Adaptive Access Points Selection for 802.11 Wireless Networks

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Abstract

Network access of a mobile node is usually accomplished by connecting to a nearby access point (AP), which is currently determined only by the signal strength, so called the Signal Strength Strategy (SSS). Even though signal strength is a simple and efficient indicator for AP connection, it does not guarantee to the best performance of data transmission. Recently, several throughput-only AP selection mechanisms have been proposed to replace signaling strategy. However, throughput-only selection could suffer from unstable connection and cause re-association frequently. In this paper, an adaptive access point selection scheme by taking into account the signal strength, throughput, and AP's load is proposed. We choose a desired AP by calculating **Eligibility of Access Point** (***EoAP***), which is a function of signal strength, throughput, and channel speed. For each nearby AP, both signal strength and channel speed are collected once the association having been established, while throughput is estimated by actually transmitting TCP/IP packets. Eventually, the AP with the largest ***EoAP*** is selected. Two experiments are presented. The first one demonstrates that the loading factor of AP could be accurately calculated, while the second experiment shows that our method provides a better performance than those of signal strength strategy or throughput-only.

Keyword: Signal Strength Strategy (SSS), Throughput-only, AP selection, Eligibility of Access Point (EoAP)

1. Introduction

The ease of installation and low infrastructure cost of IEEE 802.11 wireless networks [1, 2, 3] make them ideal for Internet access. With the spreading growth of wireless networks, there could exist several available access points (APs) around a mobile node. How to select an appropriate AP among available APs has become both research hot topics and emerging enterprise request. Currently, AP selection mechanism is based on received signal strength which is measured between the mobile node and APs within the coverage. Although this approach was simple and efficient, it caused the concentration of mobile nodes to specific APs. Several mobile nodes may be associated with only a few APs because their stronger signal, while leaving many APs of weaker signal idle. This results in unbalanced traffic load on APs in wireless networks, thereby degrading the throughput of mobile nodes. [4, 5, 6].

Recently, several AP selection mechanisms [7, 8, 9, 10, 11] have been proposed to substitute signaling mechanism. An automatic AP discovery and selection system, Virgil, was presented in [8]. Virgil scans for all available APs, and then quickly associates with each AP found during a scan. The AP's suitability is estimated by the bandwidth and round-trip-time to a set of referred servers. In Y. Fukuda's paper [10], the authors developed a decentralized AP selection mechanism to enable each of mobile nodes to select an appropriate available AP. Two types of algorithm, MLT and AALP, were presented to archive the AP selection to be fairly and efficiently. Different to the concept of throughput estimation in IP layer's connection as proposed in [10], throughput estimation based on MAC layer connection was given in [7]. I.S. Misra and A. Banerjee [11] proposed a load sensitive AP selection algorithm by considering the direction of advancement of the mobile node as well as AP load. With this approach, although the optimal AP for the mobile node can be extracted as it moves, an extra hardware support on AP is necessary. It is impractical for all APs.

Although throughput-only schemes could provide better performance than signal strength strategy, it still suffers from two problems. First of all, the various specifications of current AP products, such as 802.11a/b/g, make the measure of AP's throughput metric could be inaccurate. Secondly, higher throughput does not guarantee higher signal strength and lower load on AP. For example, as shown in Figure 1, the mobile node locates between two access points, X and Y, where AP X supports 802.11b only and AP Y supports both 802.11g. Assume that the measured bandwidth from AP X at the mobile node is 11Mbits/sec and 22Mbits/sec from AP Y. Assume the load of both APs is low. In this scenario, the mobile node with throughput-only mechanism will choose AP Y. However, the far distance and weak signal strength may cause the association with AP Y to be interrupted frequently. Consequently, the mobile node may spend a lot of time in re-associating the connection.

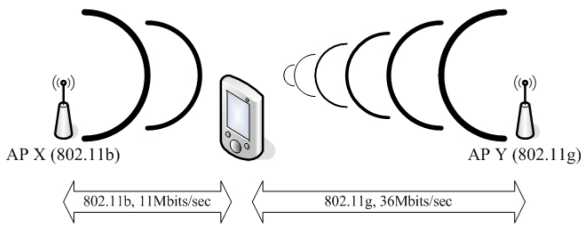

Figure 1 Association Scenario

In this paper, an adaptive access point selection scheme by taking into account the signal strength, throughput, and AP's load is proposed. A metric, **Eligibility of Access Point** (***EoAP***), which is a function of signal strength, throughput, and channel speed, is used to select an appropriate AP for the mobile node. For each nearby AP, both signal strength and channel speed are collected once the association having been established, while throughput is estimated by actually transmitting TCP/IP packets. Eventually, the AP with the largest ***EoAP*** is selected. Two experiments are also presented. The first one demonstrates that the loading factor of AP could be accurately calculated, while the second experiment shows that our proposed scheme can provide a better performance than those of signal strength strategy or throughput-only approach.

