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Providing a method in order to improve the performance of routing in ad hoc networks using family particle swarm optimization algorithm (FPSO) and fuzzy logic

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Abstract: Routing in ad hoc networks is very important because energy constraints, quality requirements of service and sudden changes of node status such as failures lead to frequent and unpredictable changes in network structure. According to the fact that ad hoc network topology changes constantly and interference of radio waves lead to lose of a large number of packets, in this paper, an algorithm is presented for routing in ad hoc networks using Family Particle Swarm Optimization Algorithm and Fuzzy Logic which uses effectively network resources in order to improve network performance. The advantages of this method include multi- criteria based flexibility and routing. The proposed method simultaneously considers three criteria of energy consumption, nodes distance size and available bandwidth and it finds the best way of sending data from source to destination. Since this method selects a route with lower energy for sending data, network lifetime is increased. Selecting a route with more available bandwidth provides a better timing for data to achieve into destination. As a result, this routing method provides better service for applicants. The results show that the proposed method has higher efficiency and higher throughput and presents efficient performance through selecting stable routes and sends more data to destination. Therefore, it can be said that using Family Particle Swarm Optimization Algorithm will be good option due to quick adaptation ability with Ad hoc network topology and its combination with fuzzy logic in order to improve the performance of ad hoc network routing.

Key words: Ad hoc network, Routing; Fuzzy logic; Family PSO; FFPSO

1. Introduction

Ad hoc network is a type of networks whose structure is organized quickly with no central mean. It means that, we require the participation of nodes and handing that packet in order to send information packet. Installation and operation of these networks are highly efficient and fast due to no need for infrastructure. Ad Hoc Networks have been considered in recent years as one of the wireless networks that provide quick and easy communication medium without the need for communication infrastructure and centralized management. (Rango and Guerriero, 2012)

Ad hoc means “For this purpose only” or "For a specific application". This term is often used in places where we aim to solve a specific problem or accomplish a specific task and its important feature is the impossibility of extending the above solution as a general solution and using it in the same issues.

This type of networks is used when there is no access to networks with infrastructure such a transmitter antenna or to use them is not economic. In principle, Mobile Ad Hoc Networks (MANETs) are designed for shared environments (Marchang and Datta, 2012)

2. Particle swarm optimization algorithm

PSO is an optimization technique based on probability laws and its basic idea was introduced in 1995 by computer scientist called Dr. Russel Eberhart and social issues psychologist called Dr. James Kennedy (Kennedy and Eberhart, 1995). This method is inspired by social behavior of birds or fish groups while searching for food in order to lead people to promising region of search space. Specific rational rules reign on the way of creatures' behavior. Birds look for food just by adjusting their physical movement with collision avoidance and each bird benefits theoretically from previous experiences and findings of other members in order to find food. This participation is a definite advantage over competing search in order to find food. The main base of PSO is information sharing among group members (Kennedy and Eberhart, 1995).

In PSO, each question answer is position of a bird in search space that is called particle. All particles have a fitness value that is obtained by fitness function that is optimization objective. PSO algorithm consists of a certain number of particles that are randomly considered as initial value. Two values of position and velocity are defined for particles that are modeled by a position vector and

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velocity vector, respectively. PSO population includes all particles that are called Swarm. According to neighborhood structure, a leader is selected in order to conduct particles research towards better areas of search space and each particle performs the following operations in any iteration:

2.1. Updating velocity

The speed of particles shows their changes and is defined as follows:

(1) $$v_i(t) = w \times v_i(t-1) + c_1 r_1 \times (p_i - x_i(t-1)) + c_2 r_2 \times (p_g - x_i(t-1))$$

The V_i elements are located in [-Vmax, + Vmax] interval in order to prevent the divergence of algorithm. In most cases, the inertia weight is used as a parameter in order to update velocity. W Parameter controls the motion of particles. (Talbi, 2009)

2.2. Updating position

Each particle updates its position based on the following equation and moves to a new position.

(2) $$x_i(t) = x_i(t-1) + v_i(t)$$

2.3. Updating the best found particle

Each particle will update its best position using the following equation

(3) $$If\ \ f(x_i) < \mathrm{pbest}_i,\ then\ \ p_i = x_i$$

2.4. Updating best found particle in total particles population

In addition, the best answer that is found in total particles population is updated by the following equation: (M-4)

(4) $$If\ \ f(x_i) < gbest_i,\ then\ \ g_i = x_i$$

3. Modeling the routing

Communication network of resolve routing problem is defined as follows: Consider G (V, E) graph where V is the set of nodes and E⊂V×V shows the sum of graph links. Three parameters of energy, distance and available bandwidth have been attributed to each link (i,j) that are expressed as follows.

