methods have been proposed for handling security related problems efficiently in WSNs [44]. There are numerous constraints in the implementation of cryptography methods in WSNs like storage, broadcasting, performance analysis and also dispensation capacities [48].

Design of cryptography based protocols requires understanding of the constraints and accomplishing sufficient encoding and decoding techniques [51]. Cryptography crashes are determined and evaluated by using the scalable parameters of improvements in WSNs, and such crashes possibly used by opponents [16]. But the substantial dismissal in WSNs escorts to exceptional probable in scheming them for progressing their stipulation of detailed provision regardless of crashes [60]. The organization should be able to acclimatize in narrative way that unanticipated damage when the organization is originally arranged [54].

Confidence establishment amongst nodes is a mandatory for appraising trustworthiness of other nodes since endurance of WSNs is dependent on combined in addition to unquestioning scenery of the nodes [64]. Cryptography in addition to confidence is two tremendously mutually dependent impressions and owing to the mutually dependence, the expressions are used as signatures, when developing protected networks [47]. But, cryptography is not the identical as confidence, the most important distinction being that it is additional complex and has superior overheads [46].

Confidence in WSNs has a momentous ingredient to engage in recreation in construction of systems and appending or reducing sensor nodes from systems, on account of the enlargement of the system, or substituting unreliable nodes in a horizontal in addition to translucent method [45]. The performance of the energetic non-linear schemes for WSNs are involving network arithmetical representations which may be griped in a specialized method by fuzzy logic. Real-time implementations like decision making systems, patterns recognition, control systems and network modeling may implement fuzzy if–then rules [49], [63].

A data-mathematical representation [50] is used for quantitative quantity of expectation in addition to build a new expectation structure with numerous conviction conclusion features. Fuzzy logic regulations calculation process is approved for modernizing node's conviction. [61]. The narrative confidence method proposes elastic in addition to practicable process in routing verdict making, believing both conviction constraints as well as nasty node recognition in multi-agent networks [65]. Performance evaluation was developed for generating effectiveness of trust model as well as multi-case trust improvement in recovering network communication dominance, trust energetic flexibility, malicious nodes recognition, attack confrontation as well as enhancements to network security [62].

In contradiction of previous methods, general experimentations have been developed for calculating effectiveness of the proposed battering resistance of system security [54].

Dissimilar behaviors are created to dissimilar behavioral data to distinguish malicious nodes and recognize their behavior data [52]. The cryptography of WSNs is then improved by numerous parameters for switching several categories of un-trusted movement. Simulation results showed that the proposed conviction management structure can disconnect ordinary nodes and un-trusted nodes and discriminate dissimilar types of un-trusted nodes [53].

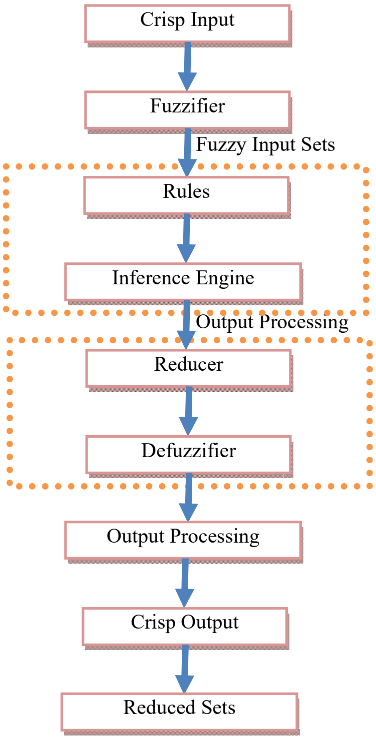

Fig. 1 Architecture of a FLS

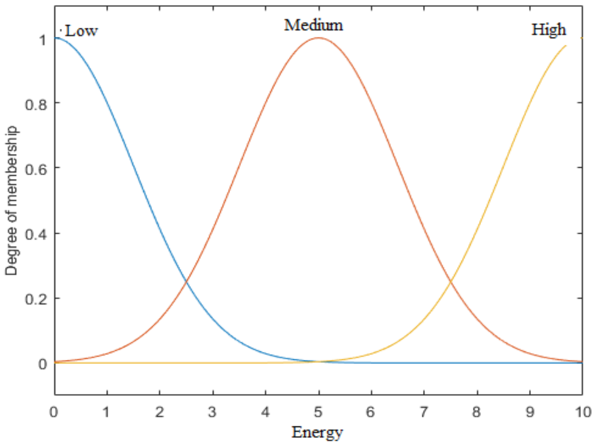

Fig. 2 Membership Function of input variable 'Energy'

