AN INVESTIGATION INTO THE HANDOVER PROTOCOL FOR INTERWORKING BETWEEN A WLAN AND CDMA2000.

by

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MASTER OF SCIENCE
IN
ELECTRICAL AND ELECTRONIC ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
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An Investigation into the Handover Protocol for Interworking between a WLAN and CDMA2000.

A thesis submitted to the Department of Electrical and Electronic Engineering of Bangladesh University of Engineering and Technology in partial fulfillment of the requirement for the degree of
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List of abbreviations and acronyms

GSM	Global System for Mobile Communication
CDMA	Code Division Multiple Access
SDO	Standard Development Organizations
AP	Access Pointer
WLAN	Wireless Local Area Network
MN	Mobile Node
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
IETF	Internet Engineering Task Force
MIP	Mobile Internet Protocol
MS	Mobile Station
BTS	Base Transceiver Station
BSC	Base Station Controller
PCF	Packet Control Function
PDSN	Packet Data Service Node
IWF	Interworking Function
BSS	Basic Service Set
ESS	Extended Service Set
DS	Distribution System
WAG	Wireless Access Gateway
PDG	Packet Data Gateway
DT	Drive Test
SSID	Service Set Identifier
RSSI	Received Signal Strength Indication
NCC	Network Color Code
BCC	Base station Color Code

ABSTRACT

Wireless local area networks (WLANs) have emerged to provide mobility or roaming capability to its nodes/terminals and have permitted connectivity to the Internet at a cheap rate using wireless access points. On the other hand, due to the recent technological achievements in cellular mobile communications, a mobile station (MS) may now be used to get connected to the Internet using CDMA 2000. Roaming of nodes/terminals between adjacent WLANs and that of an MS between CDMA 2000 networks are possible using the respective handover schemes already available. However, it would be a novel initiative for a mobile node (such as a laptop PC or an MS) to switch between WLAN and CDMA 2000 network, and vice versa, for ensuring a continuous on-line connectivity with the Internet. In this work, an investigation has been carried out into the existing interworking protocols of different OSI layers in order for them to be modified for interworking between WLAN and CDMA 2000.

As part of the current research a new roaming technique have been developed modifying the existing handover schemes. To comprehend the actual practical scenario and explore the conditions of handover, two cases have been studied, namely, WLAN to WLAN handover and CDMA to CDMA handover. Drive tests have been performed in this regard, and the relevant information and data collected from the drive tests have been scrutinized and analyzed very carefully. Some logics and underlying operating principles have been comprehended from the practical drive test data. The main challenge was to ensure how mobile Internet users would get connected to the WLAN within the hot-spots and switch to CDMA 2000 network when WLAN is not accessible. The core idea is that the mobile device (a laptop, for example) will have two interface cards installed: one for the wireless LAN interface card and another for the CDMA 2000. Both cards need to be powered on for all the time; but as long as the laptop is under any access point coverage area of a WLAN, the CDMA card remains inactive. Following the data collection, appropriate simulation analysis has been performed using the Matlab toolbox. A software named ‘WLAN-CDMA handover’ has been developed, to manage the handover between WLAN and CDMA 2000 and vice versa, using the C Sharp programming language. The developed software measures the received signal strength of the wireless LAN access point through its interface card. As soon as it detects the signal strength below a pre-defined threshold value, it activates the CDMA card and data traffic is re-routed through the CDMA network. Finally, a test bed has been developed for testing the handover between WLAN and CDMA for a simple scenario. The test confirms that the algorithm can initiate and complete successful handover as and when needed.

The advantage of a WLAN network is lower cost and higher data rate compared to a CDMA 2000 network. The mobility of WLAN is low with only over small areas, whereas CDMA 2000 offers relatively lower date rates but much higher mobility with a reliable nationwide coverage. The proposed technique, which is the combination of the two, would now result in a low cost high data rate Internet connectivity within certain hot-spots under the WLAN environment, while still obtaining reliable connection outside the hot-spots under the CDMA 2000 environment.

Chapter 1

Introduction

1.1 Background

The whole Internet World has changed by the invention of mobile technologies and devices. The main feature of these inventions is the accessibility of the Internet wirelessly by different air interfaces using the different technologies while roaming.

In the past decade, the telecommunications industry has witnessed an ever accelerated growth of the usage of the mobile communications. As a result, the mobile communications technology has evolved from the 2G technologies to the third generation (3G) technologies. Along with the standards development for providing voice service to mobile users, a group of standards to deliver data to the mobile users have evolved from both SDOs (Standards Development Organizations) and industry.

2G systems such as GSM, CDMA One (IS-95: Interim Standard-95) were designed to carry speech and low-bit rate data. 3G systems were designed to provide higher data rate services. During the evolution from 2G to 3G, a range of wireless systems, including GPRS, Bluetooth, WLAN and HiperLAN have been developed. All these systems were designed independently, targeting different service types, data rates, and users. As these systems all have their own merits and shortcomings, there is no single system that is good enough to replace all the other technologies [1, 2].

1.2 Internet and IP Addressing

The traditional addressing scheme of the Internet has been designed based on the assumption that any node only has one fixed and permanent IP address in the Internet. Consequently, any node could be easily identified by this unique IP address and its location is directly recognized in the Internet.

When a mobile device comes to the Internet, it will move from one sub-network to another sub-network. However, the IP address of the mobile device will keep unchanged and the IP address can not reflect the new location due to the traditional addressing scheme of the Internet. As a result, the packets from the new location will not be routed to the destination and the packets to the new location of the mobile device will be forwarded to the old location by the traditional Internet protocols. All the connections for the mobile device will be lost during the movement and this is regarded as IP mobility management issues [3, 4].

1.3 Literature Review

IP mobility issues can be classified into Location Management and Handover Management. Location management is used to identify the current location of mobile devices and also to keep track of their location as they move in the network. This is accomplished by the use of Access Points (AP), which is not relatively complex while handover management is to maintain the on-going connections no matter where they move in the network [4].

Handover management can be implemented in different layers of the Internet architecture based on the OSI-reference model. The OSI model is based on a proposal developed by the International Standards Organization as the first step toward international standardization of the protocols used in the various layers of communication architecture. The OSI model is designed as a 7-layer hierarchy, with each layer responsible for a specific task AS Shown in the Figure1.1.

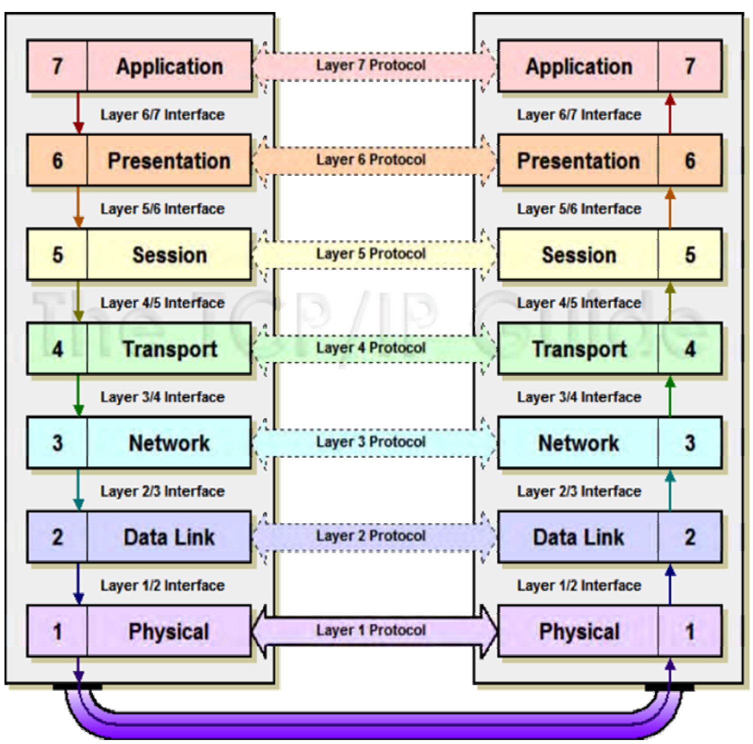


Figure 1.1: OSI Reference Model

The two lowest layers (Physical and Data link) are concerning about the physical medium and raw data transmission. And the two highest layers cover presentation and application problems [3].

The mobility management protocols have been developed in these upper two and lower two layers, currently, the focus of mobility management is not from these four layers. The Network Layer is responsible for end-to-end (source to destination) packet delivery including routing through intermediate hosts, providing the functional and procedural means of transferring variable length data sequences from a source to a destination host via one or more networks while maintaining the quality of service and error control functions. Internet Protocol (IP) is the working this layer to provide routing and forwarding functions, as well as addressing, internetworking, error handling, congestion control and packet sequencing [5].

The Transport Layer is responsible for delivering data to the appropriate application process on the host computers. It provides transparent transfer of data between two endpoints. It is also responsible for the Reliable data, Flow control, Orientation of delivery. The most well-known transport protocol is the Transmission Control Protocol (TCP). It lent its name to the title of the entire Internet Protocol Suite, TCP/IP. It is used for connection-oriented transmissions, whereas the connectionless User Datagram Protocol (UDP), another protocol of the session layer, is used for simpler messaging transmissions. TCP is the more complex protocol, due to its design incorporating reliable transmission. Stream Control Transmission Protocol (SCTP) is a new Internet Engineering Task Force (IETF) proposed standard protocol for the transport layer [6, 7].

The Session Layer provides the mechanism for opening, closing and managing a session between end-user application processes. Communication sessions consist of requests and responses that occur between applications. During the session establishment, the end points need to exchange the location information. Accordingly, when a mobile device in a session moves to another location, it will send the new location to the other endpoint to establish a new session. Based on this, a session Initiation Protocol (SIP) has been designed recently to support IP mobility [8].

Most IP mobility researches focused on this layer at the beginning and there are many brand new protocols in this layer which can support IP mobility management such as Host Identity Payload (HIP), Handoff Aware Wireless Access Internet Infrastructure (HAWAII), Cellular IP and Intra-domain Management Protocol (IDMP). The most significant protocol for mobility management is mobile IP (MIP) and it has been used very commercially and widely. There are two versions of this protocol version 4 and version 6. The mobility of Internet can be possible for this network layer protocol. Wireless Local Area Network is now popular for mobility. Mobile devices or nodes are now being used to access internet as it is possible to move while using internet; even from the coverage under one access pointer to another [9, 10].

WLAN 802.11b is a specification of IEEE 802.11 family, set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE 802). WLAN uses the re-association process to handle the mobility management. In a WLAN environment, Internet Protocol (IP) works under the Network layer to provide routing and forwarding functions, as well as addressing, internetworking, error handling, congestion control and packet sequencing. Mobile Internet Protocol (MIP) is widely used for the mobility [11].

On the other hand, a standard that can handle both voice and data is the CDMA2000 standard, which has evolved from CDMA one by third Generation Partnership Project 2 (3GPP2). CDMA 2000 is a standard for mobile communication used by hundreds of operator worldwide. So it is well established standard for mobility issues. CDMA 2000 network handles mobility by performing step-by-step soft handover mechanism to reselect the Base Transceiver Station (BTS) [12].

Code Division Multiple Access 2000 (CDMA2000) and 802.11b Wireless Local Area Network (WLAN) are the two different wireless technologies There are no standard protocols or mechanisms for Handover between CDMA and WLAN 802.11b. This thesis investigates about the handover protocol among the CDMA 2000 and WLAN 80.11b.

1.4 Objective of the Research

The objectives of the investigation are to propose the novel idea of using a combination of WLAN and CDMA2000 to ensure roaming of a mobile node in a wide geographical area. For this study and investigation will be made into the existing interworking protocols of different OSI layers in order for them to be modified for interworking between WLAN and CDMA 2000.

To develop and/or modify new roaming techniques including signal level measurement, signaling, addressing, routing, handover etc. for ensuring the mobility of a mobile node throughout a wide geographical area using the combination of WLAN and CDMA2000.

The proposed technique will result in a low cost high data rates within certain hot-spots under WLAN environment, while still obtaining reliable connection outside the hot-spots under CDMA2000 environment.

1.5 Organization of this Thesis

The thesis has been organized in to the following chapters-

Chapter 1 provides an introduction to the research describing the background, current status and the objectives of the research.

Chapter 2 gives an overview of CDMA and 802.11 WLAN in terms of the basic network architecture, mobility management and operation.

Chapter 3 describes the different types of handover and the handover management schemes. The proposition of vertical handover scheme for two heterogeneous networks consisting of WLAN and CDMA 2000 has been included at the end of the chapter.

Chapter 4 illustrates the modeling techniques used to accomplish the proposed handover between WLAN and CDMA networks after careful study and analysis of the realistic data obtained from the drive test. This chapter also presents the developed algorithms and logical models formulated.

Chapter 5 provides the simulation results for the proposed handover techniques. This chapter also describes the development of a test bed for verifying the functionality of the proposed model. The results of the verification are also discussed here.

Finally**, Chapter 6** summarizes the results of the findings and provides suggestions for future work.

Chapter 2

Wireless Access Interfaces

Wireless local area network (WLAN)-based systems are emerging as a new means of wireless public access. IEEE 802.11 WLAN family has gained increasing recognition over wired networking to make the communications world progressively more mobile. On the other hand Code Division Multiple Access technology has a significant advancement. The evolutions of CDMA2000 develop the cellular wireless telecommunications into 3G networks. Both of these two technologies can utilize the wireless access air interfaces for data communication; though they employ completely different technology.

This chapter describes these two wireless technologies in terms of network architectures, evolutions and highlight differences between them.

2.1 Code Division Multiple Access CDMA

Code division multiple access (CDMA) is a channel access method utilized by various radio communication technologies. One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a bandwidth of different frequencies. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel [12].

In CDMA each user is assigned a unique code sequence it uses to encode its information-bearing signal. The receiver, knowing the code sequences of the user, decodes a received

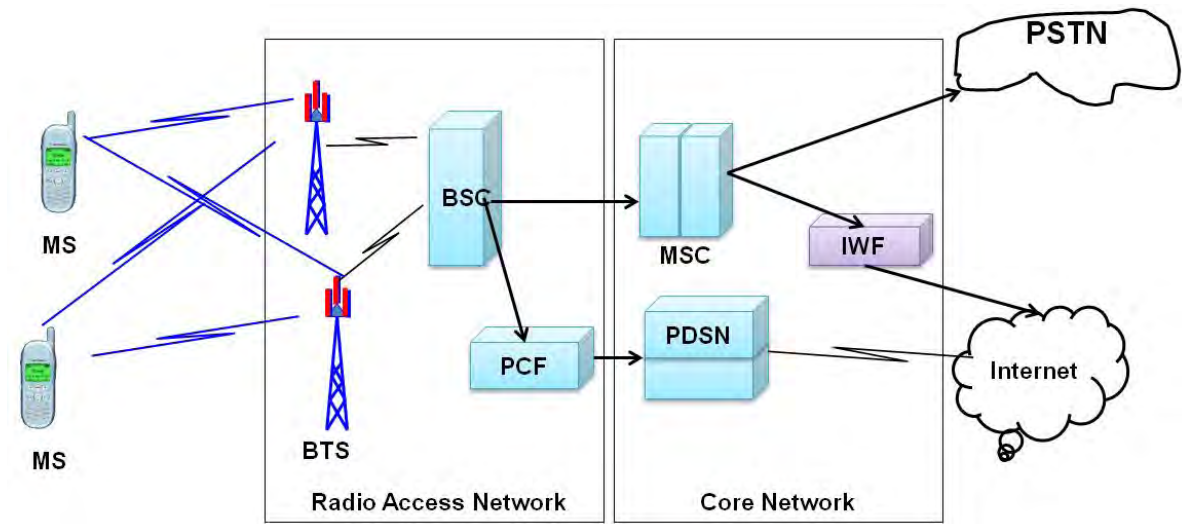
Signal after reception and recovers the original data. This is possible since the cross-correlations between the code of the desired user and the codes of the other users are small. Since the bandwidth of the code signal is chosen to be much larger than the bandwidth of the information-bearing signal, the encoding process enlarges (spreads) the spectrum of the signal and is therefore also known as spread-spectrum modulation. The resulting signal is also called a spread-spectrum signal, and CDMA is often denoted as spread-spectrum multiple access. The spectral spreading of the transmitted signal gives CDMA its multiple access capability. The important techniques necessary to generate spread-spectrum: the transmission bandwidth must be much larger than the information bandwidth and the resulting radio-frequency bandwidth is determined by a function other than the information being sent (so the bandwidth is statistically independent of the information signal).

CDMA2000 (also known as IMT Multi-Carrier (IMT-MC)) is a family of 3G mobile technology standards, which use CDMA channel access, to send voice, data, and signaling data between mobile phones and cell sites. CDMA2000 standards have been evolved from CDMA one by Third Generation Partnership Project 2 (3GPP2). The set of standards includes: CDMA2000 1X, CDMA2000 EV-DO Rev. 0, CDMA2000 EV-DO Rev. A, and CDMA2000 EV-DO Rev. B. All are approved radio interfaces for the ITU's IMT-2000. [12, 13]

CDMA2000 1x, also known as 1xRTT, is the core standard of the CDMA2000 standard family. It is symbolic of the transition of CDMA technology from the 2G to the 3G telecommunication world. The CDMA2000 1x specification provides three types of data service: short message service (SMS), circuit switched data, and packet switched data. SMS provides two-way pager-like functionality, allowing short text messages to be sent, received, and acknowledged. Circuit-switched data allows dial-up modem connections over the cellular network. Packet-switched data provides Internet Protocol connectivity.

Circuit-switching use the traditional TDM circuit to transmit data and it has the maximum rate of 19.2Kbps while packet-switching provides a point-to-point connection (PPP) between a mobile station and the packet data serving node (PDSN) and can offer data rate up to 144Kbps. [14].

The CDMA20001x network consists of three major parts: the mobile station, the radio access network and the core network. Figure 2.1 in the following page is the basic architecture of CDMA20001x networks.



MS: Mobile Station
BTS: Base Transceiver Station
BSC: Base Station Controller
PCF: Packet Control Function
PDSN: Packet Data Service Node
MSC: Mobile Switching Center
IWF: Interworking Function

Figure 2.1: The basic architecture of CDMA2000 System

The mobile station refers to a variety of mobile devices such as mobile phones, PDAs and laptops. These devices contain a CDMA2000 radio terminal used for radio communication with radio access network over the radio interface.