In equation (5), this parameter indicates the amount of consumed energy during data transmission from a node to another node:

(5) $$Energy = \sum_{(i,j)\in V} En(\mathrm{node}_i, \mathrm{node}_j)$$

As Equation (6) represents the distance between nodes:

(6) $$\mathrm{Distance} = \sum_{e \in E} Dist(e)$$

The parameters of equation (7) indicate the amount of bytes that are available at time at every link:

(7) $$Bandwidth = \min\{B(e), e \in E\}$$

The integration of Particle Swarm Optimization Algorithm and Fuzzy Logic is used for routing in proposed method that is the development of Particle Swarm Algorithm. In this way, fuzzy control system calculates the fuzzy cost of each link through receiving network status information and based on three parameters of energy, distance and available bandwidth. The fuzzy costs will be used by particle swarm algorithm as fitness criterion of each path for routing operation. Fig. 1, shows the scheme of proposed method.

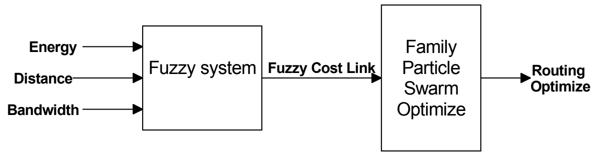

Fig. 1: Schematic of proposed method

The proposed fuzzy system inputs as defined as energy, distance and bandwidth**.** The output of fuzzy control system is fuzzy cost of each link**.**

4. Proposed method-fuzzy family particle swarm optimization (FFPSO):

Given that premature convergence is weaknesses of algorithm in Particle Swarm Optimization algorithm, in this way, the population is categorized into different categories that are called families. When a particle in one family finds the best position, this particle plays the leader role and other family members are guided on this direction. (Lu et al., 2011)

In proposed method of selecting a family in order to optimize the responses and family formation, firstly, we select groups of families with equal members from 30 members population after determining the initial distance and the target and position of each particle that are placed in a similar interval. The method steps are as follows:

As Fig. 2 shows, the steps of method are as follows:

1) Creating an initial population of N particles randomly.

2) The number of members in each family equals to m_1 and N/m_1 family formation randomly.

3) Initializing the best solution of each family (F_k) and the best current solution (g) and calculating the fitness of each particle (Eq. (11)).

4) The following steps are performed for every particle in the population:

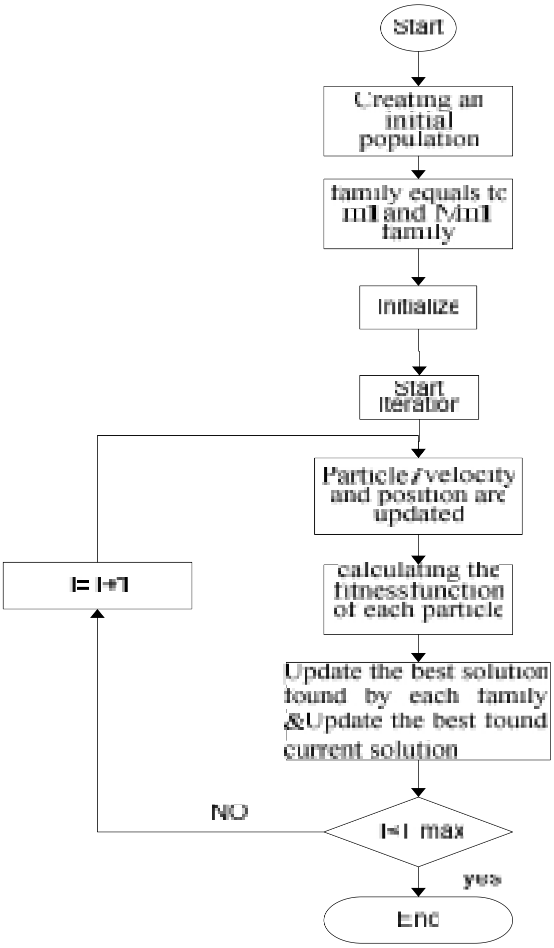

Fig. 2: Fuzzy Family PSO algorithm

a) Particle *i* velocity and position are updated based on equations (8) and (9):