On the origin of fuzzy active programming hypothesis, in trusted routing structure, [56] developed a trusted routing protocol that thrusts out untrustworthy nodes for attaining trustworthy route rescue path. A reactive routing algorithm is proposed for generating a lot of confidence links in a route discovery that finds dependable or confidence requisites of network data packets. Experimental results confirmed that the confidence-based routing algorithm is able to achieve the improvements in Packet Delivery Ratio [55], [58]. Confidence method is a mathematical representation which identifies the estimation of one node by adjacent nodes in the network. In confidence based method, owing to the prejudice of conviction assessments, it has several uncertainties [59].

II. Fuzzy Based Particle Swarm Optimization

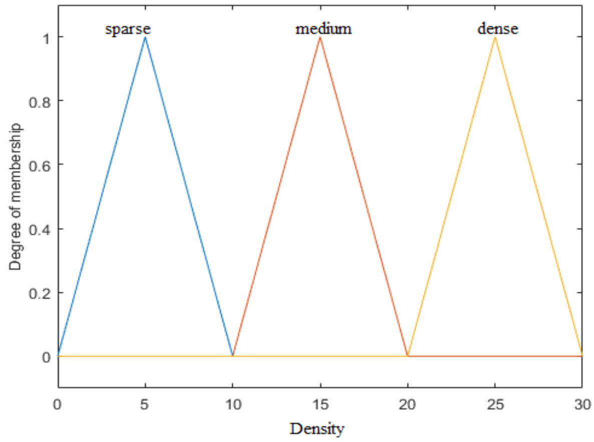

Fig. 3 Membership Function of input variable 'Density'

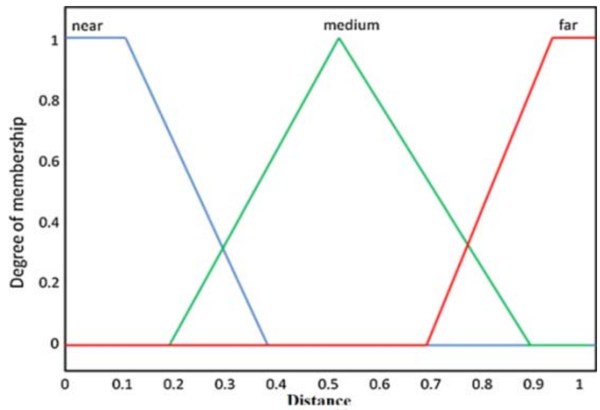

Fig. 4 Membership Function of input variable 'Distance'

Fuzzy based particle swarm optimization clustering routing protocol is implemented to find the CHs and particle swarm optimization is used for multihop routing. Importantly, three issues called residual energy; number of adjacent nodes, and the base station distance are the inputs to calculate the probability. The particle swarm optimization algorithm is used to create a link to all the CHs [10]. The fuzzy set is differentiated with different membership functions [7].

Base Station generates the network with FBPSO algorithm to computer the list of CHs, then finds and transmits control values to every sensor node and every initial node demonstrates the joining cluster based on the factor of distance and transmits control and data packets to their respective CHs.

FLS can compute the natural rules are executable in the system environment. The protocol based on LEACH uses the base station to find CHs based on three parameters. They are Centrality, Adaptation and Power Consumption [3]. If the pseudo-random number is less than the threshold value δ(n), the node will be the CH in the cluster groups. All the other nodes can perform their cluster by finding the CH that needs the low energy communication.

