A Location Related Wireless Channel Allocation Algorithm

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Abstract

The channel allocation is one of the key problems in the design of the wireless network, as it greatly influences the throughput and performance of the network. Firstly we introduce the channel propagation model, which is able to accurately reflect the signal attenuation, the network interference and other factors in the actual environment. Based on this work, we put forward the channel allocation algorithm named LRCAA, which includes two parts: the pre-allocation stage and the dynamic optimization stage. The LRCAA is verified by the experiment, which shows it can converge to a stable optimal point and obtain a better network performance.

Keywords: *Channel Allocation; Wireless Network; Network Throughput; Interference*

1. Introduction

In recent years, with the increasing demand of data services, wireless LAN (WLAN) based on the IEEE802.11 protocol has become a hot research[1]. WLAN is the combination of computer network and wireless communication technology, which uses the wireless transmission medium. Compared with traditional wired networks, WLAN uses the electromagnetic wave for information transmission with greater flexibility, and easier installation, more economical and practical. But wireless networks are still faced with many problems, such as only three non-overlapping channels in 802.11b/g mode, and lack of wireless resources issue, which will seriously hinder the further development of the wireless networks. Reference [2] utilizes weighted graph colours to address the channel allocation problem for WLANs. Reference [3] uses client-driven mechanisms to address the joint problem of channel assignment and load balancing in centrally managed WLANs.

Channel allocation scheme greatly influences the throughput and performance of the network. Reference [4] firstly quantifies all constraints into a number of formulas in the wireless mesh networks (WMNs) architecture, and then uses the constraints as the condition, and finally tries to get the maximum network throughput. Reference [5] combines channel allocation with routing protocol, and the entire channel allocation process is a complex optimal iterative process. The speed of the convergence of the channel allocation algorithm decides the number of network resource consumption.

As multi-radio devices are becoming more and more useful in WMNs, many researchers devote themselves to study channel assignment problems in WMNs. For example, References [6,7] consider channel assignment together with routing or scheduling in order to maximize network throughput. Authors in [8] consider the channel allocation problem in rural mesh networks using directional antenna. Reference [9] puts forward a distributed dynamic channel-allocation algorithm adapted to the dense network of AP (Access Point). Each AP automatically adjusts its channel independently to achieve the optimal channel allocation, when all APs can transmit information. Reference [10] introduces a payment formula to ensure the existence of a Strongly Dominant Strategy Equilibrium (SDSE), and when the system converges to a SDSE, it also achieves global optimality in terms of the effective system-wide throughput. References [11, 12] adapt a distributed channel allocation algorithm cantered on AP to detect interference.

Based on the measurement over a small test-bed, we find the relationship between the network throughput and the channel interference. Then, we introduce the channel propagation model, which can reflect the signal attenuation, the network interference and other factors in the actual environment well and truly. Based on these, we propose the LRCAA, a location related channel allocation algorithm converging to a stable optimal point and obtaining a better network performance.

2. The Channel Propagation Model

Usually there exist interferences among adjacent APs, which will directly affect the network throughput. In our actual network environment, indoor coverage radius is about 50 to 70 meters, and the number of wireless terminals access to a single AP is 20 or so. Under the condition of all the APs in the same channel, we test the network throughput. The result is shown in figure 1, from which we can see when the number of AP increases from 1 to 3, the network throughput drops to nearly one third of the original one.

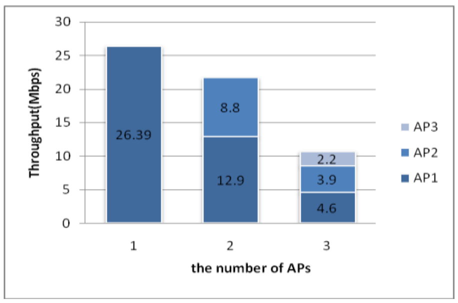

Figure 1. The Network Throughput in the Case of the Co-channel Interference

Firstly we give the following definition.

Definition 1. S denotes the set of APs in the entire network, N represents the number of elements in S, ap_i denotes the i th AP in S, and c_i represents the channel assigned to the $ap_i (i = 1, \ldots N)$.

Definition 2. The wireless access user set $U = \{u_1, u_2, ..., u_{Num}\}$, where u_i represents a user in the network m and Num represents the total number of users.

Definition 3. The network estimated throughput rate $T_m = \sum_{i=1}^{Num} R_i \times p_i \times Eff_i$. R_i represents data transfer rate of the ap_i, with the unit is Mbps. p_i denotes the probability of the channel occupied by the user u_i. Eff_i is the transmission efficiency of the user u_i, which is also the payload transmission ratio, and affected by many factors such as transmission rate, frame spacing, head overhead, frame header and so on.

