Minimization of Handoff Failure by Introducing a New Cell Coverage Area in the Handoff Region

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Abstract

Presently, IEEE 802.11 based wireless local area networks (WLAN) have been widely deployed for business and personal applications. The main issue regarding wireless network technology is handoff or hand over management, especially in urban areas, due to the limited coverage of access points (APs) or base stations (BS). When a mobile station (MS) moves outside the range of its current access point (AP) it needs to perform a link layer handover. This causes data loss and interruption in communication. Many people have applied efficient location management techniques in the literature of next generation wireless system (NGWS). However, seamless handover management still remains an open matter of research. Here we propose a method to minimize the handoff failure probability by effectively placing a wireless local area network (WLAN) AP in the handoff region between two neighboring cells. The WLAN coverage, on one hand, provides an additional coverage in the low signal strength region, and on the other hand, relieves the congestion in the cellular network. Moreover, we perform the channel scanning (required for horizontal handover between the two base stations) within the WLAN coverage area, thus minimizing the handoff failure due to scanning delay.

Keywords—*WLAN, IEEE 802.11, Handoff, Handoff latency, MS (mobile station).*

1. Introduction

In recent years, different wireless technologies have been implemented starting from 2G and 3G cellular system (e.g. GSM/GPRS, UMTS, CDMA 2000), metropolitan area networks (e.g., IEEE 802.16,WiBro), wireless local area networks WLANs (e.g., IEEE 802.11a/b/g, Hiper-LAN), and personal area networks (e.g. Bluetooth). All these wireless networks are heterogeneous in sense of different radio access technologies, the communication protocols that they use and the different administrative domains that they belong to [1]. The actual trend is to integrate complementary wireless technologies with overlapping coverage so as to provide the expected ubiquitous coverage and to achieve the Always Best Connected (ABC) concept [2].

IEEE 802.11b standards have become increasingly popular and are experiencing a very fast growth upsurge as it is cheap, and allow anytime or anywhere access to network data. However, they suffer from limited coverage area problem [3] and it is necessary to use this technology in the most prudent manner.

1.1 WLAN

A Wireless Local Area Network (WLAN) links two or more devices using some wireless distribution method (typically spread-spectrum), and usually provides a connection through an access point to the wider internet. This gives users the mobility to move around within a local coverage area and still be connected to the network [4]. In mobile network WLAN is used to transmits and receives radio signals between mobile station (MS) and access point(AP) which can be either a main, relay or remote base station. A main base station is typically connected to the wired Ethernet. A relay base station relays data between remote base stations, wireless clients or other relay stations

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to either a main or another relay base station. A remote base station accepts connections from wireless clients and passes them to relay or main stations. Connections between "clients" are made using MAC addresses [4].

1.2 Channel distribution

IEEE802.11b and IEEE802.11g operates in the 2.4GHz ISM band and use 11 of the maximum 14 channels available and are hence compatible due to use of same frequency channels. The channels (numbered 1to14) are spaced by 5MHz with a bandwidth of 22MHz, 11MHz above and below the centre of the channel. In addition there is a guard band of 1MHz at the base to accommodate out-of-band emissions below 2.4GHz. Thus a transmitter set at channel one transmits signal from 2.401GHz to 2.423GHz and so on to give the standard channel frequency distribution as shown in [Figure 1].

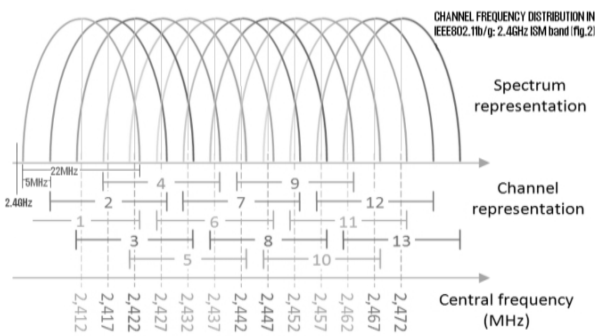

Figure 1.Channel allocation

It should be noted that due to overlapping of frequencies there can be significant interference between adjacent APs. Thus, in a well configured network, most of the APs will operate on the non-overlapping channels numbered 1, 6 and 11.