(8)

$$V_i(t+1) = wV_i(t) + c_1 r_1 (F_k(t) - X_i(t)) + c_2 r_2 (g(t) - X_i(t))$$

(9) $$X_i(t+1) = X_i(t) + V_i(t+1)$$

In these equations, X_i is the current position of particle, V_i is particle velocity, W is inertia weight, r_1 and r_2 are random numbers in [0,1] interval, c_1 and c_2 are acceleration coefficients, F_k(t) is the best solution found by kth family and g(t) is the best position found by all families in tth repetition.

b) Calculating the fitness of each particle (path) based on fitness function and based on network model by the following equations:

$$Route\_cost_{j,d}^{n} = \sum_{l=1}^{t} Fuzzy\_Cost_{l}^{l+1}$$

(10)

In equation (10), $Route\_cost_{j,d}^{n}$ is the desirability of going from node n (l=1) to node d (l=t) through node *j*. $Fuzzy\_Cost_{l}^{l+1}$ is link fuzzy cost between neighbor nodes of *l* and *l+1*.

Then, fitness of each path is calculated based on fitness function of the following equation (11):

$$Fitness_{j,d}^{n} = \frac{1}{Route\_cost_{j,d}^{n}}$$

(11)

In equation (11), $Fitness_{j,d}^{n}$ is the fitness of each particle path between source node of *n* and destination node of *d* through node *j*.

c) Updating the solutions found for each particle:

• Update the best solution found by each family (F_k):

(12)

If $\quad Fitness(i) < Fitness(F_k) \quad$ then $\quad F_k = X_i$

• Update the best found current solution(g):

(13)

If $\quad Fitness(i) < Fitness(g) \quad$ then $\quad g = X_i$

5) If the number of iterations reached maximum or fitness function to minimum base, go step 6, otherwise return to step 4 and repeat the algorithm.

6) Find the optimal path and end algorithm.

In the proposed method, triangular input fuzzy system was chosen, taking into account three criteria of energy, the distance between nodes and available bandwidth. In membership functions of input variables and for describing the fuzzy rules, symbols of L, M, H and below symbols were used with 9 quality ratings in order to show low, medium and high output membership function and VL (very low), LM (low- medium), LH (low- high), ML (medium-low), MM (medium), MH (medium- high), HL (high-low), HM (high- medium) and VH (very high). 27 laws are defined for fuzzy rule base of this paper that are shown in the following tables.

Table 1: Fuzzy rule base, when consumption energy is low (L)

Bandwidth / Distance	L	M	H
L	HL	HM	VH
M	MH	HL	HM
H	MM	MH	HL

Table 2: Fuzzy rule base, when consumption energy is medium (M)

Bandwidth / Distance	L	M	H
L	ML	MM	MH
M	LH	ML	MM
H	LM	LH	ML

Table 3: Fuzzy rule base, when consumption energy is high (H)

Bandwidth / Distance	L	M	H
L	LH	ML	MM
M	LM	LH	ML
H	VL	LM	LH

The fuzzy cost is calculated according to equation (14):

(14)

$$Fuzzy\_Cost_{ij}(t) = \frac{\sum_{l=1}^{M} \overline{y}^{l} \prod_{i=1}^{n_f} \mu_{A_i^l(x_i)}}{\sum_{l=1}^{M} \prod_{i=1}^{n_f} \mu_{A_i^l(x_i)}}$$

In equation (14), $Fuzzy\_Cost_{ij}$ is obtained using Mamdani implication and non- fuzzy method. Non- fuzzy cost centers mean of the link between nodes i and j is i. M is the number of fuzzy rules of membership functions in fuzzy set, n_f is the number of membership functions for input variables and $\mu_{A_i^j}(x_i)$ is fuzzy amount of membership functions.

5. Simulation model specifications

The assumed network model consists of 20 stations that are randomly created in order to test and evaluate the performance of proposed method (FFPSO) using FPSO algorithm in network. Table 4 shows the specifications of simulation model. Eight different scenarios including two states of without error and with error and two types of CBR and Exponential traffic are considered in order to evaluate the performance of network.

Table 4: Simulation model specifications

Parameter	Amount
The number of nodes in network	20
Package size	4Kb
Simulation environment dimensions	100m*100m
Simulation Time for every scenario	600S
Bandwidth distribution	[100 Kbps ,500 Kbps]
Distribution of energy	[10mw, 30mw]
Distance distribution	[10m,100m]

Table 5 shows the parameters used in proposed method.

