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A Multimedia and VoIP-Oriented Cell Search Technique for the IEEE 802.11 WLANs

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1. Introduction

With the development and widespread of diverse wireless network technologies such as wireless local area networks (WLANs), the number of mobile internet users keeps on growing. This rapid increase in mobile internet users records a phenomenal growth in the deployment of the IEEE 802.11 WLANs (IEEE Std 802.11, 1999) in various environments like universities (Corner et al., 2010; Hills & Johnson, 1996), companies, shopping centers (Bahl et al., 2001) and hotels. This category of networks then will be the underlying basis of ubiquitous wireless networks by decreasing infrastructure costs and providing stable Internet connectivity at anytime and anywhere (Kashihara et al., 2011; Kunarak & Suleesathira, 2011). Hence many believe that are expected to be part of the integrated fourth generation (4G) network. At the same time, voice over IP (VoIP) is expected to become a core application in the ubiquitous wireless networks, i.e., the next generation cell-phone. Recently, many users have easily used VoIP communication such as Skype (Skype, 2003) in wireless networks. However, in the mobility context WLANs become not appropriate to the strict delay constraints placed by many multimedia applications, and Mobile Stations (MSs) cannot seamlessly traverse the 802.11 Access Points (APs) during VoIP communication due to various factors such as the inherent instability of wireless medium and a limited communication area. MSs are required to find and then to associate with another AP with acceptable signal quality whenever they go beyond the coverage area of the currently associated AP. The overall process of changing association from one AP to another is called *handoff* or *handover* process and the latency involved in the process is termed as handoff latency.

Thus, even if an MS can avoid communication termination at handoff, the following problems must also be resolved to maintain VoIP communication quality during movement. First, the timing to initiate handover is also a critical issue. In fact, late handover initiation severely affects VoIP communication quality because the wireless link quality suddenly degrades. Second, how to recognize which AP will be the best choice among available APs is an issue of concern. Thus, to meet the lofty goal of integrating the next generation networks and to maintain VoIP communication quality during movement, the above requirements must be satisfied.

In fact, in 802.11 networks, the handoff process is partitioned into three phases: *probing* (scanning), *re-authentication* and *re-association*. According to (Mishra et al., 2003; Bianchi et al., 1996) the handoff procedure in IEEE 802.11 normally takes hundreds of milliseconds, and almost 90% of the handoff delay is due to the search of new APs, the so-called *probe delay*. This rather high handoff latency results in play-out gaps and poor quality of service for time-bounded multimedia applications. Other than the latency concern, the MS association with a specific AP is based only on the Received Signal Strength Indicator (RSSI) measurement of all available APs. This naïve procedure needs to be tuned since it leads to undesirable results (many MSs are connected to a few overloaded APs). The handoff process should take into account other context-based parameters, i.e. the load of APs.

In this chapter, we propose an optimized VoIP-oriented version of the Prevent Scan Handoff Procedure (PSHP) scheme (Rebai et al., 2009a, 2010, 2011) that will decrease both handoff latency and occurrence by performing a seamless prevent scan process and an effective next-AP selection. Basically, the IEEE 802.11 PSHP technique reduces the *probe phase* and adapts the process latency to support most of multimedia applications. In fact, it decreases the delay incurred during the discovery phase significantly by inserting a new Pre-Scan phase before a poor link quality will be reached. The available in range APs are kept in a dynamic list which will be periodically updated. As a complementary proposition, the authors in (Rebai et al., 2009b) integrated an effective AP selection based on Neighbor Graph (NG) manipulation and a new heuristic function that employs multiple-criteria to derive optimized search. Furthermore so far, to our knowledge, no adaptive techniques with crosslayering approach have been addressed, on transmitting real-time applications during a handover process. However various cross-layer adaptive rate control methods coupled with the MAC link adaptation have been presented for voice/video applications. Analyzing the opportunity from the literature, this research study focuses on IEEE802.11 handoff optimization using codec adaptation mechanism based on both parameters: codec type and packet size. Through real experiments and performance evaluation, we show effectiveness of the optimized PSHP draft which accomplishes a VoIP transmission over an 802.11 link without interruptions when altering between available APs. The rest of the chapter is organized as follows. Section 2 presents overview of handoff procedure performed in IEEE 802.11 WLANs and discusses related works. We present in section 3 operation details and several simulation results of PSHP Medium Access Control (MAC)-Layer handoff method (Rebai et al., 2011). The new VoIP-oriented PSHP technique and its experimental analysis are shown in section 4 followed by concluding remarks in section 5.

2. Backgrounds and related works

2.1 The Handoff Process in IEEE 802.11

Typically the 802.11 WLAN was originally designed without the consideration of mobility support, MAC layer handoff mechanism enables MSs to continue their communication between multiple nearby APs. However, in regard to the mobility in the WLAN, there exists a problem to support the VoIP applications. When a MS performs handoff to the other AP, it should suffer from significant handoff latency causing the service degradation of the VoIP service where the typical VoIP application requires maximum 20~50ms packet arrival time. First we define the following terms: the coverage area of an AP is termed by Basic service set (BSS). Extended service set (ESS) is an interconnection of BSSs and wired LANs via distributed system (DS) as shown in Figure 1.

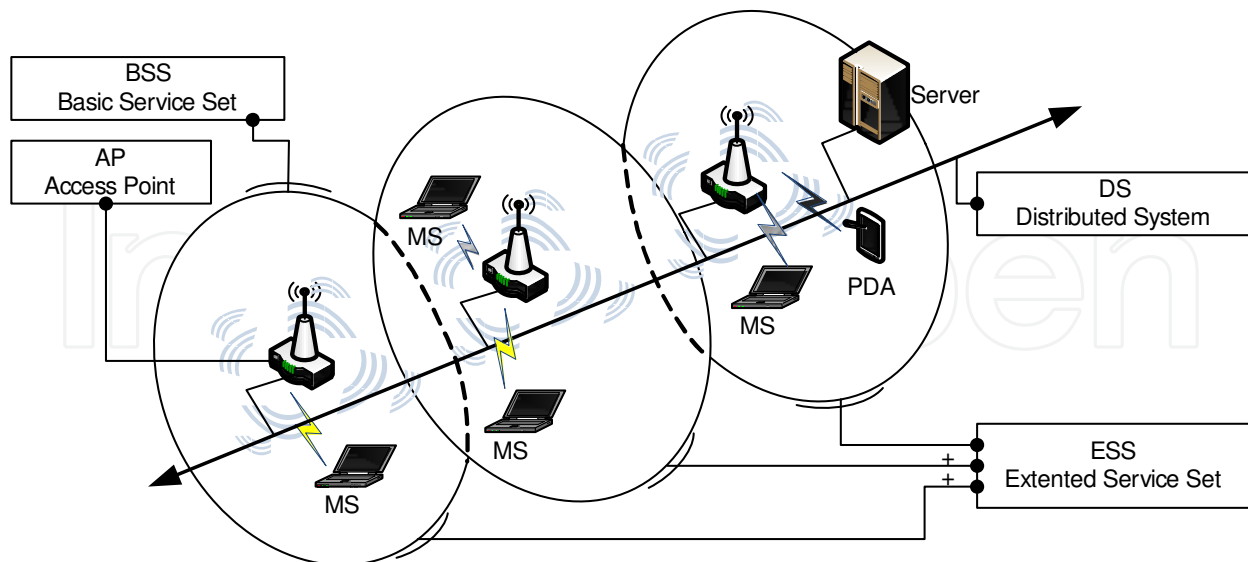


Fig. 1. The IEEE 802.11 infrastructure mode

The inter-cell commutation can be divided into three different phases: *detection*, *probing* (scanning) and *effective handoff* (including *authentication* and *re-association*). In order to make a handoff, the MS must first decide when to handoff. A handoff process in IEEE 802.11 is commonly initiated when the Received Signal Strength (RSS) from current AP drops below a pre-specified threshold, termed as handoff threshold in the literature (Mishra et al., 2003; Raghavan et al., 2005). Using only current AP's RSS to initiate handoff might force the MS to hold on to the AP with low signal strength while there are better APs in its vicinity. As shown in Figure 2, when a handoff is triggered, an AP discovery phase begins and a MAC layer function called scan is executed. A management frame called *De-authentication* packet is sent, either by the mobile station before changing the actual channel of communication which allows the access point to update its MS-affiliation table, either by the AP which requests the MS to leave the cell. Since there is no specific control channel for executing the scan, the MS has to search for new APs from channel to channel by temporarily interrupting its association with the old AP. The scan on each channel can be performed by either passively listening to beacon signals or actively exchanging probe messages with new APs. After a new AP is found and its RSS exceeds Delta-RSS over the old AP, the MS will change its association to the new AP and a *re-authentication* phase begins. During the passive scan mode the MS listens to the wireless medium for beacon frames which provide the MS with timing and advertising information. Current APs have a default beacon interval of 100ms (Velayos & Karlsson, 2004). Therefore, the passive scan mode incurs significant delay. After scanning all available channels, the MS performs a *Probe* phase (used in active mode) only for the selected AP. As mentioned the polled AP is elected only based on RSSI parameter. The 802.11k group (IEEE Std. 802.11k, 2003) works on improving the choice of the next AP taking into account the network. In the active scan mode, the MS sends a *Probe Request* packet on each probed channel and waits *MinChannelTime* for a *Probe Response* packet from each reachable AP. If one packet at least is received, the MS extends the sensing interval to *MaxChannelTime* in order to obtain more responses and the channel is declared *active*. Thus, the waiting time on each channel is irregular since it is controlled by two *timers* (not as passive scan). The selected AP exchanges IEEE 802.11 authentication messages with the MS.

During this phase one of the two authentication methods can be achieved: *Open System Authentication* or *Shared Key Authentication*. Detailed authentication packets exchange has been addressed in (Rebai et al., 2011). After that the MS is authenticated by the AP, it sends *Re-association Request* message to the new AP. At this phase, the old and new APs exchange messages defined in Inter Access Point Protocol IAPP (IEEE Std. 802.11F, 2003). Furthermore, once the MS is authenticated, the association process is triggered. The Cell's information is exchanged: the ESSID and supported transmission rates.

During these various steps, the MS will be not able to exchange data with its AP. Based on values defined by the IEEE 802.11 standard, it is observed that the *re-authentication* which comprises an authentication and an association spends no more than 20ms on average, but a scanning delay may take between 350 and 500 ms and increase considerably the overall *handoff latency* (Mishra et al., 2003; Bianchi et al., 1996). An additional process is involved when the MS needs to change its IP connectivity (Johnson et al., 2004). In such a scenario, the MS needs to find a new access router. Also, the address binding information has to be updated at the home agent and corresponding agent (Cornall et al., 2002).

