Channel Allocation Optimization Scheme for Wireless Mesh Network Based On Genetic Algorithm

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Abstract: This template explains and demonstrates how to prepare your camera-ready paper for Wireless mesh network can reduce inter-channel interference and increase network throughput through multi-interface multi-channel technology. This paper researches how to allocate channels to minimize interference, so as to improve throughput. In view of the shortcomings of the previous protocol interference model, this paper proposes a protocol model that can describe interference more accurately. Because the channel allocation problem is an NP problem, this paper optimizes channel allocation through genetic algorithm and obtains the relative optimal solution of channel allocation in a short time. The results show that channel allocation by genetic algorithm can reduce a lot of channel interference and improve the network throughput significantly. Compared with other channel allocation schemes, this scheme has higher network throughput..

1. Introduction

With the rapid development of society, people's wireless communication technology is more and more demanding. Existing wireless communication technologies can no longer meet the control of today's complex environment, and the wireless mesh self-group network developed by ad-hoc has emerged.

Wireless mesh network has a multi-to-multi point network topology. Each network node is connected by wireless multi-hop through other nodes adjacent to each other. Therefore, it has the advantages of simple deployment and installation, great stability, flexible structure, high bandwidth and so on. In special environment or emergency communication, such as military communications, disaster rescue, forest control and other scenes are very suitable.

Because of the limited channel resources, how to get greater throughput and lower latency through optimal allocation channel under the limited channel resources is an important problem. In the past, wireless mesh networks were composed of single interface nodes, and the network throughput was low. By configuring multiple interfaces to nodes, nodes can communicate with multiple nodes over different channels at the same time, which can effectively increase network throughput. The channel optimal allocation of multi - interface multi - channel mesh network has become a critical problem. In this paper, a genetic algorithm is proposed to optimize channel allocation, as to obtain minimal channel interference, and significantly improve network throughput.

2. Related work

In [1], a partial overlapping channel allocation algorithm based on interference perception is proposed, which is used to optimize channel allocation by constructing the signal to noise ratio matrix to measure inter-link interference and minimize interference. In [2], a partial overlapping channel allocation algorithm for interference avoidance and load balancing is proposed, which optimizes link scheduling by using heuristic algorithms to increase the number of links that can be scheduled per time slot, depending on the interference situation and the importance of the link. [5], a distributed gateway selection algorithm is pro-posed, and a cross-layer concept is proposed to predict the environment dynamics by learning automatons, so as to allocate channels. In [6], a resource management method based on the transmit power control algorithm of omnidirectional antenna and directional antenna is proposed, and channel allocation is carried out on the premise of ensuring minimal interference between virtual networks. In [7], a problem based on inter-channel interference and load balancing is proposed to maximize network capacity. The algorithm can select the best channel according to the channel interference of the neighbor node, and then assign the channel to a link, enabling it to withstand more traffic and reduce network congestion.

3. System model

3.1 Network model

The wireless mesh network consists of N nodes, L links. The network topology is represented by an undirected graph $G=(V,E)$ where $V=\{v_1,v_2,v_3,\cdots\}$ is a set of nodes, and $E=\{e_1,e_2,e_3,\cdots\}$ is a set of links. Each link needs to be assigned a common channel to connect it. Assume that there are k orthogonal channels, and each node has m interfaces. The number of channels allocated by channel i is R_i. So $R_i \leqslant m$.

Network topology matrix A:

$$A_{ij}=\begin{cases}1, & A\ link\ between\ node\ i\ and\ j\\ 0, & No\ link\ between\ node\ i\ and\ j\end{cases} \tag{1}$$

Channel assignment matrix B :

$$B_{ij}=\begin{cases}K, & A_{ij}=1\\ 0, & A_{ij}=0\end{cases}\quad K=1,2,\cdots k \tag{2}$$

3.2 Interference model

First define the distance between the two links. The two vertices of l_i are v_p and v_q. The two vertices of l_j are v_m and v_n. The distance between the two links is: $d(l_i,l_j)=\min\{d(v_p,v_m),d(v_p,v_n),d(v_q,v_m),d(v_q,v_n)\}$.

If the node transmits range is d_{tra}, and $A_{ij}=1$, the link conflict C_{ij} is:

$$C_{ij}=\begin{cases}1, & d(l_i,l_j)\leqslant 2\\ 3-\dfrac{d(l_i,l_j)}{d_{tra}}, & 2<d(l_i,l_j)<3\\ 0, & 3\leqslant d(l_i,l_j)\end{cases} \tag{3}$$

Interference between two links also depends on the traffic and transmission speed of the link. With the smaller the traffic and the higher transmission speed, there is less interference to the other link. We assume that the traffic on each link is the same, so interference to the other link is inversely proportional to the speed S of transmission of that link.

