Improving Access Point Association Protocols Through Channel Utilization and Adaptive Switching

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***Abstract*— In this paper, we propose a distributed access point selection scheme by which nodes select an appropriate access point to associate with based on each individual device's channel utilization. We define channel utilization as the ratio of required bandwidth to estimated available bandwidth. By incorporating channel utilization into the access point association protocol, we can effectively reduce unnecessary reassociations and improve upper layer performance such as throughput and packet delivery delay. We have further enhanced our association protocol by using adaptive switching to schedule the switching to neighboring access points (APs), ultimately bringing down the association overhead. When channel utilization is combined with adaptive switching, we observe a significant performance improvement compared to traditional association approaches.**

I. Introduction

The widespread WiFi availability presents many choices to a wireless user in terms of which AP it can associate with [1]. Current commercial association schemes are mostly based on received signal strength indicator (RSSI) measurements or consecutive beacons lost, and perform poorly in many situations because they overlook the load and bandwidth of the AP. Alternative schemes are proposed to address these shortcomings, such as in [2], [3]. However, most of these methods are either centralized schemes or need special features from the APs, such as a designated server to collect and analyze the bandwidth utilization, and distribute the association decisions throughout the network. As a result, these methods demand significant modifications to the existing infrastructure, therefore making it difficult and unrealistic to apply them.

In this paper, we propose a distributed association scheme based on channel utilization. We observe that most of today's popular Internet applications have a minimum bandwidth requirement. However, bandwidth requirements are generally not taken into consideration when making link layer decisions. We use a new metric, channel utilization, to measure the available bandwidth compared to the clients' bandwidth requirement. By incorporating channel utilization information, we can effectively reduce unnecessary reassociations and improve upper layer performance in terms of throughput, packet delivery delay, etc. We have designed a protocol in which clients make association decisions based on their individual channel utilization, and we further enhanced the protocol's performance by introducing adaptive algorithms to schedule the switching to neighboring APs, so that overhead from excessive association can be avoided.

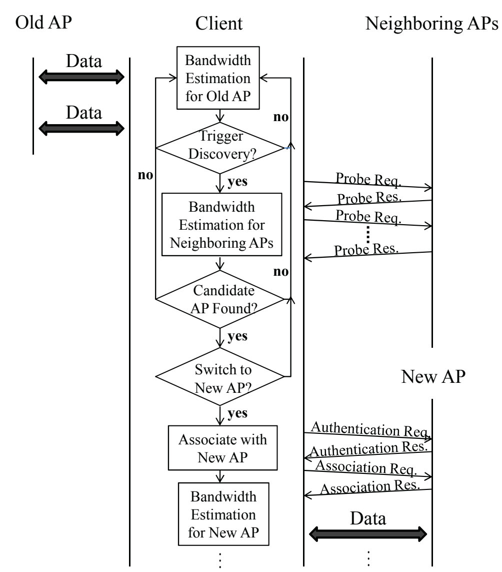

Fig. 1. The association protocol framework.

II. System Overview

Fig.1 shows the protocol framework for our proposed association protocol. The protocol starts when a node is actively exchanging data frames with its current associated AP, during which the client periodically estimates the available bandwidth for the current association. As opposed to the association protocol used in the 802.11 MAC which merely evaluates the RSSI, in this work, we propose to use the available bandwidth of neighboring APs by applying a bandwidth estimation scheme as part of the probing phase. By the end of probing, the

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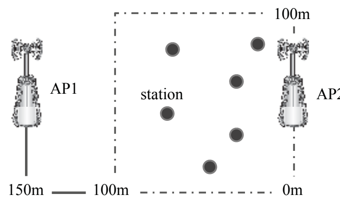

Fig. 2. The Topology of Simulation

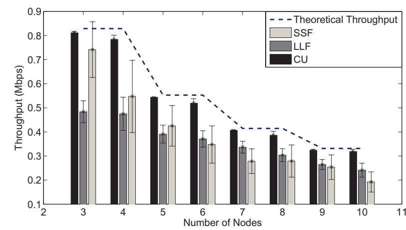

Fig. 3. Average Per-Station Throughput.

