ISSN:2231-0711
www.ijcset.net

A Fast MAC Mechanism for Handoff Process in Heterogeneous Wireless Networks

Pavan Kumar Tummala, Ramesh Babu Battula, Srikanth Vemuru, Rajasekhara Rao Kurra
{pavankumar_ist, rameshbabu_ist, vsrikanth, rajasekharrao.kurra}@kluniversity.in

Department of Computer Science and Engineering,K L University

ABSTRACT-Next generation wireless communications will likely rely on integrated networks consisting of multiple wireless technologies. Hybrid networks based, for instance, on systems such as WMAN and WLAN can combine their respective advantages on coverage and data rates. WLAN is provided in hotspots, places like coffee bars, airports, shopping centers etc. where the hotspots are covered by access points. As the mobile node moves, it may leave the current wireless network and enter another wireless network; vertical handoff should be taken to the new network so as to maintain the current connection. Existing methods require more time for the vertical handoff process, which causes serious problems for multimedia applications. Vertical handoff delay should be minimum to have seamless vertical handoff communication. To achieve seamless handoff communication a Layer2 handoff method is proposed. In this method, a mobile with two radios of dual-mode capability, and WLAN having the extended region capability is used. The second interface is switched between 802.16 and 802.11 to know ahead to which network it is about to enter. Mobile node comes to know about its nearby network before actually entering the network, thereby reducing vertical handoff delay, making it suitable to seamless vertical handoff Communication.

Keywords-Horizontal handoff, Vertical handoff, IEEE 802.11, WiMax.

1. INTRODUCTION

During the past decade both telecommunication and Internet technologies have been in a phase of rapid development. 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. 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.

During the last years, IEEE802.11 Wireless Local Area Networks have been deployed widely and 802.11 access points (APs) can cover areas of a few thousand square meters, making them suitable for enterprise networks and public hot spot scenarios such as airports and hotel. Recently, WMAN using IEEE802.16 standard has been receiving much attention because of the high data rate support, the intrinsic QoS capabilities and the much wider area of coverage that enables ubiquitous connectivity. An interworking between those two technologies has been considered as a viable option towards realizing the 4G scenario. However, this interoperation raises several challenges especially when seamless session continuity is required for e.g. media calls like VoIP or video stream. The deployment of an architecture that allows users to seamlessly switch between these two types of networks would present several advantages to both users and service providers. By offering integrated 802.11/802.16 services, users would benefit from the enhanced performance and high data rate of such combined service. For the providers, this could capitalize on their investment, attract a wider user base and ultimately facilitate the ubiquitous introduction of high speed wireless data.

The design of a network architecture that efficiently integrates WLAN and WMAN is a challenging task. The objective is to make the interoperation between both technologies as seamless and as efficient as possible, both from the end users and from operatorâ€™s perspectives. A common usage scenario is when a WLAN user is admitted into a WMAN environment and then obtains IP connectivity. Other scenarios are more challenging, for example when a WLAN subscriber initiates a VoIP call along with video streaming and data transfer in its WLAN zone and subsequently hands off to a WMAN environment while both video and audio sessions as well as data transfer continue seamlessly without having much vertical handoff delay. The 802.16 based WMAN were designed from the beginning to support QoS [2]. Finally, the decision when to switch between those different networks is also not an easy task. Ongoing efforts are on the way in IEEE802.21 WG in order to integrate different type of networks by introducing MIH (media independent handover) which aims to achieve a seamless handoff among different wireless networks regardless the type of technology [3].