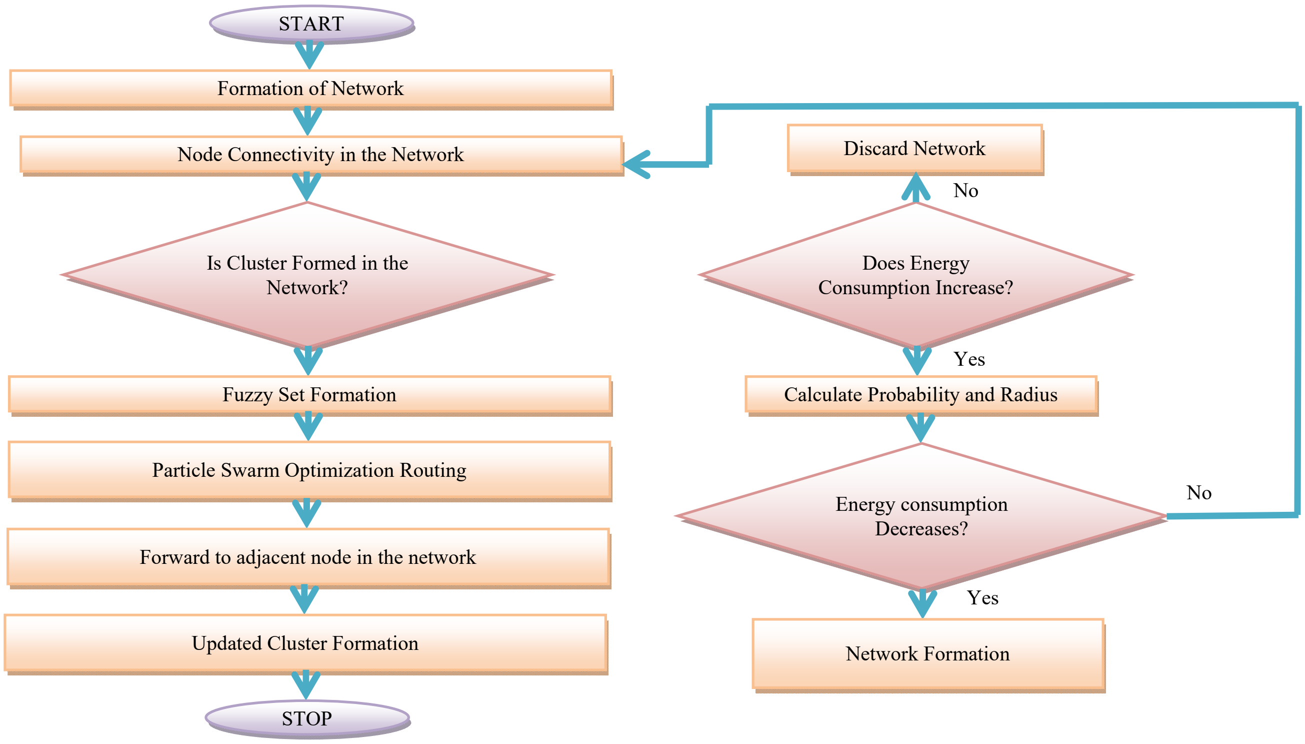

Fig. 5 Flowchart for the Proposed Work

In the second state, the CH can use the TDMA to communicate with the nodes in their clusters [11].

$$\delta(n) = \frac{P_{CH}}{1-P_{CH} \times \left(g \bmod \frac{1}{P_{CH}}\right)} \quad (1)$$

where P_{CH} is the probability for CH, g is the number of groups and n is the group of sensor nodes.

The Fuzzifier can have every crisp input in the Fuzzy set. The crisp input vector c' = (c_1', ... c_p').

$$\sigma_{Ci}(c_i) = 1, \text{ if } c_i = c_i' \quad (2)$$

$$\sigma_{Ci}(c_i) = 0, \text{ if } c_i \neq c_i' \quad (3)$$

The three inputs have the interval [0,1]. Figs. 2-4 demonstrate the membership functions of Energy, Density and Distance.

