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Scheduling and Routing in Multi-Channel Allocation based on the Greedy Algorithm for Wireless Mesh Network

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Considering the channel dependence, this paper designs greedy algorithm in Multi-Channel Allocation joint scheduling and routing. Unlike the traditional multi-channel Wireless Mesh channel allocation, the proposed scheme considers scheduling and routing, and the network is divided into two states by network segmentation. The linear planning allocation method is used to minimize the average end-to-end delay for the maximum transmission link number； for the total channel resource and routing scheduling problem for link consumption that adopt the integer linear programming method modelling, the greedy heuristic algorithm can be used. The simulation analysis shows that the algorithm of this paper can effectively improve the throughput of the network.

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1. Introduction

Wireless Mesh Network has become one of the most promising networking technologies of Ad-Hoc Wireless Network and Automatic Configurable Wireless Network, which can provide mobile users with flexible adaptive wireless internet connection [1]. Based on the greedy algorithm, when a node needs to send or forward a control packet, it, firstly among its own all adjacent nodes, selects a nearest node todestination node as control group next-hop, then the node is paged to the structure links, and the control group is forward to the node. This process is repeated until the data packet reaches the destination node [2].

The channel allocation is summarized as a linear programming problem to find a channel allocation method that maximizes the number of transmission link [3]. The constraints of linear programming include the number of nodes and interfaces. When all variables (channels, interfaces, interferences, etc.) are integral values, this problem thus becomes the integer linear programming problem. The complexity of integer linear programming is exponential, and the greedy heuristic algorithm is a good way to solve the problem [4].

2. Problem Description

2.1 Channel Allocation to Meet the Constraint Condition

In the channel allocation problem, there is also a channel dependency problem when the channel is switched[5]. In Fig. 1, it is assumed that there are only two transceivers per node, and when Node D detects that the load on Channel 3 is too heavy, the transceiver that communicates with E will be tuned to Channel 7 and node E will communicate with D is transferred to Channel 7, since Node E and Node H use the same transceiver, Node H also needs to tune the transceiver with E to Channel 7. The chain reaction in a network caused by changing a channel of a transceiver in a node in the network is called a channel dependency problem[6]. The channel dependency can make the network to become congested and reduce the throughput of the network. Therefore, the design of channel allocation algorithm also needs to consider how to avoid channel dependence [7].

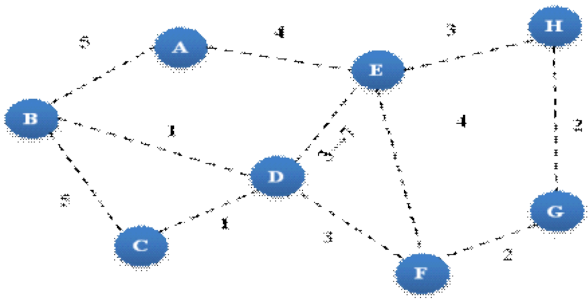

Figure 1: Channel Dependence

Description of the segment as follows:

The number of nodes in the network segmentation includes the number of nodes in the network area and the radius of the node communication. In the study of the network segmentation time ratio, the number of nodes and the node communication radius are taken as influencing factors to examine their influence on the network segmentation time ratio, whether the network segmentation can be determined according to Equation (2.1)

$$D = \begin{cases} 0, where \sum_{i=1}^{N}\sum_{j=1}^{N} l(i,j) = \frac{N(N-1)}{2}, i \neq j \\ 1, where \sum_{i=1}^{N}\sum_{j=1}^{N} l(i,j) < \frac{N(N-1)}{2}, i \neq j \end{cases} \quad (2.1)$$

Where D is 0 to denote that the network is not divided, and all nodes can establish a connection; D is 1 for network segmentation; N is the number of nodes in the network [8].

The network segmentation is affected by the number of nodes and the node radius of the communication. The network may be in one of the following two states at different times: State 1, the number of nodes in the network is small, but the communication radius of each node is large. The number of nodes in the network is large, but the communication radius of each node is very small. The two states may cause the network to have the same network segmentation degree [9].