Handover decision criteria used by existing mobility management technologies can be classified according to the information measured on upper/lower layers. In this section, we clarify characteristics of the existing handover decision criteria on upper/lower layers. Mesh routers and mesh clients are the two types of nodes in WMNs. A mesh router not only has gateway/bridge functions, but also has routing functions to support mesh networking. It is usually equipped with multiple wireless interfaces built on either the same or different wireless access technologies to improve the flexibility of mesh networking. Mesh routers have minimal mobility, form a multi hop network topology, and can self-configure a wireless broadband mesh backbone for local communication and information delivery to/from a wired Internet backbone via wired gateways. The wireless backbone provides multi-hop connectivity between a mobile client and a gateway. Moreover, the integration of WMNs with various existing wireless networks such as cellular, wireless-fidelity (Wi-Fi), and worldwide inter-operability for microwave access (WIMAX) networks can be accomplished through the gateway/bridge functionalities in mesh routers. With the integration of multiple wireless access technologies, the wireless mesh backbone provides a viable solution for users to access the Internet anywhere anytime. Compared to wired networks, e.g., cable or optical networks, the wireless mesh backbone is an economic alternative to broadband networking, especially in underdeveloped regions. The main Terminology that is followed in this paper is to propose a new and realistic approach for handoff and handover between 802.11 (Wi-Fi) and 802.16 (Wi-Max) networks. We designed an algorithm which combines the data rate and channel occupancy in order to fairly balance the users among the two networks. It can be easily integrated in all 802.11 and 802.16 products. By the algorithm we simulate and shows the significant gain compared with the appropriate networks involving the disjoint use of the load or the data rate as a trigger metric. The same methodology can be applied for the Horizontal handover also.

The main scope of our paper is to decrease the mean time switching between one network to another network along with an effective means of communication techniques. Existing WLANs can provide low-cost data services and have been widely deployed in traffic hotspots such as offices, hotels, shopping malls, schools, university campus, and airports. On the other hand, IEEE 802.16 can provide high speed wireless services in wide areas. As a result, the integration between a wireless mesh backbone (based on IEEE 802.16 standards) and WLANs can create a complete wireless solution for delivering broadband Internet services to the hotspots instead of cable, DSL, and T1 level services.

In the converged network, both intra-technology handoff and inter technology Handoff takes place. Intra-technology handoff is the traditional Horizontal Handoff (HHO) process in which the mobile terminal hands-off between two Access Points (AP) or Base Stations(BS) using the same access technology. On the other hand, inter-technology handoff, or Vertical Handoff (VHO), occurs when the MN roams between different access technologies. The main distinction between VHO and HHO is symmetry. While HHO is a symmetric process, VHO is an asymmetric process in which the MN moves between two different networks with different characteristics. This introduces the concept of a preferred network, which is usually the underlay WLAN that provides better throughput performance at lower cost, even if both networks are available and in good condition for the user.

2. RELATED WORK: HANDOFF's

This section provides information of the background work on vertical handoffs and various vertical handoff strategies. This section gives a brief background work and outline of various techniques that can be adopted as handoffs. The authors gave the techniques in the name of Fast Handoff as they tend to minimize the handoff delay incurred. In heterogeneous wireless networks, the mobile devices or mobile stations will be equipped with multiple network interfaces to access different wireless networks. These new mobile devices will provide the user for network access and connectivity but also generate the challenging problem of mobility support among different networks [2][3]. Users will expect to continue their connections without any disruption when they move from one network to another. This important process in wireless networks is referred to as ***handoff*** **or** ***handover***.

In the context of cellular networks a handoff is defined as the mechanism by which an ongoing connection is transferred from one base station (BS) to another. The BS's are the infrastructure (i.e. antennas, towers) that is deployed by the cellular operator to provide service in a geographic area. In this simple case, if we consider that both BSs use the same access technology, as in current cellular systems, we can say that homogeneous wireless networks perform horizontal handoffs. Such handoff mechanisms mainly use signal strength measurements from the surrounding BSs to trigger and to perform the handoff decision. The HHO algorithm decides in which BS should the connection be transfer to and it is usually the one which provides the highest signal level to the mobile device. A vertical Handoff can be classified as following figure 1.

