Multiple WNIC-Based Handoff in IEEE 802.11 WLANs

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Abstract—We propose a novel scanning scheme for IEEE 802.11 by equipping Access Points (APs) with multiple Wireless Network Interface Cards (Multi-WNICs), one of which is set to operate in an exclusively reserved channel for the scanning purpose. In this environment, a STA (Station) can easily search neighboring APs by scanning the reserved channel. Our simulation results demonstrate that the proposed scheme ultimately reduces the overall scanning time to improve the handoff latency.

I. INTRODUCTION

As real-time services such as Voice-over-IP require more stringent Quality-of-Service requirements, it becomes necessary to provide the IEEE 802.11 STAs (STAs) with seamless handoff. Many efforts have been made to improve the 802.11 handoff. In [1], the authors empirically show that scanning is the most time-consuming job out of the operations constituting a handoff in IEEE 802.11 Wireless Local Area Network (WLAN). For this reason, the studies have been focused on reducing the scanning time [4]–[7]. Particularly, the authors of [4], [5] propose seamless 802.11 handoff schemes by utilizing multiple Wireless Network Interface Cards (Multi-WNICs). In their proposed schemes, STAs with Multi-WNICs are designed to try a scanning by using a WNIC, which is dedicated to the scanning function, while the rest are used to exchange data frames. Therefore, their schemes are useful for preventing data frame transmission interruptions during a scanning process. However, their benefit is limited in that they require STAs to have at least two WNICs despite the fact that commercial STAs do not have Multi-WNICs generally.

In this letter, we propose APs to be equipped with Multi-WNICs while a STA has only a single WNIC. All the Multi-WNICs of an AP are set to use the same Basic Service Set IDentity (BSSID). One of them is configured to operate in an exclusively reserved channel for the scanning purpose. That is, all the APs have one WNIC operating in the reserved channel. Then, a STA scans only the reserved channel without needing to scan other channels, thus reducing the scanning time significantly. Additionally, it is possible that the serving AP continues to exchange data frames with a scanning STA in the reserved channel. It implies that the proposed scheme can avoid data frame transmission interruptions even if STAs have a single WNIC.

The letter is organized as follows: in Section II, we overview the 802.11 scanning and propose an active scanning scheme utilizing Multi-WNICs. In Section III, the proposed scheme is comparatively evaluated via simulations. In Section IV, we conclude this letter.

II. BACKGROUND AND PROPOSED SCHEME

For the 802.11 active scanning, a STA should broadcast Probe Request frame(s) in a channel, and then, wait for Probe Response frames, which nearby APs receiving the Probe Request(s) reply with. Subsequently, the STA repeats the scanning procedure in other channels. The 802.11 standard specifies two configurable parameters determining how long a STA should wait for Probe Responses after sending a Probe Request, namely, MaxChannelTime and MinChannelTime. MinChannelTime is the minimum time that a scanning STA stays in a scanned channel while MaxChannelTime is the maximum [2]. Typical commercial 802.11 devices apply 20 ms and 40 ms to MinChannelTime and MaxChannelTime, respectively [8].

Large values of Min/MaxChannelTimes enhance the probability that a scanning STA finds nearby APs successfully even in a channel with heavy contention while it incurs a long scanning delay. That is, if the channel becomes busy during MinChannelTime, the STA stays in the channel for MaxChannelTime. Typically, a scanning STA cannot receive/transmit data frames during a scanning process, especially, while it scans channels other than that of the serving AP. Therefore, it is important to determine appropriate Min/MaxChannelTimes, which is not easy. The authors of [7] recommend aggressive 1 ms and 10 ms for Min/MaxChannelTimes, respectively, in the 802.11b WLANs. Along with the Min/MaxChannelTimes, the number of employed channels is a major factor influencing the overall scanning delay. The authors of [6] propose a scanning scheme employing the neighbor graph, informing the list of channels occupied by neighboring APs, so that a STA can scan a reduced set of channels.

We here propose that APs are equipped with Multi-WNICs. In a single AP, Multi-WNICs use the same BSSID, and hence, STAs can roam across the Multi-WNICs without reassociation. Moreover, one of the AP’s Multi-WNICs is configured to operate in a reserved channel for the scanning purpose. A STA can find nearby APs easily by searching APs only in the

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1BSSID is identical to the AP’s Medium Access Control (MAC) address.
reserved channel, thus eliminating redundant scanning trials in all other channels. Since STAs search APs only in the reserved channel, even the neighbor graph is not required. In order to realize the proposed scheme, we design a protocol with a timing diagram in Fig. 1.