2.2 The Metric between Routing and Scheduling and Modeling

In order to ensure the basic interoperability between different paths selection in an extensible framework, the IEEE 802.11s standards define the default link metric based on airtime consumption to measure the radio-aware path. When the frame passes a link, Formular (2) is used to calculate Ca to measure the total amount of channel resources consumed by the link. The path metric is the sum of all the links in the path [10].

$$Ca=[O_{ca}+ O_p+] \quad (2.2)$$

The channel access fee Oca, protocol cost Op and test frame length Bt are constant, whose value depends on the specific IEEE 802.11 transmission technique. Two parameters of r and e_{fr} respectively are units Mb/s for bit transmission rate and the frame error rate of the length Bt of the bit torrent test frame. The transmission rate r is the rate of MP transmission of a standard size (Bt) frame in the current condition, and its value is independent of local rate adjustment. The frame error rate efr is the probability of frame loss due to transmission error when the standard size (*Bt*) frame is under the current transmission bit rate (*r*)[11].

In order to solve the problem of routing and link scheduling, this paper adopts integer linear programming (ILP) method to model. For Each link $e = (i, j) \in E$ in the different packets responding data flow f, this paper defines 0-1scheduling variable:

$$x_{(i,j)f}^{t} = \begin{cases} 1, & The\ link\ (i,j) of\ data\ flow\ f\ is\ triggered\ in\ time\ slot\ t \\ 0, & other \end{cases} \quad (2.3)$$

Compared with the traditional wireless mesh network, the method of routingand scheduling separation and processing is different, 0-1. The variables comprehensively determine the data stream time slot of the link scheduling. Under satisfaction of the constraints, the result of the scheduling will eventually be obtained by tracing the triggering path of the data stream; at the same time, the routing results of each node can be uplinked to be gathered to the gateway.

In the MR-MC network with infrastructure, the channel assignment algorithm can be implemented by the gateway as Channel Assignment Service achieve the channel assignment for each routing node. In the MR-MC network without infrastructure, each node independently manages the radio frequency, which requires the inter-node interaction information to obtain the channel distribution in the local area. At the same time, the individual node will adjust the channel after the RF channel according to the channel allocation algorithm, which will affect the channel distribution in the area. The channel distribution process of a node is a process, then these distributed processes due to lack of global time frame are caused by the distribution of channel fluctuations, so how to make stable network channel distribution in a relatively short period of time is that the MR-MC network channel Assignment must solve the problem.

The basic idea of the greedy algorithm starts from the initial solution of the problem step by step. According to an optimization measure, each step must ensure that the local optimal solution can be obtained. Each step only considers a data. His selection should meet the conditions of local optimization. If the next data and the partial optimal solution are no longer feasible solutions, the data is not added to the partial solution until all the data is enumerated or the algorithm can no longer be added.

Process of implementing the algorithm:

(1) To apply the same rule to turn the original problem into a similar, smaller subproblem;

(2) To form an initial solution to the problem

While (can take a step forward)

Find a solution element for a feasible solution;

(3) A solution of all the elements of the solution into a feasible solution.

According to the principle of greedy algorithm, the channel allocation on the channel can parallel work as far as possible.

2.3 Description of the Algorithm

Suppose the num be *M* of the concurrent transmission link scheduling(CTLS) in the network and all CTLS is C1,C2,……Cq……CM , the Cq scheduled time is tq. The target function is

$$Min \sum_{q=1}^{M} T_q \tag{2.4}$$

The target function minimizes the end-to-end transmission delay.

$$\omega_c=\varphi \tag{2.5}$$

$$\omega_r= \Omega_n \tag{2.6}$$

$$\{i^*,j^*\}=arg_{ij} \tag{2.7}$$

$$\omega_c=\omega_c \cup \{i^*,j^*\} ,\omega_r =\omega_r \backslash \{ i^*, j^* \} \tag{2.8}$$

During each iteration, select a node from (n – k) nodes of the rest node’s set , the setsω_r and ω_c. Compared with other nodes, the distannce of the node and *k* nodes selected form setω_c is *argmax*, but this firstly has to determine the minimum distance between every node in ω_r and the k node in omegaω_c.The number of comparisons required for each iteration is $(n-k)k$， therefore, the maximum computation of the algorithm is approximately :

$$n(n-1)/2+\sum_{k=2}^{n}(n-k)k \tag{2.9}$$

Algotrithm 1:

Construct a first sub slot $G_1$where the routing subgraph.