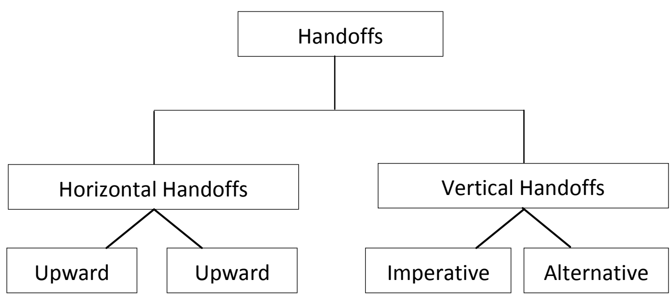

Figure 1: Handoff classifications

2.1. Factors are involved to design handoffs

1. **Normal operation:** Communication is performed using the primary interface that is associated to AP old, while the secondary interface is performing other tasks, possibly including scanning the channels.
2. **Re-association:** If it is determined that it would be beneficial to switch to a new AP, the second interface commences association with the new AP while the primary card is still used for data transfer with the old AP.
3. **Interface Switch:** As soon as the secondary interface is associated with the new AP, all of the node's outgoing traffic is sent via the secondary interface. The primary interface effectively becomes invisible, but stays up for some time to receive packets that may arrive delayed from AP(old) because of buffering or a slow bridging tables update.
4. **Completion:** Primary and secondary interfaces switch roles: the formerly secondary interface becomes primary and is used for communication, and the formerly primary interface is freed to be used for other tasks. [4],[15].

Clearly, such approach potentially completely eliminates handoff latency (i.e. latency due to both the handoff process and switching the wireless interface to a different channel). Still, under certain conditions, connectivity during a Multi Scan handoff can be negatively impacted due to lost packets (though to a much lesser degree than during a single-interface vanilla handoff). Packets queued on the primary interface will be lost if AP (old) learns that the node is associated with a different AP and will no longer accept node's packets. This is can happen if the channel of the primary interface is much more congested than the channel of the secondary interface. The vertical mobility paradigm deserves research attention from many perspectives [5],[6][14]. This thesis focuses on finding a solution to the vertical mobility problem in three categories.

The interworking between different wireless access networks has been a hot research and development topic in the past few years. Different radio access technologies present distinct characteristics in terms of mobility management, security support, and QOS provisioning. To achieve seamless mobility and end-to-end QOS guarantee for the users, these issues should be carefully addressed while developing the interworking and handoff schemes of WMNs with various wireless networks. Mesh routers in the WMNs play an important role. The 802.11 access point (AP) functions and 802.16 base station (BS) functions can be integrated into one mesh router. When an MN switches the network interface, only the link type is changed between the MN and mesh routers, and the MN still connects to the same mesh router. [10],[11],[12],[13]

In this paper, we present an interworking architecture of wireless mesh backbone and propose an effective vertical handoff scheme between 802.11 and 802.16. The proposed vertical handoff scheme aims at reducing handoff signaling overhead on the wireless backbone and providing a low handoff delay to MNs. Admission control is a QOS mechanism that protects the QOS of existing traffic flows and decides whether a new call can be admitted. In this paper, we use admission control results to make the handoff decision for the MN in the overlay area of the two networks when the MN starts a new call. Our proposed handoff decision algorithm combined with admission control can switch new calls to WIMAX to guarantee QOS support to the existing traffic flows in WLAN. Therefore the QOS support can be provided to as many users as possible.

Mobility management is a main challenge in the converged network. It addresses two main problems:

- Location management and
- Handoff management

Location management tracks the Mobile Terminals (MT) for successful information delivery. For this purpose, Mobile IP (MIP) enables seamless roaming and is expected to be the main engine for location management in the next generation networks. Handoff management maintains the active connections for roaming mobile terminals as they change their point of attachment to the network. Handoff management is the main concern of this paper.

Wireless technologies are evolving toward broadband information access across multiple networking platforms, in order to provide ubiquitous availability of multimedia applications. Recent trends indicate that wide-area cellular networks based on the 3G standards and wireless Local Area Networks (WLANs) will coexist to offer multimedia services to end users.