The radio access network handles all radio-related functionalities and it provides radio bearers between the mobile station and the core network for the transport of user data and non-access stream signaling. The main components of a radio access network are base transceiver stations, packet control function and base station controller. The base transceiver station is an entity which provides transmission capabilities between the network and the mobile station.

The BSC is an entity which provides control and management for one or more BTSs. It also provides a router function for voice and circuit-switched data between a mobile station and the mobile switching center (MSC). The packet control function routes the packet-switched data between the base station controller and the packet data serving node because the base station controller can not route it to the PDSN directly.

The core network is responsible for switching and routing data messages between the radio access network and external networks such as Internet and PSTN. The main components of the core network are MSC, packet date serving node and inter working function.

The PDSN acts as a gateway between the radio access network and the external network such as the Internet. It provides an IP address to the mobile station and route the IP packets to the external network.

The MSC is responsible as a switch and a database for setting up, terminating, maintaining and forwarding the voice and circuit-switched data. Inter working function plays the role of a bridge between the circuit-switched based voice network and the packet-switched based network. [12, 14-15]

When a mobile station transmits data using CDMA2000 1x, it first needs to register for packet data services and so sends an origination message to its BSC. The BSC replies with a base station acknowledgement to the mobile station after it acknowledges the origination message. Next, the BSC sends a service request message to the MSC to ask for radio resources. After the MSC returns an assignment request message to the base controller, the mobile station starts to set up radio resources.

After the mobile station obtains the radio resources, it still can not transmit the data because the packet-switched data can not be routed to a PDSN. Hence, the PCF in the radio access network selects a PDSN for the mobile station for this data call and sends the PDSN a registration request and waits for the positive return by registration reply sent by the PDSN. Now, the connection between the mobile and the PDSN has been established completely and the data can be transmitted between the mobile station and the PDSN. Finally, the base station controller sends an assignment complete message to the MSC notifying the connection establishment. [14]

The whole procedure to set up a data call in CDMA2000 1x network can be seen in Figure 2.2.

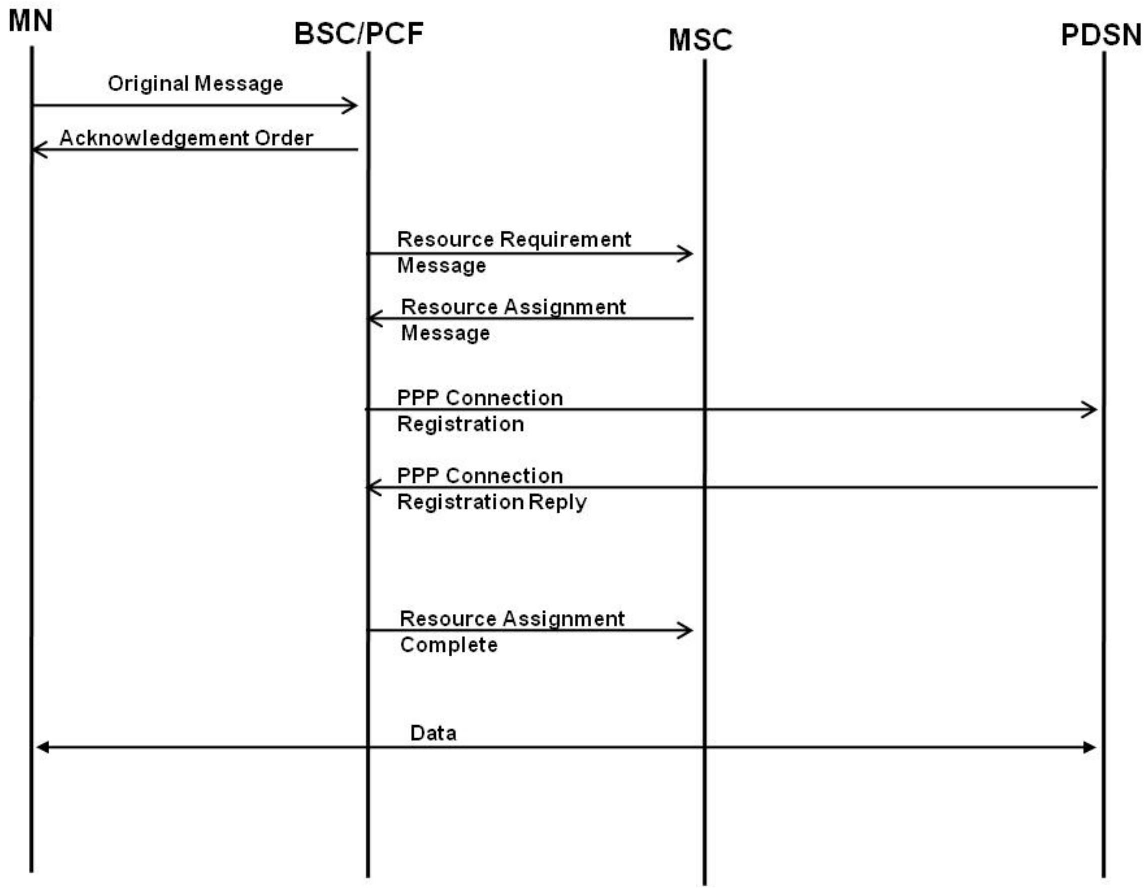


Figure 2.2: CDMA2000 1x network data call setup procedure

When a mobile station moves between the areas covered by different BTSs in a CDMA2000 1x network, the network provides a soft handover mechanism for mobility management. To do this, CDMA2000 1x network defines 4 sets to store the information of BSs according to the signal strength of the BSs. The first is the active set containing the BSs which the mobile station may simultaneously contact. The second is the candidate set which stores all the BSs not in the active set but which the mobile station can demodulate. The third is the neighbor set for the BSs which are in the vicinity of the BSs the mobile station is using currently. The last is the set of all remaining BSs.

Consider a mobile station using BTS1 and moving toward to BS2. When the mobile station detects that the signal strength of BTS2 exceeds the minimum threshold T_ADD, it initially moves BTS2 to the candidate set because the total received signal strength is not sufficient. The threshold T_ADD is dynamic and defined by a linear function of the signal strength of the total active set. When the strength of BTS2 is detected to be above the threshold, the mobile station informs this event to the network and waits for the handover direction message from the network requesting it to add BTS2 to the active set. Afterwards, the mobile station operates the soft handover.

On the other hand, when the mobile station moves away from the BTS1 and the signal strength of BTS1 drops below the T_ADD, the mobile station starts a handover drop timer. When the timer expires, the mobile station receives a handover message from the network and move BTS1 from the active set to the candidate set. When the signal strength of BTS1 keeps reducing, the mobile station starts another handover drop timer to move BTS1 from the candidate set to the neighbor set. Hence, the CDMA2000 1x network performs a step-by-step soft handover mechanism with multiple thresholds and timers [14, 15].

2.2 Wireless Local Area Network (WLAN)

A wireless local area network (WLAN) links devices via a wireless distribution method (typically spread-spectrum or OFDM radio), 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.

IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. 802.11 standards refer to a family of specifications developed by the Institute of Electrical and Electronics Engineers (IEEE) for wireless LAN technology. 802.11 standards specify the physical (PHY) and Medium Access Control (MAC) protocols of the over-the-air interface between a wireless client and a base station or between two wireless clients. The 802.11 family includes over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, which are amendments to the original standard. 802.11-1997 was the first wireless networking standard, but 802.11b was the first widely accepted one. In this thesis we focus mainly on 802.11b protocols [11].

An 802.11b WLAN network is based on a cellular architecture where the system is subdivided into cells and each cell forms a basic service set (BSS). Each cell is controlled by a Base Station or an Access Point (AP). A distribution system is used to integrate multiple BSSs to form an extended service set (ESS). A portal device acts as a bridge to connect the WLAN to the wired network such as the Internet. [16, 17]. Figure 2.3 shows the basic network architecture of an 802.11b WLAN.

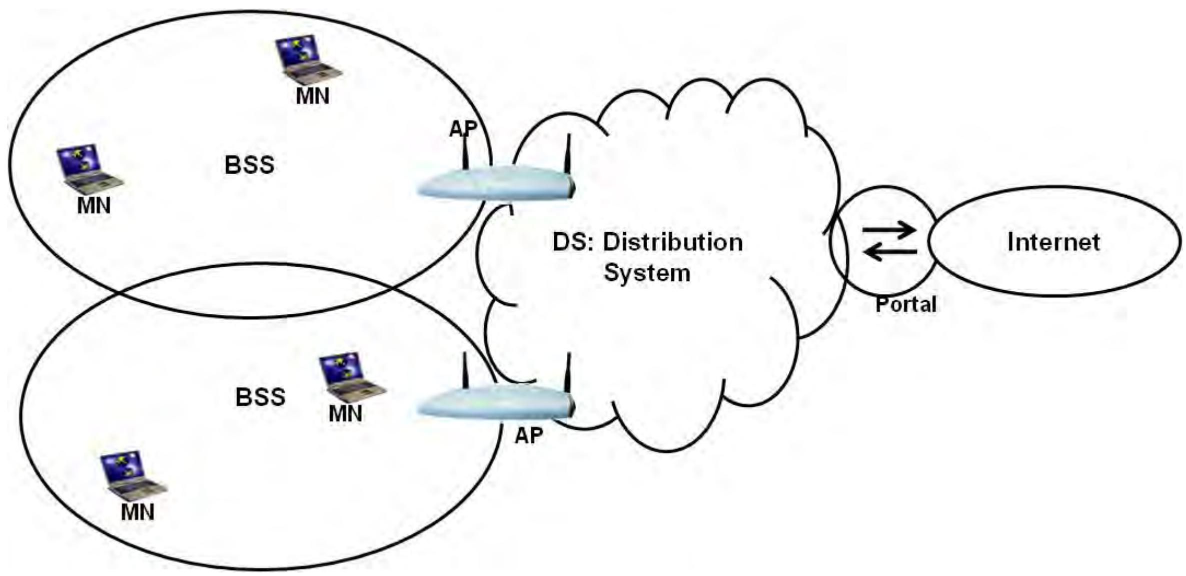


Figure 2.3: 802.11b WLAN network architecture

In Figure 2.3, the basic components of an 802.11b WLAN are the BSSs and each BSS is formed by several mobile nodes and an AP. The mobile nodes are computing devices equipped with 802.11b wireless network interfaces. The AP is used to control the traffic among the mobile nodes by controlling the wireless network interfaces of each mobile node. There are four control functions of an AP for a BSS:

1. It provides the same 802.11 radio interface protocol for all the mobile nodes. Hence, all the mobile nodes use the same wireless medium channel and they can communicate each other.

2. It also implements the 802.11 Carrier Sense multiple Access with Collision Avoidance (also known as CSMA/CA) MAC protocol to avoid traffic collisions among the mobile nodes.

3. It plays a role as a buffer to store-and-forward to packet to co-ordinate communications among the mobile nodes in a BSS.

4. When mobile nodes communicate some device outside the BSS, the AP has a bridge function to connect the mobile nodes with the device.

After a mobile node in a BSS is on, it starts the scanning procedure to obtain the synchronization information to identify the BSS. The scanning procedure can be either passive or active. If the mobile node only waits to receive a Beacon Frame containing the necessary information from an AP, this is passive scanning. On the other hand, if the mobile node sends a probe request to find the AP, this is active scanning. Passive scanning can save battery power while active scanning is more efficient.

A scan report is generated when the scanning procedure is completed and all the available APs are listed on the report. The mobile node then chooses one of the APs and joins the BSS which the AP belongs to. The procedure is known as authentication process. For the authentication process, the mobile node and AP must exchange the state information and prove the knowledge of a given password. The mobile node can authenticate with several APs at a time.

After the authentication process, the mobile node does not belong to the BSS completely.

The final step—association process is required to allow the DS knows the current location of the mobile node. Unlike authentication process, the mobile node can only associate with one access point at a time.

After choosing the AP with the best signal, the mobile node sends an association requests to the AP to start the process and the AP responses the request with a positive message containing an association ID. Hence, the AP stores all the information of the mobile node and it starts to process the messages for the mobile node. After the association process, the mobile node can transmit or receive data through the AP.

When the mobile node moves from one BSS to another BSS, the mobile node needs to move the association from the old AP to a new AP by re-association process. During the mobile node's movement, the mobile node monitors the signal from its current AP as well as other available APs in the same ESS. When the signal quality from other APs is better than the current one, the mobile node recognizes that the current AP should be changed and it starts the re-association process by sending a re-association request message to the new AP which has the best signal.

After receiving the re-association request, the new AP first subtracts the address of the old AP from the request message and then it communicates with the old AP to check whether the previous association exists or not. If the old access point does not verify that it authenticated the station, the new AP sends a de-authentication message to the mobile node and ends the re-association process. Thus, the re-association fails and the mobile node can not change the access point.

While if the previous association is authenticated by the old AP, the new AP will send a positive re-authentication message containing a new association ID to the mobile node to inform the change. Simultaneously, the new AP notifies the association change to the old AP. Consequently, the old AP sends all the data in the buffer for the mobile node to the new AP and the new AP starts to process all the traffic for the mobile node. [11, 16-18].

By now, the mobile node can use the AP as a bridge for data communications. To sum up, there are four main steps for a mobile node to access a new AP when the mobile node is moving inside an ESS: scanning, authentication and re-association. These process in 802.11WLAN is smoothly and seamless. The whole procedure for a mobile node to access an AP in a BSS and change the can be seen in Figure 2.4

So, an overview of wireless LAN and CDMA networks has been discussed in this chapter. Mainly network architectures signal diagrams are highlighted. In the next chapter handoff management has been discussed. And, finally a vertical handoff will be proposed between WLAN-CDMA networks.

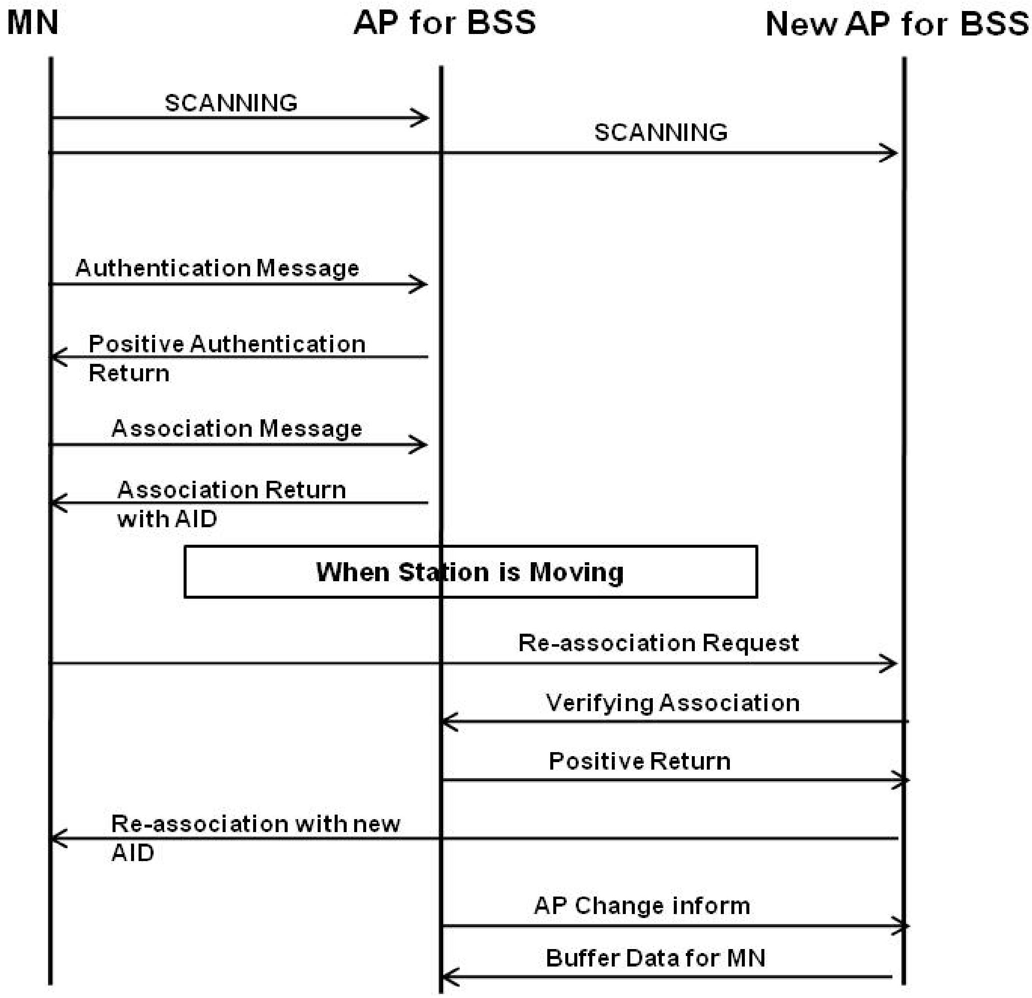


Figure 2.4: Network attachments in 802.11b WLAN

Chapter 3

Overview of Handover Management

In telecommunications, the term Handover or Handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another. There may be different reasons why a handoff might be conducted. The main intention is to provide an uninterrupted communication. When the a phone is moving away from the area covered by one cell and entering the area covered by another cell the call is transferred to the second cell in order to avoid call termination when the phone gets outside the range of the first cell; the same reason is true in case of data session. When a mobile node is moving out from an area covered by an AP (Access Pointer) to another area covered by another AP, handoff is essential to avoid the interruption in the session.

3.1 Handoff Strategy

An event when a mobile station moves from one wireless cell to another is called Hand over or Handoff. Handoff can be of two types: horizontal (intra-system) and vertical (inter-system) cases.

Processing handoff is an important task in any wireless system. Handoff must be performed successfully and as infrequently as possible, and be imperceptible to the users, In order to meet these requirements system designer must specify an optimum signal level at which to initiate a handoff. Once a particular signal level is specified as the minimum usable signal for acceptable quality, a slightly stronger signal level is used as a threshold at which handoff is made. This margin given by

$$\nabla = \Pr(\,handoff\,) - \Pr(minimum\ usable)$$

If ∇ is too large, unnecessary handoffs may occur and if ∇ too small, there may be insufficient time to complete handoff [19]. Figure 3.1 illustrates the handoff situation.