For *k=3* to *n*

If the link node edge number is greater than the number of RF interface, randomly delete a chain of roadside, the boundary of the channel distribution into a slot to determine.

Else with strong edge coloring algorithm for channel assignment on the map, and make it meet the channel number of constraints.

If the intersection is not Φ, obtained will be intersection with the node $v_i$channel within 2 hops of intersection.

Else node v_i connected to distribution channel link available, the distribution of the final settlement of any channel, and can ensure the channel and the node v_i 2 hop channel within the scope of the work at the same time.

Make sure the results can satisfy the channel number and the number of node interface constraints, theallocation of these edges in the subgraph

End if

According to the source and destination nodes on the path has not been allocated channel next hop, determine the time slot sub-graph and add a slot delete edge to the sub-graph, then go back to randomly deleting a chain of roadside, the boundary of the channel distribution into a slot to determine.

Repeat above step until all link through the source node and the destination node is assigned a channel.

And then next.

Using the channel matrix according to the matrix to find those in the 2 hop interference range without interference node. These nodes can also communicate with other nodes.

Else those who do not meet the conditions of the secondary node is taken in different time slots with other nodes.

End

End

3. Simulation Analysis

The simulation scenario uses the NS2, the sendrangeof each node is 200 m, the node movement area is 1000m x 1000m, the simulation time is 10 s, the data flow group type is CBR mode, and the communication node pairsare 8.

