Assessing Efficiency of Handoff Techniques for Acquiring Maximum Throughput into WLAN

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Abstract
When the mobile device moves from the coverage of one access point to the radio coverage of another access point it needs to maintain its connection with the current access point before it successfully discovers the new access point, this process is known as handoff. During handoff the acceptable delay a voice over IP application can bear is of 50ms whereas the delay on medium access control layer is high enough that goes up to 350-500ms. This research provides a suitable methodology on medium access control layer of the IEEE 802.11 network. The medium access control layer comprises of three phases, namely discovery, re-authentication and re-association. The discovery phase on medium access control layer takes up to 90% of the total handoff latency. The objective is to effectively reduce the delay for discovery phase to ensure a seamless handoff. The research proposes a scheme that reduces the handoff latency effectively by scanning channels prior to the actual handoff process starts and scans only the neighboring access points. Further, the proposed scheme enables the mobile device to scan first the channel on which it is currently operating so that the mobile device has to perform minimum number of channel switches. The results show that the mobile device finds out the new potential access point prior to the handoff execution hence the delay during discovery of a new access point is minimized effectively.

Keywords:
Wireless Local Area Networks (WLAN), Mobility, Handoff, Delay

1. Introduction

Due to the insufficient coverage provided by each WLAN cell, WLANs are a significant problem. The access point provides cell-specific radio coverage for each cell, which is only available within that cell. Small cells cause a high number of handoffs when the mobile device is performing mobility. The handoff process at MAC Layer scanning of APs is about 90% of the complete handoff latency [1]. If the handoff latency is not reduced, the multimedia applications like VOIP will experience a call drop or connection failure.

The handoff procedure happens as a result of mobility, which requires the MD to switch associations. To ensure the continuous transmission, an MD must make a seamless handoff when leaving the coverage area provided by one AP and entering the radio range supported by another AP. MS context and continuing communication packets are transmitted from the current AP to the next related AP during this handoff phase to guarantee the ongoing transmission. When a MS makes its movement and changes its current AP, it first starts MAC layer processing of handoff. The handoff process at MAC layer consists of step wise three phases as follows:

- Discovery
- Authentication
- Re-association

1.1 Discovery Phase The MS starts to find a new AP to associate with.

1.2 Authentication When found a best nearby AP to associate with, next the MS performs authentication procedures with the newly found AP. The AP verifies its identity and makes a registration for this new MS.

1.3 Re-association On completion of a successful authentication process, the MS makes its association from the current AP to the newer AP and completes the handoff process.

All the three phases at MAC layer jointly incurs a considerable amount of delay in handoff process where the Discovery phase puts 90% of the total handoff delay. The remaining two phases jointly constitutes a total of 10% of delay. In case of an ongoing communication such as, VOIP the probe phase puts from 350 – 500ms of latency[2]. Where the acceptable rate of latency for this sort of multimedia application is of about 50ms [3]

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2. Motivation

This study will look into concerns with seamless handoff in WLANs and present a methodology to address those issues as well as others that make it difficult to guarantee the transfer of quality of service during handoff. The handoff process of the MD from one AP to the other AP needs to be efficient enough that the ongoing transmission of the MD remains uninterrupted. However, the handoff latency in WLAN results in connection failure of the MD with the old AP before the MD successfully establishes its connection with the new AP. We developed a system to solve the issue of prolonged handoff latency during the handoff process. This system makes the MAC Layer's "Discovery" phase of the handoff process efficient and considerably cuts down on the overall time required for the search of new APs.The fast handoff process ensures the seamless mobility of MDs within the wireless network.

3. State of the art techniques

Following are the methods that are being used in reduction to WLAN latencies

3.1 Channels Pre-scan Method

The process of searching for a new AP involves scanning every channel that is open, which accounts for the majority of the overall handoff latency. Connection loss is caused by a full-scan procedure at the time of handoff detection. Therefore, methodologies have been defined in literature to avoid a full-scan process after handoff detection. Pre-scanning of channels refer to scan the channels before actual handoff process starts.