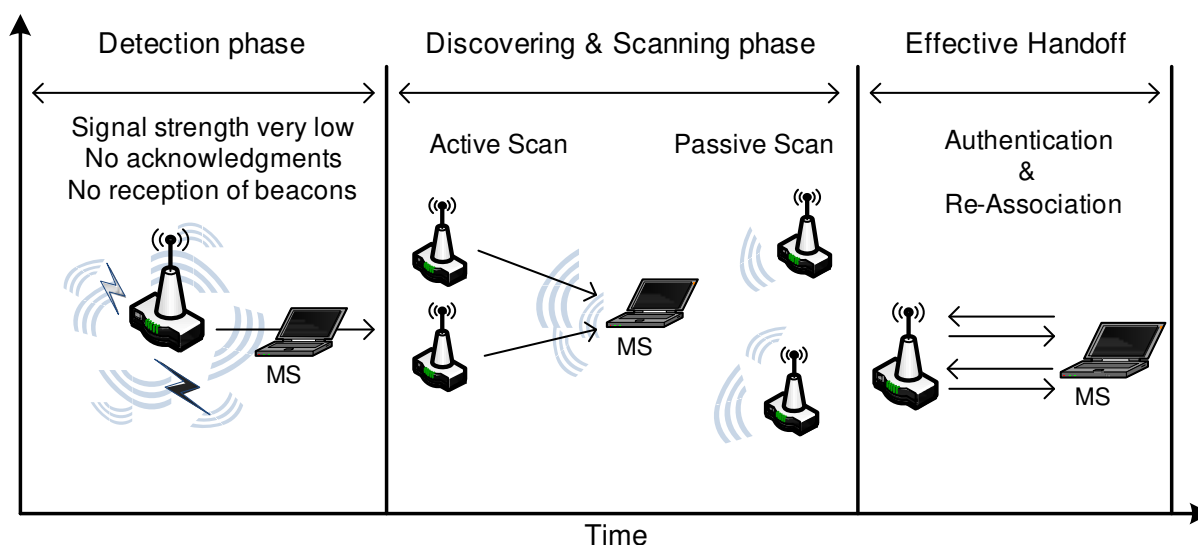


Fig. 2. The 802.11 handover phases

2.2 Literature survey

The *scan* phase of handover is the most costly in terms of time and traffic since it includes the *probe* and the *channel switching* sub-phases. Explicitly, the switching time is negligible and varies between 40 and 150 μ s as it was identified in (IEEE Std. 802.11i, 2004). Within the *passive* scan the interval between beacons is 100ms of IEEE 802.11b with 11 channels and 802.11a with 32 channels, the average latency will be respectively 1100ms and 3200ms. On the other hand, the time incurred with an *active* scan can be determined by the *MinChannelTime* and *MaxChannelTime* values. The *MinChannelTime* value should be large enough to not miss the *proberesponse* frames and obeys the formula given in Equation 1.

$$\text{MinChannelTime} \geq \text{DIFS} + (\text{CW} \times \text{SlotTime}) \quad (1)$$

where, *DIFS* is the minimum waiting time necessary for a frame to access to the channel. The backoff interval is represented by the contention window (CW) multiplied by *SlotTime*. Regarding the *authentication* and *authentication* phases latency are proportional to the

number of messages exchanged between the AP and the MS and limited to the medium access time which depends on the traffic in the cell (such management frames have no special priority). In (Velayos & Karlsson, 2004) these delays are estimated to less than 4ms in absence of a heavy traffic in the new selected cell. Thus, numerous schemes have been proposed to reduce the handoff scan delay in the 802.11 WLANs.

An interesting handoff scheme, called *SyncScan*, is proposed (Ramani & Savage, 2005) to reduce the probe delay by allowing a MS to monitor continuously the nearby APs and to record RSSs from available channel. Essentially, this technique replaces the existing large temporal additional costs during the scan phase. The absence delay of the MS with its current channel is minimized by synchronizing short listening periods of other channels (see Figure 3). In fact, the MS synchronize its next channel probing with the transmission of other APs beacons on each channel. By switching regularly and orderly on each channel, the MS reduces its disconnection delay with its actual AP. However, the *SyncScan* process suffers from regular additional interruptions during the MS absence when exploring other channels. These errors are very costly in terms of packets loss and skipped frames for time-bounded applications. Moreover, this extra charge will affect all MSs even those that will never proceed to a handoff.

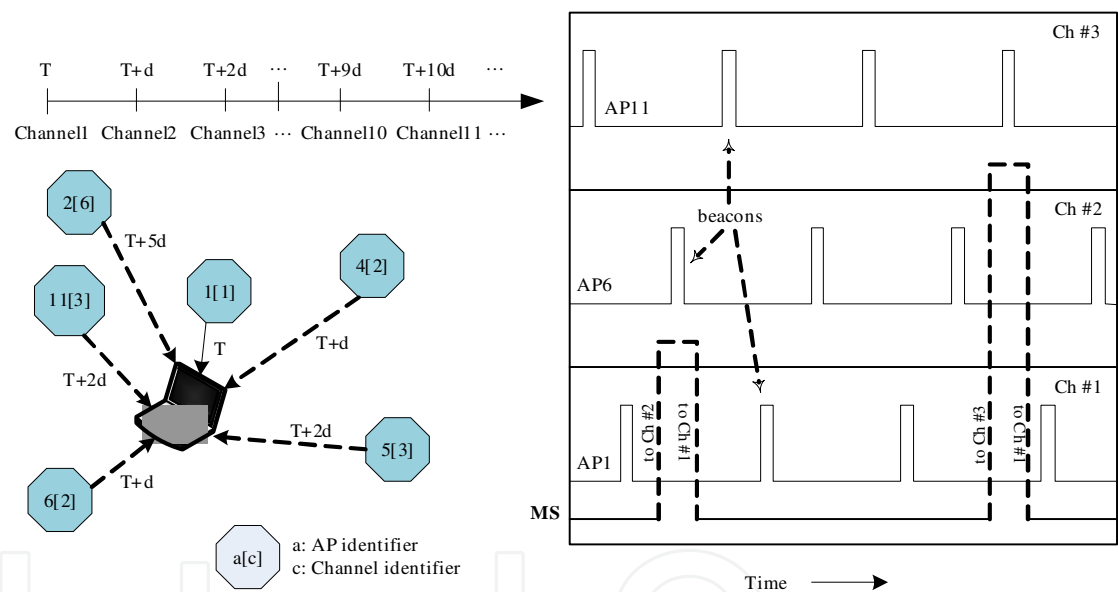


Fig. 3. The SyncScan mechanism

In (Waharte et al., 2004) authors propose an innovative solution to optimize the AP's exploration during the scan phase based on the use of sensors operating on the 802.11 network. As shown in Figure 4, these sensors are arranged in cells and spaced 50 to 150 meters. These sensors have a role to listen to the network using beacons sent periodically by in-range APs. When the MS should change its actual cell, it performs a pre-scan operation which involves the sending of a request query to the sensors. Only sensors that have received this request (in range of the MS) react by sending the list of APs that they have identified. We figure out that this solution is effective in terms of the next-AP choice and the consequent results have improved significantly the standard handoff scheme. However, it is very expensive and has an extra cost by causing an additional load of unnecessary network traffic due to the sensor use. Moreover, this method is a non compliant solution with the actual 802.11 networks and requires radical changes to adapt it.

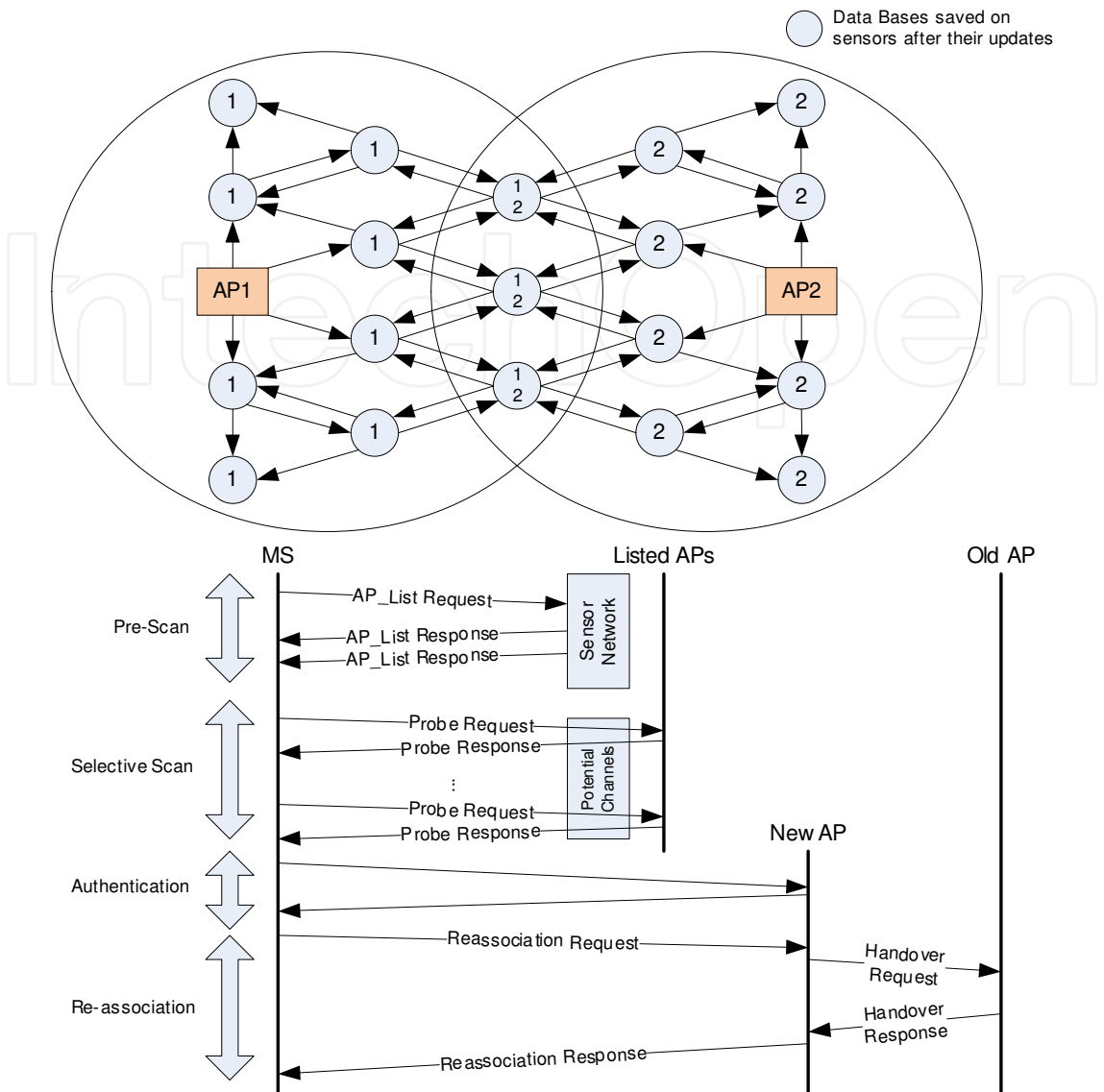


Fig. 4. Sensors-based scan handoff technique

In (Huang et al., 2006), the authors proposed a *selective scan* technique in the IEEE 802.11 WLAN contexts that support the IAPP protocol (IEEE Std. 802.11F, 2003) to decrease the handover latency. This mechanism, as shown in Figure 5, reduces the scan time of a new AP by combining an enhanced Neighbor Graph 'NG' (Kim et al., 2004) scheme and an enhanced IAPP scheme. If a MS knows exactly its adjacent APs - provided by the NG RADIUS server (Radius, RFC 2865 & 2866) - it can use selective scanning by unicast to avoid scanning all channels. They enhanced the NG approach by putting the MS to power-saving mode (PSM) to pre-scan neighboring APs. This solution reduces, in a remarkable way, the total latency of the handoff mechanism. On the other hand, it requires that the MS must have knowledge on the network architecture and its adjacent APs to be able to employ selective scan. In addition, we should take into account the number of packets added by the IAPP that may affect the current traffic. Moreover, we note that all data packets have been sent to the old AP and then routed to the new selected AP before the link-layer is updated, which corresponds to a double transmission of the same data frames in the network. Thus, it greatly increases both the collision and the loss rates in 802.11 wireless networks.