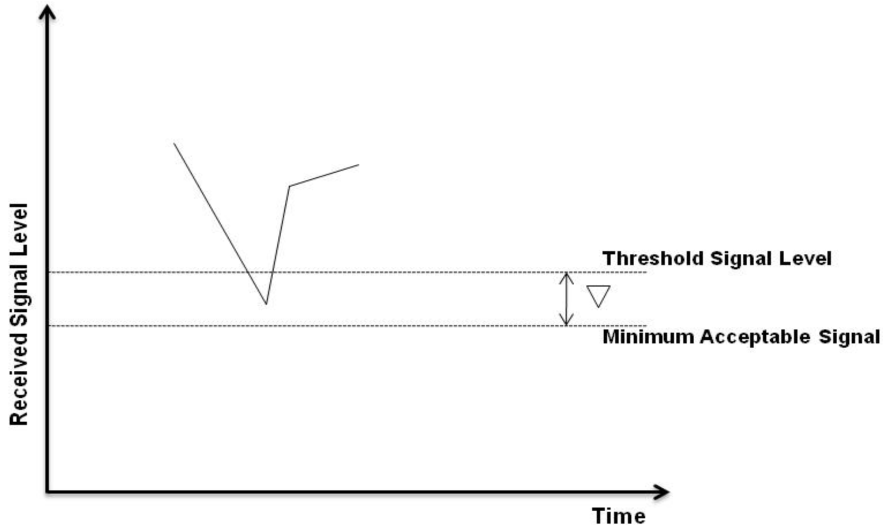


Figure 3.1: Handoff Situation

It is clear that signal strength goes down as mobile device moves away from the base station or access pointer. The ideal coverage area is circular shape as shown in Figure 3.2. It is considered that two areas covered by two stations are located adjacently. Now, if the mobile device goes away from the center of the *i* circle to the center of *j* circle, the signal strength of *i* station of becomes weak. As it moves towards the *j* circle, the strength of *j* station becomes strong. The received power as a function of distance is shown in the Figure 3.3 which approximately given by equation (3.1)

$$P(x) = A_0 \, e^{-\gamma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where, A_0 is a constant and γ is the propagation constant, which lies between 4 and 5 for mobile communication.

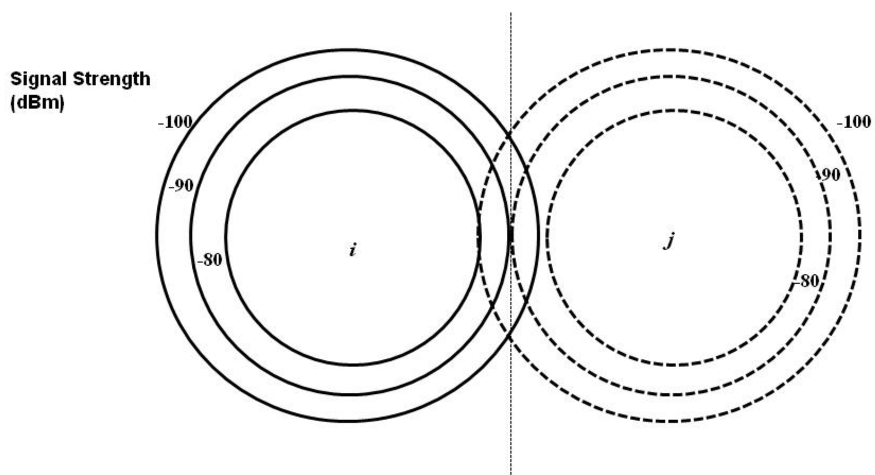


Figure 3.2: Signal Strength Contours

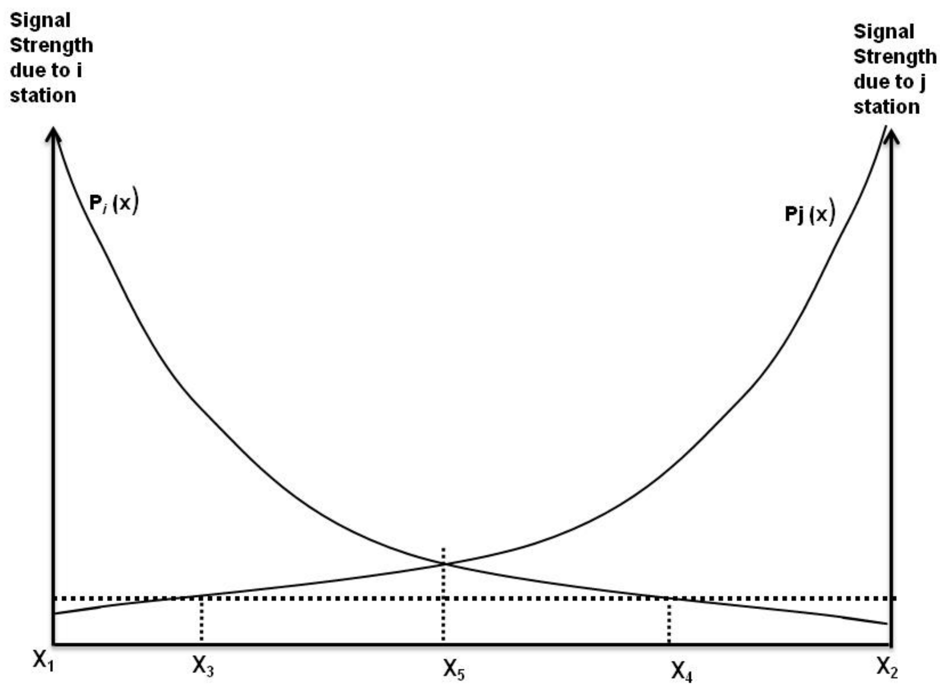


Figure 3.3: Received Power as a function of distance

At distance X_1, the received signal from station *j* is close to zero and signal strength at the mobile device can be primarily attributed by the station *j*. Similarly, at distance X_2 the signal from station *i* close to zero. To receive and interpret the signal correctly the received signal must be at a given minimum power level which shown by dotted line in the Figure 3.3 and distance X_3 and X_4 represent two such points for *i* and *j* station. Therefore X_3 to X_4 can be considered as Handoff area. One option is to do Handoff at X_5 considering different criterion [20].

3.2 Handoff Rate

Figure 3.2 shows the signal power distribution by a station is circular. But in real scenario it is not circular. Consider-

A rectangular area 'A' which is covered by the signal of a station/access point. R1 and R2 are two sides of that area shown in Figure 3.4. N1- Number of Mobile Node (MN) having Handoff per unit length in Horizontal direction. N2- Number of Mobile Node (MN) having Handoff per unit length in Vertical direction.

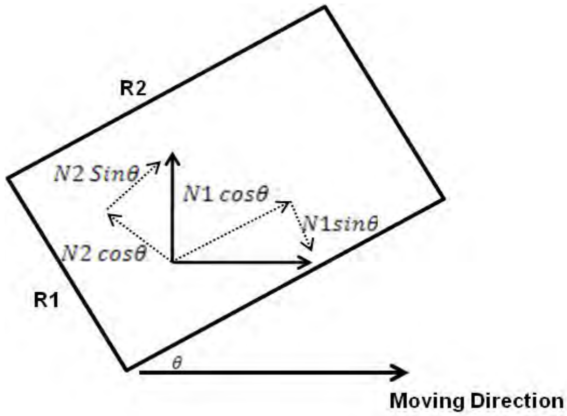


Figure 3.4: Handoff rate in a rectangular cell

So, the number of MN crossing along R1 side can be given by-

$$R1\ (N1cos\theta + N2\ sin\theta)$$

Similarly, the number of MN crossing along R2 side-

$$R2\ (N1sin\theta + N2\ cos\theta)$$

Therefore the total Handoff rate can be given by equation (1)

$$\lambda H\ = R1\ (N1cos\theta + N2\ sin\theta) + R2\ (N1sin\theta + N2\ cos\theta) \quad \text{……….. (3.2)}$$

The question is how to minimize λH for a given θ

Area, A= R1R2. Substitute the value R2=A/R1 & differentiating equation (3.2) with respect to R1 and equating to zero-

$$N1\ cos\theta + N2\ Sin\theta - \frac{A}{R1^2}\ (N1sin\theta + N2\ cos\theta) = 0$$

We have-

$$R1^2 = A\ \frac{N1\ sin\theta + N2\ cos\theta}{N1\ cos\theta + N2\ sin\theta} \quad \text{……………….. (3.3)}$$

Similarly-

$$R2^2\ = A\ \frac{N1\ cos\theta + N2\ sin\theta}{N1\ sin\theta + N2\ cos\theta} \quad \text{……………… (3.4)}$$

From Equation (3.2)

$$\lambda H = \sqrt{A \frac{N1\ sin\theta + N2\ cos\theta}{N1\ cos\theta + N2\ sin\theta}} (N1 cos\theta + N2\ sin\theta)$$

$$+ \sqrt{A \frac{N1\ cos\theta + N2\ sin\theta}{N1\ sin\theta + N2\ cos\theta}} \ (N1 sin\theta + N2\ cos\theta)$$

$$= 2\sqrt{A(N1\ sin\theta + N2\ cos\theta)(N1\ cos\theta + N2\ sin\theta)} \quad \text{………………..} \ (3.5)$$

Equation (4) is minimized if $\theta = 0$
Therefore,

$$\lambda H = 2\ \sqrt{A\ N1N2} \quad \text{……………...} \ (3.6)$$

$$\frac{R1}{R2} = \frac{N1}{N2} \quad \text{……………… } (3.7)$$

From equation (3.6) handoff rate is found. And equation (3.7) tells that handoff is inversely proportion to side of the area (rectangular area) of radius of the area (circular area) [20].

3.3 Types of Handoff

3.3.1 Horizontal Handoff

Handoff within the same wireless access network technology is considered as Horizontal handoff, i.e. a Horizontal handoff is a handoff between two network access points that use the same network technology and interface. For example, when a mobile device moves in and out of various 802.11b network domains, the handoff activities would be considered as a horizontal handoff, since connection is disrupted solely by device mobility. The following Figure 3.5 shows a simple scenario of horizontal handoff [21].

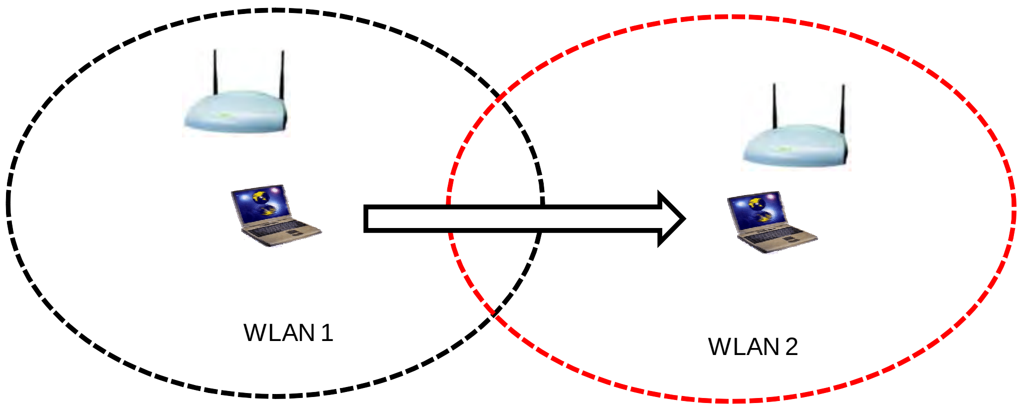


Figure 3.5: Horizontal Handoff

3.3.2 Vertical Handoff

Handoff among heterogeneous wireless access network technologies is considered vertical handoff i.e. Vertical handoff is a handoff between two network access points, which are using different connection technologies. For example, when mobile device moves out an 802.11b network into a GPRS network, the handoff would be considered a vertical handoff. The following Figure 3.6 shows a simple scenario of vertical handoff [21].

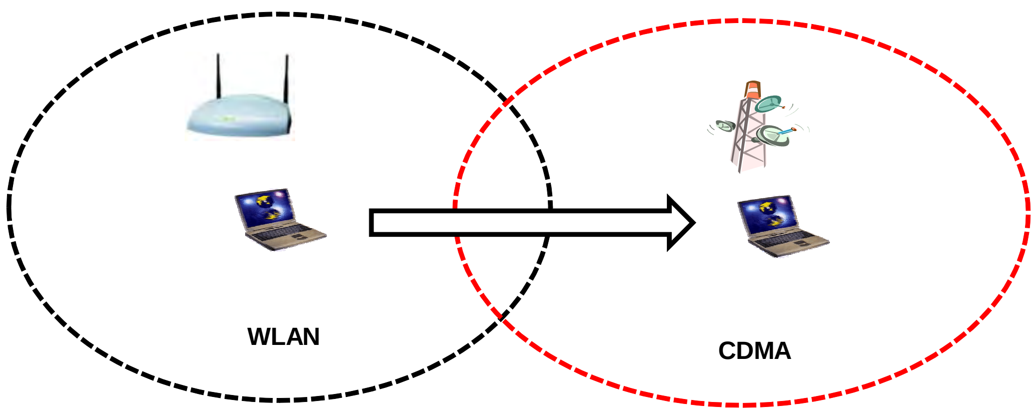


Figure 3.6: Vertical Handoff

The terminology of horizontal and vertical reflects the wireless access network technology instead of the administrative domain in comparison to macro- and micro mobility. Considering the administrative domains there are different subclasses such as follows:

• Vertical macro mobility refers to mobility among different administrative domains using different wireless technologies

• Horizontal macro mobility refers to mobility among different administrative domains using the same wireless technology

• Vertical micro mobility refers to mobility within the same administrative domain using different wireless technologies

• Horizontal micro mobility refers to mobility within the same administrative domain using the same wireless technology.

Again, considering the methods Handoff can be classified as Hard handoff and Soft Handoff

Hard Handoff: It has a brief disruption of service as it has to break before a making a switching action. Hard Handoffs are used by Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) systems.

Soft Handoff: It has no disruption of service action as it makes a switching action before the break. Multiple network resources are used by soft handoffs. Soft handoffs are used by CDMA system.

3.4 Background: A short history of Vertical Handoff

During the past decade both telecommunication and Internet technologies have been in a phase of rapid development. Till the beginning of the new millennium the development was mainly technology driven and the real user needs were many times forgotten. Still, the mobile Internet evolution has taken many important steps towards providing better quality wireless data services to a wide audience. In cellular networks, evolution for the first three generations contributed to growing data rates and enhanced communication capabilities, achieving its current peak only recently in the third generation (3G) mobile networks and handsets. At the same time wireless local area networks have achieved enormous popularity in providing wireless broadband connection in public, enterprise and residential environments. Combining these two wireless technologies has attracted researchers now for about a decade, but there still remain issues to study. The next evolutionary steps after the third generation aim to provide extended mobility with optimized data rates and services. Nomadic users have more flexibility when using multiservice networks that provide services such as seamless connection to the Internet via heterogeneous networks, advanced spatial location and navigation services and true IP based real-time multimedia. One of the key challenges in future network management is end-to-end optimization that takes into account variables such as throughput optimization, routing optimization, delay profiles for heterogeneous wireless environments and also economical profitability. The door for next generation networks and services beyond 3G is opening and is soon ready for entering. These systems are called B3G (beyond 3G) or 4G. They will make heavy use of heterogeneous networking technologies [22].

3.5 Vertical Mobility Management

Table 3.1 shows a model representing the management of vertical mobility. Looking from a top-down perspective, one can distinguish between resource management, mobility engineering and service management categories in the system architecture design.

Resource management is comprised of both direct (channel and bandwidth allocation,) and indirect (network capacity and performance optimization through various ways) resource allocation in a multiple heterogeneous wireless networks environment. Resource allocation affects directly the experienced QoS, but the end-to-end QoS also requires other management, such as prioritizing packets in the routing, using header compression over wireless links and buffering packets in the terminals and routers (limited by the QoS requirements).

Mobility engineering comprises integrating heterogeneous access networks and services, providing mobility management, and designing and implementing various protocols and middleware solutions in the different layers of the OSI protocol stack. At the core of the whole system architecture design is mobility management. Mobility management in the next generation all-IP based wireless systems uses hierarchical network architectures both in horizontal and vertical planes. Mobility management across B3G networks, where “access is the killer application” can be conceptually divided into several subtopics such as mobility and interworking scenarios, handoff control strategies, handoff algorithms, handoff performance measures, handoff methodology, handoff metrics and mobility parameters.

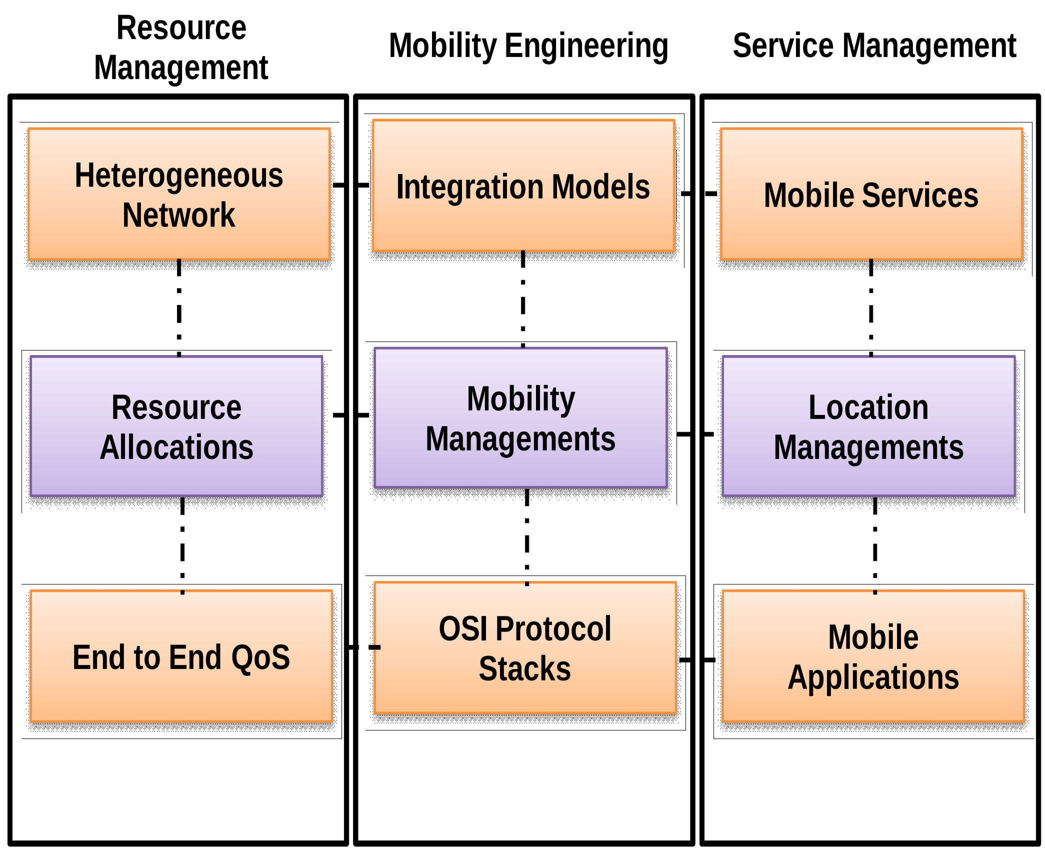


Table 3.1: Management of Vertical Handoff

Service management includes providing mobile services such as user profiles, AAA functions, and service life-cycle management through OTA functions (for downloading and upgrading services), location management (location registers and location services) and provisioning mobile applications [22-24].