Let us assume that the input variable Energy as i_1, the input variable Density as i_2 and the input variable Distance as i_3. The Output variables are probability as j1 and Radius as j_2.

A. Rule

If i_1 is F_1
i_2 is F_2
i_3 is F_3
. . . .
i_n is F_n
Then
j_1 is G_1
j_2 is G_2

$\sigma_{Fi}(c_i)$ and higher membership functions $\sigma_{Fi}'(c_i)$

$$f(i) = \sigma_{F1}(c_1) \times \ldots \times \sigma_{Fp}(c_p) \quad (4)$$

$$f'(i) = \sigma_{F1}'(c_1) \times \ldots \times \sigma_{Fp}'(c_p) \quad (5)$$

Defuzzification using the average of

$$q_j(x) = \frac{q_{jl}(x) + q_{jr}(x)}{2} \quad (6)$$

The Extend Output can be calculated as

$$q^j_{cos}(x) = [q_{jl}(x), q_{jr}(x)] \quad (7)$$

B. Algorithm

Step 1: Compute Probability and Radius
If Base station receives sensor nodes information, then
  Calculate probability and radius using FLS
    Sensor node (x) is in alive
      (fx.probability, fx.radius) = FLS (fx.energy, fx.density, fx.distance)
End If

Step 2: Calculate optimized Cluster Node

$$Cocn = [((xpn-xpd)/n) + 0.5] \quad (8)$$

Step 3: Calculate Path

$$\text{Path} = \text{Sort}([\text{f.probability}],\text{'descending'}) \quad (9)$$

Step 4: Generate CH

Path (i) = initialClusterHead
increase the Cluster
if distance of (Path (i), f_j) is less than
$f_{Path(i)}$ x radius then
f_j is notClusterHead
increase the value of i
otherwise f_j is the clusterHead
If CH (QS =Small and CS=Near and RE=High)
Then
Selected CH is extra to optimal cost path to
Accomplish sink
If CH (QS =Large and CS=Far and RE=Low)
Then
Selected CH is added to below optimal cost path
So it not selected to reach sink
Step 5: Routing

For every connection do
set beginning value $\beta_{i,j}(x) = 1$
end for
for every Cluster_Head do
calculate the O_{ij}
end for
while not end do
for every particle do
randomly find a Cluster_Head
for I = 1 to n do
calculate possibility PO_{ij}
choose alternate Cluster_Head
with possibility PO_{ij}
end for
end for
compute the routing path discovery length D_k of the k^{th} particle
generate the shortest path into short_path$_{ij}$
for every connection do
Change beginning value $\beta_{i,j}(x)$
end for
end while
Choose the shortest path into short_path$_{ij}$
Find the alternate Cluster_Head nearest into the Base_Station as the new leader
for every Cluster_Head do
transmit packet using leader control function
end for

Step 6: Energy Consumption

The Energy consumed while transmitting the node of x-bits packet with the distance can be calculated as

Energy_Transmitted (x,distance) = Energy_Transmitted_send (x) + Energy_Transmitted_received (x,distance)

Step 7: Receiving Signal

SE_n: Number of Sensor nodes
SE_{ch}: CH
CF: Cluster shaped

Phase I:
1. for each SE_n to n-1 do
2. CF_i= {SE_1, SE_2, SE_n}
3. Choose SE_{ch}
Transmit information to CH
4. CF_i (SE_1, SE_2, SE_n) → SE_{ch}
Transmit information to adjacent CH
5. SE_{ch} → Adjacent SE_{ch}
If (Energy_Consumed (SEch< Energy_ Threshold)) then
select new Sch within CF

Step 8: Network Formation

Let SY be the system where
SY = {nu, SE_i, PR, CHE, NM}
nu: Number of Sensor Nodes
SE_i: Network Sink Node
CHE: CH
NM: Network
nu = nu_1, nu_2, …., nu_n
SE_i = sink node count
PR = PR_1, PR_2, …, PR_n

Base Station generates the network with FBPSO algorithm to compute the list of CHs, then finds and transmits control values to every sensor node and every initial node demonstrates the joining cluster based on the factor of distance and transmits control and data packets to their respective CHs.