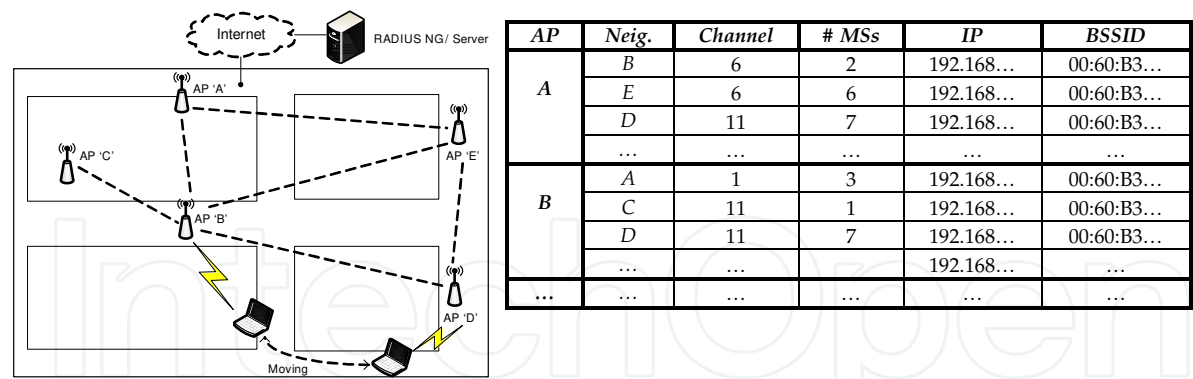


Fig. 5. The NG-based handover architecture

In (Chintala et al., 2007) the authors proposed two changes to the basic algorithm of IEEE 802.11 which reduce significantly the handover average latency using inter-AP communications during the scan phase. In the first proposed scheme (as shown in Figure 6), called Fast Handoff by Avoiding Probe wait (FHAP), additional costs incurred during this phase are reduced by forcing the potential APs to send their probe response packets to the old AP using the IAPP protocol and not to the MS which was sent the probe request. Therefore, the MS will avoid the long probe wait and then the packets loss is considerably reduced without any additional cost in the network. Consequently, during the probe phase the MS switches between channels and sends the probe request. Then it switches back to its actual AP to receive the probe responses.

However, based on this approach we note that the handover threshold should be adjusted so that the MS can communicate with its AP after the probe phase. Also, while the probe response packets are received via the current AP and not on their respective channels, the MS will not be able to measure the instantaneous values of RSSI and then evaluate the sensed channels quality.

In (Chintala et al., 2007; Roshan & Leary, 2009) the authors improved their first solution by proposing a new mechanism called Adaptive Preemptive Fast Handoff (APFH). The APFH method requires that the MS predetermines a new AP before the handover begins. Then, the handover threshold is reached, the MS avoids the discovery phase and triggers immediately the re-authentication phase. This process will reduce the total handover latency to the re-association/authentication delay. The APFH method splits the coverage area of the AP depending on the signal strength in three areas: safe zone, gray zone and handover zone. As its name indicates, the safe zone is the part of the coverage area where the MS is not under a handover threat. The gray area is defined as an area where the handover probability is high. Therefore the MS begins collecting information on a new best AP. This second mechanism removes the entire handover latency and respects the strict VoIP transmission constraints.

Many research works were done on the network-layer regarding the challenge to support the mobility in IP networks – i.e. IPv6 (Johnson et al., 2004; Cornall et al., 2002). A detailed review of the most relevant methods and a deep time study of the handoff process have been presented in (Rebai et al., 2009a, 2009b; Ramani & Savage, 2005).

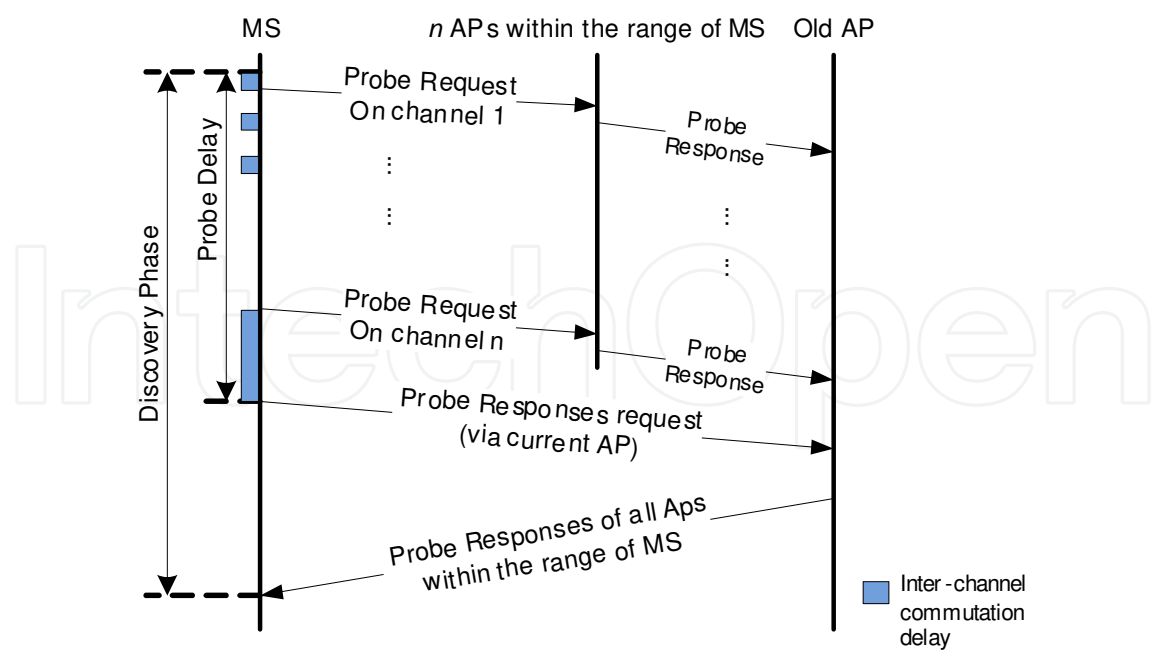


Fig. 6. The discovery phase of the FHAP method

3. Prevent-Scan Handoff Procedure (PSHP)

In (Aboba, 2003) it has showed that the typical handoff latency in IEEE 802.11b with IAPP network may take a probe delay of 40 to 300ms with a constant IAPP delay of 40ms. To allow the IAPP protocol to reduce this delay, we firstly have imposed (Rebai et al., 2009b) that the MS must authenticate with the first AP of the ESS. The IAPP based pre-authentication (Orinoco T.B., 2000) is achieved even before MS enters into the discovery state, thus it does not contribute to the handoff latency. Then we have proposed (Rebai et al., 2011) to define a new threshold other than the existing handoff threshold. It is called Preventive RSSI and termed by ($RSSI_{prev}$) and defined in the given Equation 2.

$$RSSI_{prev} = RSSI_{min} + (RSSI_{max} - RSSI_{min})/2 \tag{2}$$

where, $RSSI_{max}$ indicates the best link quality measured between a MS and its AP. As its name implies, the $RSSI_{prev}$ is a value of the *link quality* above which the MS is not under the threat of imminent handoff. Starting from this threshold the proposed algorithm detects the mobility of a MS and triggers the next-AP search which can offer a better link quality.

A continuous *pre-scan* process is generated in which the MS should switch channels and wait for beacons from potential APs. Since the switching and waiting delays are greater than the maximum retransmission time of 802.11 frames (4ms), time-bounded packets may be dropped by the MS (not able to acknowledge them). To overcome this drawback, the algorithm let the MS announces a Power Saving Mode (PSM) before switching channels (Baek & Choi, 2008). This causes the AP to buffer packets until the MS returns to its channel and resets the PSM mode. These buffers will not be overfilled during the PSM mode (very short in duration). In addition the *pre-scan* is programmed so that it does not disturb the existing traffic flow between the MS and its AP. Figure 7 presents the new state machine for a MS showing the various amendments that we have added to the basic algorithm.

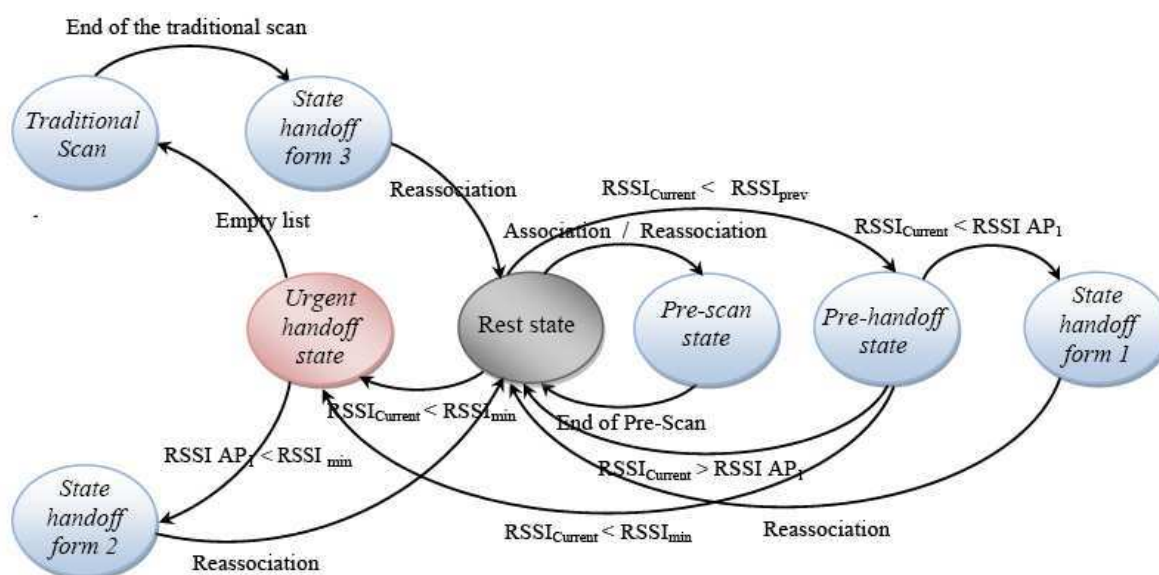


Fig. 7. State machine of the PSHP procedure performed by the mobile station

The major advantage of the proposed scheme resides in the periodicity of checking for a new AP offering a better quality of link for forthcoming transmissions. The pre-scan phase is launched each α defined by the following Equation 3:

$$\alpha = \left[(T_{switch} + MaxChannelTime) \times N \right] \times 1.5 \quad (3)$$

where, T_{switch} is the switching delay from one channel to another, and N is the number of available channels.