2.2. Wireless Local Area Network (IEEE 802.11)

IEEE 802.11 are becoming popular in hot spot areas such as convention centers, airports, shopping malls, and so on. Unlike existing wireless Internet services, public wireless LAN system can provide high speed Internet connectivity of up to 11Mbps using portable devices such as laptop computers and Personal Digital Assistance (PDA). This section provides with the architecture of 802.11 and the handoff process and delays incurred in the handoff.

2.2.1 WLAN Architecture

We will look at the general terminology before going into the details. A device that an end-user interacts with to connect to the network that they wish to communicate with will be referred to as a mobile terminal (MT). There must be a device in place to allow access to a network. This mechanism is the equipment at the cell phone tower for the cellular network and the access point in the 802.11 world. This equipment will be referred to as the base station (BS) or Access Point (AP). The area covered by an Access Point (AP) is called Basic Service Set (BSS). An Extended Service Set (ESS) is a set of one or more interconnected BSSs and integrated local area networks that appear as a single BSS to the logical link control layer at any station associated with one of those BSSs. Usually, the interconnection between two BSS's will be a wired Network. The set of interconnected BSSs must have a common Network Name or SSID. They can work in the same channel, or work in different channels to boost aggregate throughput. A service set identifier (SSID) is a code attached to all packets on a wireless network to identify each packet as part of that network.

2.2.1 IEEE 802.11 Handoff Phases

The handoff process in 802.11 networks attempts to include all the information necessary to transition a MT from one BS to another with minimal (ideally none) loss of data. The logical steps of the handoff process are:

Discovery: The MN actively finds additional BSs in the area by sending Probe Requests on all channels and listening for responses. A MN can also passively find additional BSs in the area by receiving Beacon frames. As a MN receives either a Probe Response or a Beacon, it determines the signal strength(s) and the bit error rate(s) (BER) for each BS.

Authentication: The MN will then send Authentication Request frames to all BSs in area that have an acceptable signal strength and BER. The MT will then receive a frame either confirming or denying the authentication to that BS.

Reassociation: The MN will then send a Disassociation frame to the BS that it is currently associated to and an Association Request frame to the new BS that it has previously authenticated to. To complete the reassociation process, the new BS communicates over the distribution medium to the originating BS to indicate the handoff has occurred. The originating BS acknowledges this by sending any buffered frames to the newly associated BS.

The table - 1 shows the time taken for different phases in a Layer2/MAC handoff scheme.

Phase	Time
Scanning/Discovery	350
Authentication	10ms
Association	10ms

Table-1: IEEE 802.11 Handoff Phases

Probe delay: upon settling on a new channel, the nic passively monitors the channel for activity before sending a probe packet. However, to ensure that a lightly loaded channel does not block the scanning process, the probe-delay timer indicates a time after which a probe is sent even without monitored activity. Default values for this parameter are negligible (< 1ms).

Media contention time: the 802.11 mac protocol provides a distributed contention mechanism that can cause a probe packet to be delayed, while seeking access to the medium. On lightly loaded networks, this value is also negligibly small.

Min channel time: this represents the amount of time to wait for the first response before declaring the channel empty (i.e., no access point in range). This value is an adjustable parameter and is set differently by different systems. Different researchers have suggested ideal settings of min channel time ranging from 1ms [12] to 7ms [6].

Max channel time: this represents the amount of time to wait to collect potential additional probe responses from other access points. This value is meant to be configured based on an estimate of the number of overlapping access points and the load on the channel. Previous empirical studies suggest values of roughly 11ms for this parameter [12], [6].

IEEE 802.16 - Wireless Metropolitan Area Network (WMAN)

IEEE 802.16 is a wireless digital communications system that is intended for wireless metropolitan area networks (WMAN). It can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In contrast, the WiFi/802.11 wireless local area network standard is limited in most cases to only 100 - 300 feet (30 - 100m).