Noor Mustafa et al in [10] provide a fast handoff methodology by supporting pre-scanning of channels using selective channel mask and performs dynamic caching of responses from APs. The MD does background scanning in order to find adjacent APs and create channel masks for found APs. On getting the RSSI value lower than the pre-specified threshold value, the MD stores its status and moves to a channel from selective channel mask and sends probe request, gets the probe response and switch back to original channel and store the AP. After a certain time period, the MD selects another channel from channel mask and moves on to it after storing its status. Sends the probe request, gets the probe response(s), stores these results and get back to original channel. The found APs are sorted in descending order of their RSSI values and placed in the cache. Whenever the MD initiates the handoff procedure, the APs in the cache are tried to get associate with. In case of a cache miss, the MD performs the selective scanning of channels from available channel masks.

Ishwar Ramani et al in [11] propose a synchronization scan mechanism that is entirely based on passive scan mode. In this scan mode, the APs broadcast beacon frames on regular intervals. Most APs have the interval value set about 100ms. This paper suggests that the MDs be synchronized with the time of channels beacon broadcasts so that when a channel has expired a time duration of 100ms and is about to transmit beacon frames, the MD will have to switch on that channel and will listen to all beacon frames. At the heart of their method is the creation of a periodic schedule for MD according to channel beacon broadcasts. They define‘d’ parameter which refers to that 100ms interval of beacon broadcast. If channel 1 starts broadcasting beacon frames on time ‘t_0’, channel 2 will must broadcast on time ‘$t_0 + d$’, channel 3 will be broadcast beacon frames on time ‘$t_0 + 2d$’ and so on. This periodic schedule is feed to MDs and they start listening to beacon frames on these particular time intervals.

Deepak Y. Bhadane et al in [12] suggest a background scan process. Their proposed methodology makes use of a cache memory at MD. The MD in its cache memory stores information of the subset of the best neighboring APs and their frequency channels on which they operating. The MD monitors its RSSI value continuously. When the RSSI value lowers down a pre-defined threshold RSSI value, the MD starts handoff initiation. The MD chooses the best neighbor APs from the subset and sends a uni-cast probe request to that AP in a specific channel.

3.2 Neighbor Graph (NG) Method

The neighbor graph is an undirected graph that captures the physical placement of APs in a WLAN network. A graph is a combination of vertices and edges where the edges join up the vertices. The NG is described below.

$$NG = [V, E]$$

$$V = [AP_1, AP_2, AP_3, \ldots AP_n]$$

$$E = AP_i, AP_j$$

Here, the NG is a data structure that captures the WLAN network topology, V is a set of all the APs operating in the network and E is the direct mobility path between two APs. Using the information obtained from the NG, a MD can have the knowledge of next AP it will join in future. Handoff latency can be reduced efficiently using this proficient mechanism.

Debabrata Sarddar et al in [13] present a fast handoff mechanism in which three steps are involved

- Handoff detection
- NG algorithm
- Handoff execution

The handoff detection has been made using RSSI value of the current AP. They have defined two threshold levels for handoff initiation and handoff execution. S_{th} is the RSSI value to initiate the handoff process and S_n is the RSSI valuefor handoff execution threshold. The method includes a little change in NG algorithm that it not only gets the neighbor AP but also captures the channels on which each AP is working, the SSID and BSSID information and the load of neighbor AP.

$$V = v_i : v_i = [AP_i, SSID, BSSIDChannelNumber$$

The MD continuously monitors RSSI value if $RSSI \leq S_{th} and RSSI \geq S_n$ the NG algorithm starts and the information is saved in the cache on NG server. The MD gets this information and tries to associate with AP present in that information. When the $RSSI \leq S_n$ the MD reads NG information and sends probe request message to the best AP.

Minho Shin et al in [14] present a novel scheme for AP selection using a concept of neighbor graph and neighbor graph pruning. NG determines the neighboring APs and their respective channel numbers so that an AP needs not to scan all the channels in search of a new AP. The NG pruning concept is used to ensure that an AP does not wait for more probe responses other than the adjacent AP. The NG pruning concept is achieved with the help of neighbor overlap graph. This is to find exact neighboring APs which are overlapped and are not far enough to be non-overlapped. The AP sends probe request message and waits for probe response only from the over-lapped AP thereby avoiding probe responses from APs on that channel that are not overlapped.