3.6 Technical aspects for Vertical Mobility

It is discussed that Vertical handover occurs between two heterogeneous networks. Some different management is required to make such handover which is discussed in the previous section. There must some technical issues for this kind of mobility. Also some procedure and algorithms are required to follow to make handover. In the following sections some of the required technical features are pointed-

Dual mode card

To support vertical handover, a mobile terminal needs to have a dual mode card that can work under both WLAN and other 3Gnetworks frequency bands and modulation schemes.

Interworking architecture

For the vertical handover between WLAN and other 3G networks such as CDMA 2000 networks, there are two main interworking architecture: tight coupling and loose coupling. The tight coupling scheme, which 3GPP adopted introduces two more elements WAG (Wireless Access Gateway) and PDG (Packet Data Gateway). So the data transfers from WLAN-AP to a Corresponding Node on the internet must go through the Core Network of CDMA2000.

Loose coupling is more used when the WLAN is not operated by cellular operator but any private users. So the data transmitted through WLAN will not go through Cellular Networks [23].

Handover metrics

In traditional handovers, such as a handover between cellular networks, the handover decision is based mainly on RSS (Relative Signal Strength) in the border region of two cells, and may also be based on call drop rate, etc. for resource management reasons. In vertical handover, the situation is more complex. Here user preference, network conditions, application types, cost etc. are also included.

Handover decision algorithm

Based on the handover metrics mentioned above, the decision about how and when to switch the interface to which network will be made. Many papers have give their reasonable flow chart based on the better service and lower cost, etc. while some others, using fuzzy logic or neuron network to solve the problem.

Mobility management

When a mobile station transfers a user's session from one network to another, the IP address will change. In order to allow the Corresponding Node that the MS is communicating with to find it correctly and allow the session to continue, Mobility Management is used.. The Mobility Management problem can be solved in different layers, such as the Application Layer, Transport Layer, IP Layer, etc.

Handoff procedure

The handover procedure specifies the control signaling used to perform the handover and is invoked by the handover decision algorithm. Vertical handover refers to a network node changing the type of connectivity it uses to access a supporting infrastructure, usually to support node mobility [24, 25].

3.7 Conclusion

The fundamental characteristics of 802.11b WLAN and CDMA2000 in terms of network architecture were discussed in the last chapter.

The first remarkable difference between these two network technologies are the range of supported service. All the services supported by 802.11b WLAN are available by CDMA2000. The CDMA2000 standard supports a variety of circuit-switched and packet-switched services including voice, video applications, SMS (short message service), MMS (multimedia messaging service), email, fax, while the 802.11b WLAN only supports the corresponding packet-switched services. Coverage also differs heavily between CDMA2000 and WLAN networks. A CDMA2000 network is based on the cellular concept. Although a base station only covers a small area, a large area can be divided into many small areas or cells each covered by a separate base station.

There are two benefits of this concept. Firstly, the mobile station can use the same frequency in one cell as the one other mobile station use in another non-overlapping cell. Secondly, the transmitter power can be lowered by reducing the base station covered area. Also, CDMA2000 1x provides soft handover mechanism so the mobility of the mobile station is high. On the contrary, 802.11 WLAN incorporates a non-cellular concept in terms of much smaller locally situated network islands, the so-called hot spots. Usually these 802.11 WLAN hot spots areas only cover homes, small enterprises, campuses, hotels, hospitals, airports etc, so the coverage of 802.11 WLAN is local. Also, WLAN provides re-association process to make the mobility of the mobile node low. Hence, the advantages of CDMA2000 network comparing to WLAN are more available service, increased capacity, reduced transmitter power and huge coverage.

Another significant difference is in the data rate. CDMA2000 network supports data rates up to144kbps while 802.11b WLAN is much faster than CDMA2000 and can support data rates up to 11Mbps. The costs of deploying these two network technologies are also very different. A CdMA2000 network is based on cell and each cell needs a BTS, which makes CDMA2000 network so costly. Also, the license and frequency use fees are very expensive. These two aspects make the deployment of CDMA2000 networks hard. Normally, building a CDMA2000 networks needs the permission of a government and is run by a large company. In contrast, the 802.11 WLAN deployments require relatively cheap access points and there is no license or frequency fee for the 802.11 WLAN. It is easy for an individual to create a WLAN at home.

Hence, the advantages of WLAN network are low cost and high speed in comparison to CDMA2000 network. Table 3.2 shows the comparison between the CDMA and WLAN

Characteristics	CDMA2000	WLAN
Services	Circuit- packet- switched and services	Packet-switched services
Data rates	Ranging from 144kbps to 4.8Mbps	Up to 54Mbps
Coverage	National/international coverage	Local coverage
Power control	Flexible power control	Max. effect of 100mW required
Mobility	High	Low

Table 3.2: Comparison between CDMA and WLAN

To sum up, both WLAN and CDMA2000 have their strengths and weaknesses. WLAN provides much higher data rates, however the mobility of WLAN is low with only over small areas, whereas CDMA2000 offers relatively lower date rates but much higher mobility with reliable nationwide coverage. As a result, by combining them, it may be possible to achieve high data rates within certain hot-spots, while still obtaining reliable connection outside of the hot-spots. How to ensure that mobile users use WLAN to connect to the internet within hot-spots and switch to CDWA2000 when WLAN is not accessible thus becomes crucial to the evolution of mobile world.

Therefore in this chapter there is an overview of handoff management. Handover rate is derived for a simple rectangular cell. Types of handover are discussed also in this chapter. Finally, a vertical handover is proposed between WLAN and CDMA network. In the following chapter, description on the investigation process of handover in WLAN networks and CDMA networks are included. The investigations have been carried out by accomplishing the drive test. The results of the investigation are used to formulate an appropriate algorithm and develop a logical model for accomplishing the proposed handoff.

Chapter 4

The proposed Handover Model between WLAN and CDMA

This chapter is discussed about the investigations for handover managements for two cases are- between two WLAN hotspot areas covered by two AP and between two CDMA BTS. For this, Drive Test (DT) has been performed for the two scenarios mentioned below and realistic handover data has been obtained.

Scenario 1: Handover between two WLAN areas
Scenario 2: Handover between two CDMA cells

With the help of these data, algorithms have been generated for the WLAN-WLAN handover and CDMA-CDMA handover. Then considering all data, combining all algorithms an Empirical Model has been developed for WLAN-CDMA 2000 handover.

4.1 Handover between two WLAN areas (Scenario 1)

Following figure 4.1 shows the two hotspots covered by two Access Pointers AP1 and AP2. Important thing is the two areas are partially overlapped by each other. A drive Test (DT) has been performed for investigations for handover management under exactly the same scenario as depicted Figure 4.1 at level 14 of Axiata Bangladesh Limited office premises.

One area covered by AP1 and another by AP2. During the DT AP1 has been considered as the Serving Access Pointer with SSID (Service Set Identifier) XX (Let) and AP2 is the neighbor Access Pointer with SSID YY. When Mobile Node (MN) moves from area1 towards area2 the signal level (RSSI) of the two APs has been monitored. Hanover has been occurred when significantly change in signal level has been observed.

4.1.1 Analysis for Handover between two WLAN

Following points have been noted during the DT

- After every Specified time (usually 250ms) a Prob request is send to the Serving AP (AP1) to check the signal levels; in case of the signal level is below a threshold (usually -90 dBm) level, starts for handoff.

- If Signal level of AP1 is greater than AP2 by 15 dB, handoff is initiated.

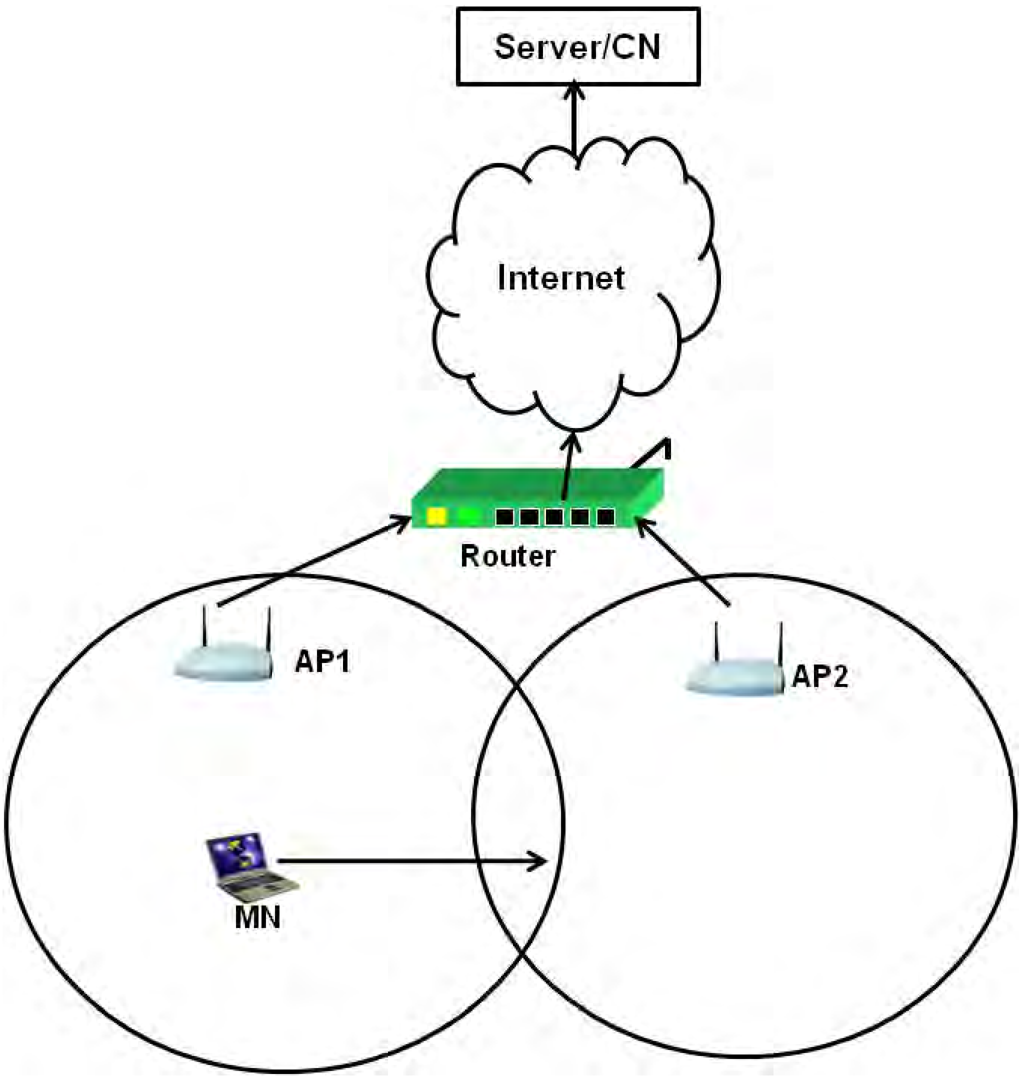


Figure 4.1: Mobile Node moves from AP area to another AP area

Following Table 4.1 shows the Drive Test result in a simplified form.

Serving AP (AP1)			**Neighbors AP (AP2)**		
SSID	**RSSI**	**Channel**	**SSID**	**RSSI**	**Channel**
XX	-65	F1	YY	-92	F2
XX	-64	F1	YY	-91	F2
XX	-68	F1	YY	-90	F2
XX	-69	F1	YY	-90	F2
XX	-70	F1	YY	-90	F2
XX	-70	F1	YY	-88	F2
XX	-70	F1	YY	-89	F2
XX	-71	F1	YY	-86	F2
XX	-72	F1	YY	-85	F2
XX	-75	F1	YY	-85	F2
XX	-75	F1	YY	-84	F2
XX	-76	F1	YY	-84	F2
XX	-76	F1	YY	-82	F2
XX	-78	F1	YY	-81	F2
XX	-78	F1	YY	-77	F2
XX	-79	F1	YY	-77	F2
XX	-79	F1	YY	-75	F2
XX	-79	F1	YY	-75	F2
XX	-80	F1	YY	-73	F2
XX	-80	F1	YY	-72	F2
XX	-81	F1	YY	-71	F2
XX	-82	F1	YY	-71	F2
XX	-82	F1	YY	-71	F2
XX	-82	F1	YY	-69	F2
XX	-83	F1	YY	-69	F2
XX	-83	F1	YY	-68	F2
XX	-68	**F2**	YY	-83	**F1**
XX	-66	**F2**	YY	-84	**F1**
XX	-66	**F2**	YY	-85	**F1**
XX	-65	**F2**	YY	-85	**F1**
XX	-64	**F2**	YY	-86	**F1**
XX	-62	**F2**	YY	-86	**F1**

Table 4.1: Drive Test Results (simplified) under two Access Points

Analyzing the data found in the drive test for handover when mobile node moves from one AP to another AP the following curves are obtained. They show the received signal strength as a function of distance from the AP.

Figure 4.2 and Figure 4.3 shows the signal level of AP1 and AP2 consecutively. Figure 4.4 shows the handover occurs at a particular time. An Algorithm/ Flow chart has been developed for the Handover between two AP incase of wireless LAN handoff. And Figure 4.5 shows that algorithm