Link layer standard transmission rate is S_c, the actual transmission rate is S_r, so $\alpha=\dfrac{S_r}{S_c}$. The interference of link i to link j is :

$$I_{ij}=\frac{C_{ij}}{\alpha_i} \tag{4}$$

The total interference in the network is:

$$I=\sum_j\sum_i\frac{C_{ij}}{\alpha_i} \tag{5}$$

4. Channel allocation Scheme

4.1 Optimizing the model

Give the network topology and transmission speed of each link. The optimization model is:

$$\min\ I = \sum_j \sum_i \frac{C_{ij}}{\alpha_i} \tag{6}$$

$$subjet\ to:$$

$$B_{ij} \neq 0, \forall A_{ij} \neq 0$$

$$B_{ij} = B_{ji}$$

$$R_i \leqslant m$$

Each link must allocate channels. Two nodes with a link should be allocate the same channel. The number of channels allocated by the node should not exceed the number of interfaces.

4.2 Genetic Algorithms

Channel allocation is a mixed integer nonlinear programming. It has been proven to be an NP problem, so we use Genetic Algorithms to solve this optimization.

Genetic algorithm is a highly parallel, random and adaptive optimization algorithm, based on "survival of the fittest". The "chromosome" group encoded by the solution of the problem continuously evolves through replication, crossover and mutation. Eventually, it converges to the most suitable group, so as to obtain the optimal or satisfactory solution of the problem.

(1) Init population: L links and k channels were numbered respectively, and the channels were randomly allocated to each link. Repeat the random allocation p times to form the initial population

1. Init population
The initial population is p
The algorithm begins:
$i = 0$
While $i \leqslant p$
$j = 0$
While $j \leqslant L$
Generate a random integer in [1,k]
$j = j + 1$
End
$i = i + 1$
End

(2) Fitness function: Our goal is to find the minimum value of network channel interference, the inverse of I can be used as an fitness function.So $f = \frac{1}{I} = \frac{1}{\sum_j \sum_i \frac{C_{ij}}{\alpha_i}}$.

(3) Population selection: Using proportional selection, if the fitness of the individual is f_i, then the proportion of this individual in the next generation is $\frac{f_i}{\sum f_i}$

(4) Population crossing and variation: For the individuals to the next generation, the same gene sites of different individuals are exchanged and mutated to produce new individuals. This prevents you from falling into local optimizations.

(5) Algorithm end: When the number of iterations reaches the preset number of iterations, the algorithm ends.

5. Algorithm simulation

5.1 Simulation parameters

It has been proved in literature [4] that 2-4 interfaces are optimal. Considering cost and network interference, we chose three interfaces for each node, namely $m=3$. In the 802.11b/g standard, although there are 11 or 13 channels, there are only three orthogonal channels, namely $k=3$.

Using the following parameters to simulate the algorithm

Table 1. Parameters

Number of channels	3
Number of interfaces	3
Number of nodes	10~20
Standard transfer rate	5.5Mb/s
Transfer rate	5.5Mb/s、11Mb/s
Communication protocol	802.11b/g
Transfer distance	100m
Number of iterations	200
Initial population	100
Generation gap coefficient	0.9
Cross probability	0.9
Probability of variation	0.05

5.2 Simulation Results

In Matlab,10 to 20 nodes are randomly generated, and links are randomly generated between two nodes whose distance is less than the transmission distance. Channel allocation is optimized for the wireless network.

Figure 1 shows the optimization process for 15 nodes, and we can clearly see the entire process of channel interference optimization. After many iterations, the network interference is significantly reduced, and the optimal solution is obtained.

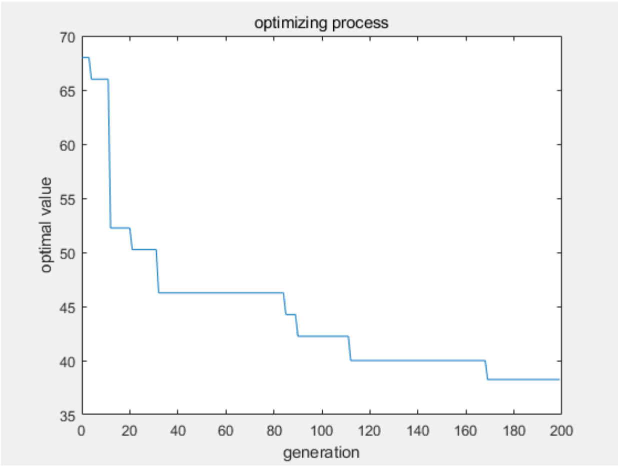

Figure 1. Optimization process of channel interference

10~20 nodes were randomly generated. Figure 2 shows the minimum interference in the initial population and the minimum interference after optimization. It can be seen that channel interference is greatly optimized in all cases.