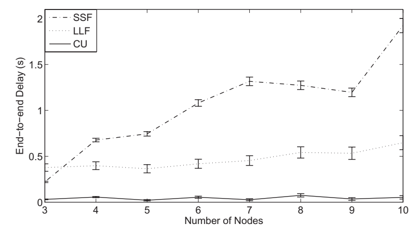

Fig. 4. Delay and Jitter among contending stations

client will choose a candidate AP based on the AP's available bandwidth, the client's bandwidth requirement, as well as the perceived signal strength.

III. Probing trigger based on channel utilization

Internet applications have widely varying bandwidth requirements. Consider an example where a mobile device is running an email application, and the mobile is experiencing temporarily degraded level of signal quality. According to the traditional RSSI approach, the client should switch its association. However, since the application currently running is best-effort with light bandwidth requirements, we may not want to switch APs as even the current low signal quality may be sufficient to meet the application's (light) bandwidth requirement. Additionally, it may well be the case that the signal quality is only briefly degraded, and thus a switch might actually do more harm (e.g. additional overhead) than the good it provides. On the other hand, consider the case where the mobile device is running a video application and is in a significant need of increased bandwidth. Although the device might be experiencing very good signal quality (e.g. it is physically close to the AP), the AP may be heavily loaded, and thus cannot spare much bandwidth to the mobile. RSSI-based AP handoff schemes prevent the clients from searching for better APs until the perceived signal strength degrades to a certain level, and this will cause the clients' packet queues to be quickly saturated, resulting in packets being dropped.

Based on the above discussion, integrating bandwidth requirements into the association process is beneficial. We have examined various methods for estimating the available bandwidth, and details of the estimation schemes used in our protocol are deferred to the poster.

Next, we define Channel Utilization for an AP_i (CU_i) as follows:

$$CU_i = \frac{\textit{Bandwidth Requirement}}{\textit{Available bandwidth estimation for } AP_i}. \quad (1)$$

We set a threshold value of CU: $CU_{Probing}$, and the process of probing neighboring APs is triggered when the CU for the current association (CU_c) is above $CU_{Probing}$. Therefore, given sufficient RSSI, a naive probing scheme which we call the **CU scheme** is given as:

Probing is triggered if $CU_c \geq CU_{Probing}$, and an AP i is selected as the candidate AP if $CU_i < CU_{Probing}$.

Summary of results: We have conducted experiments using the Qualnet simulator to evaluate the performance of our protocol. We deployed multiple wireless stations in the simulation scenario as shown in Fig. 2. The stations are randomly deployed in an area of $100 \times 100m^2$, which is shifted toward AP2. Under this scenario, we expect more stations to associate with AP2 than with AP1 in the legacy 802.11 or any RSSI-based association protocols. However, with the proposed CU metric, despite how the nodes are located, the load on the two APs will be more or less balanced. Another baseline protocol (LLF) always associates with the AP with the lightest load[4].

Fig. 3 shows the average per-station throughput and standard deviation of the throughput for the 3 association schemes. We observe that the proposed CU protocol shows a significant throughput improvement over the other two protocols. Compared with the traditional signal strength first (SSF) schemes, CU protocol achieves 38.4% gain on average. Further, the CU-based association also displays the smallest standard deviation for all cases, suggesting the achieved throughput among stations is often well balanced. We also present the end-to-end delay and jitter (defined as the variance of the delay) for the three protocols in Fig. 4. The CU protocol generates the lowest end-to-end delay (0.044s in average) and jitter (0.015s in average). SSF fares the worst, with its delay varying dramatically from 0.22sec to 1.92sec, with an average jitter of 0.038sec. LLF has an average delay of 0.47sec, and average jitter of 0.05sec.