1.3 Handoff

When a MS moves out of reach of its current AP it must be reconnected to a new AP to continue its operation. The search for a new AP and subsequent registration under it constitute the handoff process which takes enough time (called handoff latency) to interfere with proper functioning of many applications.
Handoff can be of many types:
Hard & soft handoff: Originally hard handoff was used where a station must break connection with the old AP before joining the new AP thus resulting in large handoff delays. However, in soft handoff the old connection is maintained until a new one is established thus significantly reducing packet loss as shown in figure[3]:

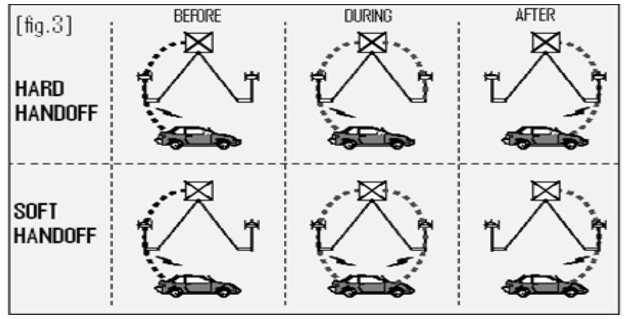

Figure 2.hard handoff & soft handoff

In NGWS(next generation wireless system),two types of handoff scenarios arise: horizontal handoff, vertical handoff[5][6].
1.Horizontal Handoff: When the handoff occurs between two BSs of the same system it is termed as horizontal handoff. It can be further classified into two:

- *Link layer handoff* : Horizontal handoff between two BSs that are under the same foreign agent(FA).

- *Intra system handoff* : Horizontal handoff between two BSs that belong to two different FAs and both FAs belong to the same gateway foreign agent (GFA) and hence to the same system.

2.Vertical Handoff : When the handoff occurs between two BSs that belong to two different GFAs and hence to two different systems it is termed as vertical handoff as shown in figure 4. A vertical handover (VHO) is the mechanism by which an ongoing connection is transferred from one BS to an AP and vice versa [8]. VHO can be classified in two categories namely upward-downward handover techniques and imperative-alternative handover techniques.
An *upward VHO* occurs from a network with small coverage and high data rate to a network with wider coverage and lower date rate. On the other hand, a downward VHO occurs in the opposite direction. As an example for this classification let's consider the case of two of the most important current wireless technologies: 3G cellular networks and WLANs. The WLAN system can be considered as the small coverage network with high data rate while the 3G cellular system is the one with wider coverage and lower data rate.
An *imperative VHO* occurs due to low signal from the BS or AP. In other words, it can be considered as an HHO. The execution of an imperative VHO has to be fast in order to keep on-going connections. On the other hand, a VHO initiated to provide the4 user with better data-rate is called the alternative VHO.

The handoff procedure consists of three logical phases where all communication between the mobile station

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undergoing handoff and the APs concerned is controlled by the use of IEEE802.11 management frames as shown below in [fig5].

1.3.1 Scanning

When a mobile station is moving away from its current AP, it initiates the handoff process when the received signal strength and the signal-to-noise-ratio have decreased significantly. The mobile station (MS) scans the channels which the new base station (BS) uses. The STA now begins MAC (Medium access control) layer scanning to find new APs. It can either opt for a passive scan (where it listens for beacon frames periodically sent out by APs) or chose a faster active scanning mechanism wherein it regularly sends out probe request frames and waits for responses for T_{MIN} (min Channel Time) and continues scanning until T_{MAX} (max Channel Time) if at least one response has been heard within T_{MIN}. Thus, $n*T_{MIN} \leq$ *time to scan n channels* $\leq n*T_{MAX}$. The information gathered is then processed so that the STA can decide which AP to join next. According to [7], 90% of the handoff delay comes from channel scanning.

1.3.2 Authentication

Authentication is necessary to associate the link with the new AP. Authentication must either immediately proceed to association or must immediately follow a channel scan cycle. In pre-authentication schemes, the MS authenticates with the new AP immediately after the scan cycle finishes. IEEE 802.11 defines two subtypes of authentication service: ‘Open System’ which is a null authentication algorithm and ‘Shared Key’ which is a four-way authentication mechanism. If Inter Access Point Protocol (IAPP) is used, only null authentication frames need to be exchanged in the re-authentication phase. Exchanging null authentication frames takes about 1-2 ms.

1.3.3 Re-Association

Re-association is a process for transferring associations from old AP to new one. Once the STA has been authenticated with the new AP, re-association can be started. Previous works has shown re-association delay to be around 1-2 ms. The range of scanning delay is given by:-
N × Tmin _ Tscan _ N × Tmax
Where N is the total number of channels according to the spectrum released by a country, Tmin is Min Channel Time,Tscan is the total measured scanning delay, and Tmax is Max Channel Time. Here we focus on reducing the scanning delay by minimizing the total number of scans performed.