Definition 4. The subset of S that sharing the same channel with ap_i produces the total interference as follow.

$$Inter(ap_i) = \sum_{ap_j \in AP[i]} Inter_i(ap_j) \times num(AP[i]) \qquad (1)$$

In the Eq.(1), $AP[i]$ represents the subset of S that share the same channel with ap_i, obviously $AP[i] \subseteq S$. $Inter_i(ap_j)$ represents the interference of ap_j on ap_i , $num(AP[i])$ represents the number of APs in $AP[i]$. $Inter_i(ap_j)$ and $num(AP[i])$ describe two important factors that affect network interference. $Inter_i(ap_j)$ describes the size of the overlap area between ap_j and ap_i , while $num(AP[i])$ describes the number of APs in the same channel.

There are many interference factors affecting network channel, we will equivalent the interfere factors to the signal strength detected by the AP, then $Inter_i(ap_j)$ can represent the signal power that ap_j transmit to ap_i, as $Inter_i(ap_j) = Signal_j(ap_i)$.

Definition 5. The network interference factor $\lambda = \left(\sum_{i=1}^{N} Inter(ap_i) \right)^2 \Big/ N \times \sum_{i=1}^{N} Inter(ap_i)^2$. If all the APs are under the same interference, that is all of the APs get the channel in the same probability, then $\lambda = 1$. When the interference is not balanced among all the APs, that is each AP get the channel on the imbalance, then $\lambda = 1/N$.

Definition 6. The network throughput $T = T_m \times \lambda$, where the network estimated throughput T_m and network interference factor λ are affected by the transmission rate, the transmission efficiency, and AP co-channel interference performance loss.

In order to accurately reflect the real environment, which includes the propagation attenuation and the interference and so on, we present the model as follows.

$$A = 32.5 + 20\log f + 20\log d + \sum P_l \times N_l \qquad (3)$$

In the Eq.(3), A represents the signal propagation loss, measuring in dB, f represents the frequency, measuring in MHz, d represents the distance between signal source and the test point, measuring in metre(m), P_l is the attenuation coefficient of the barrier, measuring in dB, and N_l is the number of the barriers. This model can accurately reflect signal attenuation and interference and other factors in the actual environment.

3. The LRCAA Algorithm

Based on the above analysis, we divide the channel allocation into the pre-allocation stage and the optimizing stage, and give the following assumptions and definitions.

Assumption 1. For any $ap_i \in S, i \in N$, we have known that the space coordinates of ap_i is (x_i, y_i, z_i) .

Definition 7. The $Atten_i(j)$ is the attenuation value that the signal transmit from ap_j to ap_i.

$$Atten_i(j) = 32.5 + 20\log f_i + 20\log d_{ij} + \sum P_{mi} \times N_{mi} \qquad (4)$$

In the Eq.(4), f_i is the frequency of ap_i, measured in MHz, d_{ij} is the physical distance from ap_j to ap_i, measured in meter(m), P_{mi} is attenuation coefficient of the barrier, measured in dB, and N_{mi} is the number of the barriers. There are different obstructions from ap_j to ap_i, and obstructions of the shape, structure and materials have different effects on the wireless signal attenuation. Here we take into account the attenuation of various obstacles along the propagation path.

Definition 8. The T_{ij} represents the logic distance that is calculated by the attenuation values according to the conversion factor δ, $T_{ij} = Atten_i(j) \times \delta$.

With the conversion factor δ, we convert the attenuation value $Atten_i(j)$ to a logical distance T_{ij}, just as the physical distance d_{ij} between ap_i and ap_j.

Definition 9. $Dis[i] = \{T_{ij} \mid j \in N, i \neq j\}$ represents the set of distances between ap_i and the others $ap_j \in S(i \neq j)$.

Definition 10. The set $G_i = \{< j, T_{ij}, c_i > \mid j \in N, i \neq j, c_i \in C \cup \{0\}\}$, whose elements in ascending order by the value of T_{ij}.

Definition 11. The set S' is the assigned channel AP set, and the set S'' is the unassigned channel AP set. Initially, $S'' = S, S' = \varnothing$.

Definition 12. C is the set of channels, in the 802.11b/g, 2.4G mode, which contains three non-overlapping channels $\{1,6,11\}$.

Definition 13. L is the set of the weighted edges l, $ap_i \in S$ is a node in the space，and assigning channel for ap_i means adding a weighted edge l_{ij} between ap_i and $ap_j \in S'$.

Definition 14. dis_th denotes the distance threshold value obtained from the experience. Then $l_{ij} \leq dis\_th, (l_{ij} \in L)$.

The LRCAA algorithm is described as follows.

A. The pre-allocation stage

1) Calculate the set G_i according to all elements $ap_i \in S$. The elements in G_i are in ascending order with respect to T_{ij}, and $c_i = 0$.

2) Select any ap_i from S, and add ap_i to the set S' and the queue L, then assign the channel c_i to ap_i, and delete ap_i from the set S''.

3) Select two minimum values T_{ij} and T_{ik} from $Dis[i]$, T_{ij} corresponds to the distance between ap_i and ap_j, and T_{ik} corresponds to the distance between ap_i and ap_k.

