A Mutil-Rate Access Point Selection Policy in IEEE 802.11 WLANs

Zhihong Liu, Yaping Liu, Zhenghu Gong, Lin Chen
School of Computer
National University of Defense Technology
Chang Sha, China
zeroun1031@gmail.com

***Abstract*—In wireless local area networks (WLANs), there could be several available access points (APs) around a Station (STA). How to select the most appropriate AP among those available APs has become a hot research topic. The conventional selection policy, which selects one AP with the best RSSI, makes the loads among APs be distributed unevenly and degrades resource utilization rate. Recently, several AP selection mechanisms have been proposed, which can facilitate the load imbalance and improve the network performance. However, due to the effect of Mutil-Rate in IEEE 802.11a/b/g protocol, the accuracy of AP selection could be reduced. In this paper, we propose a Mutil-Rate Access Point selection (MRAPS) policy, which not only considers overall received signal strength indication(RSSI), throughput and transmission rate, but also can be implemented easily. In addition, we perform computer simulations using the OPNET modeler in order to verify the performance of our scheme. The results show that our proposed selection policy outperforms the conventional policy.**

Keywords- Mutil-Rate; Wireless LAN; AP Selection; Load balancing

I. INTRODUCTION

Over the last years, IEEE 802.11 WLANs have been widespread deployed depending on the superiority of low cost and easy to be accessed. With the spread of wireless LAN, multiple APs could be available there for a STA. Before a STA accesses to the network resource, the association between a STA and an AP must be accomplished. In order to discover available APs, STA uses either active or passive scans. In the active scan, the STA broadcasts probe request frames, and the AP that received probe request frames sends a probe response frame to announce its presence. In the passive scan, the STA listens to the beacon frames that the APs periodically broadcast. The STA can obtain information like the Service Set Identifier (SSID) and the RSSI from the probe response or beacon frames, then selects an AP to join based on the information it grabbed. In IEEE 802.11 protocol, the selection policy is merely based on the RSSI. Although this policy is simple and easy to implement, it causes the STA concentration of the AP which has strong RSSI, while leaving many APs with weaker signal idle. In addition, it has been pointed out that the conventional selection policy which is based on the RSSI causes the load imbalance, leads to bad performance and even network congestion [1, 2]. Therefore, the AP selection policy in IEEE 802.11 WLANs has become a key point of affecting the performance in load balancing [3, 4].

Recently, several AP selection policies have been proposed in academic circles, which can facilitate the load imbalance and improve the network performance. However, those AP selection policies haven't proposed the quantitative analysis of the effect causing by the Mutil-Rate in IEEE 802.11a/b/g protocol. Mutil-Rate would bring impact to the AP selection as follow: Firstly, the evaluation of APs' throughput could be inaccurate. The STA with lower rate would affect those with higher rate and then degrades the global throughput [5]. Secondly, higher throughput does not guarantee stronger RSSI and higher quality of service [6]. For example, as shown in Figure 1, the STA can scan AP 1 and AP 2 nearby. Assume that AP 1 supports 802.11g and its transmission rate is 36Mbits/sec, while AP 2 supports 802.11b and its transmission rate is 11Mbits/sec, and the load of both APs is low right now. In this scenario, the STA with throughput-only based policy will choose AP 1 because it seems that the STA can obtain higher local throughput. However, due to the far distance between the STA and AP 1, the RSSI is weak, which may lead to the instability of the connection and may be interrupted frequently. Accordingly, the quality of service is insecurity.

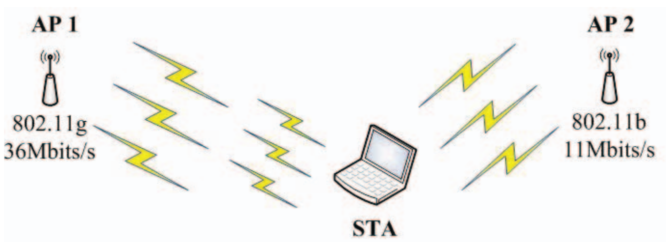

Figure 1. Mutil-Rate AP selection scenario analysis.

In this paper, basing on the study of the AP selection in IEEE 802.11 WLANS, we propose a Mutil-Rate AP selection (MRAPS), which not only considers overall RSSI, throughput and transmission rate, but also can be easily implemented. The proposed algorithm is more compatible with existing WLANs as well. The remainder of this paper is organized as follow: Section 2 presents an overview of IEEE 802.11 WLANs AP selection and related work. Section 3 provides detailed explanation of the proposed algorithm. Section 4 shows the

978-1-61284-774-0/11/$26.00 ©2011 IEEE

performance analysis results of our simulations. Finally, we conclude our paper in Section 5.