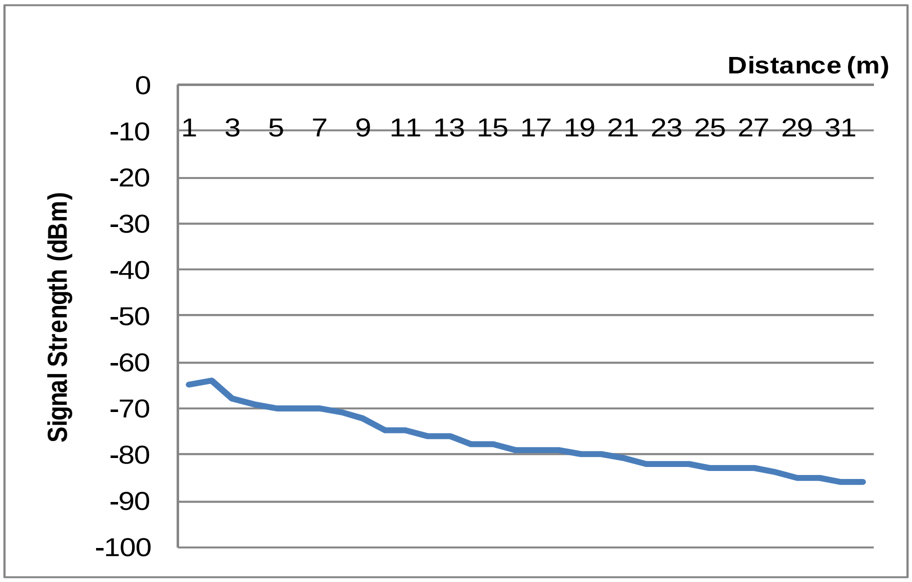


Figure 4.2: Signal Level of Serving AP as a function of distance

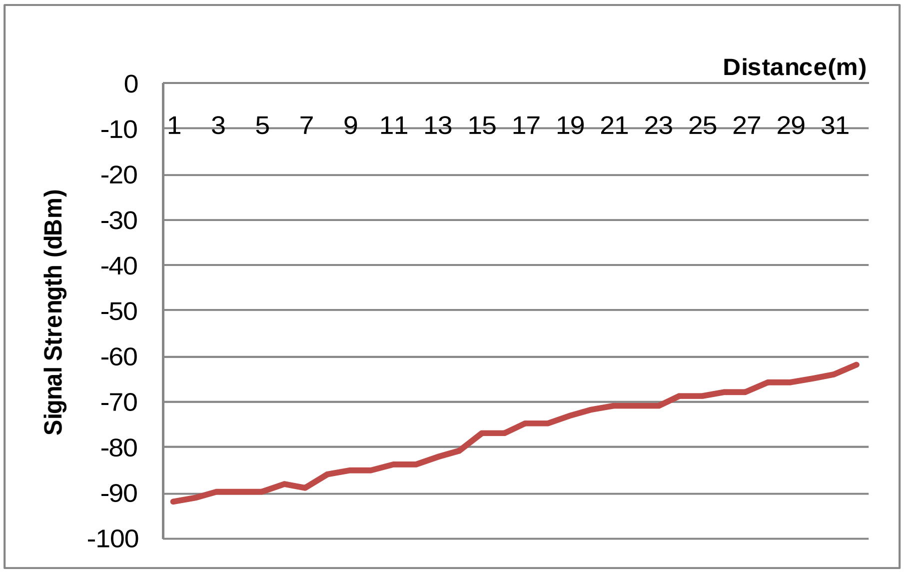


Figure 4.3: Signal Level of Neighbor AP as a function of distance

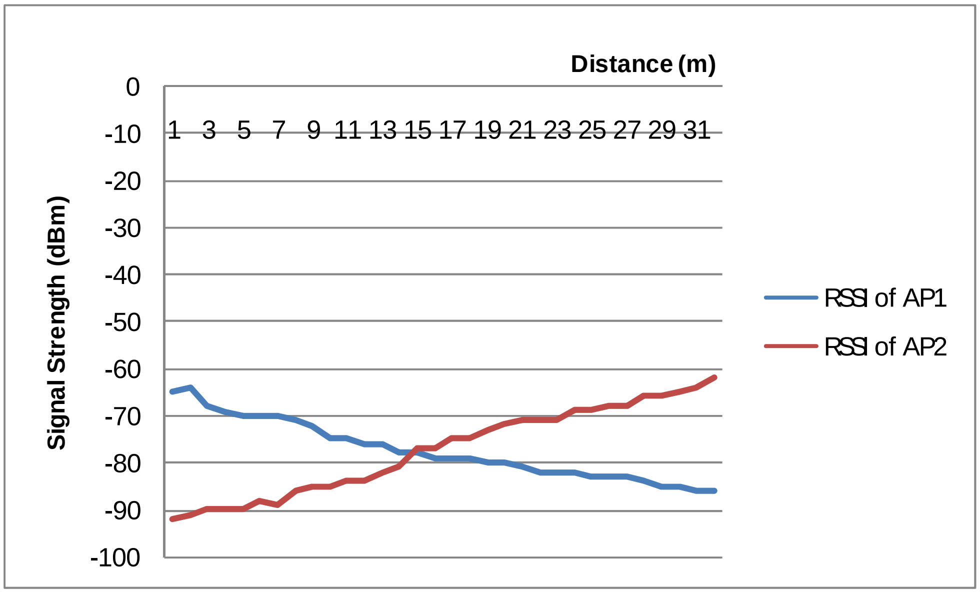


Figure 4.4: Handoff occures between two access points

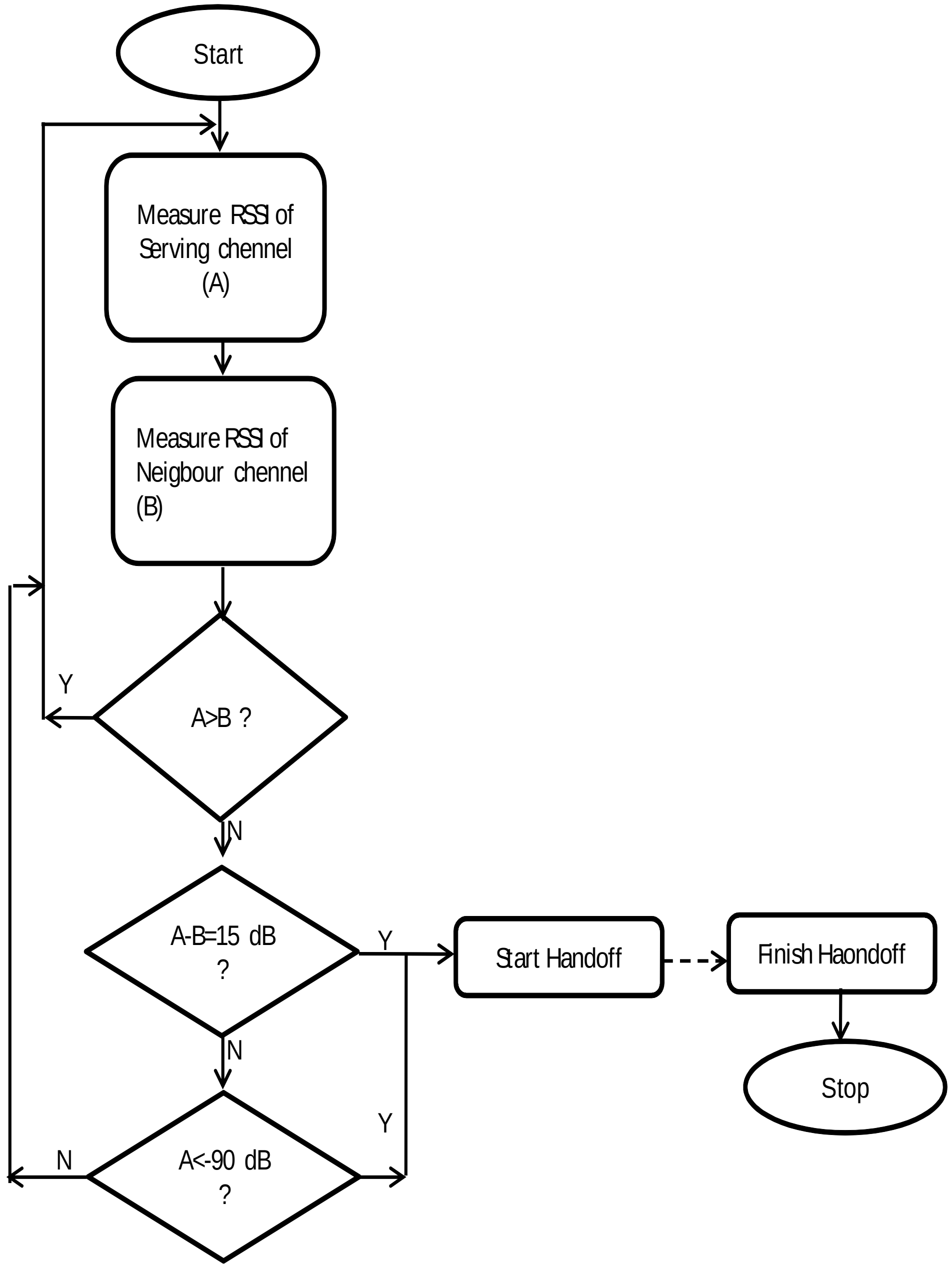


Figure 4.5: Flow chart of Handover between two APs incase of WLAN

4.2 Handover between two CDMA BTS (Scenario 2)

Drive Tests (DT) have been performed in case of handover between two Base Stations. A case has been taken at Sylhet where only two Base Stations are used to cover only the highway coverage of the Axiata Bangladesh Limited. The realistic data has been obtained form the DT.

4.2.1 Analysis for Handover between two CDMA BTS

During the DT it has been observed how the Received Signal Level (Rx_Lev) change and for what kind of change in signal strength initiates the handover. Base Station can

	Serving Cell			Neighboring Cell 1		
Sample	Channel	Rx_Lev		Channel	Rx_Lev	
1	2-3-57	-80	f1	3-3-52	-89	f2
2	2-3-57	-81	f1	3-3-52	-87	f2
3	2-3-57	-82	f1	3-3-52	-87	f2
4	2-3-57	-91	f1	2-3-55	-87	f3
5	2-3-57	-84	f1	2-3-55	-88	f3
6	2-3-57	-84	f1	3-3-52	-86	f2
7	2-3-57	-86	f1	2-3-55	-85	f3
8	2-3-57	-83	f1	2-3-55	-85	f3
9	2-3-57	-82	f1	3-3-52	-88	f2
10	2-3-57	-84	f1	3-3-52	-89	f2
11	2-3-57	-85	f1	3-3-52	-88	f2
12	2-3-57	-86	f1	3-3-52	-87	f2
13	2-3-57	-90	f1	3-3-52	-88	f2
14	2-3-57	-89	f1	3-3-52	-86	f2
15	2-3-57	-88	f1	3-3-52	-89	f2
16	2-3-57	-84	f1	3-3-52	-88	f2
17	2-3-57	-85	f1	3-3-52	-89	f2
18	2-3-57	-85	f1	3-3-52	-86	f2
19	2-3-57	-86	f1	3-3-52	-88	f2
20	2-3-57	-87	f1	3-3-52	-90	f2
21	2-3-57	-88	f1	3-3-52	-89	f2
22	2-3-57	-89	f1	3-3-52	-87	f2
23	2-3-57	-89	f1	3-3-52	-86	f2
24	2-3-57	-90	f1	3-3-52	-86	f2
25	2-3-57	-90	f1	3-3-52	-86	f2
26	2-3-57	-90	f1	3-3-52	-85	f2
27	2-3-57	-91	f1	3-3-52	-85	f2
28	2-3-57	-91	f1	3-3-52	-84	f2
29	2-3-57	-92	f1	3-3-52	-83	f2
30	2-3-57	-92	f1	3-3-52	-82	f2
31	2-3-57	-94	f1	3-3-52	-81	f2
32	3-3-52	-82	f2	2-3-57	-93	f1
33	3-3-52	-84	f2	2-3-57	-92	f1
34	3-3-52	-83	f2	2-3-57	-90	f1
35	3-3-52	-85	f2	2-3-57	-90	f1
36	3-3-52	-84	f2	2-3-57	-88	f1
37	3-3-52	-86	f2	2-3-57	-86	f1
38	3-3-52	-85	f2	2-3-57	-89	f1
39	3-3-52	-84	f2	2-3-57	-88	f1
40	3-3-52	-84	f2	2-3-57	-90	f1

Table 4.2: Drive Test Results (simplified) under two Base Stations

be recognized by the carrier they are using. Carrier contents NCC and BCC with the BCCH frequencies. Following table shows the simplified report of the drive test

Here Carrier frequency comprised by BSIC(NCC+BCC)-BCCH Frequency. For convenience the 'Channel' is noted by f1 or f2. Analyzing the data found in the drive test for handover when mobile node moves from one Base Station to another following curves are generated-

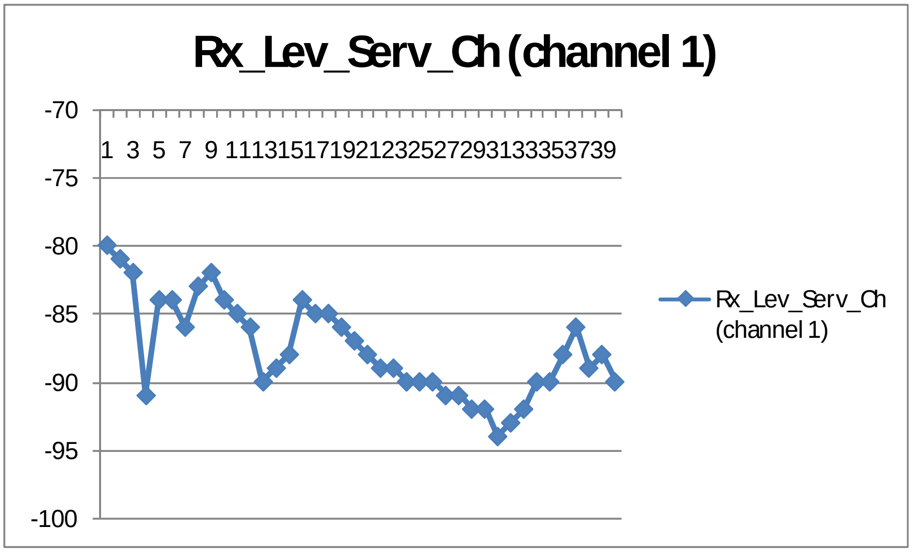


Figure 4.6: Signal Level of Serving cell as a function of time

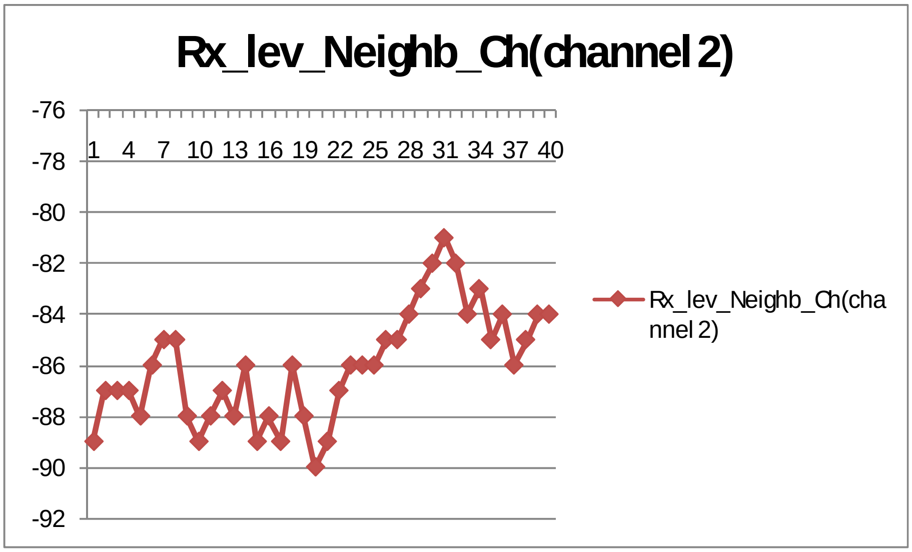


Figure 4.7: Signal Level of Neighbor cell as a function of time

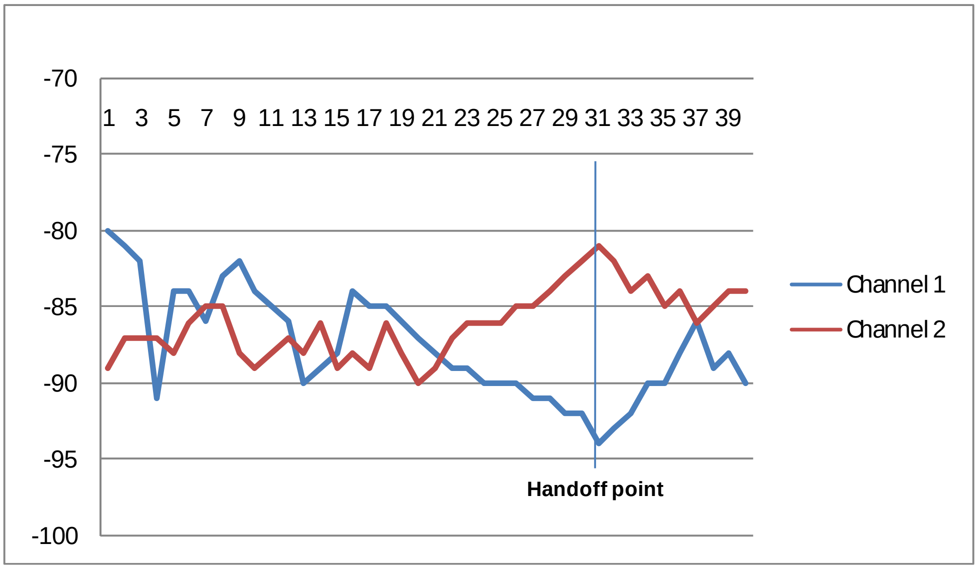


Figure 4.8: Handoff occures between Base Stations

Figure 4.6 and Figure 4.7 shows the Rex Level of Neighbor and serving Channel consecutively. Figure 4.8 shows the handover occurs at a particular time. Important notes are -every sample exists for 480 ms and handover occurs only when the Neighbor Channel Signal Level (Rx_Lev) is greater than Serving channel Signal level for Ten consecutive samples. An Algorithm/ Flow chart has been developed for the Handover between two Base Stations. Following Figure 4.9 shows that algorithm

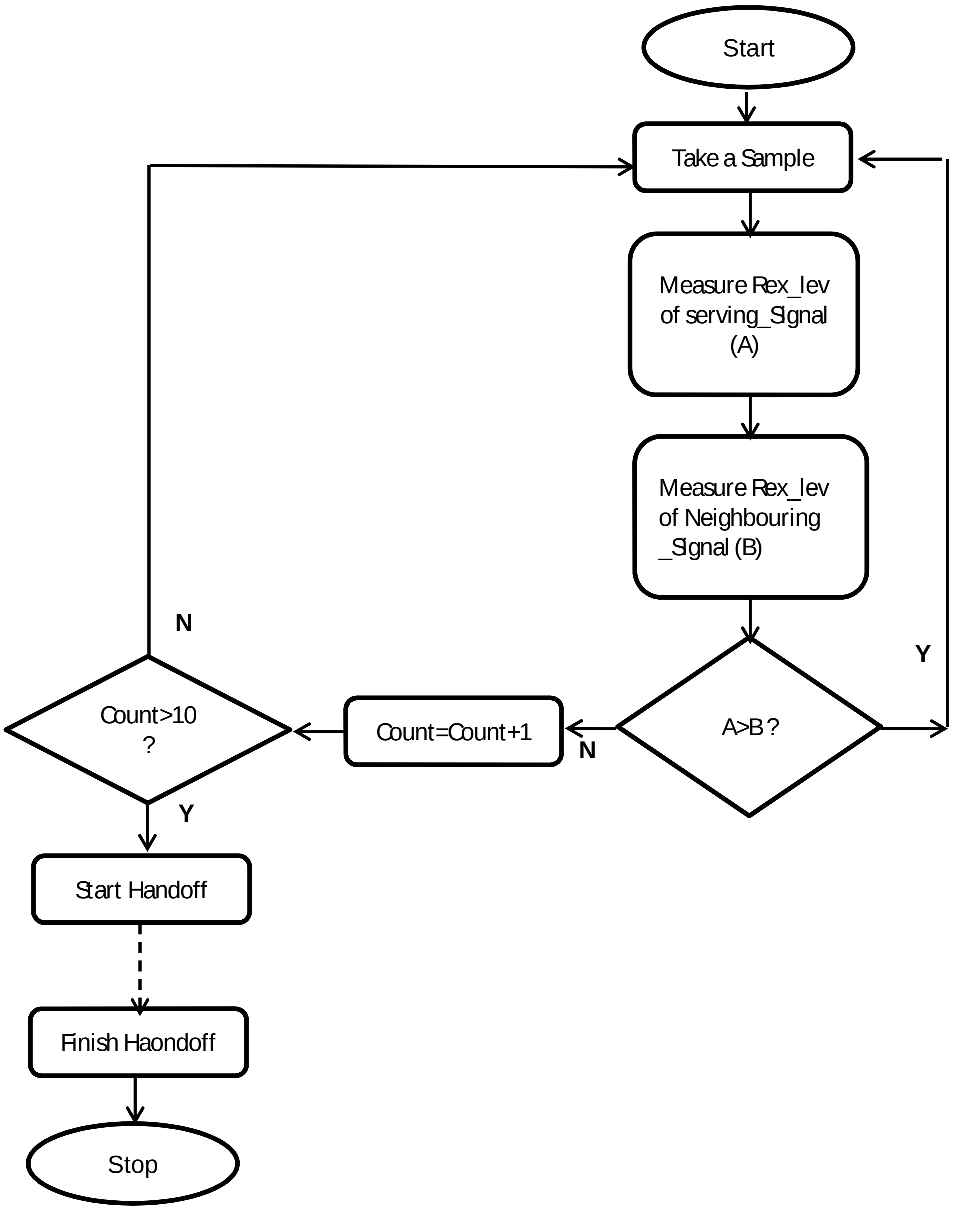


Figure 4.9: Flow Chart of Handover between two Base Station

4.3 Modeling for the Proposed Handover between WLAN and CDMA 2000

After an extensive study of the data obtained form the practical field by the drive test, an algorithm has been developed for handover between the WLAN and CDMA. A sample case has been considered, which is depicted in Figure 4.9. Two areas have been covered by two separate access point. If any Mobile node wants to move from the area under AP1 to area under AP2, there s/he must be offline as there is no WLAN coverage between the two areas. Now Mobile node can go with online if there is CDMA coverage between the two areas. An algorithm has been developed considering the simple case shown in Figure 4.10.

