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A fast handover method for 802.11 wireless networks using combined GPS and SNR

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Abstract: In this paper, we propose a method for increasing the handover performance of the 802.11 link layer. The method reduces the number of scanning channels by referencing an AP map based on GPS. Also, by monitoring the SNRs of the mobile node and neighbor APs, it enables the handover to maintain a higher SNR than a given threshold. The experimental results establish that it has an average disconnection rate of 6.7% and an average SNR of 16.8 dB. It is 8.1% lower rate and 42% higher SNR than the method that makes a handover to the nearest AP without considering SNR. Also, it is 4.1% lower rate and 26% higher SNR than the method used by MadWifi.

Keywords: link-layer handover, IEEE 802.11, GPS, SNR

Classification: Science and engineering for electronics

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1 Introduction

Wireless networks based on IEEE 802.11 have become wide-spread in metropolitan areas. Mobile nodes (MNs) using the wireless networks such as PDAs or smart phones not only provide a basic Internet access, but have also evolved to provide location-based services using cheap GPS chips.

To provide wireless network services over a large area, 802.11-based APs, which have a coverage area of about 100 meters, must be installed on a large-scale. In this environment, handovers frequently occur, due to the movements of MNs, and these cause a disconnection problem and performance degradation of applications such as VoIP. To solve this problem, studies have been actively conducted in fast and intelligent handover methods [1, 2, 3, 4, 5].

2 Related works

Handovers are broadly divided into link layer and IP layer handovers. This paper focuses on the link layer handover, consisting of scanning, authentication and association processes. Among these processes, scanning uses 90% of the total handover time [1]. M. Shin et al. proposed Neighbor Graph [2], which uses a handover pattern of a MN. By using the graph, the MN scans only given channels that are used by neighbor APs. Although it reduces the number of scanning channels, it does not consider when the handover must be performed. H. Wu et al. proposed Proactive Scan [3]. To decouple time-consuming scanning from actual handovers, a MN proactively scans other channels. It uses the transmission rates and signal strength to determine when the proactive scan and actual handover must be triggered. However, it scans all channels. Therefore, scanning uses a great deal of time, and decreases the performance of the ongoing application.

To advertise the existence of APs, APs normally periodically send beacons at 100 ms intervals. I. Ramani and S. Savage proposed SyncScan [4]. In this method, all APs in a wireless network perform time synchronization, and send beacons at given time intervals. For example, all APs operating on channel 1 broadcast beacons at time t, while APs on channel 2 do so at time $t + d$ ms, etc. A MN can determine the used channels and signal-to-noise ratios (SNRs) of the neighbor APs by periodically receiving the beacons. Because the method does not need scanning, it can reduce the handover time. However, it is difficult to perform time synchronization of all APs precisely. In addition, it incurs a beacon monitoring overhead.

J. Montavont and T. Noel proposed a handover method using a GPS-equipped MN [5]. If the distance between a MN and the current AP is greater than a given threshold, the MN sends its current coordinates to a server. Subsequently, the server finds the minimum distance from the MN to all other APs, and then sends the MAC address of the candidate AP to the MN. The method reduces the handover time, because the MN can perform direct handover to the AP without scanning. However, because it only uses the distance and does not consider the SNR, the MN can perform handover to a nearest AP, which has a low SNR.

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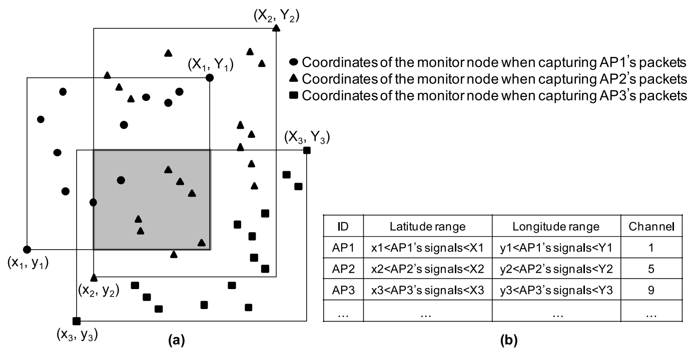
In this paper, we propose a handover method using combined GPS and SNR. This reduces the number of scanning channels by referencing an AP map based on GPS. Also, by monitoring the SNRs of the MN and neighbor APs, it enables the handover to maintain a higher SNR than a given threshold.

3 Proposed handover method using combined GPS and SNR

In the proposed method, a monitor node (operating in 802.11 monitor mode) traverses in a test-bed wireless network, and generates an AP map. MNs download the map and use it for handover. As the monitor node with GPS traverses, it captures packets transmitted by neighbor APs. When the SNR of the packet is above a given threshold, the monitor node records the coordinates of the node along with the BSSID and the channel number of an AP as shown in Fig. 1 (a). Based on the data, a table is generated, consisting of the ranges of latitude and longitude and the used channel numbers of APs, as shown in Fig. 1 (b). In this paper, we denote this table as an AP map. When a MN enters the network, it downloads the AP map from a server. If the SNR between the MN and current associated AP is below a given threshold, the MN scans only given channels using the AP map and current location of the MN. For example, when the MN needs to scan for a new AP in the grey area of Fig. 1 (a), it references the AP map and determines that its neighbor APs are AP1, AP2 and AP3. And then, it scans only 1, 5 and 9 channels.



