Network allocation vector (NAV)-based opportunistic prescanning process for WLANs

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Tracking neighbouring access points (APs) or channels is an essential function to achieve fast handoff over WLAN. However, scanning other channels interrupts the ongoing communications of a station. To minimise this, the proposed method utilises a network allocation vector (NAV) to scan neighbouring channels, so that a station is able to track neighbouring APs without additional communication interruptions.

Introduction: As Wi-Fi-equipped mobile devices are getting popular, handoff over IEEE 802.11-based wireless networks has recently been extensively studied in layers 2 and 3 [1–3]. It is well known that probing neighbouring networks causes major delays in the overall handoff process [4] because a station (STA) requires scanning of all operating channels defined in the IEEE 802.11 standard. Hence it is crucial to reduce the probe delay to achieve a fast handoff. Recent studies prove that a prescan method reduces the handoff process [1–3]. In a prescan method, STAs scan other channels before the actual handoff begins. Through the prescan, STAs collect and update information about neighbouring access points (APs), and track the change of signal quality from them. When the handoff is required owing to signal degradation with the current serving AP, the STA tries to associate with a neighbouring AP with the best link quality from the information obtained from the prescan process. In the prescan, a method to track neighbouring channels is periodically conducted during the normal communication period before the actual handoff is required. DeuceScan [1] and the method surveyed by [1] use a prescan approach to reduce the layer-2 handoff latency. These methods require time synchronisation between APs and periodic channel changes. More recently, prescan overlapped with data transmission is proposed in [2]. However, extra hardware devices, i.e. wireless network interface cards (WNICs) must be attached to APs. In addition, intentional power save mode is also used for the prescan which interrupt ongoing communications.

In this Letter, we propose a network allocation vector (NAV)-driven prescan and early-handoff that are totally backward compatible with legacy systems. The focus of the proposed method is how to scan and track signals from neighbouring APs without interrupting ongoing communications of a mobile. Therefore, we utilise a NAV for the prescan. In addition, if any better AP is detected through a NAV-driven scan, a STA begins the handoff process immediately without waiting for degradation of the signal strength from the current AP.

Motivation: According to IEEE 802.11-based WLANs, any other STAs except two STAs engaging in communication hold their transmissions during a NAV period that is wasted for STAs not engaged in the communication. Moreover, the NAV duration is prolonged in the IEEE 802.11e standard [5] owing to supporting a normal EDCA transmission opportunity (TxOP) and a block acknowledgment (ACK) to transmit a burst of data frames. Therefore, our proposed method attempts to utilise the NAV period for STAs not involved in the transmission to schedule the prescan process. Therefore, they keep tracking the channels around them, so that they instantly choose the appropriate channels from a candidate channel-set to be associated with when a handoff is initiated. As a result, it helps to reduce probe delay. Since the STA does not engage in the transmission, there is no risk that the STA will miss any frame intended to itself during the NAV period while it is away from the serving channel when performing the prescan process. We also propose an early-handoff that initiates a handoff process when a received signal-to-noise ratio (SNR) of any neighbouring AP is a certain level higher than that of the currently associated AP. This helps to enhance the network performances because the channel quality (i.e. data rate) becomes better if there are closer APs.

Protocol operation: When a station powers on and associates an AP, it scans all possible channels. During the initial scanning process, a station stores neighbouring APs' information detected during the scanning process in a hit-channel list (HCL). The list records basic service set identification (BSSID), received signal strength indicator (RSSI), beacon interval (BI), and beacon arrival time (BAT) for each detected AP.

When a STA is in a NAV, it starts the following prescan process.

Step 1: From HCL, the STA decides whether or not there is any channel expected to transmit a beacon during the NAV period.
Step 2: If there are such channels (called candidate channels), the STA lists up the channels and decides the scanning order of the listed channels. The order is decided based on the BAT of each channel. The channel with the smaller BAT is scanned first.
Step 2-1: The STA turns from the serving channel to the chosen channel, and listens it to detect a beacon frame.
Step 2-2: When a beacon is received, the signal strength from the beacon frame is updated in HCL. If no beacon is received or the signal strength of the beacon frame is lower than a threshold of SNR (ThSNR), the information of the channel is deleted from the HCL.
Step 2-3: The channels in the order are continuously scanned until all the channels in the order are scanned or the NAV period is completed.
Step 3: If no channel is expected to transmit a beacon during the NAV period, it switches to any other channel not in the HCL. The scanning order of un-hit channels follows the order of channel number defined in the IEEE 802.11 standard.
Step 3-1: After turning to the channel, a STA sends a probe-request message when the channel is idle for the period of 2*SIFS.
Step 3-2: Once receiving a probe-response, the STA waits for maxchanneltime [5] and updates the HCL with the information obtained from all received probe-response messages.
Step 3-3: If a probe-response is not received, the STA waits for minchanneltime [5].
Step 3-4: If a frame is not detected during scanning a channel and the remained period in the NAV is longer than NAV_{min}, the next channel is scanned as illustrated in step 3-2. NAV_{min} is defined as follows:

$$NAV_{\min} = 3^{*}SIFS + T_{\text{ProbeRequest}} + T_{\text{ProbeResponse}} \tag{1}$$

where $T_{ProbeRequest}$ and $T_{ProbeResponse}$ are transmission times of probe-request and probe-response messages, respectively.
Step 3-5: Processes from step 3-1 to 3-4 are repeated until the NAV period is completed.
Step 4: When the NAV period is completed, the STA goes back to the serving channel.
Step 5: If the power of the received preamble signal of the associated channel is lower than the triggering-threshold or any SNR of the channels in the HCL is difference-threshold higher than that of the associated channel, the handoff process immediately begins over the channel. If there is no channel available in the HCL when the handoff process is triggered, it scans all channels using the legacy method specified in the IEEE 802.11 standard.

Fig. 1 illustrates an example of the proposed prescan process where channel A and D are in HCL and channel B and C are not in the list.

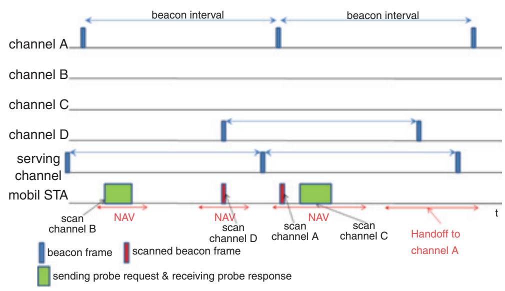

Fig. 1 *An example of channel scan*

Performance evaluation: Simulations are carried out by using the IEEE 802.11a-based simulator in [6]. All APs and 200 STAs are randomly distributed in a 500 × 500 m area. All STAs move around following the random waypoint mobility model [7] with the speed ranges from 5 to 30 m/s and the pause time ranges from 0 to 10 s. BI, the triggering-threshold, and the difference-threshold are set to 100 ms, −90 dBm, and 40 dB, respectively. The minchanneltime and maxchanneltime are configured to 1 and 10 ms, respectively [3]. The traffic load is saturated. STA's channel switching time is set to 200 μs like an Intel device [8]. Scanning delay, defined as the time spent in finding a suitable AP when handoff is triggered, is not considered because it is overlapped with data transmission time in the proposed method. The scanning delay overlapped with data transmission does not affect system performance because it does not cause handoff delay. In multiple WNIC-based handoff [2] and the proposed method, the scanning delay is overlapped with data transmission. For this reason, we evaluate the throughput of a tagged AP as the performance metric.

Deuce, MWH, and NAVH in Fig. 2 indicate the method proposed in [1], in [2], and in this Letter, respectively. Most commercial off-the-shelf WLAN products are implemented with adaptive rate control (ARC). However, to see the effect of the handoff overhead, we also run the simulation without ARC (w/o ARC), where the physical layer data rate is fixed at 6 Mbit/s. In addition, the performance of NAVH without early-handoff (w/o EH) is evaluated, where ARC is used. As the number of APs increases, nodes can enjoy better SNR because of the shorter average distance from APs and, as a consequence, throughputs of all three schemes increase. Deuce and MWH deteriorate the throughputs because using intentional channel change or power save mode for the prescan interrupts ongoing communications. NAVH does not interrupt ongoing communications for the prescan and it shows better throughput. This is illustrated by the throughput of NAVH w/o EH. Furthermore, early-handoff in NAVH increases throughput more. While triggering handoffs in deuce and MWH are delayed until the SNR of the beacon falls down to triggering-threshold, early-handoff in NAVH triggers the handoff earlier than the other two methods do. Therefore, it enhances the channel qualities so that it increases the average data rate. Without ARC, NAVH shows a little less throughput than the other two methods as shown in the bottom three plots in Fig. 2 because early-handoff increases the number of handoffs. Thus NAVH w/o ARC suffers from more handoff delay caused by the switching channel than others. Since the data rate is fixed at the lowest rate, the better SNR caused by early-handoff has no merit in the NAVH w/o ARC. In this case, the handoff delay overwhelms the merit of reduced scan time.

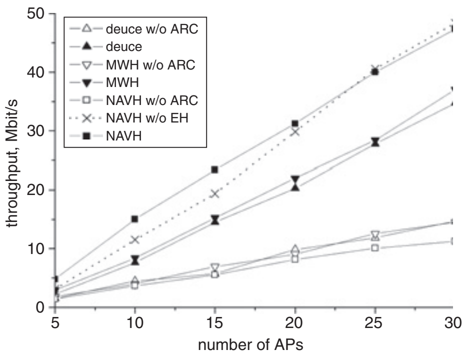

Fig. 2 *Throughput against number of APs*

Conclusion: NAVs, which are wasted time periods in the IEEE 802.11-based protocol, are fully utilised for scanning signals from neighbouring APs. Scanning during NAV duration does not interrupt any ongoing communications and is backward compatible. In addition, the average data rate is improved because the handoff is triggered earlier using the scan information.

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One or more of the Figures in this Letter are available in colour online.

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