Hye-Soo Kim et al in [15] present a selective scan approach using neighbor graph algorithm. Their approach maintains a NG server that provides information to MD when necessary. On handoff execution the MD reads NG file from NG server. The NG file contains information about the direct adjacent APs and their channels of the current AP. The MD reads that file and performs a selective scan by sending probe request message to only that AP and waits for probe response. After receiving a probe response the MD does not wait for Max Channel Time expiration and switch on t the next channel to probe other adjacent AP. This way MD scans only potential APs and channels and do not switch and scan all channels

3.3 Mobile Station Mobility Prediction Method

S Pack and Y Choi in [20] propose MD's authentication at the time of association. The MD gets itself authenticated with not only one AP but also with nearby APs selected through frequent handoff Region. The concerning issue is how to select the neighbor APs. For this purpose the Frequent Handoff Region has been designed which is a set of all adjacent AP that have a good probability to be visited in the next future. A handoff event log database is created which includes all the previous handoff events including Sequence Number, Previous AP, Next AP, Join time, Exit time. The next AP predictability is done by the two parameters handoff ratio and residence time. The handoff ratio is calculated as

$$H_{i,j=} \sum_{k=1}^{N(i,j)} 1 \div R_k(i,j)$$

Here, $N_{(i,j)}$ is number of times handoff occurred from AP_i to AP_j and $R_{(i,j)}$ is the residence time of a MD in K^{th} handoff from AP_i to AP_j. The handoff ratio determines the weight for the edge of a bi-directional graph to predict the next AP. The highest weighted value edge will be considered the next mobility path.

Weetit Wanalertlak and Ben Lee in [21][22] presents a technique named Global Path Cache in order to reduce probe delay when finding new APs. Mohsin et al. has been publishing literature related to significance of schemes to improve efficiency of systems and their maintenance[23][24]. The main idea behind GPC technique is to keep record of previous mobility patterns of mobile stations and frequency of their occurrences, based on these two parameters prediction for the future handoff association is made. GPS maintains a local history at client side using Handoff Sequence Window (HSW) based on N access points, containing current AP and N-1 past APs. There is a cache maintained in the MD side that contains HSW comprising the current AP, N-1 past APs, the next AP and a counter value that is incremented as the MD associates with the next AP. When the MD sends re-association request frame, the server performs two actions against it. It first updates that HSW in its data base. Secondly, it performs next AP prediction. If the server database has maintained already any of record for this current cache key it returns back to MD a Prediction response in which the potential APs are sorted in descending order of their counter value.

4. The Proposed MS Handoff Scheme Flow Chart

Following figure represents the scheme of Handoff. Data transmission starts to flow from current AP cache. As a second step, registration of device is carried out. RSSI is measured to determine correspondence efficiency into WLAN setup. At step 3, RSSI current is processed then NAP file is looked up. Lookup File methodology is applied to find out efficient bandwidth and channels. This would eventually determine potential access point prior to handoff and enhance the maximum frequency. As soon as process is accomplished, re-authentication takes place to acquire maximum throughput.