802.16 Handoff Procedure

Let us explain the IEEE 802.16 handoff procedure briefly. A BS periodically broadcasts a neighbour advertisement management message to identify the network and identify the characteristics of the neighbour BS to associated MN. A MN may decode this message to find out information about the parameters of the neighbour BS. Each MN will thus be able to scan the neighbour BS and measure the signal strength. If necessary, an MN may select neighbour BS and prepare for the future handoff by performing ranging and association procedures. Through ranging, the MN can acquire the timing, power and frequency adjustment information of the neighbour BS. The target BS-MN association information is reported to the serving BS. [6]

The MAC layer (L2) handoff is divided into two phases; the handoff pre-registration phase and the real handoff phase. During handoff pre-registration, the target BS is selected and pre- registered with the MN. However, the connection to the currently serving BS is maintained and packets may exchanged during the pre-registration phase. In the real handoff, MSS releases the serving BS and re-associates with the target BS.

Now, let's look into the handoff procedure in greater detail. Either an MN or a serving BS may initiate the handoff pre-registration. When the MN initiates the handoff pre-registration, it may indicate a possible target BS from a signal-quality point of view. After the MN or the serving BS initiates handoff pre-registration, the serving BS may acquire information from the neighbour BS regarding their capability of serving the requesting MN. The serving BS may further notify the neighbour BS (through the backbone) of the impending handoff. [Fig. 1] shows an example of MAC layer handoff call flow initiated by the MN. After receiving the handoff request (MNHO-REQ) from the MN, the serving BS sends an

HO-pre-notification to the candidate target BSs, and the receiving party responds with an HO-pre-notification-response, which include ACK or NACK of impending handoff for the MN. Then, the serving BS selects the target BS and sends an HO-RSP message, including the target BS-ID, to the MN. The MN shall transmit an HO-IND message for final indication that it is about to perform a real HO. After the HO pre-registration phase, the real HO procedure is started. The serving BS releases the MN and the MN synchronizes with the target BS. Thereafter reauthorization and re-establishment of IP connectivity are taken [5],[6].

3. FAST HANDOFF METHOD FOR HETROGENEOUS WIRELESS NETOWRKS

3.1. Voronoi Diagrams

Out approach is mainly focussed on predicting the next AP before actually taking a handoff. Generally, during a MN's movement, the coordinates of the AP's and MN are to be considered for predicting the next AP. Initially, the MN is close to its parent AP. We consider the scenario by drawing a Voronoi diagram as shown in Figure 4. Simply, a Voronoi Diagram can be defined as "if we are given a set of points S, and the Voronoi diagram for S is the partition of the plane which associates a region V(p) with each point p from S in such a way that all points in V(p) are closer to p than to any other point in S". In general, the set of all points closer to a point c of S than to any other point of S is the interior of a convex polytope called the Dirichlet domain or Voronoi cell for c. The set of such polytopes tessellates the whole space, and is the Voronoi tessellation corresponding to the set S. Voronoi diagrams have a surprising variety of uses:

- **Nearest neighbour search** -- For a query point q, finding its nearest neighbour from a fixed set of points S is simply a matter of determining which cell in the Voronoi diagram of S contains q.
- **Facility location** -- Suppose we have to look for a location, and to minimize interference with existing similar locations, it should be located as far away from the current location as possible. This location is always at a vertex of the Voronoi diagram, and it can be found in a linear-time search through all the Voronoi vertices.
- **Largest empty circle** -- Suppose you needed to obtain a large, contiguous, undeveloped piece of land on which to build a factory. The same condition used for picking McDonald's locations is appropriate for other undesirable facilities, namely that it be as far as possible from any relevant sites of interest. A Voronoi vertex defines the center of the largest empty circle among the points.
- **Path planning** -- If the sites of S are the centres of obstacles we seek to avoid, the edges of the Voronoi diagram define the possible channels that maximize the distance to the obstacles. Thus in planning paths among the sites, it will be ``safest" to stick to the edges of the Voronoi diagram.

3.2. WLAN to WMAN Handoff

At backbone level proposed protocol, uses Optimized link state Fish eye routing, it determines routing decisions using a table-driven routing mechanism similar to link state. The table-driven ad hoc routing approach uses a connectionless approach of forwarding packets, when ever a route is desired. It relies on an underlying routing table update mechanism that involves the constant propagation of routing information.