II. RELATED WORK

Depending on the architecture, we categorize AP selection as centralized approach and decentralized approach. In the former, centralized approach, there is an admission control server connected with WLANs, which centrally controls the association between the STA and the AP [7]. This approach can allocate the loads in the situation as a whole, but it needs additional hardware that higher cost is necessary. Moreover, these products do not take into account compatibility with other vendors, which would cause interoperability problem. In the latter one, decentralized approach, the association is controlled by the STA. Each STA selects the AP based upon some discipline automatically. Different from the former approach, there is no need to add extra devices. However, it makes a decision merely based on the interest of itself, which can't overall planning the global loads. Consequently, the two approaches both have pluses and minuses. Whereas, decentralized approach is more popular depending on the merit of low cost and easy to be implement. Lately, many decentralized AP selection policies have been proposed [8, 9, 10, 11].

Reference [8] propose a decentralized AP selection policy by overall considering the number of STAs associate with an AP and RSSI. Due to the different STAs have different communication volumes. It can't reflect the precise loads of APs only by means of the number of STAs. An AP selection mechanism based on the delay of the network is proposed in [9], it uses the time equation between probe request frames and probe response frames to evaluate the loads of APs, but the delay is related to link condition, which also can't reflect the status of the loads. In [6], an adaptive AP selection scheme by considering the signal strength, throughput, and AP's load is proposed, but it estimates the throughput by actually transmitting TCP/IP packets, which need to spent additional time. In Y. Fukuda's paper, two algorithms are given, Maximizing Local Throughput (MLT) and Avoiding APs with Larger PER (AALP). MLT applies the policy based on the local throughput, and STAs evaluate each nearby AP. Because MLT hasn't concerned the throughput of other STAs, authors propose AALP to optimize MLT, but haven't given the quantitative analysis.

Studies mentioned above propose AP selection policies from various angles, but they haven't take into account the affect of Mutil-Rate co-exist phenomenon in IEEE 802.11 a/b/g WLANs. In this paper, we focus on the Mutil-Rate wireless network environment, propose an AP selection policy that take into consideration of RSSI, throughput and transmission rate, which solve the problem that Mutil-Rate bring about efficiently. In the next section, we will describe our Mutil-Rate AP selection.

III. MUTIL-RATE AP SELECTION

An ideal AP selection should not only balance the loads of global network, but also guarantee the quality of service. The conventional selection policy selects the AP with strongest RSSI, which is pointed out that causes load imbalance and bad performance [1, 2]. Subsequently, AP selection algorithms based on throughput are popular. Let's review MLT we mentioned above, although this policy select the AP which will bring higher local throughput, but it can nothing more than maximize its own achieving throughput. Afterwards, taking into account the wireless resource should be shared among STAs, authors propose AALP. AALP algorithm decreases the evaluated weight of the AP whose packet error rate greater than 0.5, thereby, makes the STA avoid selecting the AP has higher packet error rate. However, AALP haven't proposed the quantitative analysis of the effect causing by the Mutil-Rate in IEEE 802.11a/b/g protocol. Consequently, overall consider RSSI, throughput and transmission rate is necessary for excellent AP selection. What appears later, we will describe our AP selection MRAPS.

A. Decision Metric

From [12], the fundamental access method of the IEEE 802.11 MAC is a DCF known as carrier sense multiple access with collision avoidance (CSMA/CA). The STA shall listen to the medium. If the medium is determined to be idle, the STA waits a $DIFS$ interval and exchange short control frame RTS/CTS , and then, it can send a frame. If the medium is determined to be busy, after waiting a $DIFS$ interval, the STA shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. Beside, the AP shall wait a $SIFS$ interval before sending an ACK to the STA when it receives a frame. Accordingly, transmission time T_k used for the STA k successfully transmitting a frame of length L bit is as follow:

$$T_k = T_{RTS} + T_{CTS} + DIFS + 3SIFS + \frac{L}{Rate_k} + T_{ack} \tag{1}$$

Certainly, we shall take into account of the wireless link condition between STAs and APs. We assume packet error rate is P , average transmission time $\overline{T_k}$ used for the STA k sending and receiving a frame correctly can be given by:

$$\overline{T_k} = T_k + \sum_{i=1}^{\infty} P^i \cdot (1-P) \cdot i \cdot T_k = \frac{T_k}{1-P} \tag{2}$$

If we assume the ideal case in which there is no collision, N STAs that association with an AP evenly share the wireless access resources, so the STA k 's throughput θ_k can be given by:

$$\theta_k = \frac{L}{\overline{T}_k \cdot N} = \frac{L \cdot (1-P)}{T_k \cdot N} \tag{3}$$