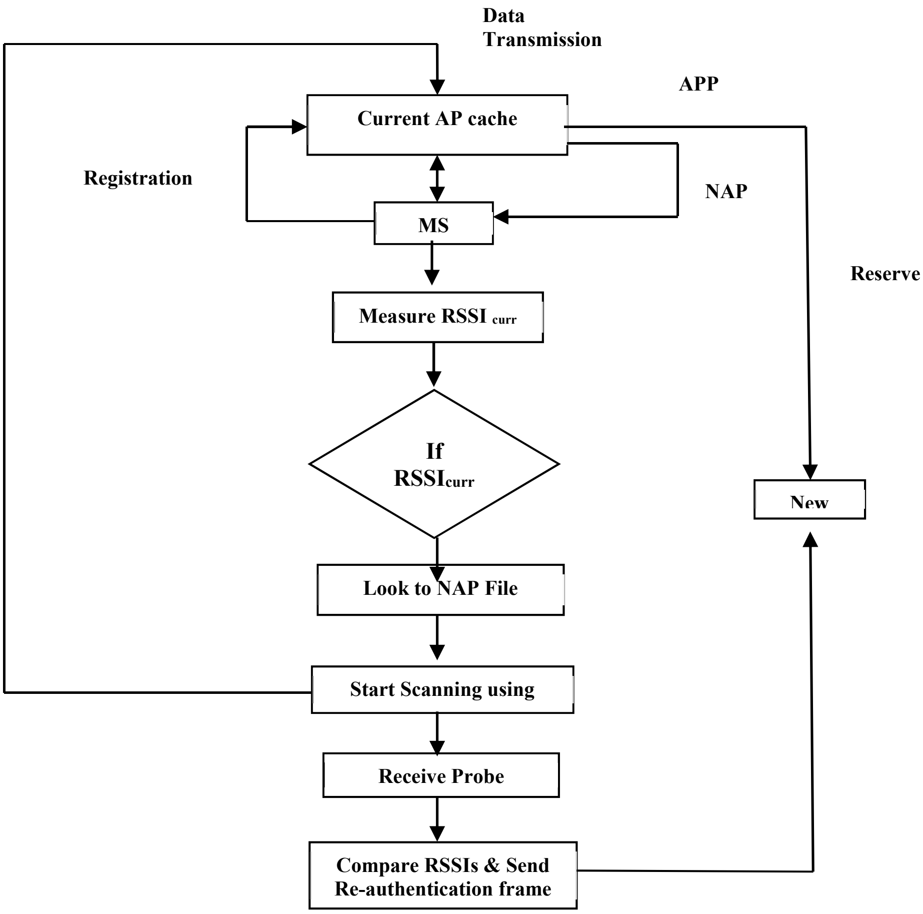


Figure 1: WLAN Network Topology

4.1 The Proposed Scheme Description

The AP creates a fixed size memory block for the data frames intended for this MD and saves the MD's unique ID to its cache when an MD associates with it. A Neighbor Access File is sent by the AP to the MD in response. The NAP file is stored by the MD in its limited cache memory. Following the MD's launch of continuing data exchange transmission.

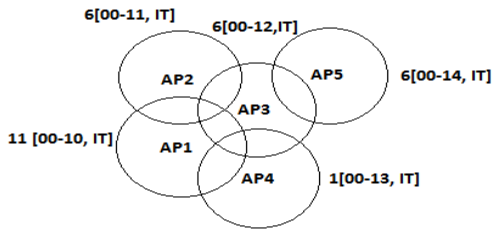
Meanwhile, the MD monitors the RSSI value received from the current AP. The moment this RSSI value reaches to $RSSI_{Pre\text{-}Scan\_HO\text{-}Threshold}$, the MD starts scanning in background by switching its current active mode to Power Save Mode. The MD sends direct probe request frames to all the neighboring APs received in the NAP file. The MD looks in the NAP to know if any neighbor AP is operating in the same channel so as to scan that channel first. This reduces the time for channel switch which is of 5ms. The MD waits on each channel for MinChannel Time because in traditional WLAN handoff procedure the MD if does not receive any probe response during MinChannel Time, the channel is said to be empty. After the MinChannel Time expiration the MD switches to other channel and sends probe request frame. It waits for MinChannel Time and get probe response. After the MD has collected all of the probe responses it compares the received RSSI values of all neighboring APs to get the AP with strongest RSSI value.
The MD discards the other APs and sends the re-authentication frame to newly found best AP. During this AP found and handoff execution process the ongoing transmission data frames are stored in the AP cache against that MD unique ID. When the MD has found new AP, the IAPP is informed to transmit the data frames to that newly found AP. Hence the latency has been reduced also the data frames are not lost during that handoff procedure. Following figure describes the complete scheme.

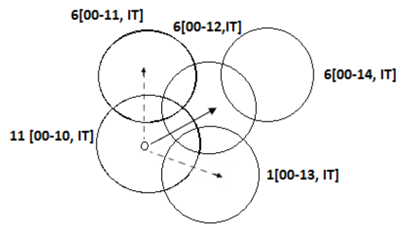
5. Results and Discussion

5.1 Network Topology

Network topology is the design of the network that defines how the network nodes are connected with each other. A WLAN network topology refers to the arrangement of APs in an ESS that create a network. The WLAN network for the proposed system consists of five AP. All of these APs jointly form an Extended Service Set and provide radio coverage to MDs.
The description of APs operating in the described WLAN network topology is mentioned below

- AP1 → Ch [BSSID, SSID] → 11[00-10, IT]
- AP2 → Ch [BSSID, SSID] → 11[00-11, IT]
- AP3 → Ch [BSSID, SSID] → 06[00-12, IT]
- AP4 → Ch [BSSID, SSID] → 01[00-13, IT]
- AP5 → Ch [BSSID, SSID] → 06[00-14, IT]





- Figure 4.2: MD Handoff From AP [00-10] to AP [00-12]

5.2 Scenario One

In scenario one the MD makes its movement from AP [00-10] to AP [00-12].