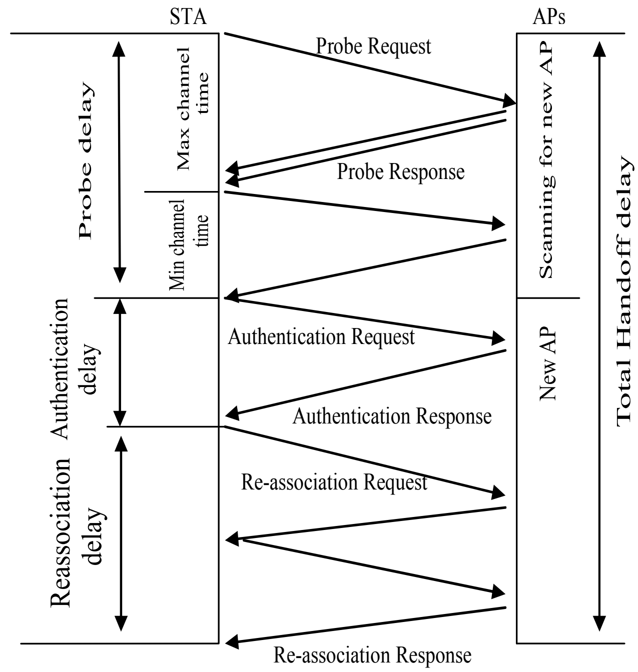

figure 5. Handoff process

One of the most important reasons of handoff failure is the handoff latency caused by channel scanning and excess wireless traffic. Many methods have been proposed in order to minimize handoff failure, but handoff failure is still an issue unsolved in the cellular world. Here we propose to minimize the handoff failure probability by effectively placing a WLAN AP in the handoff region between two neighboring cells. We also perform the channel scanning (required for horizontal handover between the two base stations) within the WLAN coverage area, thus minimizing the handoff failure due to scanning delay.
In section II we take you through the various works that have already been done to achieve this and in section III we introduce a new method using the WLAN router by which we intend to reduce the handoff failure probability. This is followed by performance evaluation of our proposed technique using simulations in section IV after which in section V we propose a few areas in which further improvement can be made. Finally, we provide an extensive list of references that has helped us tremendously in our work. But first, let us take a brief look at the structure of IEEE802.11x WLANs and the handoff process.

2. RELATED WORKS

In recent times, a large amount of research is done in improving the handoff technologies of cellular as well as IEEE 802.11 based networks. In the past few years, many methods based on neighbor graph [9] and geo-location on APs [4] has been proposed, where the authors have proposed selective channel mechanisms. In [10] Li Jun Zhang et a. proposes a method to send probe requests to the APs one after the other and perform handoff immediately after any AP sends the response. This allows us to scan fewer channels. All these processes involve scanning of APs, it may be selective or all APs may be scanned. These methods are therefore time consuming as well as have a certain probability of handoff failure. In [11] and [12], authors use GPS based access point maps for handoff management. Handoff using received signal strength (RSS) of BS has been proposed previously. Using dynamic threshold value of RSS for handoff management for MSs of different velocities has been described in [13].

3. PROPOSED WORK

Here, we propose to reduce the handoff failure probability by placing a WLAN router in effective handoff region. A high traffic density increases the probability of handoff failure. Thus by integrating a WLAN with cellular networks, the traffic density of the cellular network (CN) is partially reduced, thereby minimizing the handoff failure probability to a great extent.

In an idealized model we approximate the overlapping circular cell areas by hexagonal cells that cover the entire service region through frequency reuse concept where every cell marked similarly can use the same frequencies being out of range from each others' signal strength. Now let us consider two adjacent hexagonal cells. We define threshold signal strength of a cell as the signal strength after which the handoff is initiated. We place a WLAN router between the threshold signals of either cell i.e. with the router being at the midpoint of the line of the two AP's as shown in Figure 3.

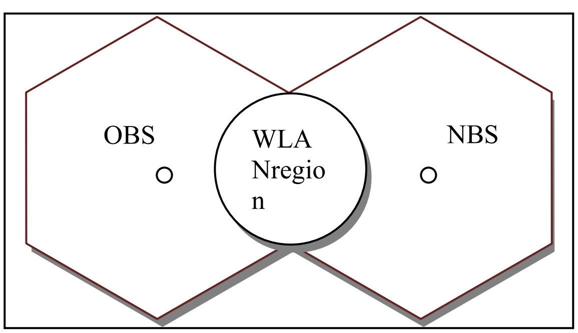

Figure6. The position of the WLAN in the handoff region

3.1 Received Signal Strength (RSS) Measurement of WLAN

IEEE 802.11b WLAN provides a bit rate of 11 Mbit/s and operates on 11 out of 14 distinct frequency channels. Path loss for a WLAN (*PL*) is given by:

$$PL=L+10 \times Y \times \log(d) + s$$

Here L is constant power loss, γ is the path loss exponent with values between 2 to 4, d represents the distance between the mobile station and WLAN AP and S represents shadow fading which follows Gaussian distribution. The Received Signal Strength (RSS) for WLAN (RSS_{WLAN}) in dBm is:

$$RSS_{WLAN} = PT - PL \quad \ldots\ldots\ldots\ldots (1)$$

Here *PT* is the power transmitted.

