WIRELESS INTERNET MOBILITY

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ABSTRACT

The ubiquotus internet use together with the proliferation of wireless devices such as pdas, laptops and palmtops has triggered the need of wireless internet mobility. However there are several challenges that need to be address to be able to support mobility. This report highlights several problem in supporting host mobility and propose solutions in the literatures to concludes on the most efficient way in achieving seamless user mobility without suffering too much from degraded quality of services.

Keywords: *internet mobility, mobile ip, wireless*

1. INTRODUCTION

Internet has become the most powerful tool of communication in this digital era as its users have been exponentially increased in the last couple of years. This, together with the advancement of mobile devices such as palmtop, personal data assistances, and mobile phones has triggers the need for internet mobility. People want to have access to the internet and other IP based services anytime, anywhere and they should be able to move without any disruption and disconnection.

Currently, people can access the internet and other IP-based services through one of several kinds of link technologies. These are either through a wired link, wireless LAN or cellular systems. One could have a dial-up or broadband connection from home or office using wired link directly to ISP or through their networks. One could also access internet using wireless adaptor installed in their laptops or perhaps downloading contents simply by using mobile phones. These different link technologies would obviously have different interfaces, access bandwidth and services.

In the future, however, networks are most likely to consist of wireless heterogeneous systems Currently, there are many link layer technologies. There are Bluetooth, infrared, Wireless LAN and cellular systems, with the latest two being the most widely deployed. People would want to utilize the most of each system. For example, one would want to use a wireless LAN adaptor to access internet within a building, since it is cheaper and has a bigger bandwidth, while continuing to browse the internet using cellular interface when moving outside the boundary of WLAN. Hence, internet mobility will become the norm rather than an exception.

There are several challenges that need to be addressed in order to support internet mobility. The most fundamental problem is the way an IP-based service like the internet routes its packets to destinations according to the IP address. These addresses are fixed locations in a network, which means that if a mobile host moves, its attachment to the network will be changed; hence its IP address will also change.

2. RELATED WORK

Several schemes have been proposed to solve this problem. One of the most prominent of these schemes is the Mobile IP protocol (Perkins, 1998) which is the standard protocol set by Internet Engineering Task Force (IETF) for host mobility. Mobile IP solves the above problem by allowing a mobile node to have two IP addresses, one is a home address which is the IP address given by its' home agent ISP. The other is a foreign address or co-located address which is the address given by or used in the foreign network where the mobile node is moving into. Any packet destined to a mobile mode will be delivered via its' home agent, by the use of 'tunnelling' mechanism, thus maintaining the same IP address. Mobile IP is most useful for covering a wide area but suffers inefficiency problems in local mobility (Valko, ----). Other schemes such as HAWAII and Cellular IP provide better performance when used in micro-scale movements.

The other problem with wireless internet mobility is how to integrate different wireless access systems such as Wireless LAN and internet cellular system eg. GPRS/UMTS and CDMA to become an all IP-based network and for a mobile host to be able to switch from one interface to another without any disruption to the ongoing data transfer. There are some proposals for this integration scheme including tightly coupled and loosely coupled systems.

This report will highlight mobility management in wireless internet; discuss several mobility management proposals in WLAN and cellular system as well as integration between the two systems. The conclusion will provide the most efficient way of achieving host mobility without suffering too much from degraded quality of service.

The first section will introduce the challenges associated with internet mobility. Description of mobility in Wireless LAN will be outlined in the next section. Next mobility in cellular systems will be discussed in particular the 3G systems, UMTS and CDMA. In addition, the proposed integration schemes between WLAN and Cellular will be analysed. Finally, the conclusion will talk about the most efficient way of achieving host mobility.

3. FACTS AND DISCUSSION

To begin our discussion on wireless internet mobility, we need to have a general understanding of the fundamentals of wireless network infrastructure such as WLAN and Cellular Networks in particular 3G technologies such as UMTS and CDMA. Figure 2 shows the setting for describing wireless data communication and mobility. As can be seen from figure 2, the main elements in the wireless network are (Kurose & Ross, 2004):

- *Wireless hosts* (Mobile node). The end system devices that run applications eg. Laptop, palmtop or pda. The host may or may not be mobile but since our discussion is on mobility, we assume that the host will be mobile and will also be referred to as Mobile Node (MN).
- *Wireless links*. Connection between a host and base station or another wireless host. Different wireless link technologies have different transmission rates and coverage.
- *Base station*. Responsible for sending and receiving data to and from wireless host that are associated with that base station. Example of a base station include cell towers in cellular networks and access point in WLAN.
- *Network infrastructure*. The larger network with which a wireless host may wish to communicate.

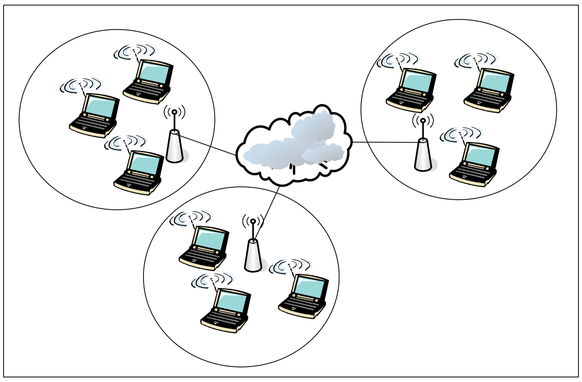

Figure 1. Elements of wireless network

Each wireless network infrastructure has to have some way to support host mobility within its subnet and/or domain eg. handover between base stations.

