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IEEE 802.11 handoff latency improvement using Fuzzy Logic

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Summary

Multimedia transmissions are delay-sensitive Internet applications. Because mobile stations are in continual motion, handoff processes are necessary and unavoidable in wireless network environments. Because handoff processes tend to break the communication link, the research has been conducted on reducing the break time and arrival delay during Internet multimedia applications. In this paper, we propose an approach based on Fuzzy Logic to evaluate the average variation in signal strength received by a mobile station and produce a FitAP factor. This factor indicates the possible handoff access point that is suitable for the mobile station. According to the FitAP factor, a mobile station needs only to execute an active scan process once. Therefore, smaller handoff latency is expected. We compare the results from the current cell search scheme with that of the Fuzzy Logic approach. The statistical results show that the proposed method outperforms the current cell search scheme with an improved handoff latency performance. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: handoff; handoff latency; Fuzzy Logic; active scan

1. Introduction

Wireless networks have the advantage of mobility, making how a handoff affects the degree of fluency for multimedia applications in a wireless network important. For example, the maximal end-to-end delay for Voice over IP (VoIP) is about 50 ms [1]. It is regrettable that the majority of wireless LAN cannot complete L2 handoff procedures within 100 ms [2–5]. It has been observed that the L2 handoff latency would be 60–400 ms depending on the wireless card and access point (AP) vendor. The probe delay would dominate the L2 handoff latency, accounting for approximately 85% of the overall cost.

We propose a simple and efficient L2 Fuzzy Logic handoff [6–9] scheme to improve handoff latency. Fuzzy Logic evaluates the average and variation in signal strength. The most important part of Fuzzy Logic is the membership function and the control rules. We derive a FitAP factor for Fuzzy Logic. This factor indicates the possible handoff AP that is more suitable for the given mobile station along its moving trajectory. A complete active scan process could obtain the required handoff-related parameters. The traditional handoff scheme would execute about 11 active scan processes. According to the FitAP factor, a mobile station would choose the AP having the largest FitAP value and only execute the active

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scan process once. Therefore, smaller handoff latency is expected.

The organisation of this paper is as follows: the motivation and related works are introduced in Section 2. Section 3 describes the proposed approach and the simulation model. Section 4 shows the simulation results. Conclusions and future research are stated in Section 5.

2. Motivation

According to the IEEE 802.11 standard [10], there are two kinds of wireless networks (the Infrastructure Network and the Ad Hoc Network). Most wireless network applications focus on the Infrastructure Network. We survey and analyse the handoff latency source of a mobile station moving under the Infrastructure Network. The handoff latency is still large enough to affect the quality of most wireless network multimedia applications. It would be very useful if the handoff latency were improved.

2.1. Survey of Related Works

In the IEEE 802.11 standard, passive scan and active scan are defined to let mobile stations create their connections with the APs. In the passive scan mode, when the mobile station needs to switch to some other channel, it would periodically listen to receive the beacon frames generated by the APs. Under the active scan mode, the mobile station sends out a Probe Request frame and waits for the Probe Response frame from the AP in order to switch to another channel. Generally speaking, the active scan mode has shorter handoff latency than the passive scan mode. In our proposed models, we focus on the active scan mode.

The handoff latency is composed of three parts, the probe delay, authentication delay and re-association delay. In the study of Mishra *et al*. [2], it was shown that the probe delay would dominate the handoff latency by approximately 85%. It was also found that when the handoff took place, the active scan process should be applied to every possible channel (e.g. 11 channels in US [11,12]). The solution of improving the handoff latency would be a method to improve the probe delay and decrease the number of active scanned channels.

Shin and Arbaugh [3] proposed a method to improve the 802.11 handoff latency. Based on the Inter-Access Point Protocol (IAPP), the authors used the Neighbor Graph (NG) algorithm and NG-pruning algorithm to construct a data structure that represents the handoff relationship of different APs. Using this constructed relationship, the mobile station could perform an active scan for fewer channels. The result showed that the average number of channels that was scanned by the active scan process could be decreased to 2.5 and the handoff latency was improved to about 70 ms.

Kim *et al*. [4] introduced an NG based selective channel scanning method to reduce the scanning delay and minimise the disconnected time while a mobile station changes the associated access points. Shin *et al*. [5] developed a new handoff procedure to reduce the MAC layer handoff latency using a selective scanning algorithm and a caching mechanism to reduce the discovery phase.

The techniques based on NG or selective scanning algorithm are used to reduce the probe delay and provide a possible solution to improve the hand off latency. How to predict the possible channel and how to reduce the number of active scan are the common research motivations. In this paper, another kind of selective scan based on Fuzzy Logic would be proposed.

