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Improvement of Gateway Replacement in Wireless Mesh Networks Using Genetic Algorithm and Fuzzy Logic

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Abstract: The main challenge in wireless mesh networks is the arrangement and geometric design of gateways. The main function of this gateway is the establishment of connection of this kind of networks With external networks, especially the Internet. The arrangement of these nodes play key roles in quality improvement and reduction of costs in Wireless mesh network. Whenever these gateways turned to bottleneck, it will being irreversible Harms to networks functioning and performance authenticity, and it will lead to increase in the Amount of cost in this kind of network.

Keyword: Wireless mesh networks, gateway, fuzzy logic, genetic algorithm.

I. INTRODUCTION

A. *genetic algorithm*:

Genetic algorithms are tools that have been designed to simulate the natural choice mechanism ,this act takes place by searching in space problem to find better answer .genetic algorithms created with respect Darwin theory about evaluation. In genetic algorithms there are same terms [1, 2]. Gene is the basic genetic union , allele cites the different status of each gene, Chromosome allude to group of genes. A Genetic algorithm composed of same stages. Genetic algorithm starts with an initial population that contains N random solutions and each solution is represented by a chromosome. After that fitness function calculates a value for each chromosome that shows how good a solution is. Next a selection mechanism selects some of nodes as candidates to reproduce new offsprings. Crossover operator combines selected chromosomes with hope to improve them and after that, mutation changes chromosomes to produce better solutions, and then new generation is known as current population. These steps are called genetic algorithm cycle. This cycle continues until a termination criterion is reached.

B. *fuzzy system:*

Fuzzy logic and fuzzy systems [3] is knowledge –based or rule –based system. The heart of fuzzy system is a base of knowledge that consists of fuzzy if-then rules. Fuzzy if-then is if-then Term and numbers of its word is determined by membership functions. The starting point for fuzzy System is to acquiring group of fuzzy if-then rules from the knowledge of connoisseur Or the realm of relevance area.

The next step is the combination of these rules in a whole unified fuzzy. Different fuzzy system use different ways to combine these rules. The goal of fuzzy logic consist of using fuzzy system, For placing human knowledge to engineering system in systematic way that could be analyzable efficiently. In this logic, fuzzy systems make use of common structure, and fuzzy if-then rules could be used in every industrial processes and productions.

II. RELATED WORKS

In wireless mesh network (WMN) the location of the main gateway is for the efficiency of the network. Optimizing the cost is a main guideline in this kind of network. Assigning the place and arrangement of gateway in this kind of network is imperative that should be taken into consideration. Different ways has been presented in this regard and the ratio of cost/capacity is of high mportance [4, 5, 6].

One of the proposed algorithms is the CSLBA algorithm and its goal is to achieve objectives that mentioned above [4, 5]. Here CSLBA algorithm described with an example that consists of 14 nodes. Figure 1 shows this example. CSLBA algorithm consists of three main phases: 1) gateway selection, 2) cluster construction, 3)partition optimizing.

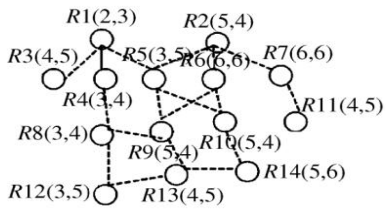

Figure 1:Wireless Mesh Network Model

The gateway in [4] is based upon these tents: selecting each gateway takes place according to equation 1 [4,6].

$$p_i = \frac{\min\left(\sum_{j=1}^{N} r_{ij}, s\right)}{cost(v_i)} \qquad (1)$$

Where S is number of nodes in each cluster is regarded as 5. r_{ij} is the number of connections and connective paths among nodes in the supposed network an adjacent matrix with 14 rows and 14 columns that shows the wireless mesh network. If two nodes are connected with one or two hops, their corresponding entry in adjacent matrix would be equated to 1. Figure 2 shows adjacent matrix for wireless mesh network presented in figure 1. Each node is organized with one couple that designates traffic and cost. In this regard the value functioning of each nodes are as Follows:

P_1=2.5, P_2=1, P_3=1,
P_4=1.6667, P_5=1.6667, P_6=0.8333,
P_7=0.8333, P_8=1.6667, P_9=1,
P_{10}=1, P_{11}=0.75, P_{12}=1.6667,
P_{13}=1.25, P_{14}=1