4) If $T_{ij} < dis\_th, T_{ik} < dis\_th$, add ap_j and ap_k to the queue L, assign $c_j, c_k (c_j, c_k \in C)$ to ap_j and ap_k respectively, and $c_j \neq c_m \neq c_n$. Then delete ap_j and ap_k from the set S''. Add the weighted edges l_{ij} and l_{ik} for ap_i , ap_j and ap_i, ap_k respectively.

5) Add ap_j and ap_k to the set S', if $T_{ij} < dis\_th, T_{ik} < dis\_th$.

6) Remove the element ap_i from the queue L, then take the up to two elements from $Dis[i]$, which ensure the removed elements are the smallest and the corresponding APs unassigned channel, and these elements are less than dis_th. Then assign the channels to these elements, which do not conflict with the channel of the ap_i.

7) If $L \neq \varnothing$, remove the first element from the queue L, and then go to (4). Otherwise, if there exist APs that have not been assigned channels, go to(2). If $L = \varnothing$, and there are no APs that has not been assigned channels, the algorithm ends.

If $L = \varnothing$, and there exist APs that have not been assigned channel, it means that the distance between any assigned APs and unassigned APs is longer than dis_th. Then we need to choose a new initial point to continue the algorithm.

B. The Optimizing stage

1) Scan and calculate the $Inter(ap_i)$, and choose the AP with the maximum $Inter(ap_i)$. If there are more than one such APs, select one randomly.

2) The current network throughput is U. Change the channel c_i to c_i' for the ap_i temporarily, where $c_i' \neq c_i (c_i' \in C)$, and recalculate the total throughput, and mark the result as V.

3) If $V < U$, it means the network throughput decreased after adjustment, then keep the original configure. If $V = U$, it means the two schemes have the same effect. If $V > U$, it means the new scheme V is better than U with the higher network throughput, then replace U by V.

4) Repeat the above steps n times, then choose U as the best scheme, and the algorithm ends.

In the pre-allocation stage, we get a local optimal channel allocation scheme. In the dynamic optimizing stage, through scanning the AP's signal strength to adjust our scheme, we can meet the practical applications' requirements.

4. The Performance Analysis

In order to verify the feasibility and performance of the LRCAA, we build a test environment, in which all APs run in 802.11b/g mode, deploy 30 APs in a 25m 50m space, where are 20 rooms with a size of 3m 8m and one public corridor, and set the default power as the minimum power. We make a comparison of our LRCAA algorithm with the LCCS.

Figure 2 shows the network throughput calculated by the LRCAA algorithm and the LCCS, respectively, in the context of increased number of APs.

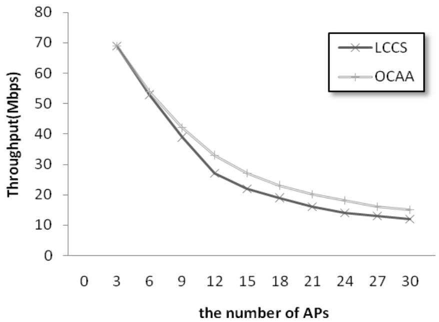

Figure 2. The Network Throughput between the Two Algorithms

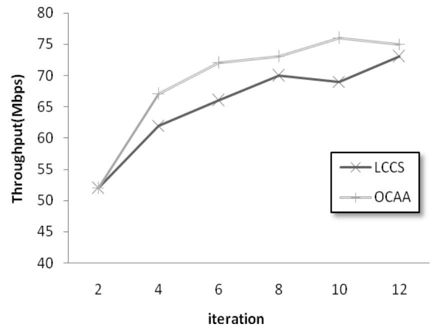

Figure 3. The Performance between the Two Algorithms

As the increase of the number of APs, the network throughput decreases. When the number of APs is 30, the LRCAA enhances the system performance by 6% or so. The performance enhancement is not obvious because in the dense AP deployment environment, in both the two AP channel allocation schemes, one AP and another AP with the same channel are not far apart, so the interference will be the near-exponential growth and the complexity will increase gradually.

Figure 3 compares the performance of the LRCAA with the LCCS on the condition of 10 APs. LCSS chooses the channel with minimum throughput value on the AP ends, which may change with the network state, and the network throughput goes larger when the algorithm iterates 10 times. The LRCAA divides the channel allocation into two stages, which brings in better convergent speed, and the network performance tends to be stable when the algorithm iterates about 8 times..

5. Conclusion

The paper has proposed the LRCAA algorithm with a better performance than the LCCS. In order to reduce the complexity, the LRCAA algorithm includes two parts: the pre-allocation stage and the dynamic optimization stage. The LRCAA is verified by the experiment, which shows it can nearly obtain the best channel allocation scheme, and get a better convergent effect.

There are several potential ways to extend our work. One possibility is to study the placement and the fairness among the APs, and the load balance on the channels. Another possibility is to consider the strategic channel assignment in the multiple collision domains. We leave these topics to future study.

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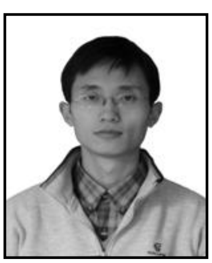

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