The sensor nodes are haphazardly allocated in the network. The sensor nodes and the base stations are the motionless of hypothesis phase. Sensor nodes are harmonized with energy restricted have the identical establishment energy, communication path is identical. Nodes have their own data such as location of the network node and energy consumption so they send to the Base station with particular energy levels during the network group stage.

To obtain the resource node's location using a network routing by representing the location optimization a_k which consumes reduced communication cost. The packet for data Communication follows some multihop sequential order.

$$a_i \rightarrow b_{i1} \rightarrow b_{i2} \rightarrow \ldots \rightarrow b_{iq} \rightarrow d \quad (10)$$

The communication cost between a_i and d can be obtained by creating the network route c_i as cost (a_i, c_i). The communication cost optimization solution can be obtained by

$$X_0 = \min \sum_{i=1}^{N} [p(a_i) \min cost(a_i, c_i))] \quad (11)$$

Modified cost reduction function given by

$$X = \sum_{i=1}^{N} p(a_i) \sum_{i=1}^{M} p(c_i \mid a_i)\, cost(a_i, c_i) \quad (12)$$

The probability distribution function that improves the communication cost by

$$G = -\sum_{i=1}^{N} p(a_i) \sum_{i=1}^{M} p(c_i \mid a_i) \log(cost(c_i \mid a_i)) \quad (13)$$

Such that

$$X = \sum_{i=1}^{N} p(a_i) \sum_{i=1}^{M} p(c_i \mid a_i)\, cost(a_i, c_i) = X_0 \quad (14)$$

The remaining energy can be obtained using the cost based function

$$cost(c_i \mid a_i) = \frac{e^{-\emptyset\ x\, cost(a_i, c_i)}}{\sum_k e^{-\emptyset\ x\, cost(a_i, c_i)}} \quad (15)$$

Fuzzy Based radius procedure is used to fix the rules for creating the CH selection and distribution. It takes several round, output of the preceding round will be the input for the successor round.

FBPSO can embrace uncertainties outcome from inaccurate inputs and compound rules that are used to select the CHs in the Routing protocol of clusters. Moreover, in this paper, we need to utilize a FLS to compact with uncertainties in WSNs.

Table I demonstrates the Possibility of Chance of the three parameters Distance, Density and Energy based on Competition Radius Process using Fuzzy Inference Rule.

C. Tailback Node Selection

```
tailback_Node_Selection(Tb)
Max_Energy = -∞;
tailback_node = NULL;
for x = 1 to n
if branch_node(i)=NULL then prolong;
else
calculate max_dist(max_dist(x), max_node(x));
compute energy_consumed (energy(x));
if energy(x) > Max_Energy
Max_Energy = energy(x);
tailback_node = x;
end if
end if
end for
return tailback_node;
```

III. Performance Evaluation

The solution for energy consumption and trust evaluation was found using 200 nodes in a certain area. The nodes were clustered using FBPSO algorithm. The simulation was done in NS2 tool. Table II illustrates the simulation parameters for the network model.

Fig. 6 shows total number of route discovery, Fig. 7 shows packet delivery ratio versus number of paths, Fig. 8 shows delays obtained in the network, Fig. 9 shows routing overload versus number of paths, Fig. 10 shows load balancing and Fig. 11 shows energy consumption ratio. The simulation result shows that the presented algorithm worked well.