2. Adaptive Approach to AP Selection

The purpose of access point selection is to locate an appropriate AP among all reachable ones around the mobile node. In order to make a better choice, an adaptive AP selection algorithm and a predefined measurement criterion are necessary. As a mobile node starts up, the algorithm is operated, and a metric called ***Eligibility of Access Point*** (***EoAP***) is automatically evaluated.

2.1 Adaptive AP Selection Algorithm

In order to efficiently select an appropriate access point among discovered APs, an AP selection algorithm is needed. In this paper, an adaptive AP selection algorithm is proposed. This algorithm firstly scans for all nearby APs. For each discovered AP, signal strength is logged, and the association with the AP is to be established. If the association is successful, the bandwidth of current channel is stored, and estimation of throughput will be operated. Following the estimation, the measurement criterion, ***EoAP***, is calculated and recorded. Finally, the access point with the largest ***EoAP*** is selected to be associated. The initial procedure of selecting an appropriate AP can be stated as in Figure 2.

```
1    scan for all nearby APs
2    for each discovered AP
3        log the signal_strength%
4        if associating with the AP is successful
5            log the channel_speed
6            estimate throughput by transmitting data
7            calculate and log EoAP
```

Figure 2 Procedure of the initial AP selection.

Since the wireless environment is not static, as mobile users join and leave so often, an adaptive way of AP selection model is preferred. In the model, three states of AP selection are defined: monitoring state, evaluating state, and associating state, as shown in Figure 3. As a user joins the wireless network, the system enters into the evaluation state (1). In this state, ***EoAPs*** of all discovered APs are calculated. The AP with the largest ***EoAP*** is chosen for association. Once the targeted AP is determined, the mobile node enters the associating state (2). If the selected AP is not able to be associated, the system will go back to the evaluating state (6) for re-evaluating. Starting from connection being established, the mobile node is in monitoring state (3). In monitoring state, the node keeps monitoring the signal strength. When the signal strength of the connected AP is below a threshold, the mobile node will re-enter into the evaluating state (4) and ***EoAP*** is calculated all over the APs within the range. If the AP with the largest ***EoAP*** is the same as the one when the node in monitoring state, the threshold is decremented accordingly and the node state is back to the monitoring state (5). The mobile node will keep monitoring until it finishes all its connection requests (7).

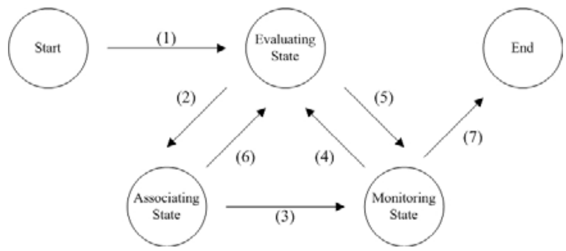

Figure 3 State transition diagram of the adaptive AP selection model

In accordance with the state changes, the initial procedure is rectified accordingly as shown in the following:

```
1    scan for all nearby APs
2    for each discovered AP
3        log the signal_strength%
4        if associating with the AP is successful
5            log the channel_speed
6            estimate throughput by transmitting data
7            calculate and log EoAP
8            if current_AP is NULL
9                reset ss_threshold%
10               go to 14
11           else if the AP with the largest EoAP is current_AP
12               decrease ss_threshold%
13
14   if association with the AP of the largest EoAP fails
15       go to 1
16
17   while
18       if signal_strength% < ss_threshold%
19           go to 1
```

Figure 4 Algorithm of adaptive AP selection.

The first part of the algorithm, from line 1 to line 7, is the same as in Figure 2. The new parameter, ***ss_threshold%***, is the lower bound of received signal strength. If ***signal_strength%*** is lower than ***ss_threshold%***, line 19 is executed, and the mobile node re-enters the evaluating state (4). The other new parameter, ***current_AP***, is the access point which the mobile node is associating with. If the ***current_AP*** is NULL, this means that the mobile node just starts up or the past association was just interrupted. In lines 8-10, if the ***current_AP*** is NULL, the ***ss_threshold%*** is reset and the mobile node will go to line 14 for entering associating state (2) without decreasing the threshold of signal strength. Line 15 will be activated when the association with the selected AP is failed. This forces the mobile node to re-enter the evaluating state (6). After the association with the appropriate AP is successful, the signal strength is kept monitoring in monitoring state (3). Line 11 means that result of re-selection is the same access point with current associated one. In such case, the threshold is decreased automatically, and the mobile node is going back to the monitoring state (5).