In the PSHP scheme we enumerate three forms of handoff that can be happened depending on network conditions. Initially, the MS is in standby state. If the RSSI value associated to the current AP degrades and reaches the $RSSI_{prev}$, then the MS switches to the pre-handoff state to check its dynamic list. It will try to find out a new AP with a corresponding RSSI value higher than the actual one. If such value exists, the MS switches to a 'handoff form1' state and performs a re-association procedure with the chosen AP. Otherwise, the MS returns to its standby state. If the measured RSSI value with the current AP is deteriorating suddenly and reaches the minimum bound (handover threshold), then the MS passes directly from the standby state to the 'urgent handover' state. In such state the MS must decide whether to perform the second or the third form of handover depending only on the instantaneous data of the dynamic list. If the first-listed AP has a value of RSSI greater than the handover threshold, then the MS switches to the 'handover form2' state. If such case does not exist, the MS switches to the 'handover form3' state in which it carries out a classical 802.11 handoff with a traditional scan procedure. We note that during the first two handoff occurrences (form1 and form2) the overall latency is equal only to the re-association delay, while using the 'handoff form3' is rare in practice (after carrying out pre-scan cycles).

3.1 Multiple-criteria AP selection technique

A second PSHP add-on mechanism for the AP selection was proposed initially in (Rebai et al., 2010). The proposed techniques aims to choose the most adapted AP from available APs

for the next handover occurrence. The basic procedure is considering only the RSSI value as an indicator of the AP quality. This naïve procedure, leads to the undesirable result that many MSs are connected to a few APs, while other APs are underutilized or completely idle. In (Chou & Shin, 2005) the authors argued that the login data with the APs can reflect the actual situation of handovers given discrete WLAN deployment. As an example (see Figure 8), two WLANs may be very close to each other but separated by a highway or a river. Conversely, if the user is moving fast (e.g. in a train), handover may need to take place among WLANs that are far apart, i.e. among non-neighbor APs. Thus, the context user history allows us to better predict the probability of the user’s next movement.

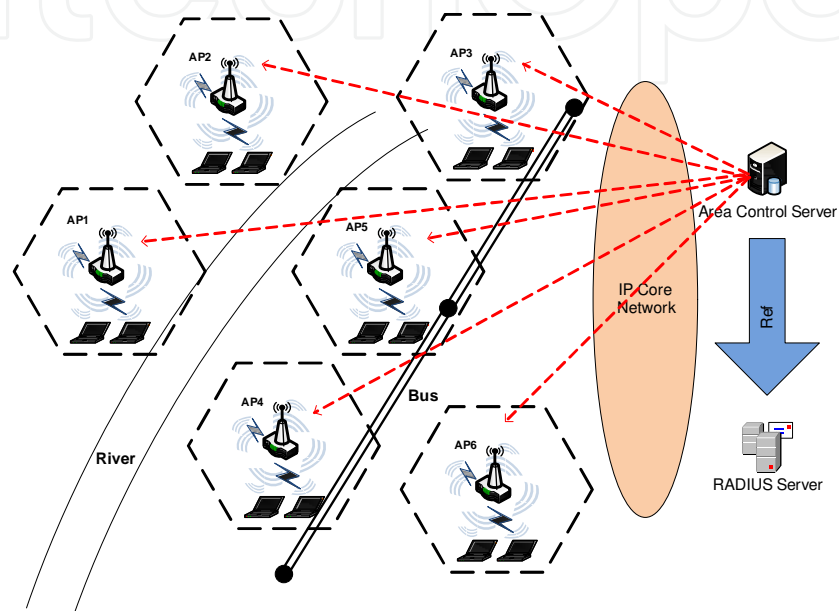


Fig. 8. Example of an IEEE 802.11 infrastructure-mode WLAN

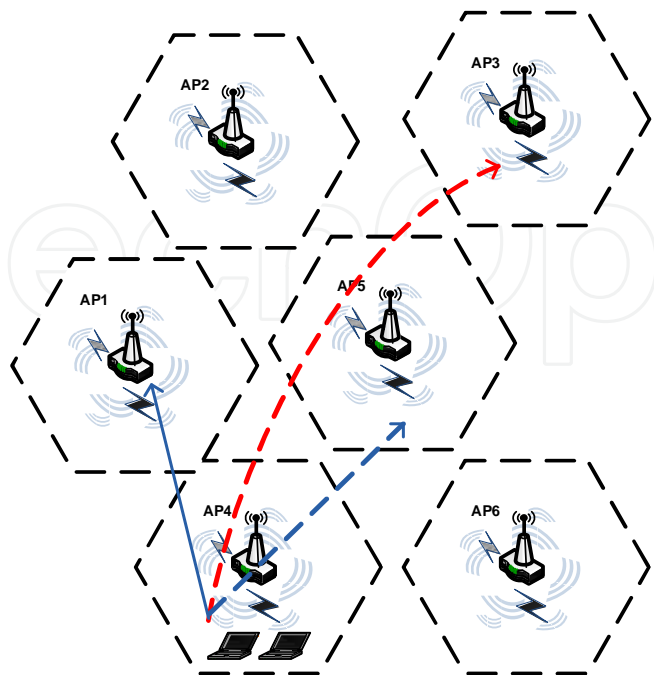


Fig. 9. Handoff scenario for a MS moving towards AP3

A new network-configuration method - that differs from the RSSI constrained process (Shin et al., 2004) – has been proposed by introducing three new network parameters to optimize the next-AP selection during a WLAN handoff procedure (Rebai et al., 2010). The first parameter reproduces the number of MSs associated with an AP to exploit the overload factor of APs. The second parameter counts the handoff occurrence between the actual AP and each potential AP, and so represents significant history-based information. This counter is incremented by one each time a handoff occurs between the corresponding two APs. It includes the location and other context-based information useful for the next AP-selection. The third parameter reproduces the number of neighbors APs of the next handover chosen AP. In other words, is reflects the number of 2-hop neighbors of the current AP through a potential AP. This “look-ahead” parameter is added to improve the choice of the next AP to maintain long-term connections. A full numerical optimization approach for the next-AP selection was discussed in (Rebai et al., 2010) as well as its application results.

To elucidate the concept further, Figure 9 shows a sample handoff situation for a mobile moving from AP4 towards AP3. The standard 802.11 approach would handoff the mobile station (MS) to AP1 based on RSSI strength only. Then after few attempts it may switch the mobile to AP5. The proposed approach would result in a handoff directly to AP5 based on better handoff history criteria between AP4 and AP5 (high occurrence because of the bus trail), and more 2-hop neighbors through AP5. As the number of MSs was increased, with a bias towards moving to AP3, this add-on heuristic technique demonstrates clear advantage over the simple RSSI only approach and reduces considerably the handovers over the WLAN.

3.2 PSHP simulation results

In this section, the performance of the proposed scheme PSHP is evaluated and compared to the basic handoff scheme (currently used by most network interface cards) and other significant works founded in (Velayos & Karlsson, 2004; Ramani & Savage, 2005; Chintala et al., 2007). The handoff latencies of all schemes for different traffic loads are presented. This is followed by discussion on the total amount of time spent on handoff for all schemes. The effect of the proposed schemes on real time traffic is explored and weighed against the basic handoff scheme. We used C++ to simulate the new 802.11 handoff versus other described techniques. The IEEE 802.11b (IEEE Std. 802.11b, 1999) networks are considered for testing the schemes. The total number of the probable channels is assumed to be 11 channels (number of all the legitimate channels used in USA for 802.11b). We employed a total of 100 APs and 500 MSs to carry out the simulations. The other parameters are outlined in Table 1.

Parameter	Value
Speed of MS	0.1 – 15 m/s
Mobility Model	Random Way Point
MinChannelTime / MaxChannelTime	7/11 ms
Switch Delay	5 ms
Handoff Threshold	-51 dB
Pre-Scan Threshold	-45 dB

Table 1. Simulation Parameters

In general, all the suggested solutions to optimize the handoff process aim to reduce the total latency below 50ms (International Telecom Union [ITU], 1988) mainly for multimedia applications. The proposed PSHP solution aims to be conforming to this restriction by reducing the total handoff delay incurred in 802.11 WLANs. We choose a free propagation model for the mobile stations. Thus, in performed simulations the received signal strength indicator value is based on the distance between a MS and its AP (RSSI-based positioning) as shown in (Kitasuka et al., 2005; Rebai et al., 2011). The adopted mobility model is based on the model of random mobility "Random Way Point Mobility Model" presented in (Boudec, 2005). The same moving model has been also adopted in other algorithms (Ramani & Savage, 2005; Huang et al., 2006; Kim et al., 2004; Chintala et al., 2007).

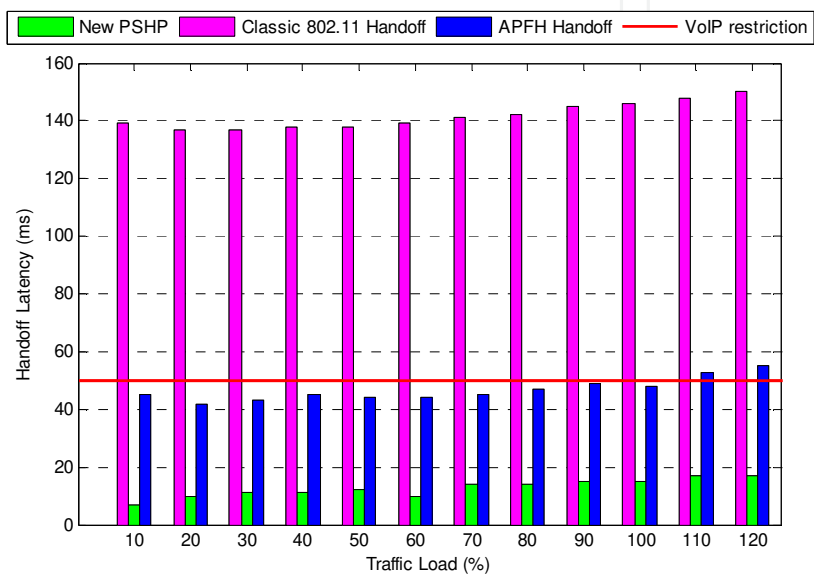


Fig. 10. Handoff Latency versus Traffic Loads

Figure 10 shows the average handoff latency against different traffic loads for the three tested schemes. The APFH scheme achieves 67.62% delay improvement while the new PSHP method attains 95.21% improvement versus the basic 802.11 handoff scheme. The handoff latency of the classical approach is consistent with the simulation results in (Velayos & Karlsson, 2004) with similar parameters. Also, we point out by observing Figure 8 that the average handoff latencies for the PSHP and APFH schemes are both under 50ms which is well within VoIP constraints. However, PSHP performs the best and the minimal handoff delay compared to the APFH (Chintala et al., 2007). This remarkable improvement is reached since the new procedure performs a cyclic pre-scan phase before carrying out a handoff and most of handoffs are accomplished early by detecting the premature quality deterioration. As in (Ramani & Savage, 2005; Chintala et al., 2007) the traffic load is computed by dividing the number of active MSs (the MSs having data to transmit) over the maximum number of MSs transmitting on one AP's cell. The maximum number of active MSs is equal to 32 in IEEE 802.11 WLANs.