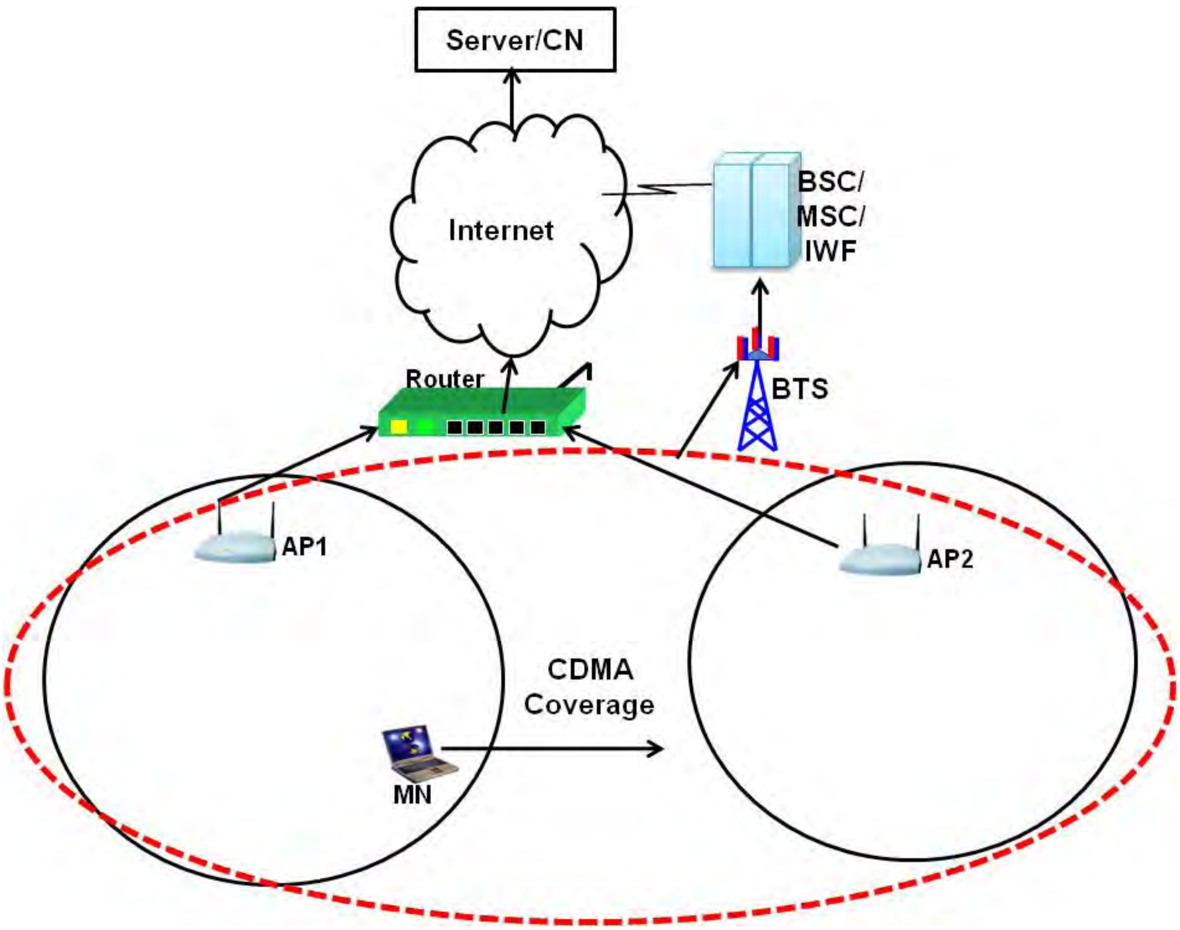


Figure 4.10: Simple Scenario- MN moves from area under AP1 to AP2 without offline using CDMA network.

4.3.1 Handover Throughput

Power P(x) in Figure 4.11 represents the power received at the mobile node (MN) from AP1. At point X1 the signal strength of AP1 is very good. As the node moves away from the AP1, signal strength becomes poor. At point X3 power is above 30%. If movement is happened further towards outside, then signal strength is really poor.
As the area covered by AP2 is not overlapped with area covered by AP1, the connection will be interrupted.

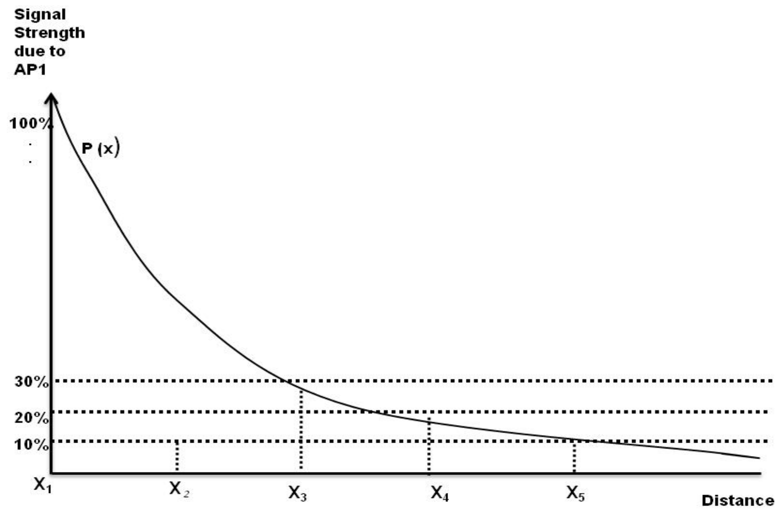


Figure 4.11 (A): Received Signal Strength at Mobile Node (theoretical)

Figure 4.11 (A) shows the power distribution as a function of distance. It is theoretical. However, the theoretical data cannot be used in accomplishing a practical handover. The real received power is different from the theoretical one. The received power P(x) has been gathered from real field data and is shown in Figure 4.11 (B).

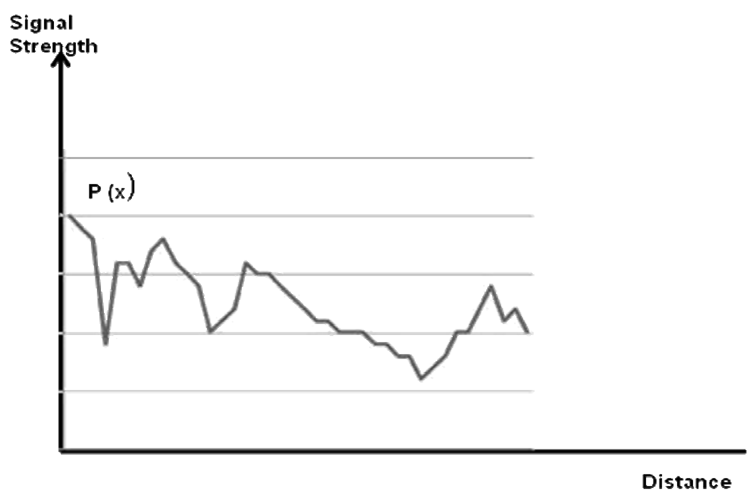


Figure 4.11 (B): Received Signal Strength at Mobile Node (Actual)

Now, using the least mean square algorithm (fitting the real data), a theoretical formula has been developed, which is given in the following equation:

$$P(x) = -a_1 e^{-4} x^4 + a_2 x^3 + a_3 x^2 + a_4 x + C \quad \text{………..} (4.1)$$

Where, $a_1 = 6.2$, $a_2 = 6.6$, $a_3 = -0.0062$, $a_4 = -0.26$ and $C = -82$

The equation (4.1) is used in the proposed handover scheme for achieving handover between WLAN and CDMA2000, and vice versa.

Again, average output power can be determined as a function of time at transition region. For this the distribution of the received signal power is considered as shown in the Figure 4.12.

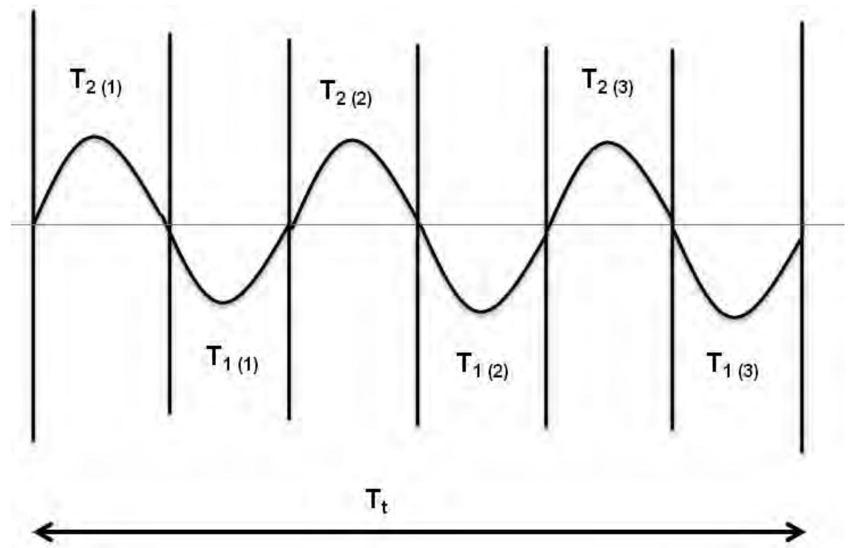


Figure 4.12: Received signal at transition region

T_t - Time Region at which the power P(x) falls below $\lambda_{threshold}$ for the first time to the point at which falls P(x) below $\lambda_{threshold}$ permanently.
T_1 - Each contagious stretch of time where $P(x) > \lambda_{threshold}$ within T_t.
T_2 - Each contagious stretch of time where $P(x) < \lambda_{threshold}$ within T_t.
$T\eta$ - Normalized Handover delay in handover transition region.
S- Average throughput in each case.
n- Number of times P(x) crosses the value λ.
Δ- Handover completion time.
r_1 – Effective data rate available over the air in WLAN.
r_2 – Effective data rate available over the air in CDMA

If the Handover is executed at each point where the signal strength crosses the $\lambda_{threshold}$ in transition region, then average throughput is as follows

$$S(t) = r2\left(T2(total) - \frac{Tn}{2}\right) + r1\left(T1\ (total) - \frac{Tn}{2}\right) \quad \text{………. (4.2)}$$

The three random variables in the above equation (4.1) are-

$$T1\ (total) = \sum_{i=1}^{n/2} T1\ (i)/Tt$$

$$T2\ (total) = \sum_{i=1}^{n/2} T2\ (i)/Tt$$

And,

$$Tn = \frac{\Delta n}{T}$$

4.3.2 Proposed Algorithm for Handover between WLAN- CDMA 2000

An Empirical algorithm has developed considering the sample case shown in the Figure 4.13 and a basic signal flow diagram has been also developed considering the sample case shown in the figure 4.9 which is shown in Figure 4.14.

In this algorithm, at first signal strength of serving access pointer has to be measured. Scan has to be initiated at the same time whether any neighbor access pointer exsists for wlan area. Any of two cases may happen:

(i) Neighbor AP exists for WLAN signal
(ii) No neighbor AP for any WLAN signal.

For the first case, WLAN to WLAN handover may be occurred if mobile node moves away form the coverage of serving station. Algorithm has been set in a way that neighbor signal strength has been measured also. Handover has to be done if neighbor signal strength is greater than serving signal at least 15 dB. This handover has to be done under the mobile internet protocol version 4 or 6 (MIPv4 or MIPv6)

Now for the second case, where no neighbor access pointer is found for WLAN coverage, need to handover to CDMA network to maintain the uninterrupted connectivity. After scanning for the neighbor signal, when no access pointer is found to WLAN to WLAN handover, serving signal strength has to be compared to the power level of -90 dBm. If serving signal strength is poor than -90 dBm, need to handover to CDMA network. For this interfacing card need may need to be activated.

The signal flow diagram has also derived shown in Figure 4.14 in the following page. When mobile Node is in a home network, it uses the home address to send or receive any packets. When it moves away form its home network and enters a foreign network, it requires re-association.

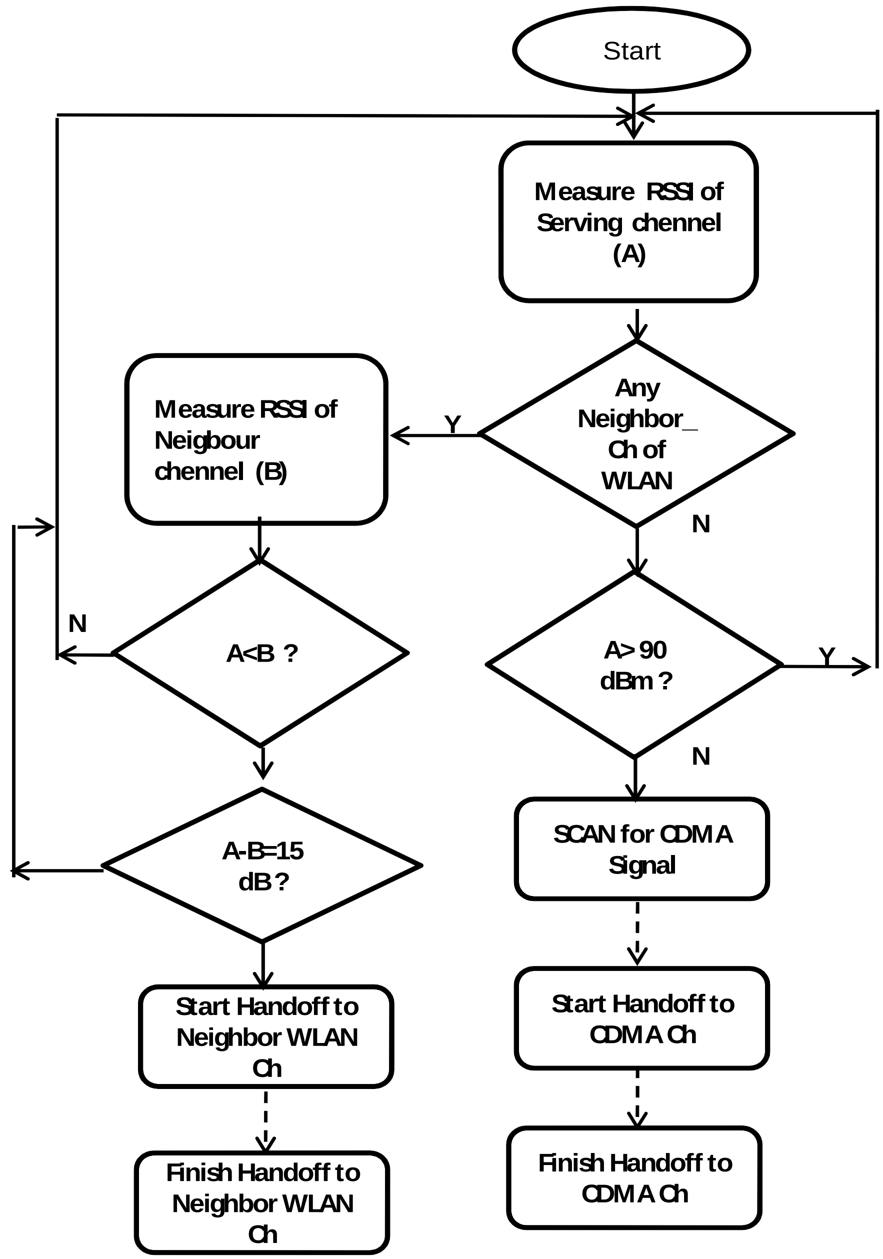


Figure 4.13: Flow chart of Proposed Algorithm for WLAN-CDMA Handover

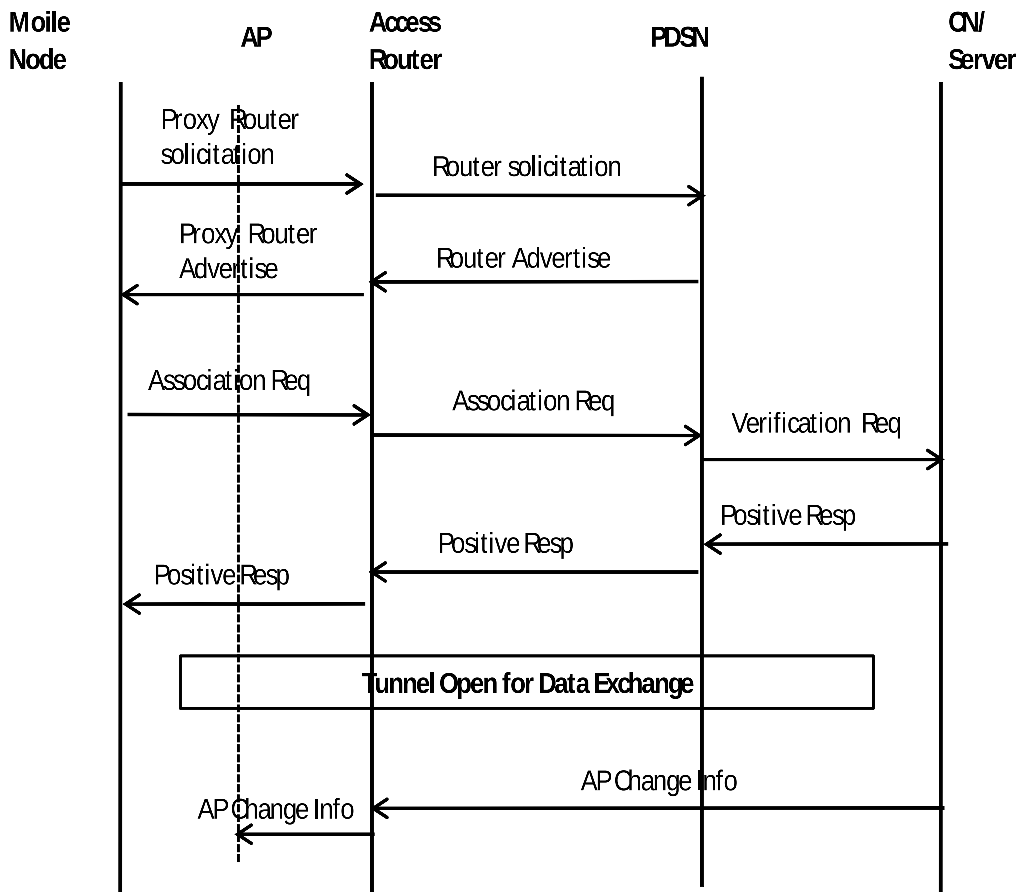


Figure 4.14: Signal flow diagram when mobile node is moving out from area under an AP to CDMA network

As it moves to a heterogeneous network rather than a same homogeneous network, access router is used one of the gateway. For association of mobile node, router needs to be solicited through packet data service network (PDSN) of CDMA network. The address verified by the server.