Received signal strength (RSS) for IEEE 802.11 b standard incorporating the path loss from equation no. (1) is tabulated in Table 1 as follows:

Table1. The RSS values for various position of MS for WLAN AP

Range	Received signal strength
50	-59.67
100	-68.70
150	-73.98
200	-77.73

Now we draw a circle with the distance of the threshold signal strength as the radius and the WLAN AP as its center. When the MS enters in this circular region as shown in Figure 4 (which depicts the coverage area of the WLAN), it sends a request for vertical handover. So, the mobile station scans for available channel and occupies one if available. This frees a channel in the cellular network, hence decreasing the traffic.

3.2 Change of Base Station in Cellular Network

Now the mobile station is under WLAN network coverage in the handoff region between the two cells. As it is in the WLAN coverage area, it is still connected and the mobile station user can enjoy seamless connectivity.

When the mobile station is to move into a particular base station, it starts the scanning process for the channels in the new base station, being under the coverage area of WLAN. The channel scanning process mostly contributes to handoff latency. Here, we minimize the handoff latency by reducing the number of base stations to be scanned to 1.Hence the number of channels to be scanned obviously becomes very low.

This scanning process occurs under the network coverage of WLAN. Hence, there is minimum handoff failure probability, which occurs mainly due to scanning delay during a handoff process.

As the scanning process terminates, the mobile station sends authentication requests and then the re-association requests which involves only two signals to be sent.

3.3 Difference between Normal Handoff and Proposed Method

The proposed method for handoff is advantageous against normal handoff because of the fact that in this case, the mobile station is always connected to the network directly to the CN AP or to WLAN AP. The mobile station after a specific threshold is under WLAN connection (if the traffic density permits) and even if it leaves the handoff region before establishing a connection with the new BS, it will be connected to WLAN until it gets connected with the new BS and hence there is minimum handoff failure in this case.

In normal handoff, if the scanning process is time consuming due to high traffic density, the mobile station leaves the handoff region before establishing connection with new BS, resulting in handoff failure.

Here, we conduct the scanning process inside the WLAN coverage area, such that the scanning delay is completely eliminated from the handoff scheme as it no longer affects the handoff failure probability. Thus:

Effective Handoff delay= Authentication Delay + Re-association Delay

3.4 Reduction of traffic due to introduction of WLAN

This handoff scheme allows a number of users to free the channels of the cellular network and avail for the WLAN coverage. This decreases traffic density of the existing APs. If E = λh = total traffic, P_b is the probability of blocking, m is the number of resources such as servers or circuits in a group

$$P_B = B(E,m) = \frac{E^m/_{m!}}{\sum_{i=0}^{m} E^i/_{i!}}$$

Here we divide the average arrival rate λ into λ_{CN} and λ_{WLAN} where

$$\lambda = \lambda_{CN} + \lambda_{WLAN}$$

$$E_{CN} < E$$

$$New\ probability\ of\ blocking\ < P_b$$

Thus, with this paper we endeavour to reduce the traffic density and call blocking probability in the handoff region in a cellular network by introducing a WLAN AP inside the handoff region.

3.5 Assignment of WLAN Channel to Specific Users

We design an algorithm on filtering the number of users who are given the option of availability of WLAN service. We locate the position of the old base station (OBS) and mobile-station (MS) by GPS technology.

We assume (X,Y) are the co-ordinates of the present BS and (x_m,y_m) are the co-ordinates of the MS and r is the radial distance of the mobile station from the old BS.

Then we have the radial distance r of the MS from its present BS is given by the equation,

$$r = \sqrt{(X - x_m)^2 + (Y - y_m)^2}$$

* We define R as signal range of the directional antenna used by the OBS */

/* We define D_{WLAN} as diametric range of WLAN coverage area */

1. *While base station connectivity not changed*

2. *If r < (R-D_{WLAN}),*

2.1 *The MS does not take any action of vertical handover*

3. *Else*

/* *We define* $\dot{r}$ = rate of change of r and mathematically

$$\dot{r} = \frac{\Delta r}{\Delta t} \quad */$$

/* Now $\dot{r}$ increases or decreases only if r changes */

/* We define T as the time taken to make a connection with WLAN AP */

3.1. If $\dot{r} * 2T < R\text{-}r$

3.1.1. Then mobile node will not be able to avail the WLAN service and wait till the next iteration comes

3.2. Else

3.2.1. The mobile node tries to make a connection with the WLAN AP.

3.2.2. The mobile nodes will be preferentially allocated channels by the WLAN AP in order of there $\dot{r} * 2T$ value.

3.3. End

4. End

5. End

This algorithm provides a filter to the number of users availing the WLAN service to avoid unnecessary vertical handover.