Based on the given results in (Mishra et al., 2003; Ramani & Savage, 2005; Kim et al., 2004) of related handoff techniques, we draw the following Table 2 resuming the total handoff delays for corresponding proposed mechanisms. We figure out a significant reduction achieved by the new PSHP algorithm compared to other solutions, and more specifically

with the basic handover mechanism. We also note that the *SyncScan* solution satisfies the time-bounded applications. However, the selective scanning method occasionally exceeds the required QoS limits. This result is due to the inefficacy of the NG graph technique to manage all network topology changes due to the continuous MS mobility. With PSHP the total latency is reduced to the re-authentication phase ($\approx 11\text{ms}$). This delay may reach 18ms because in some simulated cases a handoff occurrence is triggered during a pre-scan cycle.

Scan Technique	Total Latency
SyncScan (Ramani & Savage, 2005)	40±5ms
Selective Scan (Kim et al., 2004)	48±5ms
APFH (Chintala et al., 2007)	42±7ms
Traditional 802.11 handoff	from 112ms up to 366ms
Proposed PSHP	11±7ms

Table 2. Average latencies of different handoff procedures

Figures 11 and 12 evaluate the performance of the APFH technique – the best known solution in literature – and the new PSHP scheme against VoIP traffic. The packet inter-arrival time for VoIP applications is normally equal to 20ms (Chen et al., 2004), while it is also recommended that the inter-frame delay to be less than 50 ms (ITU, 1988; Chen et al., 2004). This restriction is depicted as a horizontal red line at 50ms in Figures 11 and 12. A node with VoIP inter-arrival time is taken and the corresponding delays are shown. The vertical green dotted lines represent a handoff occurrence. The traffic load for the given simulations was fixed to 50% and the number of packets sent to 600 ($\approx 2.5\text{s}$). We note that handoff occurrences are not simultaneous for the two simulated patterns. The MSs adopting the new PSHP algorithm detect the quality deterioration with their corresponding AP earlier than the APFH process. We note that both techniques respect the time constraint of real-time applications on recorded inter-frame delays without exceeding the required interval (50ms). However, this constraint is better managed by the new approach and the inter-packet periods are more regular and smaller. As discussed before, the PSHP handoff latency is only reduced to re-authentication delay if all handovers occur under form1 and 2. If PSHP form3 is performed, the latency is equal to the delay incurred in legacy 802.11 scanning all channels in addition to re-authentication delay.

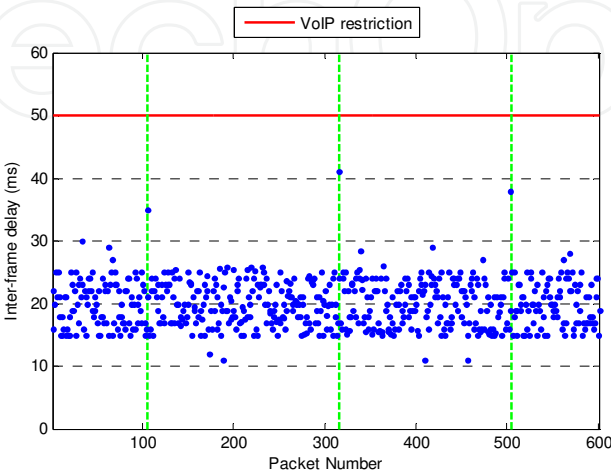


Fig. 11. Inter-frame delay in APFH (Chintala et al., 2007)

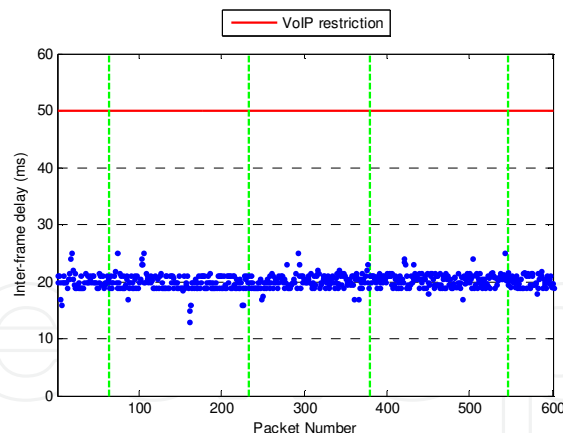


Fig. 12. Inter-frame delay in PSHP

To emphasize the last assertion we present in Figures 13 and 14, respectively, a count of handoff occurrences for both APFH and PSHP schemes according to the traffic load and the detailed number of the various handoff forms related to the new PSHP technique. We set the simulation time to 10s for each considered traffic load.

By comparing values obtained by the two algorithms in Figure 13, we easily point out that the APFH technique (Chintala et al., 2007) performs less handovers in the network than the proposed PSHP scheme. This result can be explained by the adoption of the new form of preventive Handover (termed form1). Using this new form, a MS will not wait for a minimum quality recorded equal to the handoff threshold to trigger a handover. This new technique detects early the link quality deterioration with its current AP and performs an AP-switching to potentially improve link conditions. Therefore, the periodic pre-scan adopted by the new technique offers new opportunities to enhance the link quality between a MS and its AP and a significant reduction of the total handover delay. Indeed, with the pre-scan cycle the MS can discover other APs that have a better value of RSSI than provided by the current AP and provide the means to make more intelligent choices before and during a handover. The new algorithm PSHP has a better choice for the next AP by collecting periodic RSSI measurement. Thus, the decision is earlier and more beneficial when a handover is performed (rather than relying on a single sample as in usual schemes). Consequently, the extra number of PSHP occurrences versus APFH procedure happenings is compensated by an early choice of next AP with a better offered quality.

In Figure 14, the vertical red lines represent the executed number of form1 handoffs. Blue lines represent the number of handoffs taken under the second and third form, i.e. urgent handoffs. Recall that handoff under the first form is started when the RSSI value degrades below the $RSSI_{prev}$ and above the handoff threshold. Handoffs of the second and third form start only if RSSI value is degraded below the handoff threshold. In Figure 14 we figure out for most traffic loads, urgent handoffs occur less frequently than handoffs of form1. We also state that the proposed algorithm presents true opportunity to improve link quality since most of handoff occurrences are executed before that the RSSI value degrades below the handoff threshold. Accordingly, we conclude that almost half of accomplished handoffs are done under the new first form, which explains the delay reduction of PSHP since the first form decreases the related latency considerably and improves the link quality between the MS and its current AP.

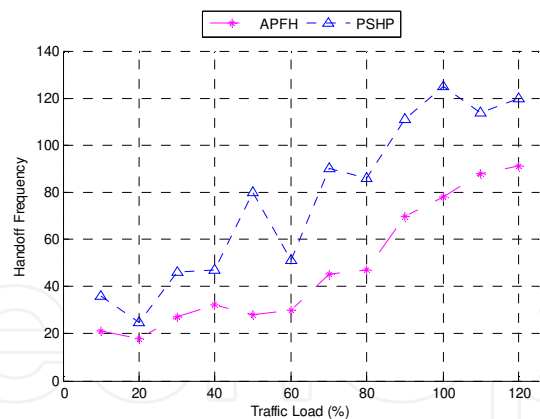


Fig. 13. Handoff Frequency

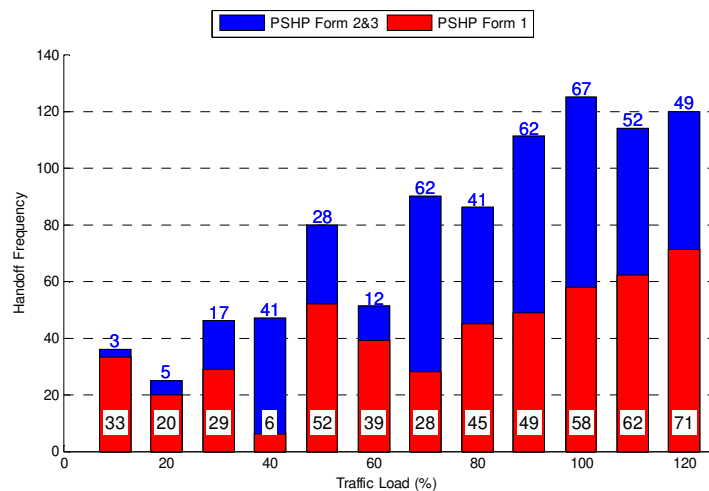


Fig. 14. Occurrence of Handoff forms in PSHP

Table 3 shows the average probability of data packets being dropped and caused mainly by handoff procedure for the three schemes (APFH, PSHP, and the classic 802.11 approach). We also add the obtained result in (Ramani & Savage, 2005; Kim et al., 2004) for *SyncScan* and *SelectiveScan*, respectively. For comparison purposes, the traffic load for all nodes is divided into real-time and non real-time traffic with a ratio of 7.5/2.5. Other than errors caused by handoff occurrences, the real-time data packets are dropped also if the inter-frame delay exceeds 50ms. The simulation time for each traffic type is 10s (equivalent to about 2500 frames). Clearly, PSHP outperforms the other three schemes and the basic 802.11 as long as the traffic load is limited. The loss probability value of the new PSHP technique is divided by two compared to these obtained by *SyncScan* and *SelectiveScan* methods and by three of that accomplished by the standard 802.11 scheme.

Scan Technique	Loss Probability
SyncScan (Ramani & Savage, 2005)	0.92 x1E-02
Selective Scan (Kim et al., 2004)	1.28 x1E-02
APFH (Chintala et al., 2007)	0.72 x1E-02
IEEE 802.11 handoff	1.62 x1E-02
New PSHP	0.53 x1E-02

Table 3. VoIP packet’s loss

In conclusion, periodic scanning also provides the means to make more intelligent choices when to initiate handoff. The new PSHP can discover the presence of APs with stronger RSSIs even before the associated AP's signal has degraded below the threshold. In addition, the pre-scan phase does not affect the existing wireless traffic since the corresponding MS will carry out a pre-scan cycle after declaring the PSM mode to buffer related packets.

3.3 Evaluation of the new add-on AP-selection heuristic

As mentioned above we add new context-based parameters for the next AP choice when a handover is triggered in the network by a MS. The result technique is not dependent on the used handoff method. Thus, we integrate the new developed heuristic function with both the classic and the proposed switching algorithm. Specifically, in the standard 802.11 method the next AP selection will be performed after the scan phase on the found APs by choosing one based on the new objective function. Regarding the PSHP procedure this choice will be performed after each pre-scan cycle only on APs belonging the associated dynamic list. This function is also performed for both handoff form2 and form3. The only algorithm modification in PSHP form1 handoff process is that the objective function is performed only on listed APs that have an RSSI value greater than the actual RSSI measured between the MS and its actual AP. By adopting this condition we always maintain the main purpose of the PSHP which is an earlier selection of a new AP that offers a better link quality. Therefore, the modified PSHP will not choose automatically the first best AP in the list. However, it will select from existing AP that maximizes the objective function and also offers a better channel link quality. We set the same simulation parameters as given in Table 1. However, we add geographic constraints by influencing some MS-AP link qualities depending on AP initial positions and by introducing initial specific values for the CNX parameter to illustrate the already performed MS-journeys in the network and a random primary associations between MSs and the given set of APs. The simulated mobility model regarding the MS moves is no longer "Random Way Point". To be closer to realistic networks and to better assess our mechanism we switch to the "Random Direction" Mobility Model which forces mobile stations to travel to the edge of the simulation area before changing direction and speed. We choose this model because of its inclusion simplicity and instead of the "City Section" Mobility Model – which represents streets within a city. By including these constrain, we evaluated of the proposed heuristic combined with handoff schemes. In Figure 15 we resume the handoff occurrences for both classic and modified handoff schemes for the standard 802.11 and the PSHP techniques according to the traffic load. We set the simulation time to 10s for each considered traffic load. We point out a perceived reduction for handoff occurrences for both schemes when using the proposed heuristic procedure during the next AP selection. The produced results with the PSHP procedure are clearly enhanced in term of handoff count by integrating the new add-on heuristic technique. This result reflects the pay effect of the new objective function that accomplishes a better AP choice for the next inter-cell commutation, and consequently, improves the total number of handoff happening by reducing worse AP selections that was based only on RSSI-measurement decisions.