Table 5: Parameters of proposed method

Description	Parameter	Amount
Primary Population	N	30
Number of family members	m_1	3
Acceleration factor	c_1	1.496
Acceleration factor	c_2	1.496
Inertia weight	W	.72984
The number of algorithm iteration	K	200

6. Simulation Results

Performance Criteria: The following criteria are considered in this paper in order to evaluate the proposed method:
• Throughput: the number of bits that are displaced in a specific period in network.
• Delay: the mean amount of time that is needed for a packet to go from one point of network to another point.
Network performance criteria are investigated in both uniform and exponential traffic situations. This means that it is investigated for delay and throughput criteria.

6.1. Throughput

In this section, FPSO algorithm throughput and proposed routing algorithm are evaluated. Figs. 3 and 4 shows throughput of two different traffic situations.

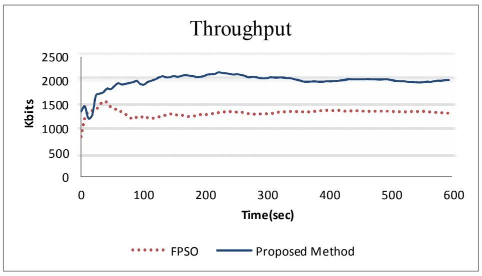

Fig. 3: Throughput Diagram of CBR traffic

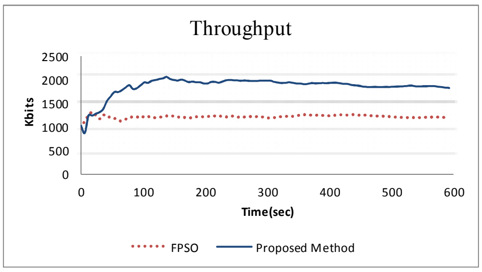

Fig. 4: Throughput Diagram of Exponential traffic

As Figs. 3 and 4 shows the throughput of proposed algorithm in both CBR and exponential traffic situations, we can say that proposed routing algorithm has increased network performance.

6.2. Delay

In this section, the delay of proposed routing algorithm is evaluated. Figs. 5 and 6 show the delay of algorithm in both uniform and exponential traffic situations.

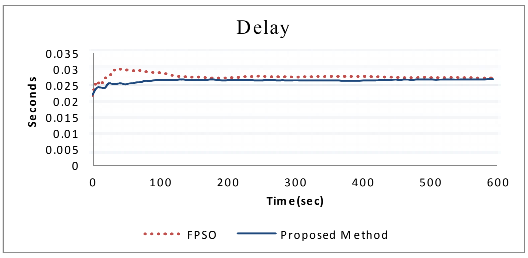

Fig. 5: Delay Diagram of CBR traffic

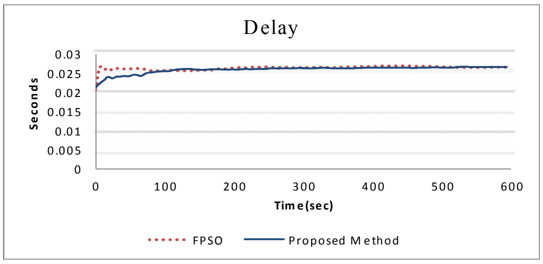

Fig. 6: Delay Diagram of Exponential traffic

Finding routes with more bandwidth reduces the delay. Comparison of curves in Figs. 5 and 6 shows that both algorithms have less delay in uniform traffic and identical delays in exponential traffic situations. It can be said that proposed method leads to less delay in normal network.

7. Conclusion

A method of routing in ad hoc networks was presented in this paper, using Family Particle Swarm Optimization Algorithm and Fuzzy Logic that uses network resources effectively in order to improve network performance. The advantages of this method include multi criteria routing and flexibility. The proposed method simultaneously considers three criteria including energy; nodes distance size and available bandwidth and find the best way of sending data from source to destination with less cost. Since this method selects a route with lower energy consumption for sending data, network lifetime is increased. Selecting a route with more available bandwidth provides a better timing for data to achieve into destination. As a result, this routing method provides better service for applicants.

Therefore, it can be said that using Family Particle Swarm Optimization Algorithm will be good option due to quick adaptation ability with Ad hoc network topology and its combination with fuzzy logic in order to improve the performance of ad hoc network routing.

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