A tunnel has been opened to exchange the data. As soon as it associated with CDMA network, automatically a different address is assigned. This address is updated in the server and this address is set as primary address. Any packet come to previous address, is rerouted to the new one.

Based on the modeling and algorithms derived in this chapter a simulation has been done using Matlab. The simulation results are discussed on the next chapter. Moreover, a simplified test bed has been developed based on this handover model which has also been discussed in the following chapter.

Chapter 5

Simulation and Test Bed Results

In this concluding chapter there are discussions about a simulation by MATLAB of the case studies in the previous chapter, a simplified test bed for the WLAN-CDMA handoff. Figures and graphs are provided in case of MATLAB simulation. For the test bed development Viusal C# is used to prepare for supporting software. Samples of codes of both MATLAB and C# are attached as Annexure of this thesis. Finally chapter is ended with the analysis of results and scopes for the future works

5.1 Simulation of Proposed Modeling

Refer to Chapter 4, a simplified model has been considered where two areas are covered by two access pointer. These two areas are separately situated; so any mobile device wants to move from one area to another would be disconnected from internet. Now if user wish to be online during the transition period, CDMA network need to be used by the user. A model has been proposed for the WLAN to CDMA handover in chapter 4. By analyzing the practical data obtained from the drive test for handover cases of both WLAN-WLAN and CDMA-CDMA handover, an empirical algorithm has been modeled which has been discussed in figure 4.10 in the previous chapter.

5.1.1 Simulation

Simulation of the algorithm shown in Figure 4.12 has been done by the MATLAB. The summary of the considerations are if signal level of the WLAN is measured below a threshold it search for neighbor. If any neighbor is found immediately starts the neighbor signal strength with exiting signal strength as well. If neighbor signal level shows the better than existing at least 15 dB then handover occurs to the neighbor one.

Now, if no neighbor signal of WLAN communication will be interrupted. To make the connection uninterrupted is started for the CDMA signal. As soon as CDMA signal is found during the searching period, it measures the existing signal level. Handover occurs if the signal goes below threshold level

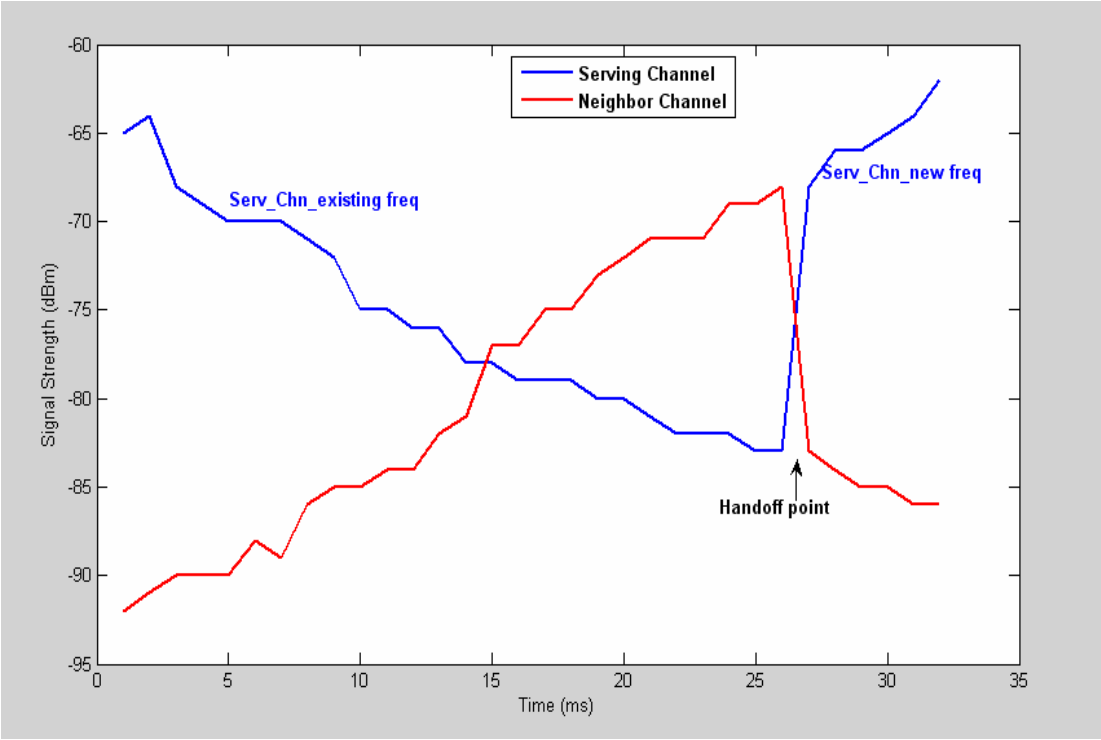


Figure 5.1: Simulation of WLAN Handover with WLAN neighbor

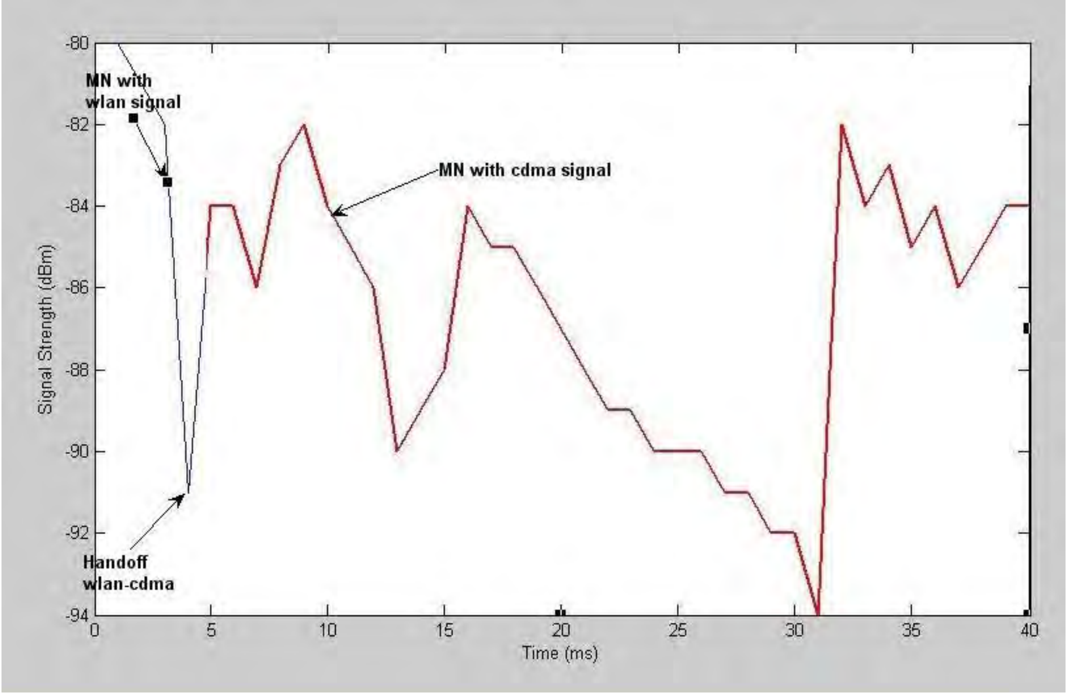


Figure 5.2: Simulation of Handover between WLAN and CDMA (no WLAN neighbor)

5.1.2 Results

From the figure 5.1 it is observed that serving channel signal under a WLAN is going down; neighbor signal strength is going better as the mobile node is moving towards the neighbor. When the neighbor signal strength is better than serving signal by at least 15 dB, handover occurs. It takes about 10 ms time after neighbor signal strength has better than existing one to fulfill this condition simulation.

From the Figure 5.2 it is observed that there is no WLAN neighbor signal during the period the mobile device is going out of the coverage of WLAN. To maintain the uninterrupted connectivity it makes handover for its data traffic to the CDMA network. As the mobile devices has both interface card active, so it takes fraction of ms time to route its data packet through the CDMA network.

These are the simulated results. There are some deliberations about of a test bed of this is simplified model of handover scenario in the following sections

5.2 Test Bed

In this section description how to set up our handover test bed between CDMA2000 and WLAN networks, which includes how to configure a Mobile node/ device (laptop) with a software 'WLAN-CDMA Handover' developed by C# code and how the interface cards are used.

The core idea is that the Mobile device (laptop) will have two interface cards-one for wireless LAN interface card and another for CDMA interface card. Both cards need to be power on for all the time but as long as the laptop under any access point coverage area the CDMA card remain inactive. The unique developed software will be the measure the signal strength of wireless LAN signal through the interface card. As soon as it will detect the signal strength poor than -90 dBm, it will activate the CDMA card and traffic will be reroute through the CDMA network.

Here assumption is that when wireless LAN signal goes beyond -90 dBm, laptop will not detect ant neighbor wireless LAN signal. In case of this thesis, the wireless LAN signal couldn't be scanned automatically. Here we have to measure the signal strength manually and need to put that value in to the software. A future scope of this test bed is to improve the software so that easily scanned the signal strength automatically.

5.2.1 Test Equipment

The equipments have been used to develop the test bed are a laptop, a wirless LAN interface card and a CDMA interface card. The DELL laptop has the Intel Core Duo Processor; operating platform is Windows XP. The wireless interface card is TL-WN422G form TP-LINK; high gain this usb card has data speed up to 54 mbps. And the CDMA interface card name is 'Zoom'. This is again an usb card. This card belongs to 'Citycell' a CDMA operator in Bangladesh-provide CDMA One with some features of CDMA 2000 services.

The above figure shows the test bad. After installing the wireless LAN card, need some configurations such IP address, Domain, subnet mask etc. After that wireless LAN is connected to the Laptop. Wireless LAN signal strength can be measured by the application software provided by the card company. CDMA card also installed with its application software provided by the CDMA operator. To connect with internet through this CDMA interface card, need to activate the card launching the application software. Now both wireless LAN card and CDMA cards are powered on. Laptop is connected with internet via wireless LAN card. Internet surfing is going on. Software 'WLAN-CDMA Handover' developed with c# code has to run parallel. We start to move the laptop away from the access pointer and measure the signal strength. As soon as we found the signal strength is poor than -90 dBm, this value is put in to the software. CDMA application software becomes start and CDMA interface card activate. Then laptop is kept out of the wireless LAN coverage; internet surfing in the same internet address/mail be still possible through CDMA coverage via CDMA interface card.

5.2.2 Software

The software 'WLAN-CDMA Handover' developed using C Sharp language. When we start the software, looks as following Figure 5.3

Last five received signal strength is shown in the display. Based on the signal strength of the serving access pointer decisions have been taken by the software whether it is required to make any handover to cdma network or not. Automatically scanning of the received signal strength at the mobile node has not been developed by this software at this stage of the thesis rather signal strength ha to be scanned by any other application software.

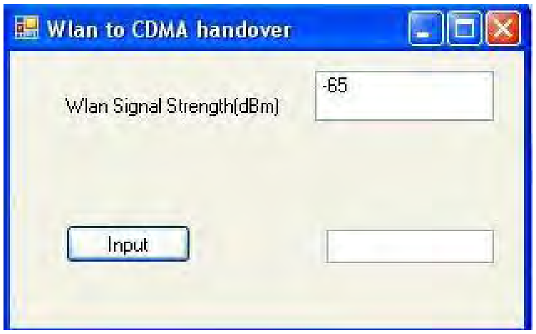


Figure 5.3(1): WLAN –CDMA Handover Software

Figure 5.3(2): WLAN –CDMA Handover Software

According to the core idea, decision to make handover is made by this software. At when the handover is required, that also done by this software. Moreover, it is required to activate or deactivate the CDMA interface card to make handover which is done by this software. Therefore, following jobs are executed by this software-

Decision to make any handover or not

This decision done based on the signal strength of WLAN. If signal strength value is below -90 dBm, it starts to keep monitor. Handover decision to CDMA network is taken if signal strength is poor than -90 dBm for a certain period of time. Once, mobile node is handed over to CDMA network, then handover to WLAN network is made when the signal strength found better than -70 dBm.

Time to make a handover or not

Time to make handover is an important issue. Already it is discussed that handover is made when ever the received signal level goes below a certain threshold level. When the mobile node at the edge of the signal boundary, it is common phenomenons that signal strength goes down and up of the threshold level. So, it may happen to try handover WLAN to CDMA and CDMA to WLAN. To avoid this ping pong affect, signal strength need to monitor for a certain time. In this software, signal value is read in every 2000 ms. Handover to CDMA network is initiated only five consecutive signal strength values of WLAN are found below -90 dBm. Once, mobile node is handed over to CDMA network, then handover to WLAN network is made only when five consecutive signal strength values of WLAN are found better than -70 dBm.

Activate/Deactivate Interfacing cards

When situation is set ready to make the handover to CDMA network, this software activate the CDMA interfacing card. On the contrary, this CDMA card is deactivated whenever handover is required to WLAN network.

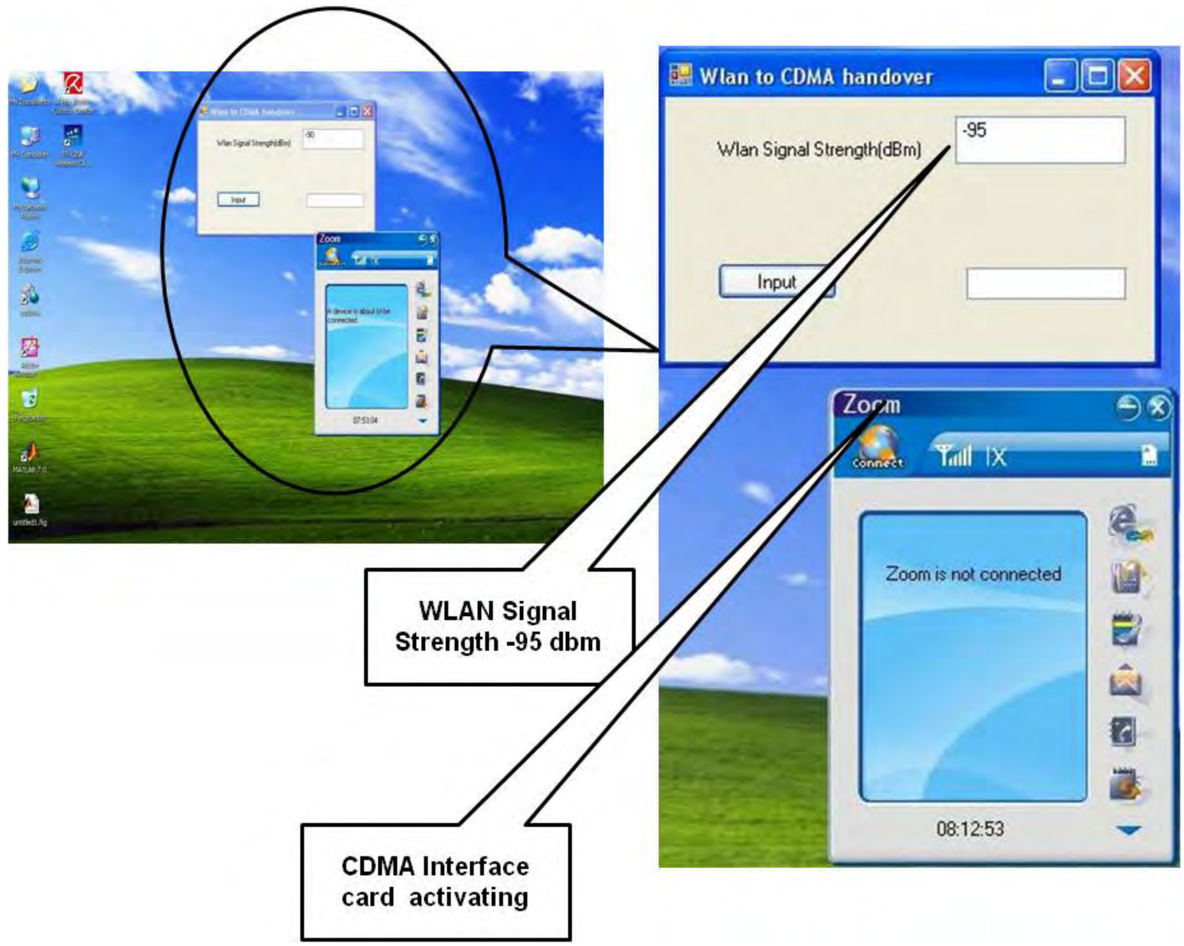


Figure 5.4: CDMA interface card Activation

5.2.3 Comparison and Contrast of the Current Research with Similar Other Work

The article in reference **[21]** describes how Vertical Handover (VHO) is supported within the QoS framework for a B3G (Beyond 3G) network where multiple heterogeneous radio access technologies are connected to IP based UMTS core network

Here, a future mobile network scenario is assumed, where different Radio Access Networks (RAN) co-exist in the same area. Here, three different RANs were assumed, which are UTRAN, GERAN and WLAN. Furthermore, common radio resource management (CRRM) mechanisms are expected to be deployed within the different RATs of B3G network.