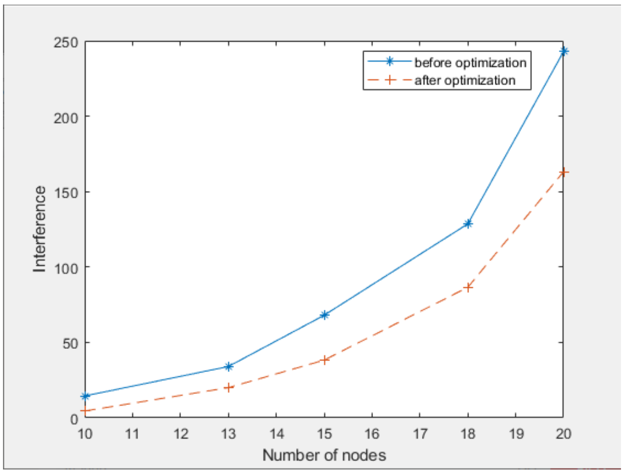

Figure 2. Channel Interference Optimization Results

According to the channel allocation scheme obtained by genetic algorithm, simulate and calculate the network throughput by Matlab, and compare to the scheme in literature [8]. The proposed scheme can improve the network throughput by nearly 17%.

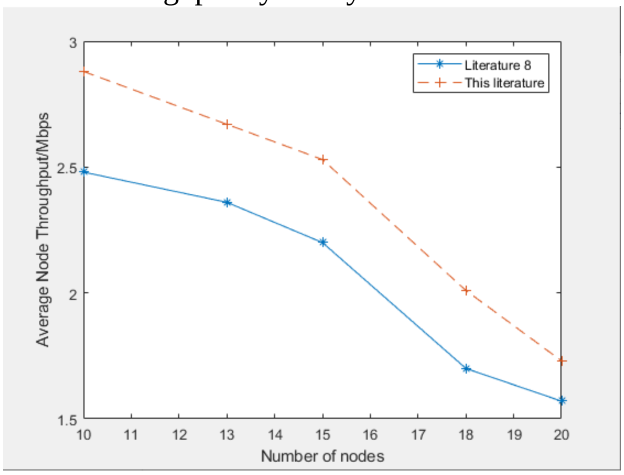

Figure 3. Scheme comparison

6. Conclusion

In this paper, the genetic algorithm is used to optimize the channel allocation in wireless mesh networks to minimize the interference between channels. According to the proposed channel interference protocol model, the real channel interference can be described more accurately. Genetic algorithm is used to solve NP problem, and the relative optimal solution of channel allocation is obtained in short time. The genetic algorithm can minimize network interference and significantly improve throughput compared with other schemes.

References

[1] Zhang Binbin. Some overlapping channel allocation algorithm based on interference perception is studied. [D]. Jilin University, 2019.

[2] Li Yujie. Multi-RF multi-channel wireless mesh network channel allocation and routing algorithm study. Chongqing University of Posts and Telecommunications, 2019.

[3] Qu Xingyu. Wireless Mesh Network Channel Allocation and Node Positioning Technology Research. Beijing University of Posts and Telecommunications, 2019.

[4] Zhu Zhenggen. Multi-interface multi-channel wireless mesh network channel allocation algorithm study. Xiamen University, 2018.

[5] A. R. Parvanak, M. Jahanshahi,M. Dehghan. A cross-layer learning automata based gateway selection method in multi-radio multi-channel wireless mesh networks [J]. Computing, 2019, 101 (8).

[6] Liang Li, Siyuan Zhang,Xiongwen Zhao,Yi Ding,Junyu Liu. Load-Balancing Channel Assignment Algorithms for a Multi-Radio Multi-Channel Wireless Mesh Networks[C]. Advanced Science and Industry Research Center.Proceedings of 2018 International Conference on Computer Modeling, Simulation and Algorithm（CMSA2018）.Advanced Science and Industry Research Center:Science and Engineering Research Center,2018:125-128.

[7] A Proposed System Using Genetic Algorithm for Energy Efficiency in Wireless Mesh Networks [J]. Gazi University Journal of Science,2019, 32 (2)

[8] Lin, Ting-Yu & Hsieh, Kai-Chiuan & Huang, Hsin-Chun. (2012). Applying Genetic Algorithms for Multiradio Wireless Mesh Network Planning. IEEE Transactions on Vehicular Technology - IEEE TRANS VEH TECHNOL. 61. 2256-2270. 10.1109/TVT.2012.2191166.