2.2 Eligibility of Access Point (EoAP)

Eligibility of Access Point (***EoAP***) takes into account the signal strength, channel speed, and throughput. It is defined as:

$$EoAP = SS\% \times TP \times LF.$$

SS% is the signal strength of the received AP which is usually converted into a percentage, while ***TP*** means the network throughput when transmitting data. ***Loading Factor*** (***LF***), defined as ***LF = TP / channel_speed***, reflects the current load of the access point. ***Channel_speed*** is the transmit rate of the current channel between the mobile node and associated AP. ***LF*** is an indicator for AP's load.

As a mobile node is turned on, it will scan all nearby APs. During the scanning phase, ***SS%*** can be detected for each discovered AP. Once the association having been established between the mobile node and the access point, the value of ***channel_speed*** is available. With an ideal condition, throughput, ***TP***, is equal to the size of all transmitted data divided by transmission time T_t. Transmitted data includes Request-to-Send (RTS) message, Clear-to-Send (CTS) message, the transmitted file, and ACKs. Thus TP can be presented as follows:

$$TP = (RTS + CTS + file\_size + ACKs) / T_t.$$

Considering the reality, signal interference results in packet loss when transmitting, the real transmission time, RT_t can be presented as follows:

$$RT_t = \sum_{i=1}^{\infty} P^i \cdot (1-P) \cdot i \cdot T_t = \frac{T_t}{1-P}$$

Due to fact that the packet error rate, ***P***, is not static, estimation only by mathematical formula is difficult. Instead, ***TP*** is calculated by measuring the time spent in data transmitting. For each AP, ***EoAP*** can be determined whenever the throughput has been figured out.

3. Experimental Results

Although the throughput of AP is a good indicator of AP load, but AP with higher load and higher capabilities may perform better than the APs of lower load. In this section, two experiments were presented. The first experiment demonstrates the ***Loading Factor (LF)***, is capable to estimate the approximating load of AP. Second experiment is to show that the ***EoAP*** is a better indicator than SSS and throughput-only schemes. In our experimental environment, signal strength is shown as percentage in all current wireless association systems, and throughput is able to be measured by transmitting data. The transmission rate of the channel which is built between the mobile node and associated AP, represents the upper bound of throughput.

3.1 Approximation of AP's Load

To demonstrate the AP's approximating load could be estimated by the ***Loading Factor***, an experimental environment is built as shown in Figure 5. In the experimental environment, there is one AP and one file server attached to AP directly. Throughput was measured by downloading a 101,472,749 bytes (about 100 MB) file from FTP server to mobile node. Mobile nodes were connected one by one. Each time a mobile mode connected, a testing file transferred among each other to increase the load of AP, while the ***LF*** was calculated. The testing data was transferred seven times. Both of the shortest and longest times are ignored. The transmission times were shown in Table 1 and 2, and the value of ***LF*** with the increasing number of mobile nodes is illustrated in Figure 6. From the Figure 6, we can observe that when the number of mobile nodes was increased, the value of ***LF*** was decreased. This result shows that the ***Loading Factor*** can be an indicator of AP's approximating load.

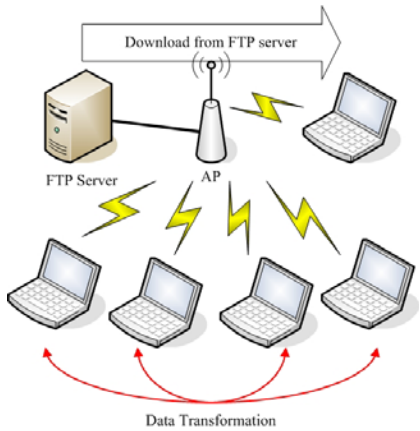

Figure 5 The experimental environment for measuring LF value

Table 1 Transmission Time (seconds) of 802.11b

	1 User	3 Users	4 Users	5 Users
	128	171	194	206
	129	165	196	206
	129	165	195	207
	131	169	195	207
	127	168	194	212
Avg.	128.8	167.6	194.8	207.6