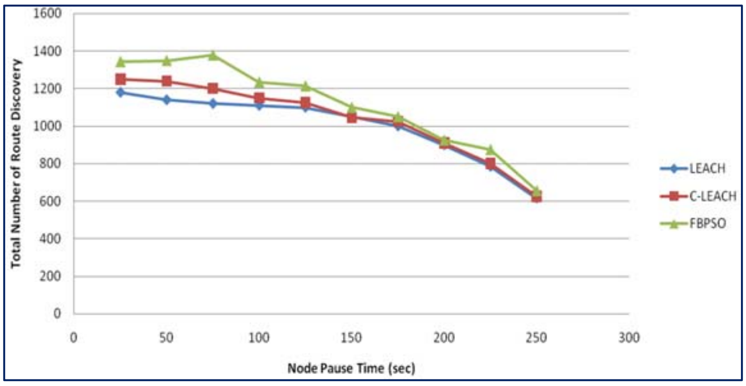

Fig. 6 Total Number of Route Discovery

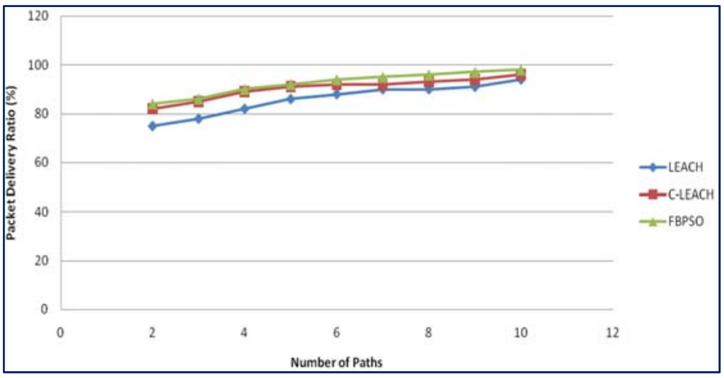

Fig. 7 Packet Delivery Ratio versus Number of Paths

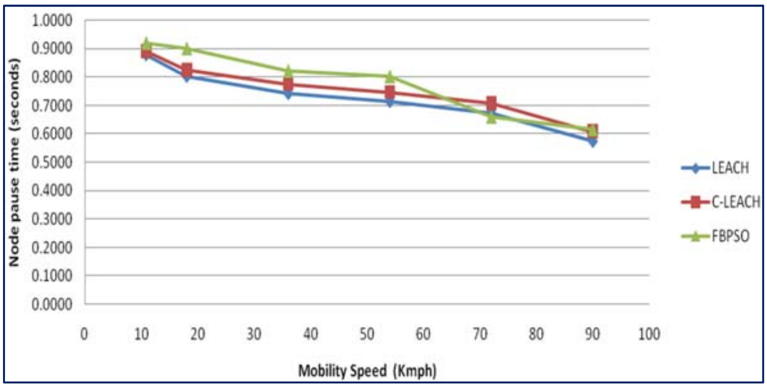

Fig. 8 Delays obtained in the Network

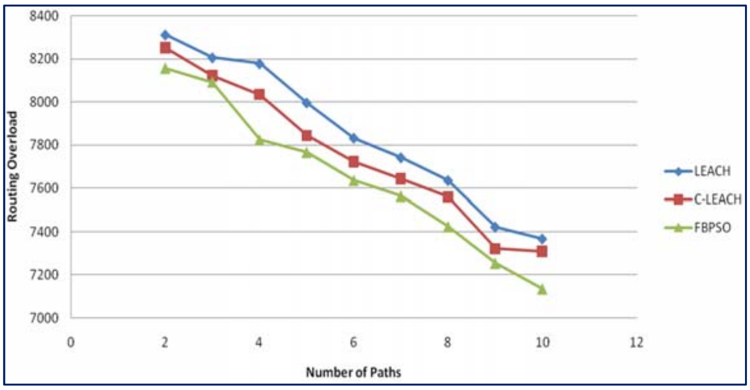

Fig. 9 Routing Overload versus Number of Paths

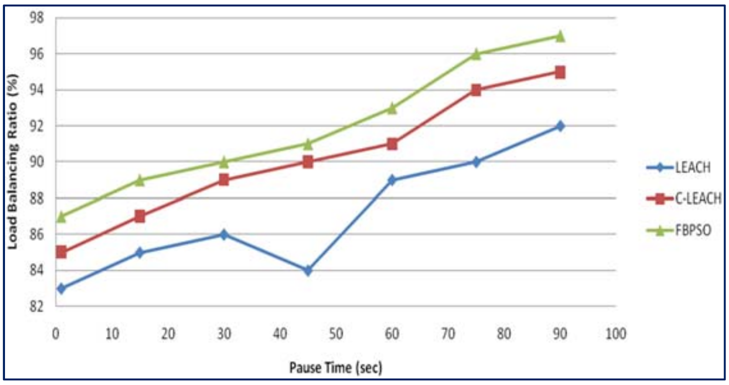

Fig. 10 Load Balancing

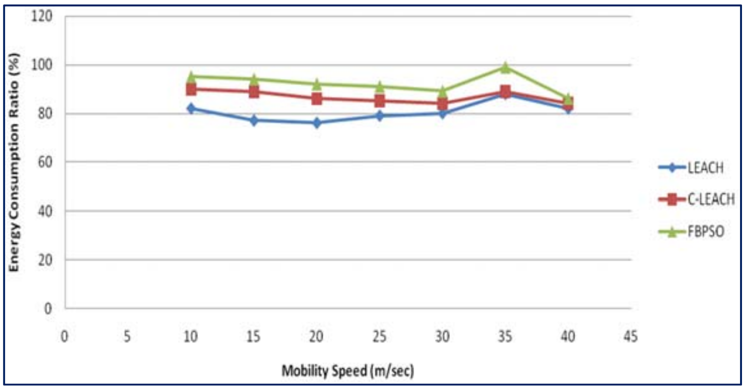

Fig. 11 Energy Consumption Ratio

IV. Conclusion

To increase the load balance and of the network in WSNs, this paper recommends an improved routing protocol Fuzzy Based Particle Swarm Optimization. FBPSO improves three important factors of distance, energy and density. Distance to the Base station as the input to compute the possibility of a node for CH and Radius. The fuzzy logic is used to decrease the uncertainties of existing in WSNs. The fuzzy introduction and Multi-hop routing method for transmission of data can handle the load balancing and reduce the consumption of the energy frequently. Better performance of our recommended algorithm has been exhibited by the simulation results. FBPSO algorithm can efficiently load balancing in the network and network lifetime.

TABLE I
Fuzzy Inference Rule

S.NO	DISTANCE	DENSITY	ENERGY	PROBABILITYCHANCE	COMPETATIONRADIUS
1	Low	Spare	Far	Very Weak	Medium