This figure shows the case in which a STA in a non-reserved channel performs a handoff by moving to the reserved channel. All three APs are equipped with two WNICs. The detailed procedure is summarized as follows: prior to a scanning, (1) a STA transmits a null frame, i.e., a data frame without a payload, with Power saving Mode (PM) bit set to 1 to inform its serving AP that it enters the Power Saving Mode (PSM), and then, the serving AP begins to buffer data frames destined to the STA. (2) The STA switches its operating channel to the reserved channel for scanning. Thereafter, it transmits a null frame with PM bit set to 0 in order to make the serving AP forward buffered data frames. This procedure is feasible since the serving AP should have a WNIC operating in the reserved channel permanently. It enables the STA to receive data frames while scanning. (3) The STA broadcasts Probe Request frames in the reserved channel. Since at least one of each AP’s Multi-WNICs operates in the reserved channel, it is not necessary to broadcast Probe Request in other channels. In case that the STA fails to find a AP in the reserved channel, it determines there is no AP in its neighborhood. (4) After the STA receives Probe Response frames, it selects the most appropriate AP to proceed with an authentication.

In the 802.11 standard [2], Probe Response is allowed to convey the AP load information, indicating how busy an AP is. We extend this information by conveying the load of all the channels in which the AP’s Multi-WNICs operate. This information can be used by the STA as a metric to determine the most appropriate AP to handoff. By considering the information, the STA can also choose an appropriate channel for its operation. After (5)-(8) performing an authentication and a reassociation for a new connection establishment with the chosen AP, finally, (9), (10) consecutive null frames with PM bit set to 1 and 0 are transmitted in the reserved channel and a non-reserved channel, respectively, to prevent the loss of data frames during a channel switching. After a channel switching, the STA can exchange data frames with the new AP.

III. PERFORMANCE EVALUATION

We use an ns2 simulation model [3] for our evaluations, which are conducted in three environments: (1) where two APs with Multi-WNICs are separated by 60 m, and a STA moves between the two APs at the speed of 3 km/h as shown in Fig. 2. In (2) grid and (3) random topologies depicted in Figs. 3 (a) and (b), respectively, a STA moves around following the random waypoint mobility model [10]. In the model, a STA moves toward a randomly selected point. Once it reaches the point, it chooses a new random destination and begins moving toward it. In the grid topology, the distance between two neighboring APs along a row or a column is set to 15 m or 30 m. On the other hand, in the random topology, APs are deployed randomly in a 90 m × 90 m region.

A STA begins scanning when the Signal to Noise Ratio (SNR) of the received frame from its serving AP drops below 18.07 dB. The MinChannelTime and the MaxChannelTime for the proposed scheme are configured to 1 ms and 10 ms, respectively. STA’s channel switching time reflecting the delay required to switch the scanned channel is a device-dependent factor influencing the scanning delay. Intel and Netgear produce devices supporting 200 µs and 6 ms, respectively [9], and hence, we consider both 200 µs and 6 ms for our evaluations.

In the subsequent performance evaluation results, we adopt the term, CSTa and CSTb, for the channel switching times of 802.11a and 802.11b devices, respectively. The 802.11b STAs are able to exchange more reliable Probe Request/Response frames while the 802.11a STAs take less time for the frame exchange because the 802.11a (802.11b) supports relatively lower (higher) but less (more) reliable transmission rates. Note that both the transmission time and the channel error affect the scanning delay, thus resulting in different delays for the 802.11a and the 802.11b. Enhanced and Typical indicate the delays without the proposed scheme.
when $Min/Max\text{Channel} \times \text{Times}$ are set to 1 ms/10 ms and 20 ms/40 ms, respectively. NG represents the adoption of the neighbor graph, containing the information about neighboring APs [6]. Additionally, Proposed shows the performance of our proposed scheme.

We consider a scanning delay, defined as a time spent in finding a suitable AP with a successful reception of Probe Responses after transmitting a Probe Request, as a performance metric. Fig. 4 shows scanning delays in case of the simple topology in which there are two APs with Multi-WNICs. In the figure, it is observed that scanning delays increase as the number of WNICs increases when Enhanced and Typical scanning schemes are used. It is because a STA should wait for Probe Responses until $Max\text{Channel} \times \text{Time}$ in every busy channel, where the number of busy channels is proportional to the number of APs’ employed WNICs. However, the scanning delays remain constant with our proposed scheme since the reserved channel prevents the STA from scanning unnecessary channels. Figs. 5 and 6 show the scanning delays in grid and random topologies, respectively. As shown in the figures, our scheme incurs constant scanning delays irrespective of the network topologies and it outperforms all the other scanning schemes, i.e., even those with the neighbor graph.

IV. CONCLUSION

We propose a simple and effective scanning scheme by reserving a dedicated channel for scanning. The evaluation results prove our proposed scheme outperforms existing scanning schemes. Typically, scanning algorithms are embedded in the device driver. It implies our proposed scheme can be easily integrated into STAs without hardware logic modification.

REFERENCES