IV. AP Switching Policy

To understand the need for AP switching policy, let us consider an example where there are 2 APs A and B, with several clients associated with A. Suppose a new client with a heavy load joins A's network, and seriously degrades the performance of the existing clients. If the clients all start to look for a better candidate, and switch to B at the same time

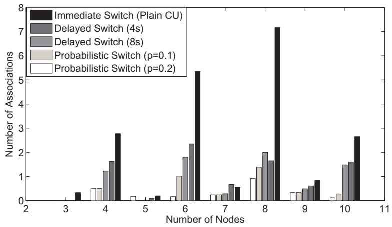

Fig. 5. Average Number of Per-node Reassociations with CU and its APS variants

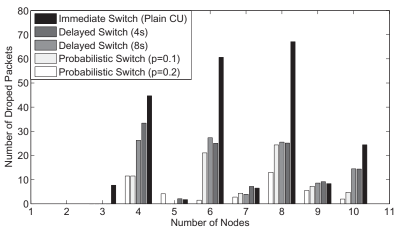

Fig. 6. Average Per-node Packets Drop with CU and its APS variants

(though independently), they will soon saturate B, and need to switch again. The worst case would be for the clients to bounce back and forth between A and B, leading to a phenomenon known as "thrashing". In fact, we have observed some severe trashing effects in our simulations, in which multiple clients switched between the same source and destination APs within less than 1 second. Some other clients only stayed briefly with the current AP before switching to another one.

We thus have the following three switching alternatives:

- **Immediate Switch.** This is the baseline scheme in which once a candidate AP is chosen, a node immediately switches its association.
- **Delayed Switch**. In this scheme, the client postpones the switching by T_{delay}, which is a random value from [0, $Delay_{max}$]. After T_{delay}, the client switches if the CU level remains above the threshold.
- **Probabilistic Switch**. In probabilistic switch, the node switches to the candidate AP with a probability p.

Summary of results: We evaluate the effectiveness of the switching policy by looking at the reduced number of reassociations and dropped packets in Fig. 5 and Fig. 6. we can see these two switching policies are quite effective. For example, Probabilistic Switch with p=0.2 can reduce the average number of reassociations by 91%, and can reduce the number of dropped packets by 90%.

V. Related Work

The general problem of load balancing in wireless LAN has been extensively studied. In [2], explicit channel switching and network-directed roaming are used to provide hot-spot congestion relief while maintaining pre-negotiated user bandwidth agreements within the network. Another major effort made by the IEEE working group is 802.11e which is an extension to the base IEEE standard to address the QoS issues. It enables prioritization and classification of services over a WLAN. The above works as well as many others require significant modification to the current communication protocol being run at the AP as well as the clients, while our scheme only requires modification at the clients. Another group of works require a centralized server to collect and distribute statistics from the network. For example, in the approaches proposed by [3], a network operation center (NOC) is needed to make association decisions, as well as balancing load of all the APs. Similarly in [5], proportional fair (or time-based fair scheduling) provides a balanced tradeoff between fairness and network throughput. The function is implemented in a central management server, and the approximation algorithms can be used for periodic offline optimization. Unlike the above mentioned works, the CU protocol we proposed enables the clients to make distributed decisions and requires no modification to the existing infrastructure.

VI. Conclusion and Future Work

As wireless LAN hotspots become more prevalent and experience more users, an efficient access point association protocol is in a great demand. Most existing association protocols rely on either the received signal strength of the access point, or the load of the access point, without considering the bandwidth requirement of the user nor the available bandwidth at the access point. In this paper, we proposed a distributed access point association protocol based upon the bandwidth situation, as well as techniques to avoid unnecessary reassociations among multiple access points. Our simulation results show that the proposed CU scheme can outperform existing schemes in many situations. The basic CU association scheme can improve the average per-node throughput by 38.4% compared to the signal-strength based scheme, and a factor of 29.1% by the load-based scheme. The enhanced protocol using AP-switching policy further reduce the average number of reassociations by 91%.

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