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
1	1	1	1	1	0	0	1	1	1	0	0	0	0
1	1	0	0	1	1	1	0	1	1	1	0	0	0
1	0	1	1	1	0	0	0	0	0	0	0	0	0
1	0	1	1	1	0	0	1	1	0	0	1	0	0
1	1	1	1	1	1	1	1	1	1	0	0	1	1
0	1	0	0	1	1	1	1	1	1	0	0	1	1
0	1	0	0	1	1	1	0	0	0	1	0	0	0
1	0	0	1	1	1	0	1	1	0	0	1	1	0
1	1	0	1	1	1	0	1	1	1	0	1	1	1
1	1	0	0	1	1	0	0	1	1	0	0	1	1
0	1	0	0	0	0	1	0	0	0	1	0	0	0
0	0	0	1	0	0	0	1	1	0	0	1	1	1
0	0	0	0	1	1	0	1	1	1	0	1	1	1
0	0	0	0	1	1	0	0	1	1	0	1	1	1

Figure 2: Adjacent matrix

In second step the clusters should be formed in wireless mesh network. To form each cluster, we should consider a number of criteria[7,8]:

a. for constructing each cluster, breadth-first algorithm is used.
b. the number of nodes in each cluster should be at the most 5 (S=5).
c. in each cluster, the number of hops between each two cluster member should be at most R=2.

In the third step , optimizing takes place in already constructed cluster, because there is still possibility in the stage of the clustering that one of the two conditions (S=5,R=2) may not satisfied. In supposed wireless mesh network, after performing three steps mesh network would be clustered as presented in figure 3.

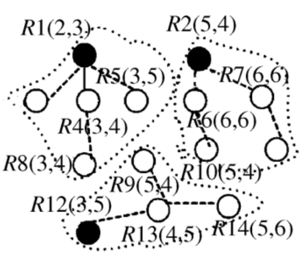

Figure 3:CSLBA Algoritm in Network Model

The variance of load is computed as presented in equation 2.

$$Var(g_1, g_2, \dots, g_k) = \sqrt{\frac{1}{k-1}\sum_{1\le i\le k}(load(g_i)-\bar{L})^2}$$

$$\bar{L} = \frac{1}{k}\sum_{1\le i\le k} load(g_i) \qquad (2)$$

In a cluster, the gateway provides the Internet access service for its members. Therefore, the total load on the gateway is equal to the total traffic in cluster. The defects that are of importance are as follows [4]:

a. in selecting the gateway, the criteria of optimizing has not been considered.
b. forming cluster after choosing gateway is not desirable and economical.
c. there is no formula for computing the cost and calculation that guarantees the accurate performance of network comes to dead end.
d. fitness criteria for choosing gateway and forming the cluster has not been considered.

III. PROPOSED ALGORITHM

As for the weak points that exist in [4] and not introducing away for computing cost, The cost of the cluster and totally the cost of wireless mesh network has been supposed. Because the most important factors in efficiency and also the enhancement of efficiency is considered cost factor, guidelines proposed to reduce these factors.

$$Cost(g_1, g_2, \dots, g_k) = \sqrt{\frac{1}{k-1}\sum_{1\le i\le k}(Cost(g_i)-\bar{c})}$$

$$\bar{C} = \frac{1}{k}\sum_{1\le i\le k} Cost(g_i) \qquad (3)$$

After computing variance of load, the cost of supposed network upon which the clustering is done, calculated via equation 3 and the following results acquired:
Load variance =2.6458
Cost=5

In order to optimize the cost and fitness criteria in next stage, CSLBA combined with genetic Algorithm (G.A) .The genetic algorithm at first step composed of chromosomes which analogues to supposed wireless mesh network with 14 gene which represents 14 nodes of network. In third step, there is a criteria such as fitness function which represents the fitness of each node in consideration as a gateway node, construction of cluster and finally optimizing network from cost. In later stage, by selecting the nodes that have higher fitness, the nodes that have more fitness become target of selection process. Then, the crossover and mutation perform and the best status will choose with emphasize to reduction of cost and enhancement of fitness and take into consideration for generating next generation in producing the network more efficiently.

Fitness function presented in equation 4 [4, 9]:

$$F(I) = \lambda_1 e^{\frac{-Cost(I)}{Max\ Cost}} + \lambda_2 e^{\frac{-Var(I)}{Max\ Var}} \qquad (4)$$

In this equation λ1 and λ_2 are selective amounts. Basic defects that exist in fitness Function are as follows: Computing energy, needed to calculate it is very heavy and difficult so we get rid of heavy Cost by eliminating this kind of calculation and converting the above exponential formula to fuzzy logic-based system and fuzzy –based Knowledge.