From equation (3) we can see, the STA k 's throughput θ_k depends on the channel occupancy time, but this equation does not consider the effect of the STA k on other STA's throughput. Before new STA k has joined the AP, the average channel occupancy time of all STAs camp on this AP can be given by:

Supported by the National Natural Science Foundation of China under Grant No.61070200 and No.61003303 ; the National Science and Technology Support Program of China under Grant No.2008BAH37B03 ; the National High-Tech Research and Development Plan of China under Grant No. 2009AA01Z432

$$\overline{T_{before}} = \frac{\sum_{i=1}^{N} \overline{T_i}}{N} \tag{4}$$

After the STA k join the AP, the average channel occupancy time can be given by:

$$\overline{T_{after}} = \frac{\overline{T_k} + \sum_{i=1}^{N} \overline{T_i}}{N+1} \tag{5}$$

If the average channel occupancy time increases, we consider that the STA k will reduce the throughput of all STAs associated with that AP. On the contrary, if the value decreases, we consider that the STA k will raise that throughput. Therefore, we use the difference between $\overline{T_{before}}$ and $\overline{T_{after}}$ to measure the effect of STA k on other STAs, the difference δ can be given as:

$$\begin{aligned} \delta &= \frac{\sum_{i=1}^{N} \overline{T_i}}{N} - \frac{\overline{T_k} + \sum_{i=1}^{N} \overline{T_i}}{N+1} = \frac{\sum_{i=1}^{N} \overline{T_i} - N \cdot \overline{T_k}}{N \cdot (N+1)} \\ &= \frac{\sum_{i=1}^{N} T_i - N \cdot T_k}{(1-P) \cdot N \cdot (N+1)} \end{aligned} \tag{6}$$

The STA will try to select the AP which not only can maximize it throughput, but also can minimize its negative impact on other STAs' throughput. Therefore, we get our metric $W(k)$ as:

$$W(k) = \frac{L \cdot (1-P)}{T_k \cdot N} + \frac{\sum_{i=1}^{N} T_i - N \cdot T_k}{(1-P) \cdot N \cdot (N+1)} \tag{7}$$

The first part of the equation (7) indicates the local throughput that new STA can archive, while the second part is a measure of its effect on other STAs' throughput. Additional, the values of parameter N, P and T_i can be obtained by the beacon and probe response frames.

B. AP Selection Algorithm

In the first place, MRAPS will scan nearby APs. In order to guarantee the connectivity, only the AP whose RSSI greater than threshold R_h will be added to the AP candidate list. Afterwards, the STA will send probe request frames over candidate list. And then, compute the function $W(k)$ with the parameter value obtained by the beacon and probe response frames. After that, the AP whose evaluation value is the best will be selected. Considering the wireless environment is dynamically changing, the AP which is associated may not always the best choose. Therefore, adaptive mechanism is necessary. Our algorithm will recompute the function $W(k)$ after some time period T_c and reassociate if it found a better AP. Besides, the time period T_c will dynamically adjusted so as to avoid unnecessary reevaluation. Figure 2 depicts the work flows of our proposed algorithm.