MN contains two radios each with dual-mode, i.e, 802.11 mode and 802.16 mode. Normally every AP periodically broadcasts its information in its range so that it can serve the covered area. But, in this approach, each AP broadcasts periodic beacons with extended range by increasing the power level. As MN is moving towards WLAN region from WMAN region, the MN receives the beacon frames from the nearby AP before actually entering into that AP's region. From the beacon frame the MN will know about the nearby AP details the MN will come to know about the WLAN before actually entering the WLAN. So, the much delay of scanning for the AP is reduced, and the mobile is left with authentication and re-association phases which take very less time.

As the MN is roaming, it may enter the overlapped region of two APs. As it entered, it may move towards one AP and away from another AP. So to which AP should we take handoff?. The MN then calculates its distance from each of the adjacent APs (as in Triangulation) using the path loss exponent models [8], [9]. These path loss exponent models based distance estimation for wireless sensor networks given, which can be used to for WLAN also. The secondary antenna calculates its distance periodically as it receives the broadcasts. So, when a MN moves, the distance from some AP constantly reduces, thereby giving a clue that it is going to enter the vicinity of that AP. The MN creates a set S of probable APs depending on the reduction in the distances. Whenever, the MN's RSSI goes below the threshold for handoff, it selects an AP from S whose rate of change of distance is the Maximum from the ones available in S. The general steps involved in the pre-handoff process are given in the form of an algorithm below.

Algorithm for The pre-handoff process

1. Initialize S = Φ where S contains the set of probable APs.
2. If RSSI < PTH then
3. A. Calculate Distance estimate vector Di of each AP_i among the periodic receiving signals.
   B. If Di progressively decreases add AP_i to S if AP_i is not present in S.

C. Repeat steps a and b until RSSI > Handoff Threshold.

4. Select AP_i with MAX r_i where r_i represents the rate of change of distance of AP_i.

Beacon Interval	100ms
Beacon Frame Size	1500 Bytes
Number of adjacent channels	6
Normal AP Range	150 mts

Table 2:IEEE 802.11 Handoff Process

This shows an example to calculate extended range using an 802.11 hardware which operates at 2.4 GHz with throughput of 54 Mbps assuming the following standard parameters. Using the above parameters, in 600ms scan, the MN finds the active channels. The maximum channels that a MN can receive are three as per the standard topology. In worst case, to scan all the channels once it takes 300ms.

We can efficiently predict the next AP if we have at least 10 readings for each channel. So, total time required for 10 readings for all the three channels is 3000ms. Therefore, total time elapsed until the end of 10 reading including the initial scan is 3600ms. Assume the MN is moving at 30 Km/hr. The distance it moves in 3600ms is 30 mts. So, the AP extended range of the AP should be at least 180 mts that is 20 \% of the normal range. However, it has to be fixed experimentally and the above calculations are only for initial analysis purposes. The main advantage of this approach is the seamless handoff due to the usage of a secondary antenna on the MN. We are not using any external source like GPS for location tracking so it eliminates the extra hardware required for those devices to function. Since, we avoided any external source; it can be deployed anywhere as and when required. For example, if we use GPS for location tracking, the location prediction might not be possible in certain conditions like indoors, dense fog environments etc. But the whole approach depends on how accurately we measure RSSI considering all loss conditions. But that is out of scope of the paper as it completely depends on the lower layers.

3.3. Handoff from WLAN to WLAN

Let us assume that the MN is in WLAN. One interface is connected to WLAN for communication. The second interface is used for detecting the next network the MN is about to enter. This second interface is switched between WLAN and WMAN mode to detect whether it is WLAN or WMAN that the MN enters in the near future. As soon as signal strength is reduced to PHT, and if the second radio is not detected any WLAN, the MN goes through MAC management messages that are used to pass control information between the MN and BS. These messages include broadcast messages, initial ranging messages, basic messages, and primary management messages. As MN reaches the edge of the WLAN range, the MN is ready to switch to WMAN.