The detailed number of the various handoff forms related to the extended PSHP technique is shown in Figure 16. As well as in Figure 14, the vertical red and blue lines represent, respectively, the executed number of form1 handoffs and the count of handoffs taken under the second and third form (called also urgent handoffs). We figure out that handoffs form1 –

performed when the RSSI value degrades below the $RSSI_{prev}$ threshold – are more triggered using the modified PSHP. We note that the proposed algorithm detects earlier the MS path and direction based on supplementary context-based information, and as a result, chooses quicker the best AP that improves the link quality and offers a continuous channel connection. Accordingly, 72% of accomplished handoffs are done under the first form of PSHP that decrease considerably the total latency and improves the link quality. As discussed before, data packets are dropped mainly by the handoff procedure and the violation of VoIP restrictions. Table 4 summarizes the data loss average probability for both classic 802.11 and PSHP approaches. As settled before the simulation time is 10s. The traffic load for MSs is equally combining real-time and non real-time traffic. The given results are the average of simulated values by varying the traffic load (from lower to higher loads).

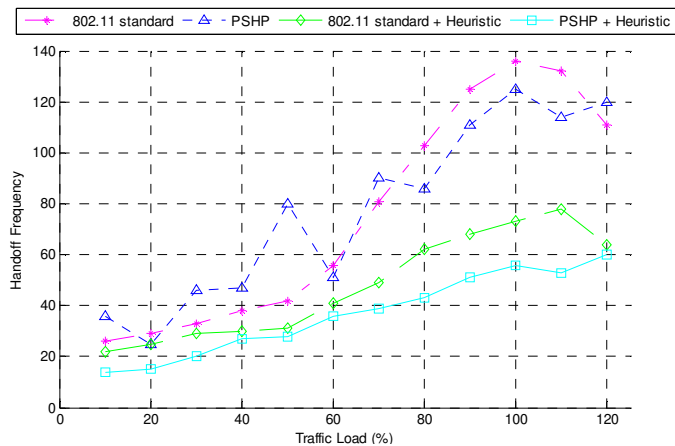


Fig. 15. WLAN Handoff’s frequency

Scan Technique	Loss Probability
Standard 802.11 handoff	1.62 x1E-02
PSHP	0.53 x1E-02
IEEE802.11+heuristic selection	0.78 x1E-02
PSHP + heuristic selection	0.32 x1E-02

Table 4. Packet’s loss with heuristic selection

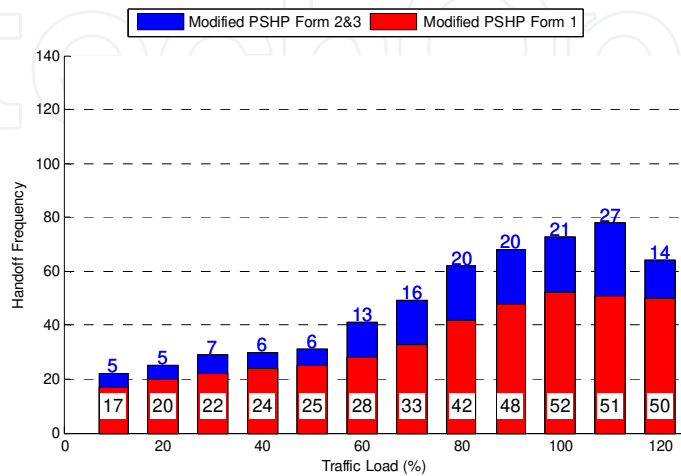


Fig. 16. Handoff Occurrence in PSHP

We note that the modified PSHP version is outperforming the standard scheme. The reduced number of handoffs and also the high percentage of form1 handoffs lead to minimize the packet loss caused by handoff procedures. Thus, we can conclude that the loss probability value obtained by the new PSHP integrating the heuristic technique includes mainly dropped packets associated to a higher traffic load and not linked to the lack of respect of QoS constrains.

In this section we have established that the proposed merit function used to evaluate network performance based on user preferences was adopted to find the best possible next-AP for the MS and to determine the optimal target AP based on a heuristic prediction process.

4. A new cross-layer signaling approach for VoIP-oriented PSHP mechanism

Although the layered architecture of the network model is designed for wired networks and it served that purpose well, it is still not efficient enough for wireless networks (Srivastava & Motani, 2005). Consequently, the wired network layering structure is not sufficient enough to support the objective of transmitting real-time applications over WLAN. There have been several methods and algorithms designed to improve the performance of wireless network for real-time transmission. However, some studies and surveys showed that cross-layer approach has a great impact on improving transmission performance of real-time traffic over wireless networks, and thus over WLAN. The concept of cross layer approach is that it allows the network layers to communicate and exchange information with each other for better performance (Ernesto et al., 2008). On the other hand, since no specific codec can work well in all network conditions (Karapantazis & Pavlidou, 2009), developing codec adaptive techniques have been proposed. Although developing this mechanism is still in its early stage (Myakotnykh & Thompson, 2009), different adapting codec rate schemes were proposed particularly for real-time applications in wired, wireless, or WLAN networks. Codec rate adaptation technique is defined as a technique that adjusts codec parameters or changes it to another codec with lower rate when the network gets congested. Codec parameters that can be considered in this technique are: packet size and compression rate (Myakotnykh & Thompson, 2009). Besides, adaptive rate approaches have been implemented using different constant bit-rate codec or variable bit-rate codec, such as AMR (Servetti & De Martin, 2003) and Speex (Sabrina & Valin, 2008). Moreover, it was shown that adaptive approaches perform better than constant bit rate (Servetti & De Martin, 2003; Sabrina & Valin, 2008). Table 5 (Karapantazis & Pavlidou, 2009), below illustrates parameters of different codecs. It was also concluded that for WLAN adapting the packet rate of a codec is sufficient with remaining the same codec type. Thus, changing packet size is an important parameter and would produce results of better quality (Myakotnykh & Thompson, 2009); hence it is considered in the approach.

Hence, our objective is to develop a cross-layering approach between MAC and Application layers. An agent will be designed and positioned as a mean of implementing the approach, which mainly aims to reduce VoIP delay and packet loss over WLAN, and therefore achieving better quality of VoIP. This section will focus on addressing a cross layer signaling technique in WLAN during handoff event by using the codec adaptive technique.

	G.711	G.726	G.729A	G.723.1
Bit rate (Kbps)	64	32	8	5.3
Bits per frame	8	4	80	159
Compression type	PCM	ADPCM	CS-ACELP	ACELP
Codec delay (ms)	0.25	0.25	25	67.5
MOS	4.1	3.85	3.7	3.6

Table 5. Voice codec Parameters

4.1 Cross Layer Adaptive Agent (CLAA)

In order to improve the QoS of VoIP during a handoff procedure, a cross-layer agent is proposed to allow the communication between MAC and Application layers. This new Cross Layer Adaptive Agent (CLAA) monitors the MAC handoff state changes and then adapts the suitable packet size and the codec type in the Application layer (Figure 17).

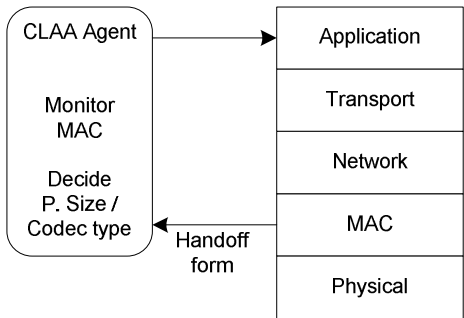


Fig. 17. Cross Layer Adaptive Agent (CLAA) model

The main function of the agent is to detect if there is a change in the PSHP state machine traced in the MAC layer. If such change occurs, it will inform the Application layer to act accordingly and better compensate either by the packet size at the codec algorithm in a dynamic manner in order to minimize channel congestion in WLAN or by codec type change. The other key point is that the agent tries to resolve congestion that the MS suffers locally firstly. If the congested MS condition is getting worse, then a second decision-phase will assist the agent to reduce the congestion.

We point that the CLAA agent is implemented only on local mode (sender side) since a global mode involves a collaboration between the sender and the receiver nodes. Such operations entail the receiver to send back to the sender information regarding the voice quality through its current AP which leads for extra network congestions during a handoff procedure. Figure 18 shows a descriptive flow chart of the local CLAA function.

Therefore, the agent chooses to resolve the handoff process issue locally at the sender side. This phase is in an open loop monitoring MAC layer and observes if any changes on the PSHP state/handover form occurred. If so, then the agent decides a new packet size/codec type and informs the Application layer to adjust. In fact, when MS detects a potential handoff (PSHP pre-handoff state) with one new cell (selected from the listed APs) offering a better quality, it initiates the handoff form1 state and simultaneously the CLAA agent decides to reduce the packet size to reduce congestion and packet loss during this short

handoff period. However if a transition from pre-handoff state to an urgent handover state is triggered by the PSHP mechanism, the CLAA will change moderately the codec type. By doing so the resultant bit rate is lowered to prevent from large delay transmissions and enhance the overall received voice quality. Of course the codec type adaptation has a minor effect to decrease the received VoIP quality; however it will eliminate the RTP stream interruption on the receiver.

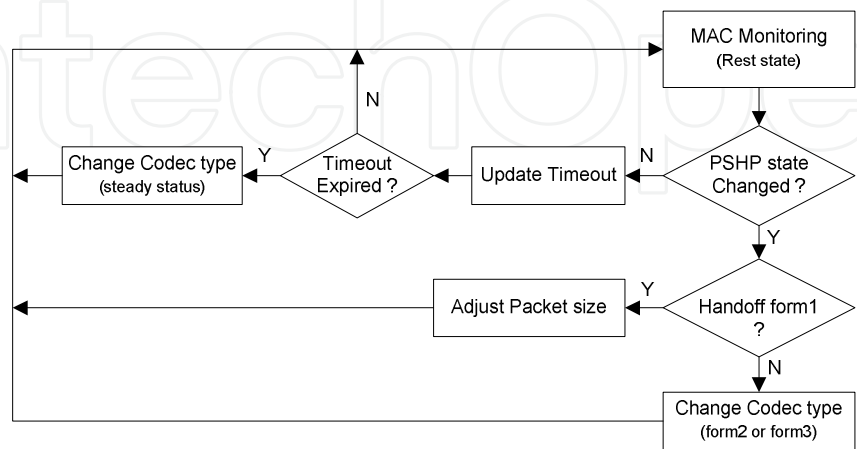


Fig. 18. CLAA flowchart and principle of operation

On the other hand, following to an inter-cell occurrence involving a codec alteration a threshold will be set, thus no consecutive changes will happen at the Application layer. If the agent detects a long steady status (Rest state in the PSHP state machine) within a pre-defined timeout, then codec type would be changed to a higher one with larger bit rate. The codec techniques are sorted based on their bit rate (as shown in Table 5) for the agent to select accordingly.