2	Low	Spare	Medium	Weak	Little Small
3	Low	Spare	Near	Little Weak	Little Small
4	Low	Medium	Far	Weak	Little Small
5	Low	Medium	Medium	Little Weak	Little Small
6	Low	Medium	Near	Lower Medium	Small
7	Low	Dense	Far	Little Weak	Little Small
8	Low	Dense	Medium	Lower Medium	Small
9	Low	Dense	Near	Medium	Small
10	Medium	Spare	Far	Little Weak	Little Large
11	Medium	Spare	Medium	Lower Medium	Little Large
12	Medium	Spare	Near	Medium	Medium
13	Medium	Medium	Far	Lower Medium	Little Large
14	Medium	Medium	Medium	Medium	Medium
15	Medium	Medium	Near	Higher Medium	Medium
16	Medium	Dense	Far	Medium	Medium
17	Medium	Dense	Medium	Higher Medium	Little Small
18	Medium	Dense	Near	Little Strong	Little Small
19	High	Spare	Far	Medium	Large
20	High	Spare	Medium	Higher Medium	Large
21	High	Spare	Near	Little Strong	Little Large
22	High	Medium	Far	Higher Medium	Little Large
23	High	Medium	Medium	Little Strong	Little Large
24	High	Medium	Near	Strong	Medium
25	High	Dense	Far	Little Strong	Little Large
26	High	Dense	Medium	Strong	Medium
27	High	Dense	Near	Very Strong	Medium

TABLE II
Simulation Parameters

Parameter	**Value**
Number of nodes	200
Size of the Network	225 m x 225 m
Energy in the beginning	0.50 J
Length of the Data packet	4000 bits
Length of the Control packet	100 bits
Sender Transmitter expand	1.1dBi
Receiver transmitter expand	1.1dBi

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