3.1 Comparsion the Performance with the Other Approach

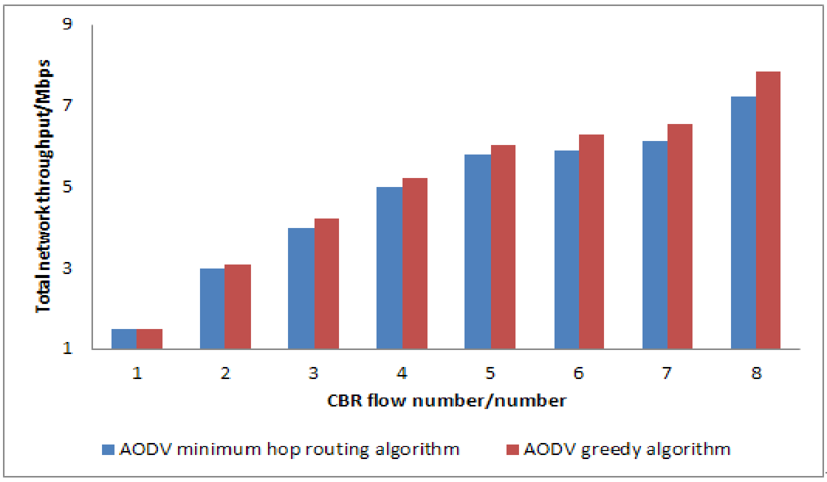

Figure 2: Total Network Throughput

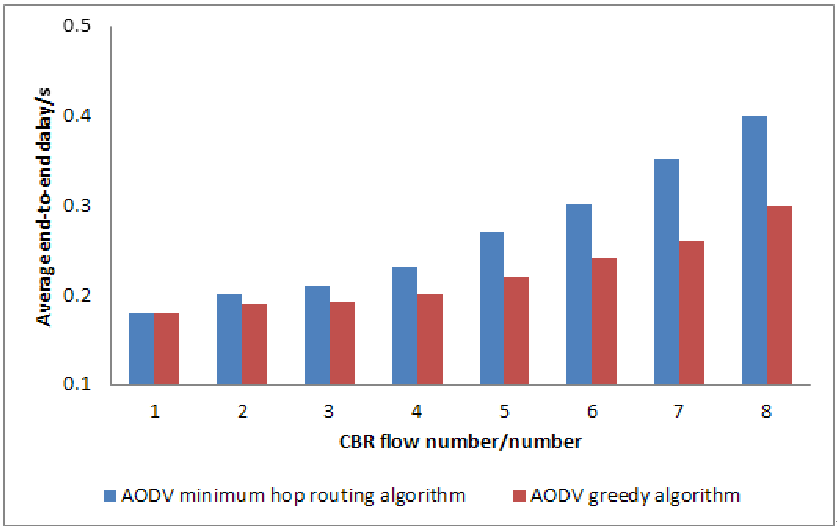

Figure 3: Average End-to-end Delay

The resulting overall network throughput and average end-to-end delay are shown in Fig. 2 and Fig. 3. The blue column means the results of AODV minimum hop, the red column means the results of the proposed algorithm. It can be seen that with the increase of the number of CBR flows in the network, the superiority of the protocol adopted in this paper is about 20%, and the delay is about 25%. The least degree of channel allocation is to achieve the allocation of optimization. Fig. 3 shows that When the sending rate of CBR is low and AODV minimum hop routing algorithm and the selecting routes are highly robust, so the greedy algorithm's advantage is not obvious. When the sending rate of CBR is low, the average end-to-end delay of two protocols are not very different. The sending speedincrease of CBR leads to the rapid energy consumption of the node,the life cycle is shorter, routing frequently fractures,and the average end-to-end delay was significantly increased. AODV minimum hop routing algorithmincrease evidently because the increase of traffic load makes its backup route inefficient rate high, and the Routing finding or maintenance takes a lot of time. AODV greedy algorithmdelay was significantly lower than AODV minimum hop routing algorithm， because AODV Greedyselect routes are more stable and the life cycle of key nodes is long.

4. Conclusion

This paper proposes AODV greedy joint concurrent transmission link scheduling algorithm. Its selected node set can ensure the minimal correlation between nodes and the minimum number of nodes can be guaranteed to meet the system performance constraint. By using the greedy algorithm as the initial solution of the channel allocation optimization model, the solution quality can be enhanced and solution timecan be reduced effectively.

References

[1]Y.ding, L.xiao,*“Channel allocation in multi-channel wireless mesh networks[J]”*, Computer Communications. 34(2011) 803-815.

[2]Doraghinejad M, Nezamabadi-Pour H, Mahani A. *“Channel assignment in multi-radio wireless mesh networks using an improved gravitational search algorithm”*. Journal of Network and Computer Applications, 2014, 3(8), pp. 163-171.

[3]Peng Y, Yu Y, Guo L, et al. *“An efficient joint channel assignment and QoS routing protocol for IEEE 802.11 multi-radio multi-channel wireless mesh networks”*. Journal of Network and Computer Applications, 2013, 36(2), pp. 843-857.

[4]Ning Z, Song Q, Guo L, et al. *“Integration of scheduling and network coding in multi-rate wireless mesh networks: Optimization models and algorithms”*. Ad Hoc Networks, 2016, 36(9), pp. 386-397.

[5]Gabale V, Raman B, Dutta P, et al. *“A classification framework for scheduling algorithms in wireless mesh networks”*. Communications Surveys & Tutorials, IEEE, 2013, 15(1), pp. 199-222.

[6]Zhu Z, Lu W, Zhang L, et al. *“Dynamic service provisioning in elastic optical networks with hybrid single-/multi-path routing”*. Lightwave Technology, Journal of, 2013, 31(1), pp. 15-22.

[7]Ren W, Zhao Q, Ramanathan R, et al. *“Broadcasting in multi-radio multi-channel wireless networks using simplicial complexes”*. Wireless networks, 2013, 19(6), pp. 1121-1133.

[8]Ahmed E, Shiraz M, Gani A. *“Spectrum-aware distributed channel assignment for cognitive radio wireless mesh networks”*. Malaysian Journal of Computer Science, 2013, 26(3), pp. 232-250.

[9]Chen Y Y, Chen C. *“Simulated annealing for interface-constrained channel assignment in wireless mesh networks”*. Ad Hoc Networks, 2015, 29(9), pp. 32-44.

[10]Saifullah A, Xu Y, Lu C, et al. *“Distributed channel allocation protocols for wireless sensor networks”*. Parallel and Distributed Systems, IEEE Transactions on, 2014, 25(9), pp. 2264-2274.

[11]Gálvez J J, Ruiz P M. *“Efficient rate allocation, routing and channel assignment in wireless mesh networks supporting dynamic traffic flows”*. Ad Hoc Networks,2013, 11(6), pp. 1765-1781.