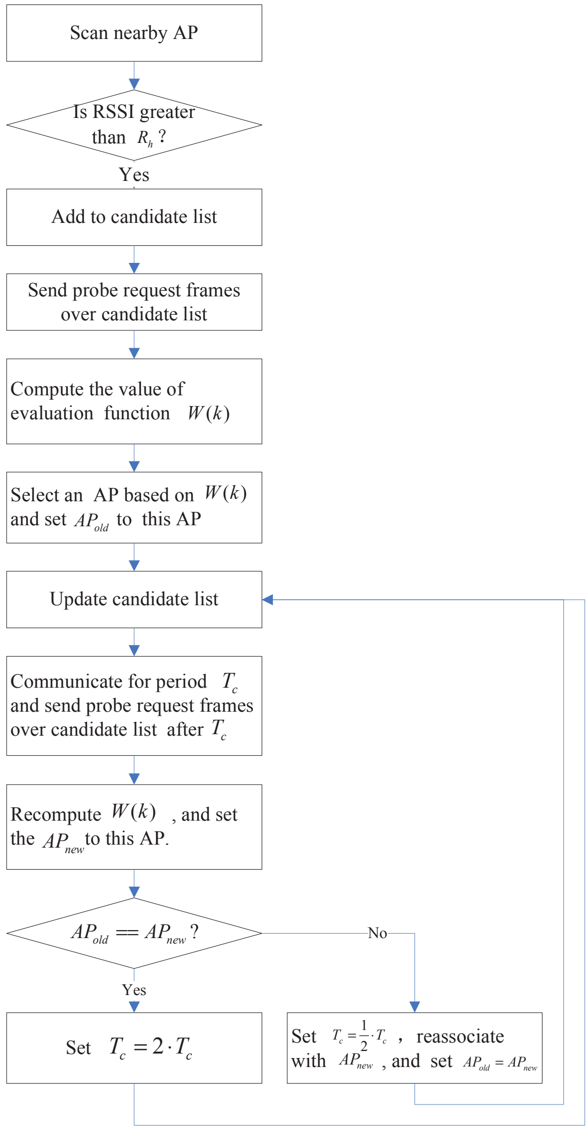

Figure 2. Flow chart of MRAPS

IV. PERFORMANCE ANALYSIS

We have conducted extensive simulation to verify the performance of MRAPS. The results are compared with the conventional policy which is based on RSSI. The simulations were done using the OPNET Modeler. In this section, we describe the simulation model first, after that, we present the simulation results.

A. Simulation Model

Simulation scenario as shown in Figure 3, there are 2 APs and 10 STAs deployed on an area of 500 ×500 square meters.

In order to verify the superiority of MRAPS in Mutil-Rate wireless environment, there are two 802.11 protocols co-exist, while AP 2, STA_8, STA_9 and new STA supports 802.11b and others support 802.11g. The transmission rate is 11Mbits/s and 22Mbits/s respectively. For optimal channel assignment, AP 1 and AP 2 operate on different channels. Each STA generates traffic to its serving AP according to an exponential On/Off traffic source. The parameter values used in our simulation are shown in TABLE 1.

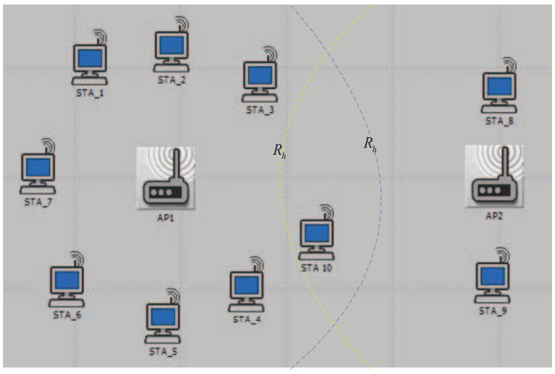

Figure 3. Simulation scenario.

TABLE I. SIMULATION PARAMETERS

Parameter	***Value***
RTS	160 bits
CTS	112 bits
ACK	112 bits
T_c	20 s
SIFS	10 s
DIFS	50 s
Traffic start time	Constant(5)
Traffic On state time	Exponential(10)
Traffic Off State time	Exponential(90)
Transmission power	30 mW
Simulation time	1 h

B. Results

We now present our simulation results. We choose throughput, delay and data dropped these three indicators to verify the performance of MRAPS. Moreover, we compare the results with the conventional policy which is based on RSSI.

Figure 4 shows the variations of time-average throughput, it can be obtained that the conventional policy's average throughput is 4671 bits/s, MRAPS's average throughput is 5462 bits/s. It can be observed that MRAPS's throughput raise about 16.93% than the conventional policy. Figure 5 also present the variations of time-average delay, the conventional policy's average delay is 0.6674 ms, MRAPS's average delay is 0.45086 ms, and thus, MRAPS's average delay reduces about 32.4% than conventional one. Figure 6 finally presents the variations of time-average data dropped, we can get the conventional policy's average data dropped is 667.4 bits/s, MRAPS's average data dropped is 468.2 bits/s, and we can see MRAPS's average data dropped reduces 29.8%. Therefore, simulation results show that MRARS outperforms the conventional one.

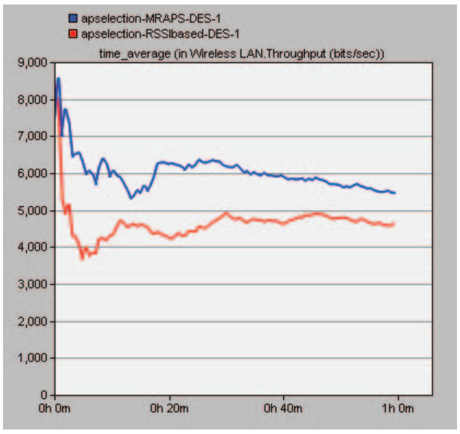

Figure 4. Time-average throughput variations.