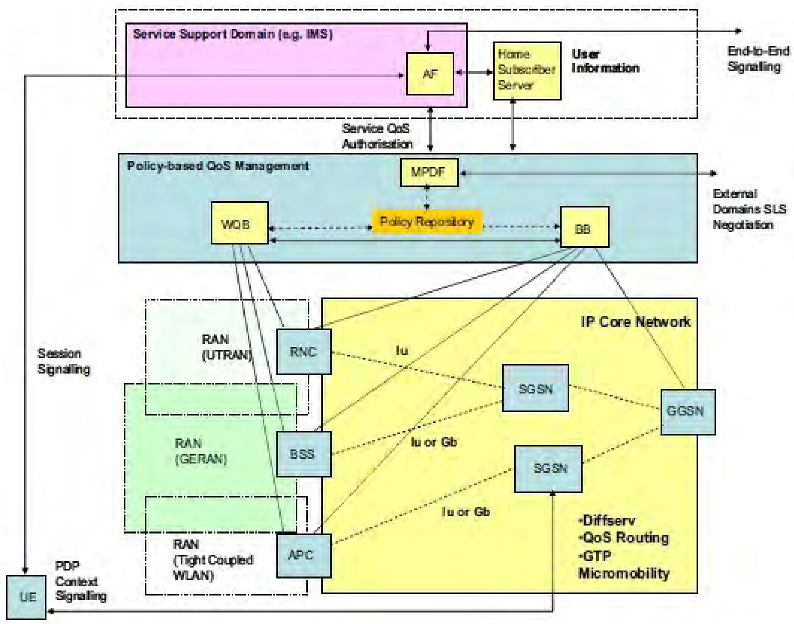


Figure 5.5: Reference B3G network UMTS-based architecture

Figure 5.5 shows the proposed B3G network architecture. Vertical Handover decision function would be managed by the mobile user when available candidate networks are not coordinated. In this scenario, a user decides which is the best network by himself, and, of course, in this decision operator and network constraints such as cost, subscription profile etc. are also implicitly considered.

Again, in the article of reference **[23]**, firstly, architectural issues of geo-telecom networks are discussed and a new concept of vertical mobility using geo-location information is presented. This line of work includes the building a framework for beyond 3G (B3G) networks or 4G networks admitting the fact that the seamless mobility among heterogeneous wireless access networks and services needs further research and development beyond the current third generation networks. The proposed architecture for the heterogeneous networks consists of WLAN and UMTS.

Secondly, a framework for the analysis of vertical handover is introduced. Here, 'data rate' has been considered in contrast to the power based algorithms. Figure 5.6 shows the handover procedure. Velocity of the terminals is also reflected on. Simulations have been performed for the vertical handover between WLAN and UMTS data network including the variables 'mean throughput', effective 'data rate'.

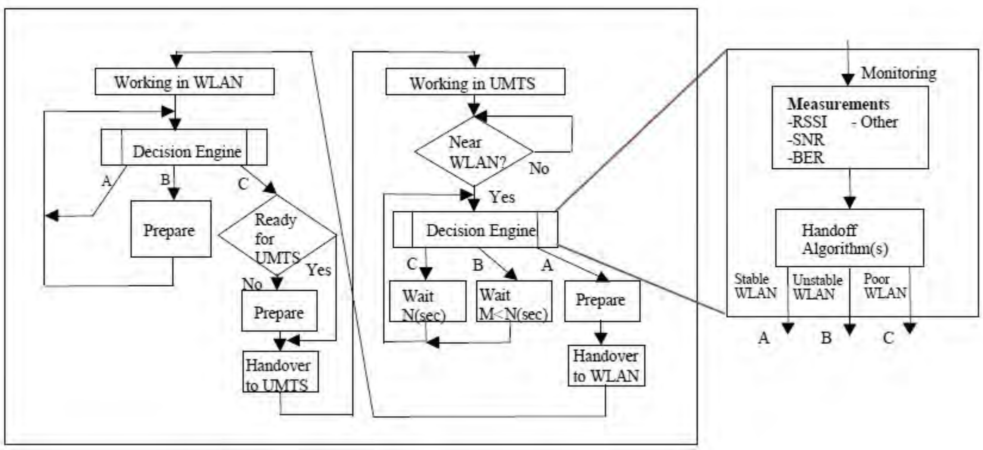


Figure 5.6: Handover procedure between WLAN and UMTS

On the other hand, the article of reference **[24]** presents a discussion on the design and the performance issues for vertical handover in the fourth generation (4G) multi networks. Various network architectures and technologies for 4G have been discussed- Universal Mobile Telecommunication System, Wireless Wide Area Network, High Aeronautical Altitude Platforms, Packet based Code Division Multiple Access etc. Traditional operations for handover detections, policies and decision metrics are able to adapt or react to user inputs and changing networks availabilities. Thus new techniques are needed to manage user mobility to allow the user to choose the most cost effective network. For example, a user may use WLAN to send a large data file, but may switch to another cellular network to carry on a voice call. Although it has been proposed to use 'Service type', 'Momentary Cost', 'Network condition' 'User preference' as decision metrics to make a vertical handover, but in the article only the two features, namely, 'Request by user' and 'Cost to network' have been considered.

To summarize, the articles [21, 23-24] proposed the vertical handovers, all of which belong to beyond the third generation (B3G) and fourth generation (4G) technologies. These are known as ‘All-IP’ based technologies. For accessing purposes, common radio resource management will be used. One interface card could be able to access all the technologies. Handover can be performed for better network (throughput/ data rate) [21.23] or user can switch to another technology for a different service [24].

However, in our current research, handover has been performed for data service between wireless LAN and CDMA2000. Both these two technologies are currently available. However, CDMA is not an ‘All-IP’ based technology. Therefore, common radio resource management cannot be deployed. Two different interface cards have been used here for managing the radio resource.

The handover protocol developed as part of the current research is completely different form those developed in the earlier work. Hence, comparison could not be made, rather the contrast has been highlighted above.

5.2.4 Results and Conclusions

From the Figure 5.4 results have been discussed. Signal strength manually scanned and need to put into the software. Now the mobile node (MN) has been connected to internet through wireless LAN interface card. If signal detect -65 dBm and put it into the software, there is no change that is CDMA card has not been activated. Now MN has moved away from the access point. Suddenly, signal strength has been detected below -90 dBm. This is value has been put in to the software. As soon as the software detects the five consecutive signal strength with below -90 dBm, it has activated the CDMA interface card which is shown in Figure 5.4. Again, whenever, five consecutive signal strength better than -70 dBm has been input into the software, CDMA interface card has been deactivated. And this is our objective to do.

Chapter 6

Conclusions and Suggestions for Future Work

6.1 Conclusions

In this thesis investigations into the handover have been done successfully for the interworking between the WLAN and CDMA. First of all overview of these two wireless interface access have been discussed. Protocols used by them are thoroughly discussed and then idea has been tried to implement. Two cases have been studied for WLAN to WLAN handover and CDMA to CDMA handover. To study these cases drive tests have been performed to comprehend the scenario and find out the conditions of handover. Drive test have been performed successfully both CDMA to CDMA and WLAN to WLAN handover cases. All the information and data collected from the drive tests have been scrutinized and analyzed very carefully. Some logics and judgments have been finalized from these practical drive test data. Empirical algorithms have been developed in case of WLAN-WLAN and CDMA-CDMA handover. After then, an algorithm have been developed using the knowledge of analyzing real field data, logics and scenario. A mathematical model has been also derived for the handover throughput in the case of WLAN to CDMA handover. Successfully simulations have been made using Matlab. The Matlab codes are attached as Appendix A. Finally a test bed has been developed for handover between WLAN and CDMA considering a simple scenario. Software has been developed for the test bed using c-sharp. Successfully handover has been performed in that test bed.

6.2 Suggestions for Future Work

This work has been extended in many ways. Handover not confirmed in case of the mobile node is downloading any file from internet. That could be incorporate in the future works. In this thesis a simple scenario has been considered with one access pointer. In future this works could be extended if the MN gets more than one signal from different access pointer. Signal strength would be scanned automatically and software will be able to take handover decision automatically. The securities for access to any network could be another scope for future works.

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Appendix A

This is Matlab code that is used simulate the handover between wlan and cdma network. Signal strength of wlan signal and cdma signal were collected in the drive test. Using these realistic data the simulations have been done.

```
% HANDOVER BETWEEN TWO CDMA CELLS
clear all; close all; clc;
%% Read data from file

num = xlsread('Handover between two CDMA Cells.xls');
     ch1 = num(:, 3); % Channel 1
     ch2 = num(:, 6); % Channel 2
     L = length(ch1);

%% Find handoff point
     duration = 10;
     ch_diff = ch2 - ch1;
     for i = duration : L
     if all(ch_diff(i-duration+1 : i)>0)
        break
    end
end

pos = i;

%% Plot handoff point

     plot(1:L, ch1, 'b', 1:L, ch2, 'r')
     text(pos, ch2(pos), 'Handoff point')


% HANDOVER BETWEEN TWO WLANS
clear all; close all; clc;
%% Read data from file

num = xlsread('Handover between two WLANs.xls');
     ch1 = num(:, 1); % AP1
     ch2 = num(:, 4); % AP2
     L = length(ch1);

%% Find handoff point
     threshold = 15;
     ch_diff = ch1 - ch2;
     candidate = find(ch_diff >= threshold);

pos = candidate(1);
```

[Contd.]

```
%% Plot handoff point
     plot(1:L, ch1, 'b', 1:L, ch2, 'r')
     text(pos, ch2(pos), 'Handoff point')


% HANDOVER BETWEEN CDMA AND WLAN CELLS
clear all; close all; clc;
neighbour = 0;
% change if necessary.
1 = neighbour, 0 = no neighbour

%% NO NEIGHBOUR
%% Read data from file

     if neighbour == 0
num = xlsread('Handover between two CDMA Cells.xls');

     ch1 = num(:, 3); % Channel 1
     L = length(ch1);

     threshold = -90;
     candidate = find(ch1 <= threshold);

pos = candidate(1);

     plot(1:L, ch1, 'b')
     text(pos, ch1(pos), 'Handoff point')

%% NEIGHBOUR

elseif neighbour == 1

num = xlsread('Handover between two WLANs.xls');

     ch1 = num(:, 1); % AP1
     ch2 = num(:, 4); % AP2
     L = length(ch1);
     threshold = 15;
     ch_diff = ch1 - ch2;
     candidate = find(ch_diff >= threshold);

pos = candidate(1);

     plot(1:L, ch1, 'b', 1:L, ch2, 'r')
     text(pos, ch2(pos), 'Handoff point')

end
```

Appendix B

This is C Sharp language that is used develop a software for a test bed of handover between wlan and cdma. Based on the signal strength of wlan signal, decision has been taken by this software whether handover is needed to cdma or not. According to the decision cdma interfacing card is activated or deactivated as well by this software.

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;
using System.IO;
using System.Diagnostics;
using MySql.Data.MySqlClient;

amespace Start
{
    static class Program
    {
        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main()
        {
            Application.EnableVisualStyles();

Application.SetCompatibleTextRenderingDefault(false);
            Application.Run(new Form1());
        }
    }
}
{
    partial class Form1
    {
        /// <summary>
        /// Required designer variable.
        /// </summary>
        private System.ComponentModel.IContainer
components = null;
```

[Contd.]

```
        /// <summary>
        /// Clean up any resources being used.
        /// </summary>
        /// <param name="disposing">true if managed
resources should be disposed; otherwise, false.</param>
        protected override void Dispose(bool disposing)
        {
            if (disposing && (components != null))
            {
                components.Dispose();
            }
            base.Dispose(disposing);
        }

        #region Windows Form Designer generated code

        /// <summary>
        /// Required method for Designer support - do not
modify
        /// the contents of this method with the code
editor.
        /// </summary>
        private void InitializeComponent()
        {
            this.components = new
System.ComponentModel.Container();
            this.button3 = new
System.Windows.Forms.Button();
            this.timer1 = new
System.Windows.Forms.Timer(this.components);
            this.listBox1 = new
System.Windows.Forms.ListBox();
            this.textBox1 = new
System.Windows.Forms.TextBox();
            this.SuspendLayout();
            //
            // button3
            //
            this.button3.Location = new
System.Drawing.Point(174, 122);
            this.button3.Name = "button3";
            this.button3.Size = new
System.Drawing.Size(75, 23);
            this.button3.TabIndex = 2;
            this.button3.Text = "Input";
            this.button3.UseVisualStyleBackColor = true;
            this.button3.Click += new
System.EventHandler(this.button3_Click);
```

[Contd.]

```
            //
            // timer1
            //
            this.timer1.Enabled = true;
            this.timer1.Interval = 2000;
            this.timer1.Tick += new
System.EventHandler(this.timer1_Tick);
            //
            // listBox1
            //
            this.listBox1.FormattingEnabled = true;
            this.listBox1.Location = new
System.Drawing.Point(49, 12);
            this.listBox1.Name = "listBox1";
            this.listBox1.Size = new
System.Drawing.Size(189, 82);
            this.listBox1.TabIndex = 3;
            this.listBox1.SelectedIndexChanged += new
System.EventHandler(this.listBox1_SelectedIndexChanged);
            //
            // textBox1
            //
            this.textBox1.Location = new
System.Drawing.Point(40, 125);
            this.textBox1.Name = "textBox1";
            this.textBox1.Size = new
System.Drawing.Size(100, 20);
            this.textBox1.TabIndex = 4;
            this.textBox1.TextChanged += new
System.EventHandler(this.textBox1_TextChanged);
            //
            // Form1
            //
            this.AutoScaleDimensions = new
System.Drawing.SizeF(6F, 13F);
            this.AutoScaleMode =
System.Windows.Forms.AutoScaleMode.Font;
            this.ClientSize = new
System.Drawing.Size(313, 176);
            this.Controls.Add(this.textBox1);
            this.Controls.Add(this.listBox1);
            this.Controls.Add(this.button3);
            this.Name = "Form1";
            this.Text = "Handoff Walan to CDMA";
            this.Load += new
System.EventHandler(this.Form1_Load);
            this.ResumeLayout(false);
            this.PerformLayout();
```

[Contd.]

```
       }

        #endregion

        private System.Windows.Forms.Button button3;
        private System.Windows.Forms.Timer timer1;
        private System.Windows.Forms.ListBox listBox1;
        private System.Windows.Forms.TextBox textBox1;
    }
}

{
    public partial class Form1 : Form
    {
        Process[] pArry = Process.GetProcesses();
        string s = "asd";
        int temp = 0;
        int[] var=new int[5];
        int opt = -1;
        public Form1()
        {
            InitializeComponent();
        }

        private void button1_Click(object sender,
EventArgs e)
        {
            System.Diagnostics.Process.Start(@"C:\Program
Files\TP-LINK\TP-LINK Wireless Client
Utility\ZDWlan.exe");
        }

        private void button2_Click(object sender,
EventArgs e)
        {
            System.Diagnostics.Process.Start(@"C:\Program
Files\ZTE Wireless Terminal\bin\App.exe");
        }

        private void button3_Click(object sender,
EventArgs e)
        {
            String MyConString = "server=localhost;
database= test ;uid= root;password=";
            MySqlConnection conn = new
MySqlConnection(MyConString);
            MySqlCommand comm = conn.CreateCommand();
            MySqlDataReader Reader;
```

[Contd.]

```
            if (textBox1.Text == "")
              {
              }
              else
              {
                  comm.CommandText = "insert into
data_table set data_scan=" + textBox1.Text + ";";
                  conn.Open();
                  Reader = comm.ExecuteReader();
                  conn.Close();
                  textBox1.Text = "";
              }
          }

          private void timer1_Tick(object sender, EventArgs
e)
          {
              String MyConString = "server=localhost;
database= test ;uid= root;password=";
              MySqlConnection conn = new
MySqlConnection(MyConString);
              MySqlCommand comm = conn.CreateCommand();
              MySqlDataReader Reader;

              comm.CommandText = "select max(id)-4 from
data_table;";
              conn.Open();
              Reader = comm.ExecuteReader();
              Reader.Read();

              temp = Convert.ToInt32(Reader.GetValue(0));
              if (temp < 0) temp = 0;
              s = temp.ToString();

              conn.Close();

              comm.CommandText = "select data_scan from
data_table where id>="+s+";";
              conn.Open();
              Reader = comm.ExecuteReader();

              listBox1.Items.Clear();
              listBox1.Items.Add("Last 5 signal strength
records:");

              for (temp = 0; temp < 5; temp++)
              {
                  Reader.Read();
```

```
                var[temp] =
Convert.ToInt32(Reader.GetValue(0));
                listBox1.Items.Add(var[temp]);
            }
            conn.Close();


            opt = 0;

            for (temp = 0; temp < 5; temp++)
            {
                if (var[temp] < -90)
                {
                    opt++;
                }
                else if (var[temp] > -70)
                {
                    opt--;
                }
                else
                {
                    break;
                }
            }

            if (opt==5)
            {
                pArry = Process.GetProcesses();
                foreach (Process p1 in pArry)
                {
                    s = p1.ProcessName;
                    s = s.ToLower();


                    // Check to see if this is the Word
process
                    if (s.CompareTo("app") == 0)
                    {

                        return;
                    }

                }

System.Diagnostics.Process.Start(@"C:\Program Files\ZTE
Wireless Terminal\bin\App.exe");

            }
```

[Contd.]

```
            else if (opt==-5)
            {
                pArry = Process.GetProcesses();
                foreach (Process p1 in pArry)
                {
                    s = p1.ProcessName;
                    s = s.ToLower();


                    // Check to see if this is the Word
process
                    if (s.CompareTo("app") == 0)
                    {
                        p1.Kill();
                        return;
                    }

                }
            }


        }

        private void Form1_Load(object sender, EventArgs
e)
        {

        }

        private void textBox1_TextChanged(object sender,
EventArgs e)
        {

        }

        private void listBox1_SelectedIndexChanged(object
sender, EventArgs e)
        {

        }
    }
}
```