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GATEWAY PLACEMENTS IN WMN WITH COST MINIMIZATION AND OPTIMIZATION USING SA AND DE TECHNIQUES

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Abstract

Wireless Mesh network is one of the cost effective solution for broadband internet connectivity. The gateways play the major role by supplying internet service to the users. Hence multiple gateways will be needed for large campus networks. The budget cost and the time to setup these networks are important parameters to be considered. Given the number of gateways and routers with the no of clients in the service area, an optimization problem is formulated such that the installation cost is minimized satisfying the QOS constraints.

The routers are replaced with gateways according to the high traffic demand. In this paper a cost minimization problem is formulated to solve the gateway placement issue in WMN. Using a local search method Simulated Annealing (SA) and a population based method Differential Evolution (DE) the network model is evaluated in NS2 simulator to achieve cost optimization. The later outperforms the SA algorithm around 20% to 30%.

Keywords: Wireless Mesh Networks, Differential Evolution, Mesh routers, Mesh gateways, Mutation, Simulated Annealing, Optimization.

1. Introduction

Wireless Mesh Network (WMN) is the recent attractive technology for applications such as metropolitan area networks, campus networks, urban areas, medical systems, surveillance systems etc.[1]. Mesh routers are different from other conventional routers in terms of coverage and power constraints.

In mesh topology every node is connected in a multihop fashion which enables the information to be transmitted in all available paths redundantly. It is one of the robust features in WMN which make them very reliable in node failures.

The mesh clients on other hand have the capability of acting as routers but not as gateways or bridges. The WMN is a self healing network since they are not

dependent on a central node .The uplink traffic generated from the Mesh client passes through the mesh router or directly to Internet Gateway (IGW) and also the downlink traffic passes to the client from the IGW.Hence IGW hop is mandatory, therefore its placement plays a vital role based on connectivity, fairness, throughput and reliability of the network [2-4]. The IGW deployment is one of the prominent design issues.

2. Related Works

Many node placement approaches are formulated by the researchers as it is one of the active research areas [5-8].A ILP for cost effective node placement problem was proposed and formulated by Wenjia Wu et.al[5].The authors have evaluated using CeNp LSA algorithm with gateway deployment constraint. To determine the positions of mesh nodes the algorithm is categorized as (a) MSC-based coverage algorithm (b) weighted clustering algorithm (c) GW-rooted tree pruning algorithm. The authors have defended that the placement algorithm is effectively good.

Tabu search method for mesh router placement is presented by Fatos Xhafa [6] and its efficacy is evaluated. A WMN-GA system is developed and the network performance is evaluated by Admir Barollia et.al. [7].The performance of the proposed system for different client distributions such as Normal, Uniform, Exponential and Weibull is observed.

3. Problem Statement

A city wide metropolitan networks or Campus wide networks need more number of gateways to improve the coverage for all mesh clients. However the cost budget on the other hand reaches beyond the limit. The main objective in this paper is to search for a low cost WMN configuration and determine the number of used gateways.

3.1 Problem Description

Let G (V, E) denote a mesh network. The nodes represent the number of mesh routers, gateways and clients. Edges represent the communication link between the nodes. Let U represent the set of mesh nodes, T set of candidate positions. Let V be the set of all nodes (routers, gateways and clients) $V \leftarrow U \cup \mathrm{T}$.

Let C_j be the set of node in the coverage range or communication range of node i.

$$C_j = \{ j \varepsilon V, j \neq i, d(i,j) \geq R \} \forall i \varepsilon U \qquad \ldots(1)$$

Where $d(i, j)$ denotes the Euclidean distance between the node i and j and R is the maximum communication range of node u.

Let the set of edges E be the set of all possible links e(i,j) i.e

$$E=\{e(i, j); i \varepsilon U, j \varepsilon C_j \} \quad \ldots(2)$$

The gateway placement problem can be formulated as a cost optimization problem, where it aims to minimize the number of mesh nodes so as to satisfy the QOS constraints. A cost minimization model is proposed based on the placement cost of mesh routers and mesh gateways.

The objective function is given by

$$Minimize \sum_{i,j=1}^{n} (C_{pi} M_{ri} + C_{pj} M_{gj}) \quad \ldots(3)$$

Where C_{pi}, C_{pj} are the placement cost of Mesh routers and gateways

M_{ri} is i^{th} Mesh Router

M_{gj} is j^{th} Mesh Gateway

$$M_{ri}= \begin{Bmatrix} 1 \text{ if mesh router is active} \\ 0 \text{ otherwise} \end{Bmatrix}$$

$$M_{gj}= \begin{Bmatrix} 1 \text{ if mesh gateway is active} \\ 0 \text{ otherwise} \end{Bmatrix}$$

Subjected to

The Euclidean distance (d) between the two gateways i and j

$$\begin{aligned} & d(i, j) \geq G_r \\ & e(i, j) \in \{0,1\} \quad \ldots(4) \\ & TH(i, j) \geq D(j) \end{aligned}$$

Where Gr is the Gateway radius (communication range) and $TH(i, j), D(j)$ denote the throughput and traffic demand of link $e(i, j)$ of routers i and j.The objective function (3) aims to minimize the placement cost of routers and gateways. The placement cost also includes the installation cost; hence it can be referred as overall cost. The constraints (4) say about the condition that the gateway radius must be less than the distance between two routers to avoid interference. A binary {0, 1} variable which equals 1 if a link is available or else 0.The demand for network coverage must not exceed more than the routers throughput.

3.2 Network Model

In this paper we have assumed a 6x6 grid network. Let each cell of square region A^2 has a mesh router in the center to give network connectivity among the clients.