Signal strength is about 90%

Table 2 Transmission Time (seconds) of 802.11g

	1 User	3 Users	4 Users	5 Users
	40	48	74	112
	40	51	63	112
	40	48	84	115
	40	49	74	103
	40	47	75	103
Avg.	40	48.6	74	109

Signal strength is about 90%

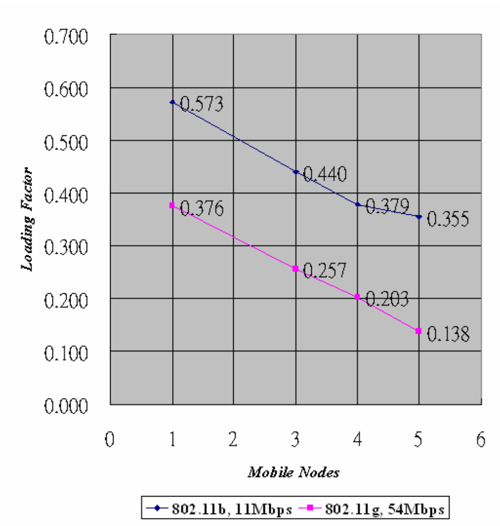

Figure 6 The value of ***LF***

3.2 Efficient AP Selection

Due to the factor of AP's signal strength was not considered in throughput-only AP selection schemes, mobile nodes may associate with an AP with weak signal. This could lead to that the connection from AP to mobile node becomes unstable. For example, the network utilization was recorded when the file was downloaded. When the transmission rate is 54Mbps (signal strength is about 90%), the network utilizations was stable during transmitting, as shown in Figure 7. When the distance between the mobile node and associated AP was increasing, the signal strength decreased (about 40%) and the transmission rate became 36Mbps. In this scenario, the utilization was much unstable as shown in Figure 8.

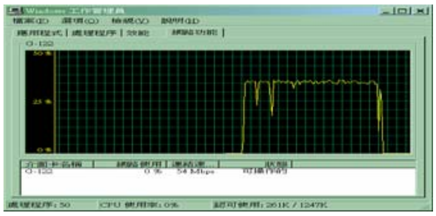

Figure 7 Utilization of 54Mbps

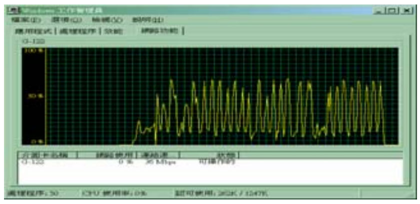

Figure 8 Utilization of 36Mbps

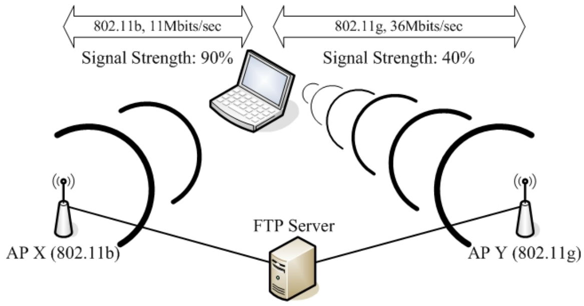

Figure 9 Simulation Environment

Such scenario could be avoided in the proposed scheme. To demonstrate it, a simulation environment is built as shown in Figure 9. In the simulation environment, a mobile node locates between two APs, where AP X only supports 802.11b and AP Y supports 802.11g. The transmission rate is 11Mbps and 36Mbps respectively. The simulation scenario is described as follows. The average transmission time is 102.8 seconds when the transmission rate was 36Mbps. The throughput is better than the connection of AP X with higher signal strength (11Mbps). Under lower signal strength situation, the mobile node always chose the AP Y based on the throughput-only AP selection schemes. In ***EoAP*** measurement, the value of ***EoAP*** of AP X is 0.406 (0.9*0.788*0.573), while the value of ***EoAP*** of AP Y is 0.087 (0.4*0.99*0.219). Thus, the mobile node will associate with AP X based on ***EoAP*** scheme.

The utilization of network interface were recorded when a 600MB file was downloaded from FTP server to both APs. The utilization of association with AP X and AP Y were shown in Figure 10 and Figure 11 respectively. As shown in Figure 10, despite the transmission throughput of AP X is worse, the connection is stable due to the stronger signal. Even some influences occurred such as people moving between the mobile node and AP X, the transmission still worked. On the other hand, as shown in Figure 11, the connection between the mobile nodes and AP Y was unstable. Because of the weak signal, the connection was interrupted while some influences happened.