ID	Latitude range	Longitude range	Channel
AP1	x1<AP1's signals<X1	y1<AP1's signals<Y1	1
AP2	x2<AP2's signals<X2	y2<AP2's signals<Y2	5
AP3	x3<AP3's signals<X3	y3<AP3's signals<Y3	9
...	...	...	...

Fig. 1. (a) Coordinates of the monitor node when capturing packets, (b) AP map

While the method [5] by J. Montavont and T. Noel finds the minimum distance from the MN to all other APs, the proposed method in this paper only checks whether or not the coordinates of the MN is in the ranges of latitude and longitude of APs in the map. Because it does not need to calculate the distances, it is simpler than the method of J. Montavont and T. Noel. Both the proposed methods in this paper and the Neighbor Graph [2] have the objective of reducing the number of scanning channels by referencing the AP map or the Neighbor Graph. However, the generation of the Neighbor Graph is more complicated than the proposed method, and it does not consider when the handover must be performed. SyncScan [4] determines a

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suitable handoff time by monitoring the beacons of the neighbor APs, but this incurs a beacon monitoring overhead. To reduce the monitoring overhead and provide a sufficiently high SNR for reliable wireless communication, we describe the following algorithm:

Algorithm

```
while ( 1 ) do
    if current status == associated then
        if current SNR < cell search threshold then
            (new bssid, new SNR) = scanning()
            if new SNR − current SNR > δ-threshold then
                handover(new bssid)
            end if
        end if
    else
        (new bssid, new SNR) = scanning()
        if new SNR > association threshold then
            associate(new bssid)
        end if
    end if
end while
```

When a MN is associated with an AP, it scans only if the SNR is below a cell search threshold. It scans only given channels using the AP map. After the MN obtains the scanning result, it compares the maximum SNR of the scanning result to the current SNR. If the difference between the maximum and current SNR is higher than a δ-threshold, the MN performs handover to the new AP. If the MN simply performs handover from the current AP, which has a low SNR, to the new AP, which has a high SNR, and does not consider the threshold, a ping-pong effect between AP1 and AP2 occurs at times between t_1 and t_2, as shown in Fig. 2 (a). When the MN is currently not associated with any AP, it immediately scans given channels in the AP map, and then it performs handover to the new AP only if the SNR of the new AP is above an association threshold. As shown in Fig. 2 (b), if the MN performs handover to the new AP, which has a lower SNR than the association threshold, the connection can be broken again, and the data transmission is frequently corrupted, due to the low SNR.

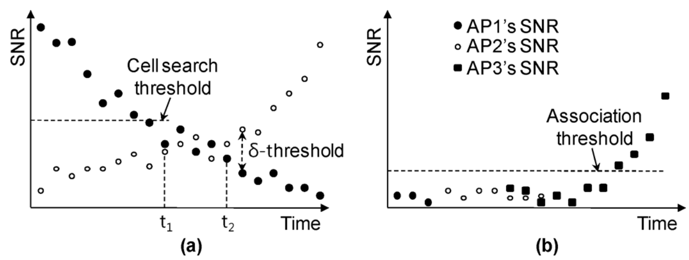

Fig. 2. (a) Cell search threshold and δ-threshold, (b) association threshold

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4 Implementation and experimental results

We used a notebook PC as the monitor node with a SiRFstarIII GPS receiver, an Atheros 802.11g wireless LAN and the Kismet packet sniffer. We set up a path on a campus yard and traverse the path. While traversing with the monitor node, we captured packets transmitted by neighbor APs. If the SNR of an AP's packet is above a given threshold, we recorded the coordinates of the monitor node along with the the BSSID and the channel number of the AP. Based on the collected data, we made an AP map like Fig. 1 (b) using the method described in Section 3. To generate an AP map used in the experiment, we traversed the campus yard in 15 minutes along the predefined path. While traversing, approximately 4000 packets were above the given threshold.

The MN was an UMPC with the same GPS receiver and wireless LAN. The AP map was stored locally in the MN. To obtain the coordinates of the MN, a *gpsd* GPS daemon and a *libgps* library were used. For scanning and handover, we used a *iwlib* library which can manipulate the wireless LAN. With the libraries, we implemented the proposed method based on GPS and SNR. We compared our method with two previous methods. The first is the method [5] by J. Montavont which uses only the GPS data and does not consider the SNR. The second method is used by the MadWifi driver, which is widely used in mobile Linux platforms. It scans the neighbor APs and performs handover to the new AP only if the MN is not associated with any AP. Even though the current AP has a sufficiently low SNR and the new AP has a higher SNR, the MN does not handover to the new AP. We excluded SyncScan [4] from the comparison group, because the modified driver which receives the time-synchronized beacons was not open to the public.