4. Simulation Results

We made simulation of our proposed method using the algorithm in the subsection of the proposed work. For justifying the practicability of our method in real models we made an artificial environment considering a seven cell cluster, that is seven APs at the centre of seven closely packed cells whose hexagonal structure provides an approximation of its signal sweeping region, and we implemented Poison's Distribution Function for incorporation of memory less property in the generation of calls in the environment.

Depending upon the level of traffic impediments we noted down the corresponding call blocking probability, that is the number of calls that terminates during handoff to the total number of handoffs in that traffic condition. The traffic of the network is taken relative to the maximum traffic. The plot of network traffic verses the call blocking probability is shown in the Figure 7. We have also shown the handoff call blocking probability, that is the number of calls that terminates during handoff to the total number of handoffs in that traffic condition, in the same base parameter in Figure 8.

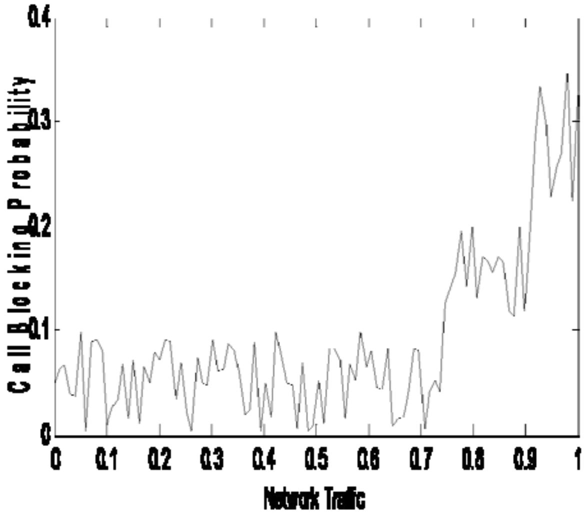

Figure7. Plot of network traffic verses the call blocking probability

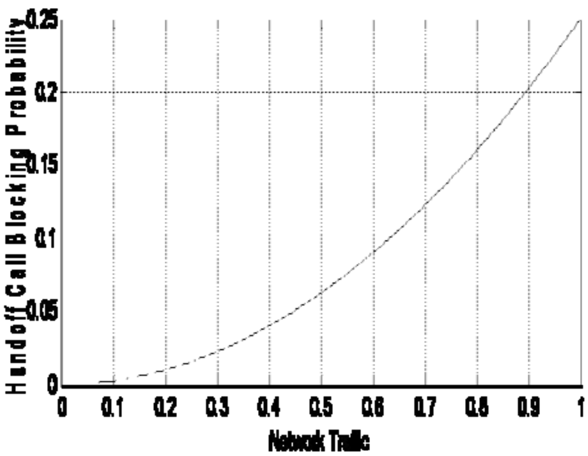

Figure8. Plot of network traffic verses the handoff call blocking probability

From Figure 5 it can be seen that the call blocking probability is below 0.1 for cases up to where seventy percent of the network is congested with a gradual increase, which is obvious for high congestion in the network. Figure 6 shows that handoff call blocking probability increases in an exponential manner with network traffic but we are able to restrict it to 25% of the maximum value which is an significant improve over the previous results. Thus our method effectively reduces the traffic blocking probability and also handoff call blocking probability.

5. Conclusion

Thus by our proposed method, we can reduce handoff failure as well as handoff latency quite a remarkable amount as we can reduce the traffic in the cellular network by introducing a WLAN AP. The various advantages of incorporating the WLAN AP in the CN thus can be enlisted as follows.

- This facility will relieve congestion on the GSM or UMTS spectrum by removing common types of calls and routing them to the operator via the relatively low cost Internet.
- This scheme allows carriers to add coverage using low cost 802.11 access points. Subscribers enjoy seamless coverage.
- This handoff procedure cuts out the scanning delay from the handoff latency components by scanning the channels while in the WLAN coverage.
- The handoff failure probability tends to zero

However, future works can be done on improving the traffic distribution between the CN and WLAN, so that handoff failure can be eliminated completely.

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