2.2. The Handoff Latency Source Analysis

The following descriptions focus on the probe delay analysis and the active scan procedure. The active scan procedure is performed when the level of signal-to-noise ratio (SNR) received by the mobile station drops down to the cell search threshold. To obtain the handoff parameter for each channel and AP, the mobile station must execute an active scan on each channel. According to the IEEE 802.11 standard, the Probe Request broadcast message frame is sent to request one channel. The APs then reply with the Probe Response frame if its BSS ID matches the data within the request frame. The mobile station would choose the AP with the maximal level of SNR after each channel has been visited. The authentication phase is entered for the selected AP after the handoff procedure.

Figure 1 shows that a mobile station transmits a Probe Request frame. There are two APs within the coverage area that would reply simultaneously with a Probe Response if they are on the same channel. The handoff procedure is described in detail below.

At point ❶ in Figure 1, the mobile station executes an active scan to transmit the Probe Request frame after gaining access to the medium. Both APs reply

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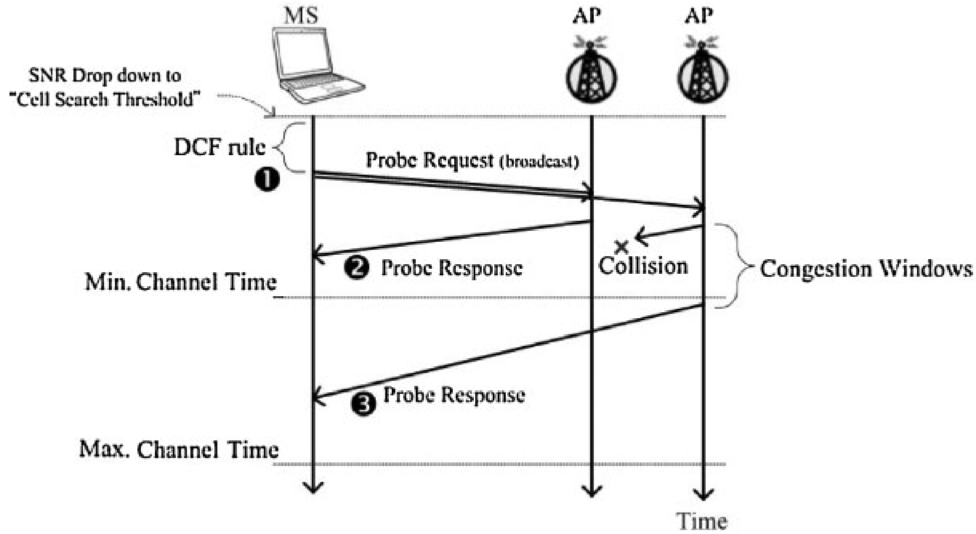

Fig. 1. The IEEE 802.11 active scan procedure.

with Probe Response frames that contain their network parameters. At point ❷ in Figure 1, the mobile station waits for the minimal channel time, Min. Channel Time, to elapse. If the medium is not busy, there is no usable AP for this channel. The mobile station then switches to the next channel and repeats the action at point ❶. If the medium is busy during the Min. Channel Time interval, the mobile station must wait for the maximal channel time, Max. Channel Time, to elapse to collect more Probe Response frames from the other APs. This is shown at point ❸ in Figure 1. Note that the second Probe Response must follow the DCF rules and wait for the congestion windows to elapse before it can be transmitted.

Through the above observation for active scan process, we find three cases that could affect the handoff latency.

Case 1: The mobile station sends out a Probe Request frame to a channel where no AP exists. The mobile station will not acquire any response from any AP but it will still need to wait for the Min. Channel Time.
Case 2: The mobile station sends out a Probe Request frame to a channel where only one AP exists. Normally, the mobile station will acquire a Probe Response frame from this AP before the Min. Channel Time expires. The mobile station will then automatically wait for the Max. Channel Time to collect the Probe Response frames from the other APs. In this case, the mobile station will not acquire any response from other APs. The wasted extended waiting time is therefore obvious.
Case 3: The mobile station needs to perform the active scan procedure for each of the channels to get all possible AP parameters. In this situation, the wasted time would gradually accumulate. The time accumulation forms the main part of the handoff latency.

3. Proposed Approach and Simulation Model

3.1. Proposed Approach

After we observed the Probe Response frame format and the beacon frame format, we found that they were almost the same. The beacon frame could be used to improve the handoff process in our proposed paper. While the mobile station receives the beacon frames, the average signal strength and the variation of signal strength would be calculated. Those data are used in the proposed Fuzzy model to evaluate the fitness value for every APs that have sent beacon signals to this mobile station. When the mobile station leaves away from the original associated AP and triggers the handoff process, the proposed handoff scheme would choose the AP with the smallest fitness value and executes only one active scan process but the traditional handoff scheme would execute full active scan process (11 active scans). The detail of the proposed Fuzzy-Logic handoff scheme is elaborated in Subsection 3.2.

Figure 2 shows that a mobile station moves along a trajectory between three APs and initially joins AP1.

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