4.2 Performance evaluation and discussions

The testbed used in the performance tests of the proposed VoIP-oriented PSHP method is shown in Figure 19. The mobile client’s 802.11b driver has been slightly modified to provide transport of the necessary cross-layer related information during handoffs. The Chariot Console [NetIQ] was used to measure the handoff performance under real-time and multimedia traffic. In all tests, three laptops (MS1 MS2, and MS3) were running VoIP sessions towards three different PC hosts (RTP Stream, Chariot G.711u script).

The measurements were taken for movements between different APs (a likelihood path is shown in Figure 19 using a dotted blue line). Both of MS1 and MS2 are implementing PSHP + the Heuristic function while MS3 uses only a standard PSHP driver. The MS1 includes also the designed VoIP-oriented CLAA Agent. All MSs were initially located in AP1, and then moved around the university lab rooms and the hallway following a predefined path and using a constant 1~2m/s speed over potential seven APs. The experiment consisted mainly to walk through the hallway (from a start point to a far end point), then to lab room#1 and finally back to the start point. In Figure 19 the red lines represent the physical separation between university rooms and the green dotted line corresponds approximately to the AP’s coverage area. Several handoffs were performed over the network during multiple three-minute experimentations for each MS.

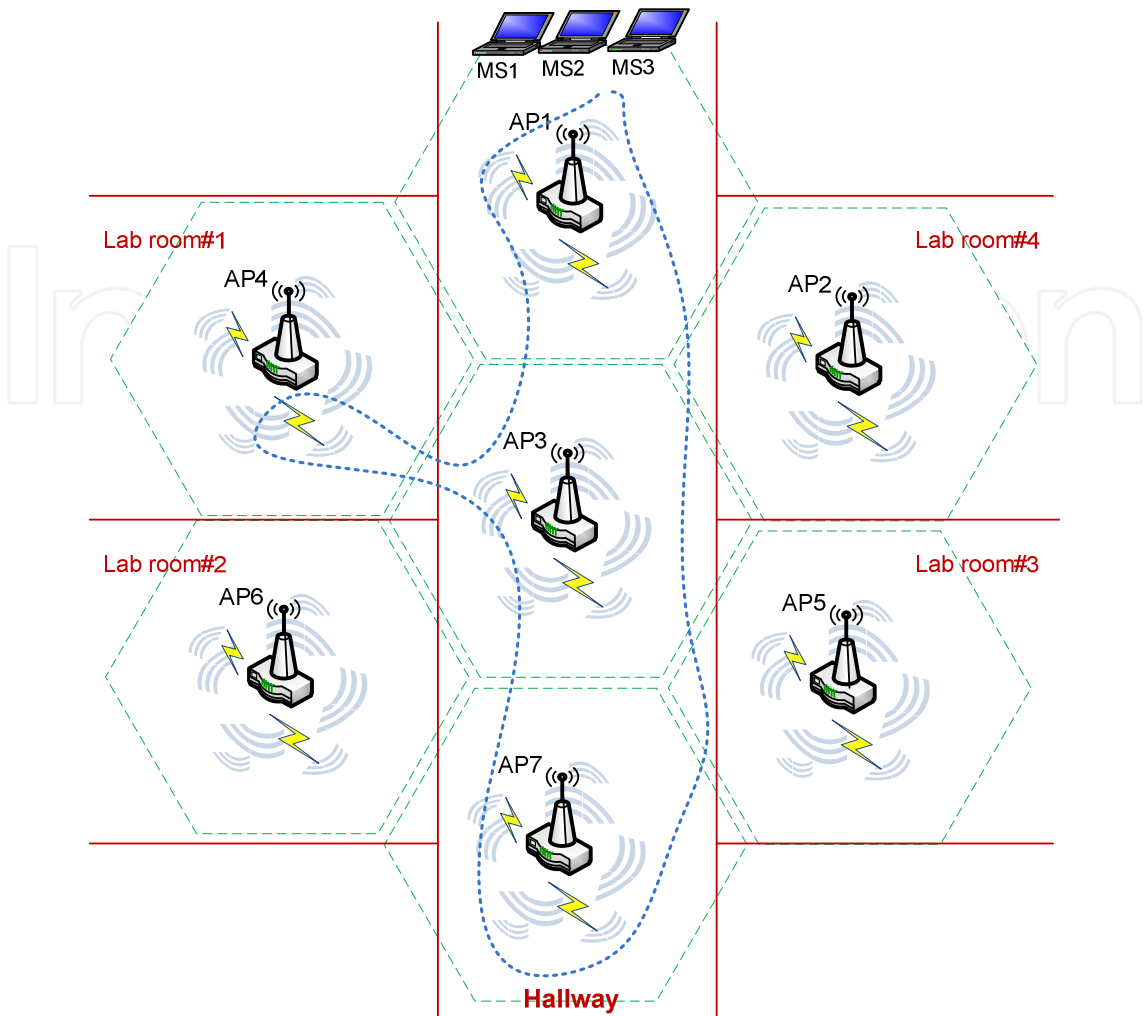


Fig. 19. Testbed for the MS’s movement and network topology

The clients MS1 and MS2 roam between APs identically: from AP1 to AP3 at around 17th second in both tests, from AP3 to AP7 at around the 31st sec., from AP7 to AP4 at around 96th sec., and back to AP1 at around the 124th sec. Since MS3 was using a standard PSHP driver (without an enhanced heuristic AP selection), it performed dissimilar handoffs approximately as follows: from AP1 to AP2 at 21st sec., then from AP2 to AP5 at 35th sec., from AP5 to AP3 at 46th sec., from AP3 to AP7 at 58th sec., from AP7 to AP6 at 69th sec., back to AP7 at 72nd sec., then from AP7 to AP4 at 104th sec., from AP4 to AP3 at 126th sec., and finally to AP1 at 155th sec. It is important to note that the initial transmission rate and codec type values are set to 11Mbps and G.711 respectively for all simulated MSs.

What can be observed from Figures 20 and 21 are the very small one-way delay and the very small packet loss performance achieved by MS1 compared to the other mobile nodes. Indeed, the CLAA integration has reduced significantly the total packet delay (caused by handoffs) by 64.5% from the PSHP+Heuristic mechanism and by 87.9% from the standard PSHP method which affects considerably the overall quality of received voice streams. Analogically, the number of the lost packets decreases to just 247 (from 538 and 2067 resulted through PSHP+Heuristic and PSHP implementations, respectively) during the three-minute RTP streaming. The high number of lost frames accomplished by standard

PSHP arises from multiple handoff occurrences during the continuous MS movement between available APs.

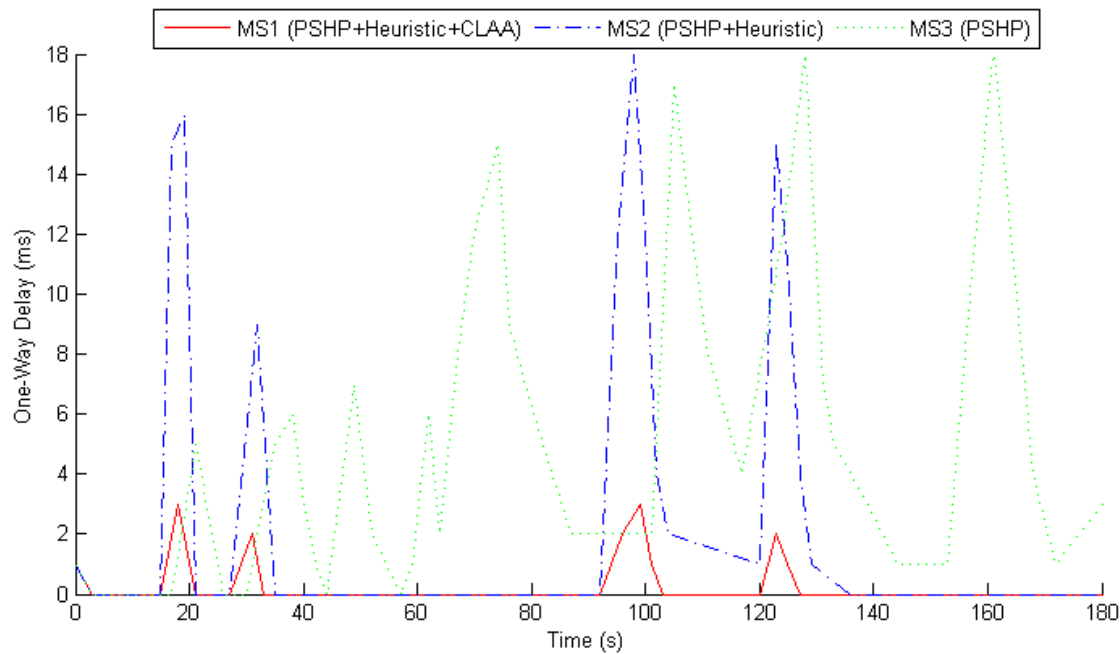


Fig. 20. Measured one-way delay from MS drivers

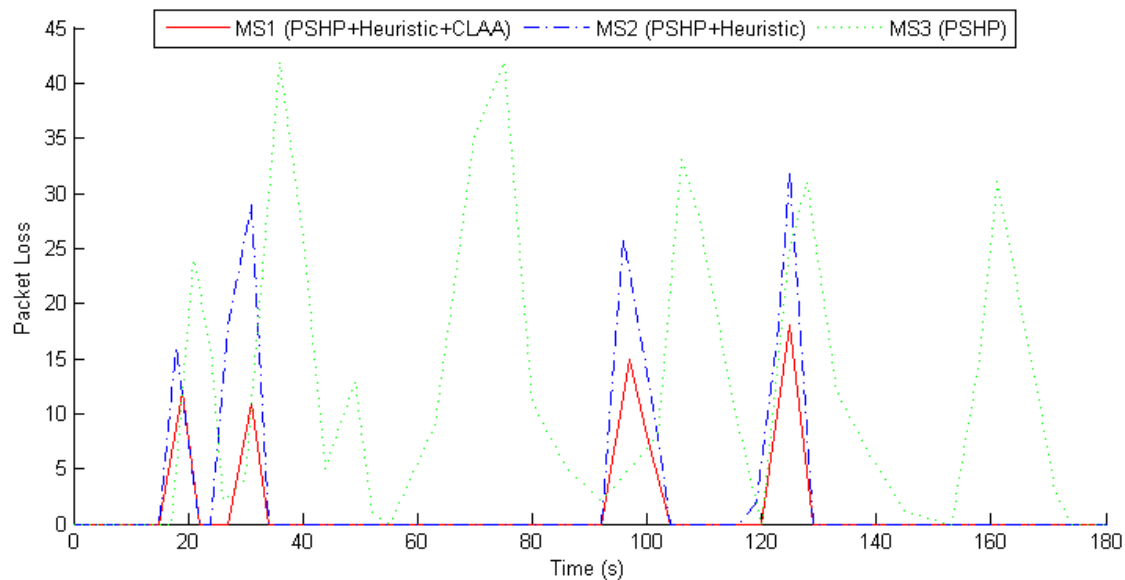


Fig. 21. Packet Loss given by the three different MS handoff

From the result given by Figure 22 the overall throughput attained by MS1 suffered a degradation of only $\approx 6.6\%$ while values of 11.8% and 14.3% were accomplished by MS2 and MS3 respectively. To determine the quality of VoIP under packet loss, the most common metric is the Mean Opinion Score (MOS) (IUT, 1996), which evaluates the effect of bursty loss on VoIP perceived quality (the Overall Voice Quality). In a MOS test, the listeners rate audio clips by a score from 5 to 1, with 5 meaning Excellent, 4 Good, 3 Fair, 2 Poor, and 1

Bad. In fact, voice and video communications quality usually dictates whether the experience is a good or bad one. Therefore, besides the qualitative description we hear, like 'quite good' or 'very bad', there is a numerical method of expressing voice and video quality given by the MOS which provides a statistical indication of the perceived quality of the media received after being transmitted and eventually compressed using VoIP codecs.