The amount of function value is not controllable in a range, so F can be defined , in a fuzzy logic and the amount of F in the range [0,1] , become more controllable And manageable. To remove the defects that was mentioned before, fuzzy logic and new definition of fitness function are used. The main reason of using fuzzy logic as mentioned is the facility in computation ,namely:

a) Trigonometric functions from accuracy facet are equal to Gaussian function. But calculation cost decreases.
b) the amount of cost in supposed mesh network is high and should be reduced by presenting fitness function in fuzzy logic.

At first, a base of fuzzy knowledge rules establishment would bring about conditions that lead to optimal selection of chromosome. For instance, the chromosome that has lower cost will have high priority. A base of fuzzy knowledge rules tell us the less the cost, the more the fitness. The symmetry of results in selecting the best fitness play a key role, so pickup $\lambda_1$and λ_2 as 0.5 ($\lambda_1$and λ_2=0.5) facilitation the process and the amount of cost and load variance are presented in 5 levels [5,6]: VL(very low)=0.01, L(low)=0.25, M(medium)=0.50, H(high)=0.75, VH(very high)=0.99, And also these parameters are used:λ_1, λ_2=0.5,Maxcost=0.99 ,Maxvar=0.99.

Table 1: fuzzy based knowledge

var / Cost	0.01	0.25	0.5	0.75	0.99
o.o1	0.98995	0.883393	0.796712	0.729376	0.678915
0.25	0.883393	0.796712	0.729376	0.678915	0.572358
0.50	0.796712	0.729376	0.678915	0.572358	0.485677
0.75	0.729376	0.678915	0.572358	0.485677	0.41e834
0.99	0.678915	0.572358	0.485677	0.41834	0.367879

The amount of fitness with respect to fuzzy based knowledge acquired in 9 levels:

Fhh=0.98995 Fhm=0.729376 Flh=0.485677
Fhm=0.88339 Fmm=0.678915 Flm=0.41834
Fhl=0.796712 Fml=0.572358 Fll=0.36787

With respect to the results of fuzzy based knowledge the less the cost, the more fitness. Table 1shows these parameters also figure4 shows relation between const and fitness.

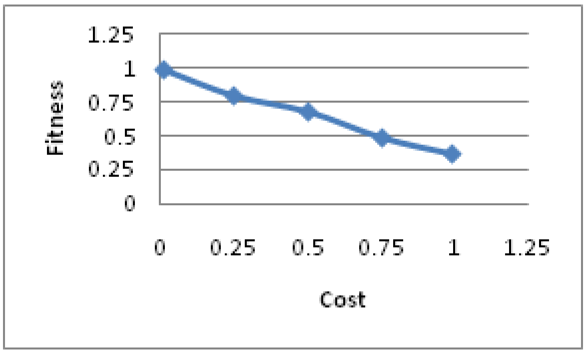

Figure 4: relation between cost and fitness

At first some appropriate chromosome for initial population should be selected, so that each Chromosome includes 14 genes and each genes represents a node in problem Space. First the best chromosome by CSLBA algorithm should be selected. In the Process of suitable chromosome enhancement use CSLBA, but it is not good for optimizing because it does not select another chromosome. For selecting different chromosomes, nextbest method is used which select a node as gateway node with second highest p_i value. the strategy of this method is presented in table 2.

Table 2:suggested:scheme

P1	P2	P3	equal binary
best	best	best	0 0 0
best	best	nextbest	0 0 1
best	nextbest	best	0 1 0
best	nextbest	nextbest	0 1 1
nextbest	best	best	1 0 0
nextbest	best	nextbest	1 0 1
nextbest	nextbest	best	1 1 0
nextbest	nextbest	nextbest	1 1 1

By selecting and combining gateways as best and nextbest, 8 different Reasonable (acceptable) chromosomes will be chosen, based upon these chromosome each of them possess 14 genes, regard to R=2 And S=5 crossover and mutation are performed. Once initial population created the genetic algorithm cycle starts. This cycle illustrated in figure 5.

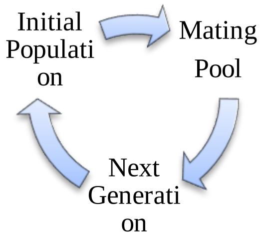

Figure 5: cycle of genetic algorithm

For selection each time one chromosome is chosen according to that one of 8 Status and highest fitness concerning that possess Highest fitness value is chosen. In other words, the best chromosome would be the best fitness in Output. Selection function choose 14 nodes in terms of their chromosome fitness from among initial population and put it in next generation. In the next stage crossover function Combines the chosen chromosome that are in next generation and generate next generation .