The MD when associated with AP[00-10] first time, It received a NAP file. As the RSSI reaches $RSSI_{pre\text{-}scan\_hreshold}$ the MD switches o PSM and start scanning. The delay values in scanning APs of NAP file is given below

Table 1: MD Handoff latencies

CH[BSSID]	Delay
11[00-11]	1ms + 20ms (Probe + Stay-Time)
06[00-12]	5ms + 1ms + 20ms (Channel Swich Time + Probe + Stay-Time)
01[00-13]	5ms + 1ms + 20ms (Channel Swich Time + Probe + Stay-Time)

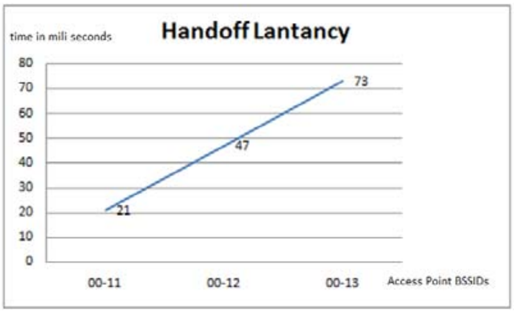


Figure 4.3 Handoff Latency Graph mobility from AP[00-10] to AP[00-12]

The MS is moving from AP [00-10] to AP [00-12] the total latency incurred in AP scan phase reaches up to 73ms.

5.3 Scenario Two

Here is a second scenario where the MD makes its movement from AP [00-12] to AP [00-13].

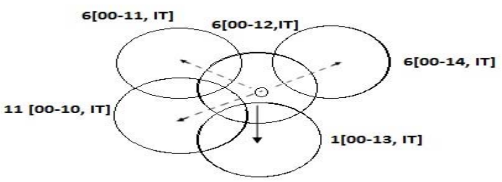


Figure 4.4: MD Handoff from AP [00-12] to AP [00-13]

MD gets the Received Signal Strength Indication values for four neighboring APs. This is maximum number of neighbors among all of the APs. The delay values in scanning neighboring AP is mentioned below

Table 2: MD Handoff Latencies

CH[BSSID]	Delay
06[00-14]	1ms + 20 (Probe + Stay-Time)
01[00-13]	5ms + 1ms + 20 (Channel Switch Time + Probe + Stay-Time)
11[00-10]	5ms + 1ms + 20 (Channel Switch Time + Probe + Stay-Time)
11[00-11]	1ms + 20 (Probe + Stay-Time)

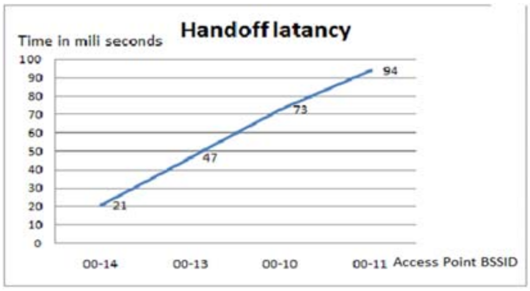


Figure 4.5: Handoff Latency Graph Mobility from AP [00-12] to AP [00-13]

The maximum new AP find latency goes up to 94ms from AP [00-12] to AP [00-13]

6. Conclusion

WLAN technology is highly used in wireless network technology due to its low cost, easy configuration and implementation, high bandwidth and enhanced data rates. All these characteristics make WLAN more prevalent in public spaces and more than that many private spaces. The seamless handoff management is however an issue in WLAN networks due to the limited size of radio coverage provider APs. Thesis suggests a new scheme to reduce the handoff latency at medium access control layer. The proposed scheme efficiently discovers the new access point for the mobile device to associate with before the actual handoff process starts. So when the handoff execution initiates, the mobile device directly makes its association with the found access point. With the proposed scheme the handoff latency is reduced effectively and the mobile device performs a seamless handoff. This seamless handoff ensures less connection drops and guarantees quality of service for the users of the multimedia applications e.g., voice over IP.

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