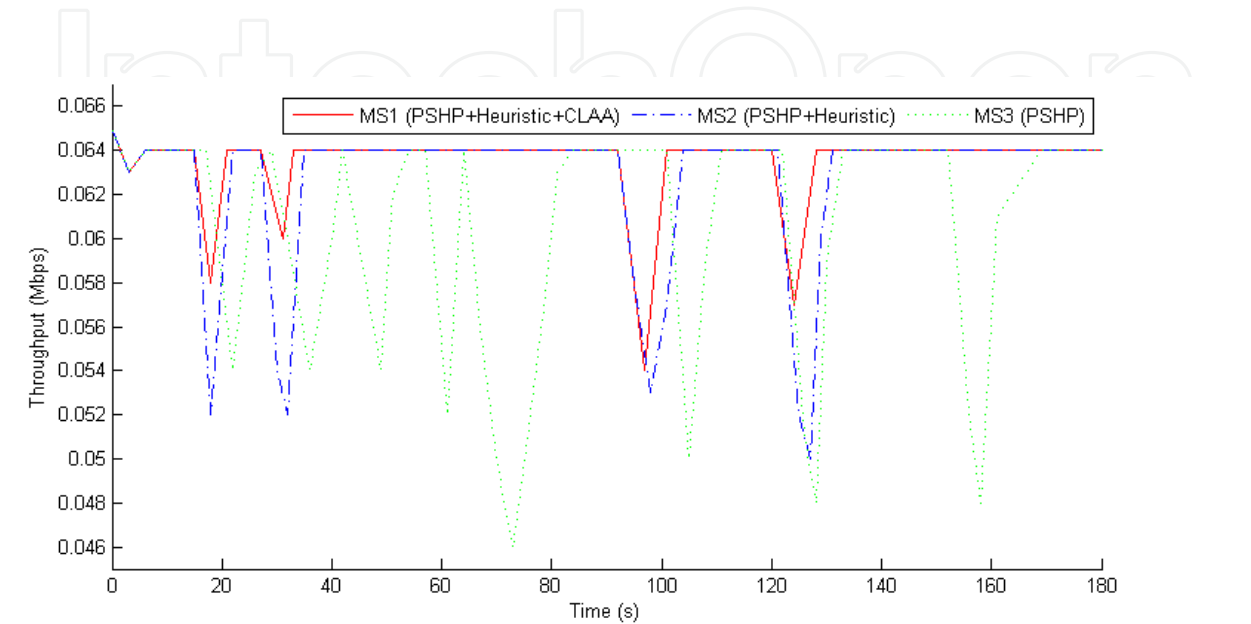


Fig. 22. Throughput measurements versus VoIP streaming elapsed time

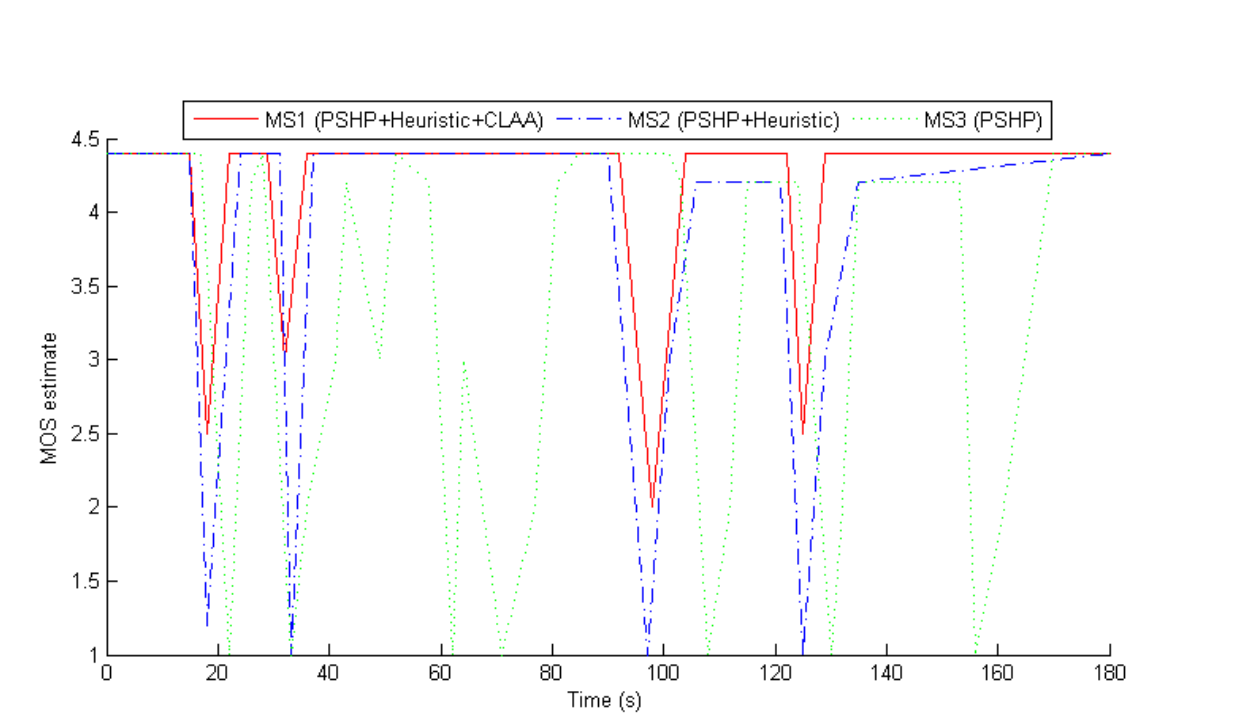


Fig. 23. MOS estimate of received voice quality

The MOS estimate of conducted test experiments shows in Figure 23 that the call was not interrupted with all MSs; It only suffered substantial quality degradation with a low peak at MOS=1, and quickly restored its initial quality (MOS=4).

Based on the above VoIP session experiments, we notice that MS1 (PSHP+Heuristic+CLAA) roams between different APs and all related test results are enhanced. In fact, the MOS mean values obtained by MS1, MS2 and MS3 handoff implementations are 3.86, 3.35 and 3.04 respectively; hence a considerable enhancement of 15.2% from PSHP+Heuristic and 28.6% from the standard PSHP was achieved by the new VoIP-oriented technique. This is due to the fact that the integrated CLAA agent cooperates between the MAC and Application layers and then contributes in shortening the total handoff latency during movements by adjusting the packet size and the codec type when needed. Thus, it preserves efficiently the VoIP session and maintains a satisfactory aggregate throughput. As also verified by the MOS estimate, the minimum measured MOS value during the MS1 test is equal to 2 (which match 'Poor' quality). This value was reached only one time (around the 98th second). However using the other two handoff versions a minimum MOS value of 1 (symbolizes Bad quality) was measured several times over the real streaming experiments.

5. Conclusions

VoIP over WLAN applications are rapidly growing due to the features they offer over the traditional public switched phones and their support symbolize at present an emerging challenge for 802.11-based WLANs. However, the integration of these two technologies still facing quality challenges to meet the quality obtained from the traditional telephony system. Besides, mobile stations in WLAN suffer the continuous inter-cell handoff issue, which affects the quality of the perceived voice. In order to keep a VoIP communication several commitments should be satisfied: eliminating communication termination, initiating appropriate handover based on reliable handover triggers and selecting the next AP with good link quality.

We firstly highlighted some of the technical challenges and related literature on the ongoing research force, especially focusing on approaches for enabling multimedia transit, as well as convenient and effective handover over IEEE802.11 mobile environments. Then we have revisited the PSHP handoff technique. As demonstrated, the continuous scanning PSHP technique offers significant advantages over other schemes by minimizing the time during which an MS remains out of contact with its AP and allowing handoffs to be made earlier and with more confidence. The result is a staggering 95% reduction of handoff latency compared to the typical procedure. As a second contribution we took into account additional network-based parameters to drive a better next-AP choice. This new add-on profit function is used to insert new factors reflecting resource availability, location, and other context-based information. Thus, the overall network performance is improved by electing from available APs, the one that increases the benefit of the next handoff occurrence.

In particular, this chapter presented another PSHP version satisfying between user requirement and network conditions and avoiding unnecessary handoffs as well. The policy is to minimize handoff delay for real time service and to reach an acceptable level for non-real time services. A pre-scanning phase is periodically activated to consider whether the

handoff should be triggered. During the AP selection procedure, the heuristic function is adopted to find candidate APs satisfying preference of a user and minimizing the overall delay. PSHP is using four handoff metrics, RSS, (AP-extensibility) number of neighbors, (load) number of users per AP, and historical traffic (old occurred handoffs) as inputs to determine the optimal target network.

Furthermore, one of the challenges in the next generation of wireless communications is the integration of existing and future wireless technologies and supporting transparent and seamless vertical handoffs (between different networks standards and technologies) without degrading the QoS between these heterogeneous networks. Hence, this research work proposed a Cross-Layer Adaptive Approach (CLAA) in order to enhance the QoS of VoIP over WLAN with help of an agent. The Cross layering concept has been shown to have a great impact on the performance of the wireless networks. Adapting code parameters in the Application layer according to the network condition has also shown better performance of real-time applications. Thus, the new scheme would be easily extended to cover inter-networks handoff decision toward universal 4G ubiquitous access.

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The nowadays ubiquitous and effortless digital data capture and processing capabilities offered by the majority of devices, lead to an unprecedented penetration of multimedia content in our everyday life. To make the most of this phenomenon, the rapidly increasing volume and usage of digitised content requires constant re-evaluation and adaptation of multimedia methodologies, in order to meet the relentless change of requirements from both the user and system perspectives. Advances in Multimedia provides readers with an overview of the ever-growing field of multimedia by bringing together various research studies and surveys from different subfields that point out such important aspects. Some of the main topics that this book deals with include: multimedia management in peer-to-peer structures & wireless networks, security characteristics in multimedia, semantic gap bridging for multimedia content and novel multimedia applications.

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