3.3.1. Handoff from WLAN to WMAN:

Let us assume that the MN is in WLAN. The moving MN may enter either WLAN or WMAN in the near future. To know towards which network is the MN is moving, the second interface is switched between WLAN mode and WMAN mode. As the MN is moving, if it receives the beacon frame from the nearby AP, the MN comes to know that it is about to enter another BSS of WLAN. So, the MN will be equipped with the necessary information about the AP that it is about to connect. If the MN enters the overlapped region of two or more BSSs, the AP is selected to which the rate of change of movement is more. The So the handoff delay will be reduced to that of authentication and re-association delay, which is minimal.

4. CONCLUSSION

This paper proposed MAC is useful to provide fast handoff between the heterogeneous networks like IEEE 802.11 and WiMax. It is useful to reduce the delay time for handoff. High data rate is possible with this approach. In this approach some requirements are required to provide quality of service and to reduce MAC overhead is low in different access mechanisms.

REFERENCES

[1] I.F. Aklyildiz et al,. "NeXt Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey" Computer journal, vol. 50, Sept'2006, pp. 2127-2159

[2] I.F. Aklyildiz, Won-Yeol Lee, and Kaushik R.Chowdhury. "Spectrum Management in Cognitive Radio Ad-Hoc Netowrks", IEEE Network journal, July/August 2009, pp. 6-12.

[3] B. G. Evans and K. Baughan, "Visions of 4G", Electronics and Communication Engineering Journal, Dec. 2002.

[4] K. Pahlavan, P. Krishnamurthy, A. Hatani, M. Ylianttila, J. Makela, R. Pichna, and J.Vallstom, "*Handoff in Hybrid Mobile Data Networks*," IEEE Personal Communications, April 2000, pp34-46.

[5] P. Krishnamurthy, K. Pahlavan, M. Ylianttila, J. Makela, and R, "*Analytical Framework for Handoff in Non-Homogeneous Mobile Data Networks*," Proceedings of PIMRC'99, Osaka, Japan, September 1999, pp.760-764.

[6] B.G. Evans and K. Baughan, "*Visions of 4G*,"Electronics and Communication Engineering Journal, Dec. 2002.

[7] H. Soliman, C. Castelluccia, K. El-Malki, and L. Bellier, "*Hierarchical Mobile IPv6 Mobility Management (HMIPv6)"*, Internet draft, June 2004.

[8] R. Koodli, "*Fast Handovers for Mobile IPv6*", Internet draft, July 2004.

[9] X. Fu, T. Chen, A. Festag, H. Karl, G. Schaefer, and C.Fan,"*QoS-Enabled Mobility Support for IP-based Networks*", IPCN'2003, Dec. 2003.

[10] Mi-Sun Do, Youngjun Park, and Jai-Yong Lee, "*Channel Assignment with QoS Guarantees for a Multi-Class Multi-Code WI-FI System*," IEEE Transactions, Vehicular Technology, Volume51, pp:935-948,Sep'2002.

[11] Mark Weiser, "*Some Computer Science Issues in Ubiquitous Computing*", ACM , Communications, vol. 36, no. 7, July 1993.

[12] Hyosoon Park, Sunghoon Yoon, Tachyoun Kim, Jungshin Park, Misun Do and Jaiyong Lee, " *Vertical Handoff Procedure and algorithm between IEEE802.11 WIMAX and WI-FI Cellular Network*".

[13] Ben Liang "*Application Signal Threshold Adaptation for Vertical Handoff in Heterogeneous Wireless Networks",*.

[14] Kyung-ah Kim "A Seamless Handover Mechanism for IEEE 802.16e Broadband Wireless Access",.

[15] Ishwar Ramani "*SyncScan: Practical Fast Handoff for 802.11 Infrastructure Networks*".

[16] Yongqiang Zhang "*Vertical Handoff between 802.11 and 802.16 Wireless Access Networks*".