Pseudo code relevance to selection mechanism proposed in figure 6 .

```
K ← 3
for i=1:1:population_size

  for j=1:1:k
   n(j)  ←  ceil(rand()* population_size)
  max ←  fit(n(1))
  maxindex  ← n(1)
  for j=2:1:k
  if(fit(n(j))>max

  max ← fit(n(j))
  maxindex  ← n(j)

  nextgeneration(i,:) ← population(maxindex,:)

 nextgeneration
```

Figure 6: Pseudo code for selection function

```
Pm ← 0.3
for i=1:1:population_size
   ppp ← rand()
   if(ppp<pm)
   cp ← ceil(rand()*3)
   nextgeneration1(cp) ← 1-nextgeneration1(cp)
   nextgeneration2 ← nextgeneration1
   nextgeneration2;
```

Figure 7: Pseudo code for mutation function

Finally, next generation2 will be considered as population. Table 3 represents results after one time using genetic algorithm, the following results acquired.

Table 3: results after one time executing genetic algorithm

	P1 P2 P3	P1 P2 P3	
1	1 1 0	nextbest nextbest best	Var= 5.5076 cost=4 fitness=0.4376
2	1 1 0	nextbest nextbest best	Var=5.5076 cost=4 fitness=0.4376
3	1 1 1	best nextbest nextbest	Var= 11.5326 cost= 9 fitness=nan
4	1 0 1	nextbest best nextbest	Var=3.7859 cost=1 fitness=0.7487
5	1 0 1	nextbest best nextbest	Var= 3.7859 cost=1 fitness=0.7487
6	0 0 1	best best nextbest	Var=3.7859 cost=1 fitness=0.7487
7	1 1 1	nextbest nextbest nextbest	Var= 11.5326 cost= 9 fitness=nan
8	0 1 1	best nextbest nextbest	Var= 11.5326 cost= 9 fitness=nan
9	1 1 1	nextbest nextbest nextbest	Var= 11.5326 cost= 9 fitness=nan
10	0 1 0	best nextbest nextbest	Var=5.5076 cost=4 fitness=0.4376
11	1 0 0	nextbest best best	Var=2.6458 cost=5 fitness=0.4561
12	0 0 1	best best nextbest	Var= 3.7859 cost=1 fitness=0.7487
13	1 0 1	nextbest best nextbest	Var=3.7859 cost=1 fitness=0.7487
14	0 0 0	best best best	Var=2.6458 cost=5 fitness=0.4561
15	1 1 0	nextbest bextbest best	Var= 5.5076 cost=4 fitness=0.4376
16	0 0 1	best best nextbest	Var= 3.7859 cost= 1 fitness=0.7487
17	1 1 0	nextbest nextbest best	Var=5.5076 cost=4 fitness=0.4376
18	1 1 0	nextbest nextbest best	Var=5.5076 cost=4 fitness=0.4376
19	0 0 1	best best nextbest	Var= 3.7859 cost=1 fitness=0.7487
20	0 1 1	best nextbest nextbest	Var= 5.5076 cost=4 fitness=0.4376

We have reduction of cost and enhancement of fitness in proportion to first Model (best best best).

Table 4: a) results of base model

P1 P2 P3	cost	Fitness
Best Best Best	5	0.4561

b) Results of suggested scheme

P1	P2	P3	cost	Fitness
best	best	nextbest	1	0.7487
nextbest	best	nextbest	1	0.7487

c) Results of base model

P1	P2	P3	cost
best	best	best	5

b) Results of suggested scheme

P1	P2	P3	cost
best	next best	best	4
nextbest	nextbest	best	4

After 100 iterations executing genetic algorithm the best result and best below status get convergent.

Table 5: Convergence after 100 iterations

P1	P2	P3	cost	Max fitness
next best	best	nextbest	1	0.7487

IV. CONCLUSION

In this paper, we focus on the gateway replacement strategy with minimum cost and best fitness on the gateways .First of all, a metric is presented to describe the cost on the gateways, and the gateway replacement problem is addressed. In previous work, the change of topology and the traffic distribution is not considered. The key idea is to select the gateway nodes according to their traffic/cost ratio, and to improve the cost through scanning and shifting methods. The other is to use a genetic algorithm, which has the advantage of global search for multiple goals, and can get the optimal solution at the price of gateway replacement in wireless mesh networks. Thus, we provide a trade-off for network design. Simulations done in MATLAB and results show that proposed algorithm has better performance.

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