Reducing handover delays for seamless multimedia service in IEEE 802.11 networks

Doohyun Lee, Daehee Won, Md. Jalil Piran and Doug Young Suh

In IEEE 802.11 wireless local area network (WLAN) environments, handovers occur when a mobile node (client) moves from the coverage area of one access point (AP) to that of another AP. In particular, a handover in multimedia streaming settings requires a series of tasks to be executed – recognising the disconnection to the currently associated AP, searching for other APs in client visibility and so on. The time taken to perform these tasks gives rise to an interruption of service for about 6 s, which greatly decreases users' quality of experience (QoE). To reduce service disruptions caused by handovers in IEEE 802.11 networks, a soft proactive handover scheme that exploits the received signal strength indicator (RSSI) and scalable video coding (SVC) is proposed. The proposed scheme predicts the time that a handover process is going to start using the RSSI values and receives the lightweight base layer code of the SVC-encoded video during a certain interval before the predicted handover starts. Experimental results show that the proposed scheme can minimise service interruption times during the 802.11 handover operations, thereby increasing QoE.

Introduction: The handover as defined in IEEE 802.11 wireless local area network (WLAN) [1] is a time-consuming process. During the handover delay, no user traffic can be exchanged between the access point (AP) and the terminal. Therefore, the whole handover process needs to be completed as fast as possible in order to avoid any interruption of the data traffic [2]. Especially, multimedia streaming applications generally consume a significant amount of network resources so the temporary disconnections or delays that mobile clients experience during handovers can severely degrade the perceptible video quality.

To address the handover latency and resulting service disruptions, this Letter proposes a soft proactive (SP)-handover scheme that can be applicable at the application level. In 802.11 WLAN environments, service disruptions usually occur in the network boundaries where the received signal quality is low because of discovering optimal AP [3], and thus the available bandwidth for streaming multimedia content is limited. The scheme first predicts the time that a handover is going to start (handover prediction) based on received signal strength indicator (RSSI) thresholds and pre-fetches the quality-reduced, but lightweight, streaming data during a certain period before the predicted handover start time. The data reserved via such pre-fetches are used to provide continuous services during the handover process. Moreover, the scheme uses scalable video coding (SVC) to lower the quality of streaming content. SVC allows the video signal to be encoded into multiple streams in temporal, spatial and quality dimensions [4]. When the RSSI has frequent fluctuations, unnecessary handover predictions grow, which decreases the efficiency of the proposed scheme. To prevent this, the proposed scheme includes RSSI filtering that mitigates signal fluctuations.

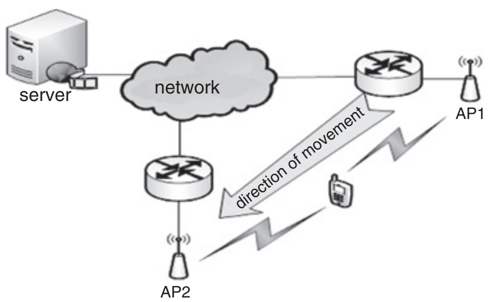

Fig. 1 *Handovers in multimedia streaming environment*

Proposed method: This Section describes the SP-handover scheme proposed in this Letter. Fig. 1 shows a typical handover scenario in WLANs. The streaming service server receives a binding request message sent over the network. The terminal (mobile client) monitors the RSSI of all visible APs and chooses the one that has the highest power (suppose that in this scenario AP1 offers the strongest signal). The terminal sends a request for service to the server via AP1. The server then transmits the SVC-encoded video data at the enhancement layer to AP1, and AP1 delivers it to the user terminal. If the RSSI between the terminal and AP1 falls below a threshold while transmitting the video, the terminal sends a request for the SVC code at the base layer to the server and receives lightweight base layer bitstreams until the AP1 connection is lost. The proactive handover mechanism that provides mobility and handover predictions is used to reserve base layer video data in advance. Once the current AP connection is lost, the terminal's service request is sent via the next AP, AP2 in this case. The process described here is repeated when transferring from one AP to another.

Equations of proposed method: In SP-handover filtering, this measure is applied to (1), a variant of the Friis formula [5]

$$d = \frac{c}{4\pi f} \times 10^{L/20} \quad (1)$$

Equation (1) can be developed further as (2)–(4). Suppose that d_n represents the current location of a mobile client and $v_{\max}$ is the maximum walking speed. The equations below calculate the next location of the mobile client and a range of signal loss. t denotes the time taken to move from the current location to the next location

$$d_n - v_{\max}t < d_{n+1} < d_n + v_{\max}t \quad (2)$$

$$\frac{d_n - v_{\max}t}{d_n} < 10^{(L_{n+1}-L_n)/20} < \frac{d_n + v_{\max}t}{d_n} \quad (3)$$

$$1 - \frac{4\pi f v_{\max}t}{c} \times 10^{-L_n/20} < 10^{(L_{n+1}-L_n)/20} < 1 + \frac{4\pi f v_{\max}t}{c} \times 10^{-L_n/20} \quad (4)$$

Suppose that R denotes the transmitted signal strength. The signal strength at the nth location is $R = R_n – L_n$. With this, (5) below can be developed. In the SP-handover filtering, when a measured RSSI value is not within the range, the maximum or minimum value of the range is used as the RSSI value

$$-20\log\left(10^{-R_n/20} + \frac{4\pi f v_{\max}t}{c} \times 10^{-R/20}\right) < R_{n+1} < -20\log\left(10^{-R_n/20} + \frac{4\pi f v_{\max}t}{c} \times 10^{-R/20}\right) \quad (5)$$

Fig. 2 shows the original RSSI data and the RSSI data filtered by the proposed SP-filter and several variants of the conventional lowpass filter (LPF) used as a typical example of a signal filter for reducing fluctuation [6]. As can be seen from this Figure, the signal filtered by the proposed SP-filter has less fluctuation than those filtered by the LPF.