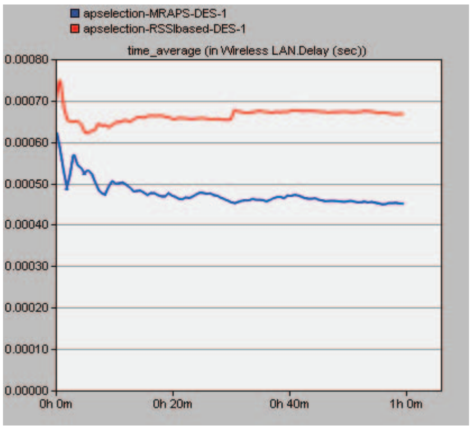

Figure 5. Time-average throughput variations.

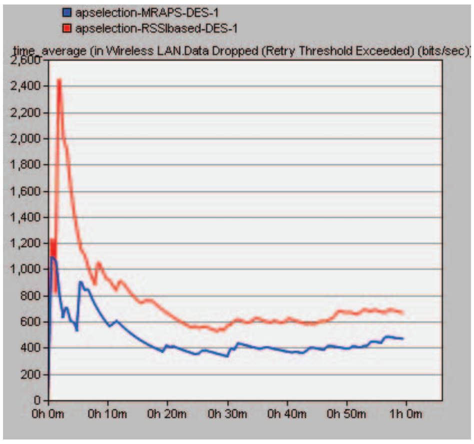

Figure 6. Time-average throughput variations.

V. CONCLUSIONS

In this paper, we propose to take both metrics into account when selecting an AP: the local throughput can archive and the negative impact on other STAs' throughput, and then, we proposed a Mutil-Rate AP selection policy, which not only overall considers RSSI, throughput and transmission rate, but also can be easy to implement. As the simulation results show, our policy outperforms the conventional one and is more suitable for current wireless environment which is complex and uncertain.

Nevertheless, this study is not perfect. Several issues are needed to be considered, such as the seamless hand-off in association and a more practical experiment. Recently, the studies about open source project OpenWrt [13] and Madwifi [14] are processing explosively, it is appropriate to set up wireless device develop platforms. Therefore, implement our algorithm on devices and verify its performance will become our next focus.

REFERENCES

[1] G. Judd and P. Steenkiste, "Fixing 801.11 access point selection". In Poster in Proceedings of ACM Mobicom, Pittsburgh, 2002.

[2] Y. Bejerano, S. Han, and L. Li, "Fairness and load balancing in wireless LANs using association control". In Proceedings of ACM Mobicom, Philadelphia, 2004,pp. 315-329.

[3] S. Vasudevan, K. Papagiannaki, C. Diot, J. Kurose and D. Towsley, "Facilitating Access Point Selection in IEEE 802.11 Wireless Networks," Proc. Internet Measurement Conf., Usenix Assoc., 2005, pp. 293–298

[4] A.J. Nicholson, Y. Chawathe, and M.Y. Chen, "Improved Access Point Selection," Proc. Conf. Mobile Systems, Applications and Services, ACM Press, 2006, pp. 233–245.

[5] M. Heusse, Franck Rousseau, Gilles Berger-Sabbatel and Andrzej Duda. "Performance Anomaly of 802.11b," Proc. Joint Conf. IEEE Computer and Information Societies, IEEE Press, 2003, pp. 836–843.

[6] I-Ping Hsieh, Fu-Min Chang, and Shang-Juh Kao, "Adaptive Access Points Selection for 802.11 Wireless Networks", Proceedings of Communication Systems and Networks Conference . 2007

[7] Balachandran, A., Voelker, G. M., and Bahl P., "Hot-Spot Congestion Relief in Public-area Wireless Networks," Proceedings of WMCSA'02, Callicoon, 2002, pp. 70–82.

[8] I. Papanikos and M. Logothetis, "A study on dynamic load balance for IEEE 802.11b wireless LAN". In Proc.COMCON, 2001.

[9] Jyh-Cheng Chen, Tuan-Che Chen, Tao Zhang, Eric van den Berg, "Effective AP Selection and Load Balancing In IEEE 802.11 Wireless LANs", Global Telecommunications Conference, 2006, pp: 1-6

[10] Y. Fukuda, T. Abe, and Y. OIE, "Decentralized Access Point for Wireless LANs," In the Proceedings of WTS, 2004.

[11] Xin Wan, Xingming Wang, Ung Heo, Jaeho Choi, "A New AP-Selection Strategy for High Density IEEE802.11 WLANs". International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery. 2010

[12] IEEE. " Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control （MAC） and Physical Layer （PHY） Specifications," IEEE Standard 802.11, 1999.

[13] http://openwrt.org/

[14] http://madwifi.org/