For each method, the experiment repeated five times. For each trial, we traversed the campus yard on foot in 15 minutes with the MN. The SNRs of the MN were recorded every second and the start and end times of disconnections due to the handover were also recorded. The cell search threshold, δ-threshold and association threshold were set to 10, 6 and 6 dB, respectively. Fig. 3 shows the average disconnection rate and average SNR of five trials of each method. The average disconnection rate is the average of disconnections at a given time. For example, if there are two disconnections among the five trials at a time t, the average disconnection rate is 40% at the time t.

MadWifi handovers to the new AP when there was no association with the current AP. However, the MN using only GPS data handovers to the new AP if there is a nearer AP than the current AP, and the proposed method also handovers to the new AP, if there is an AP with a higher SNR than the current AP. Because of this, the MN handovers more frequently in Fig. 3 (b) and (c) than Fig. 3 (a). While the average disconnection rate of MadWifi is about 10.8%, the rate of the proposed method is about 6.7%. Compared with MadWifi, the proposed method has a lower scanning time and performs handover to a more suitable AP using the three thresholds, thus, it has a

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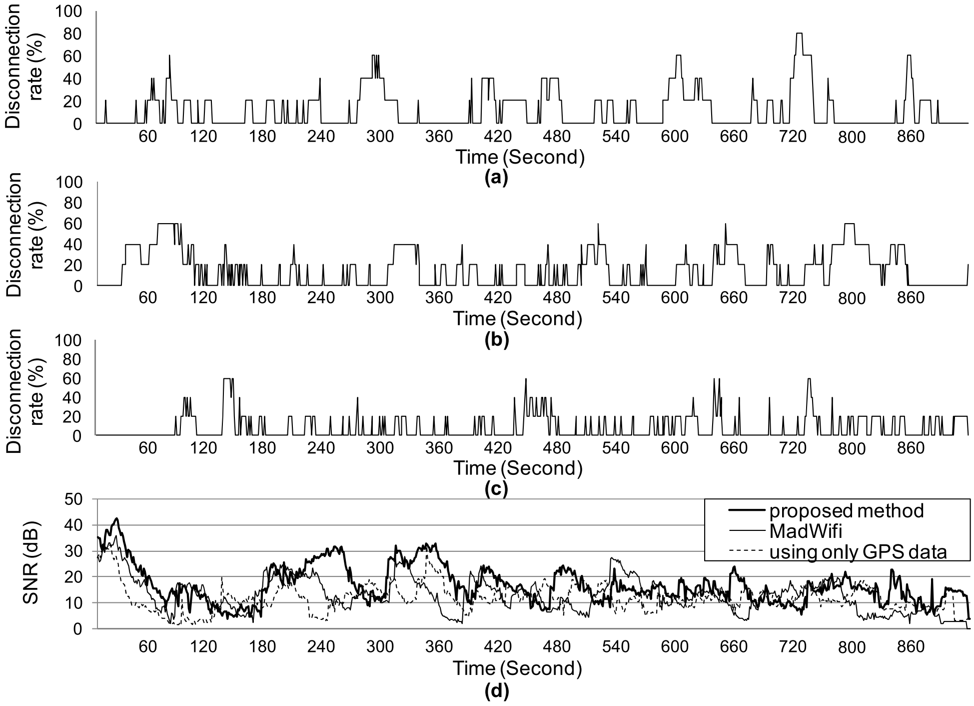

Fig. 3. Average disconnection rates of (a) MadWifi, (b) using only GPS data, (c) proposed method, and (d) average SNRs of the three methods

lower rate than MadWifi. By contrast, the method using only GPS data has the highest average disconnection rate of 14.8%, because the MN can frequently handovers to a nearest AP, which has a low SNR.

In Fig. 3 (d), the average SNRs of the methods using only GPS data and MadWifi are 11.8 and 13.3 dB, respectively. The proposed method has a higher average SNR of 16.8 dB. In addition, in terms of a comparison of the time period that the SNR falls below 10 dB, the proposed method has a shorter time period than others, because it starts scanning and performs a handover when the current SNR is below the cell search threshold of 10 dB.

5 Conclusions

In this paper, we proposed a method in which a MN with GPS and an AP map can reduce the number of scanning channels using a simple comparison operation. Also, we described a handover method that has a reduced scanning time and maintains a higher SNR than a given threshold. The experimental results established that the proposed method has an average disconnection rate of 6.7% and an average SNR of 16.8 dB. It is 8.1% lower rate and 42% higher SNR than the method that makes a handover to the nearest AP without considering SNR. Also, it is 4.1% lower rate and 26% higher SNR than the method used by MadWifi.

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