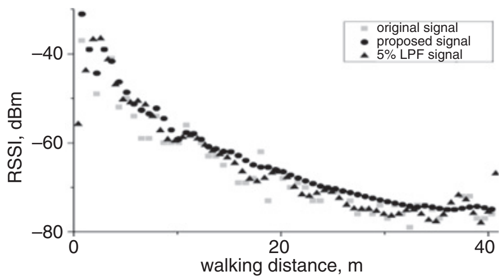

Fig. 2 *Comparison of SP-filtering and lowpass filtering results*

Simulation environment: For the proposed simulation, the 'Soccer' video in 4CIF resolution was encoded using SVC in the experiments. The given quantisation parameters of the SVC enhancement and base layers were 25 and 32, respectively.

Table 1: Parameters of SP-handover filtering

Symbol	Explanation	Value
c (m/s)	Propagation velocity	3×10^8
f (Hz)	AP's frequency	2.485×10^9
$v_{\max}$ (m/s)	Maximum walking speed	2.5
t (s)	Time interval of measurement	0.1
R (dBm)	Transmitted signal strength	10

In the proactive handover environment, FPT was set to −55 dBm (FPT = −55 dBm) and FHT was set to −70 dBM (FHT = −70 dBm).

HPT was four times the maximum estimate of RSSI variations at a 99% confidence level and HFT was twice the maximum estimate of RSSI variations at a 99% confidence level.

Table 1 represents the parameters of SP-handover filtering. The parameters include those in real network environment.

Figs. 3*a* and *b* represent a mobile user's movement across cells and the terminal's RSSI values that vary as the user moves using the suggested media, the environment variants and parameters. The simulation result is based on the simulation environment above.

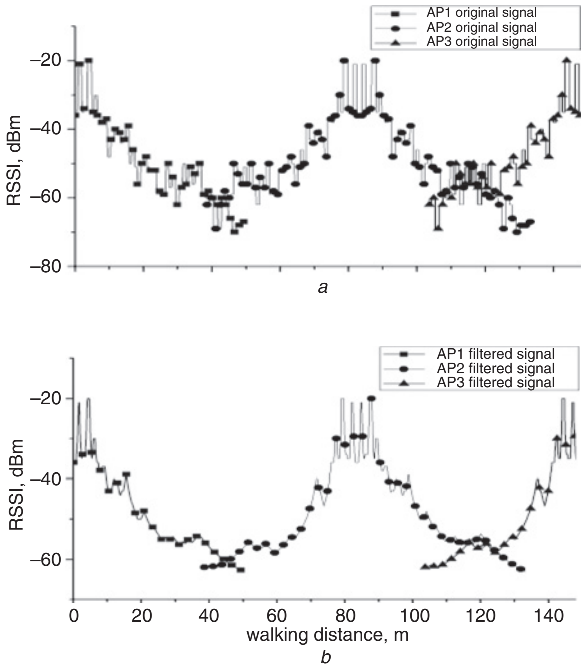

Fig. 3 *Original and filtered RSSI values*
a Original
b Filtered

Simulation result: In the 802.11 standards, the classical handover scheme has the average latency of about 6 s [7]. In Table 2, it is assumed that all predicted handovers actually occur. Compared with the service interruptions times of the classical and proactive handover schemes, the proposed handover scheme has much shorter service interruption times. This shows that the proposed scheme can contribute to providing multimedia streaming services without interruption of service for 30 min.

Table 2: Service interruption times of different handover schemes for 30 min

Velocity (m/s)	Total interruption time during 30 min play (s)								
	Classical overlap distance			Proactive overlap distance			Proposed overlap distance		
	5 m	15 m	25 m	5 m	15 m	25 m	5 m	15 m	25 m
2.0	270	270	270	351	63	346	0	0	0
1.6	270	270	270	378	234	441	9	0	0
1.0	270	270	270	387	297	495	23	0	0
0.5	270	270	270	392	320	513	27	0	0

Conclusion: In 802.11 WLAN environments, hard handover strategies cause long handover latency, which leads to perceptible video quality degradation, and thus customer's dissatisfaction with a streaming service. The SP-handover scheme proposed in this Letter reduces interruptions of streaming service by predicting probable handover occurrences as well as by mitigating the RSSI fluctuations. With the SP-filter included in the proposed scheme, unnecessary handover predictions (or useless bindings) are minimised, thereby increasing the bandwidth utilisation efficiency. In addition, the proposed scheme employs quality adjustments based on SVC encoding in order to support multimedia session continuity requirements. In the experiments, it was demonstrated that the proposed scheme was able to lower service interruption times for moving users. A drawback of the proposed scheme is that the video quality that the mobile end users experience can decrease or the video data pre-fetched and reserved before handovers is not enough to provide continuous streaming services during the handover process if the gap between the base and the enhanced SVC layers is not adequate. In the future, the proposed scheme will be applied to the streaming of H.264 format (.264 file) to support the seamless H.264 playback and a way to extend the current 2-layer SVC scheme to a multi-layer scalable scheme will be studied.

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