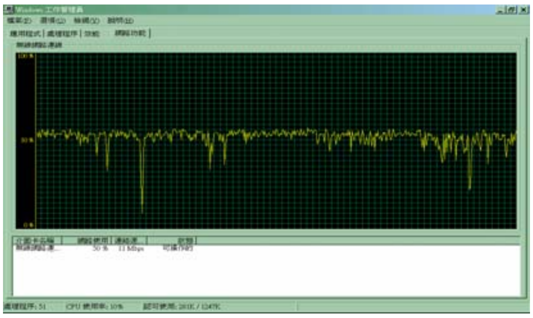

Figure 10 Utilization of Association with AP X

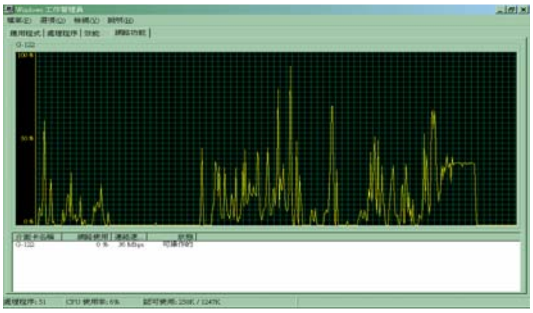

Figure 11 Utilization of Association with AP Y

4. Conclusions

As a mobile node moves in an infrastructure wireless network, the access point to be associated with should be determined promptly and efficiently. Currently used signal-based strategy is fast but not efficient in terms of throughput performance. Several studies have reported the improvement by calculating the throughput only. With respect to the concern of the most suitable AP selection, consideration of throughput only is not enough. In this paper, we proposed an adaptive access point selection method which takes into account the signal strength, throughput, as well as AP's load. For each AP within the range of the mobile node, the proposed scheme determines the association by calculating the ***Eligibility of Access Point*** (***EoAP***), which is defined as the product of signal strength (***SSS*)**, throughput (***TP***), and AP's loading factor (***LF***). The experimental results showed that ***LF*** is an appropriate estimate of AP's load and ***EoAP*** can provide a better performance than that of signal strength strategy or throughput-only approach.

Nevertheless, this study is not perfect. Several important issues are needed to be included, such as the computation overhead and a more complete simulation. In the future study, seamless hand-off requirement will be taken into consideration. As the type of mobile nodes varies, different devices may have different QoS requirements. Various AP selection strategies may be developed accordingly. And the mobility will become a reality only when the mobile node can access an appropriate AP promptly, efficiently, and transparently.

References

[1] 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, September 1999.

[2] B. P. Crow, I. Widjaja, J. G. Kim, and P. T. Sakai, "IEEE 802.11 Wireless Local Area Networks," IEEE Communications Magazine, Vol.35, No. 9, pp. 116–126, September 1997.

[3] The Working Group for WLAN Standards, http://www.ieee802.org/11/.

[4] A. Balachandran, P. Bahl, and G. Voelker, "Hot-spot congestion relief and service guarantees in public-area wireless networks", SIGCOMM Computer Communication Review, 2002.

[5] Y. Bejerano, S. Han, and L. Li, "Fairness and load balancing in wireless LANs using association control", Proceedings of ACM Mobicom, Oct 2004.

[6] G. Judd and P. Steenkiste, "Fixing 801.11 access point selection", Proceedings of ACM Mobicom, Pittsburgh, Aug 2002.

[7] S. Vasudevan, K. Papagiannaki, C. Diot, J. Kurose, and D. Towsley, "Facilitating Access Point Selection in IEEE 802.11 Wireless Networks", ACM Sigcomm IMC, Berkeley, October 2005.

[8] A. Nicholson, Y. Chawathe, M. Chen, B. Noble, and D. Wetherall, "Improved access point selection", ACM Mobisys, June 2006.

[9] D. Larson, R. Murty, and E. Qi, "An Adaptive Approach to Wireless Network Performance Optimization", Technology@Intel Magazine, feb/mar 2004.

[10] Y. Fukuda, A. Fujiwara, M. Tsuru, and Y. Oie, "Analysis of access point selection strategy in wireless LAN", Vehicular Technology Conference, 2005.

[11] I.S. Misra, and A. Banerjee, "A Novel Load Sensitive Algorithm for AP selection in 4G Networks, CODEC 2003, Calcutta, INDIA, 2003.