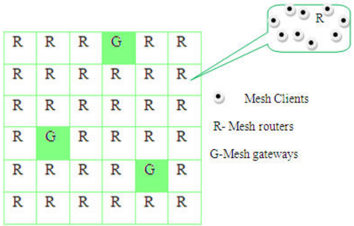

Fig.1. Grid network with Mesh Routers and Gateways in the cell.

The gateway radius and traffic weight in each cell can be calculated as

$$Gr = round\frac{\sqrt{Nr}}{2\sqrt{Ng}} \qquad \ldots(5)$$

where Nr and Ng are the number of gateways and routers.

4. Optimization Methods

4.1 Simulated Annealing (SA)

Generally SA algorithm is based on Hill climbing algorithm. According to hill climbing it will simply accept the neighbor solutions that are better than the neighbor and get stuck in local optimums. Simulated annealing avoids this problem. An initial high temperature is initialized with a current solution. The algorithm searches for the next neighbor solution with respect to the objective function. Here in our work it searches for the minimum cost value and accepts as new solution. The algorithm is looped until for decrease in temperature and the solution is updated with a good acceptable solution.

Algorithm 1: Gateway Placement with cost Minimization using SA

N $\rightarrow$ No. of moves T $\rightarrow$ current Temperature

For i=1 to N **do**

Generate new neighboring solutions and evaluate the new objective function f_{new}

If $f_{new} < f_{old}$ **then**

Accept and update the solution

Else

Accept with probability $P(T) \leftarrow e\frac{-(fnew - \text{fold})}{\text{T}}$

Update if the solution is accepted

endif

endfor

4.2 Differential Evolution (DE) Algorithm

DE algorithm is one of the simplest of among all evolutionary methods. It has excellent convergence characteristics and only involves few parameters. The parameters are mutation, crossover and selection operators [9].It is a population based method and a powerful optimizer even though it is simple.

Algorithm 2: Gateway Placement with cost Minimization using DE

Set generation counter n=0;

Initialize the control parameter, S and CR

Initialize the population size Np

Initialize the population vector of x_n individuals randomly

While stopping condition not reached **do**

For each individual $x_i(n)$ **do**

Evaluate the fitness $f(x_i(n))$

Create a mutated vector Y_M using the mutation function

Create an offspring $x_i'(n)$ by applying cross over

If $f(x_i'(n))$ is better than $f(x_i(n))$ **then**

Select $f(x_i(n))$

End

Else

Select $f(x_i'(n))$

End

End

End

Return the individual with best fitness solution.

In this paper the cost optimization problem is evaluated and compared using both the algorithms SA and DE.The no. of routers and gateways are the decision parameters which are assigned randomly and the initialization table is created with respect to the population size. The minimal cost value is reached after much iteration. The stopping criteria allowed is less than 2%.

5 Results and Discussions

The network model is implemented in the network simulator Version2.The placement of nodes is performed using the Simulated Annealing (SA) and Differential Evolution Algorithm (DE) methods.Let the population size be 100, cross over operator CR=0.5 and scaling factor S=0.6 . In a terrain dimension of 1000mx1000m the mesh clients are distributed. The mesh routers are placed randomly and the routers act as gateways when the traffic demand is high. The total no of mesh routers Nr=36. According to Zhou [4] the throughput computation depends on the number of routers, gateways, number of hops and capacity of routers. The comparative result of the deployment cost of nodes using SA and DE methods for 10 iterations is shown in figure 2.The installation cost for different instances of mesh devices is tabulated in table1.

Table-1: Comparison with different instances of mesh devices.

No. of routers	No. Of gateways	Installation Cost of Mesh devices(units)	
		SA	DE
35	1	1490.6953	789.6317
34	2	1467.4587	743.7665
33	3	1412.6312	701.5399
32	4	1389.7931	675.9456
31	5	1356.6535	638.4231
30	6	1308.6535	621.7553
29	7	1229.2636	613.8323
28	8	1109.8878	601.7660
27	9	967.9847	589.9523
26	10	875.7894	548.2080

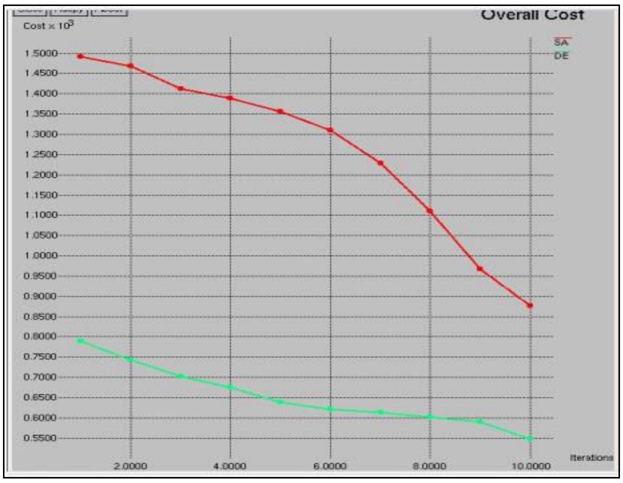

Fig-2: Evaluation of cost minimization model using SA and DE Techniques.

Conclusion

One of the important objectives is cost effective design in WMN. The overall cost includes the positioning of the routers and the installation cost.DE algorithm mutates for best minima results. The observed results show that the cost of placing the mesh devices is minimized using the DE algorithm compared to the SA algorithm. The work can be further extended using fuzzy DE and observe the effect of crossover parameter for minimizing the cost.Multiobjective optimization problem gives further solution for efficient design of the WMN.

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