3.1 Mobility Management in IP-Based Wireless LAN

Wireless LAN has become the most important access network technologies in the Internet today. Although there are many developments on technologies and standards for wireless LAN, but IEEE 802.11 wireless LAN standard also known as Wi-fi (wireless fidelity or hot spot) has emerged as the most prominent one.

This can be seen from the rapid growth of the number of public hot spots. There was an estimated 71,000 public hot spots in the US by 2003 (Kurose & Ross, 2004) and it is predicted that the number will keep increasing. Popular world chain franchises such as Starbucks and McDonald offers Wi-Fi access in many of their locations. Cellular network providers have been installing hot spots to give their users higher rate data services in certain locations.

There are several 802.11 standards for wireless LAN technology including 802.11b, 802.11a and 802.11g with 802.11b being the most prevalent one, even though 802.11a and 802.11g are also widely available. 802.11b and 802.11g operates in the same 2.4 GHz frequency but the latter have a significant higher data rate of up to 54 Mbps compared to 802.11b with maximum data rate of 11 Mbps. 802.11a on the other hand operate in the range 5 GHz with data rate of up to 54 Mbps (Geier, 1999).

Handoff within WLAN subnet

In IEEE 802.11 standard, a basic architecture of WLAN is the basic service set (BSS) which consists of one or more wireless stations and a central base station called Access Point (AP). In order to increase the physical range of a wireless LAN, companies and universities will often deploy multiple BSSs either within the same IP subnet or different IP subnet within the same administrative domain. These BSS are connected through a so called *distribution system* (DS) to form an extended service set (ESS). DS communicate to other parts of the infrastructure by means of *portals* (which is usually a router connecting different networks). The issue raised here is-how do wireless stations seamlessly moved from one BSS to another while maintaining ongoing TCP sessions?

When BSSs are within the same IP subnet, then handoff process is straightforward. Figure 3, shows a specific example of mobility between BSSs in the same subnet. As mobile node H1 moves away from AP1, it detects a weakening signal then starts to scan for a stronger signal. When H1 receives *beacon frame* from AP2, it then disassociates itself from AP1 and associates with AP2. Because the device connecting AP1 and AP2 is a hub, then H1 is still using the same IP address and therefore maintaining its ongoing TCP sessions.

Handoff between WLAN subnets

On the other hand, a more sophisticated approach is required when a mobile node is moving towards a BSS which belongs to a different subnet. WLAN standard does not specify how packets are exchanged between access points, so implementation is left to the vendors. IETF is currently working on a standard called Internet Access Point Protocol (IAPP) to handle this (Moelard and Trompower, 1998). Another solution is to use network-layer mobility such as MobileIP (Perkins, 1998).

3.2 Mobile IP

Host mobility can be offered in several different layers of the OSI layer. Cellular systems like GPRS, CDMA and wireless LAN has incorporated it into the link layer. Proposal such as Mobile IP concentrate on host mobility in the network layer, whereas others have proposed that mobility should be done at the session layer or transport layer (Snoeren, 2001).

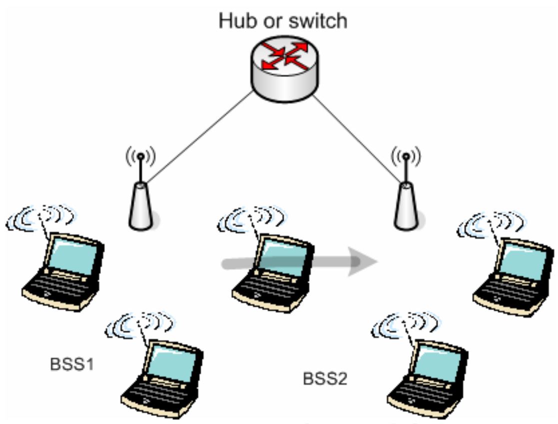

Figure 2. Intra-subnet mobility

However, mobility support will be best if handled at the network layer, since providing mobility at the link layer will result in a reinvention of mobility support for each new wireless system, whereas implementing it in a session or transport layer requires changes to the underlying layers which should be avoided in the internet. Solving mobility problems at network layer will result in reusable mobility infrastructure for all link technologies.

MobileIP is the IETF standard for internet mobility. It makes use of a so called home agent (HA) and foreign agent (FA). Home agent is a Mobile IP specific entity residing in Mobile Node (MN) home network, whereas Foreign Agent resides in a foreign network that a mobile node is moving into. In MobileIP, an MN is allowed to have two IP addresses, one for its' home network and the other is a care-of address given or used in FA. Figure 4 shows the interaction of different entities in Mobile IP.

When a mobile node moves from its home network to a foreign network, it registers itself to the Foreign Agent in that network and asks for a care-of-address. It then registers this address to its home agent. Obviously, other entities in the internet are not aware that MN has moved and is still sending packets to MN's original IP address. Home Agent then intercepts all the incoming packets for MN and tunnels them to the Foreign Network which should then deliver the packets to MN.

In MobileIP there are three main steps to be executed (Perkins, 1998), namely: *Agent discovery*. Upon entering a new network or returning to its' home network, every mobile node must learn the identity of the corresponding foreign or home agent. This can be done by either of two methods namely *agent advertisement* and *agent solicitation*. In *agent advertisement*, foreign or home agent periodically send out a router discovery messages that contain the agent's IP address, list of care-of addresses, its services and other additional information needed by the mobile node. A mobile node that does not want to wait for an agent advertisement message could send an *agent solicitation* message. An agent receiving the solicitation will forward an *agent advertisement* directly to the mobile node.

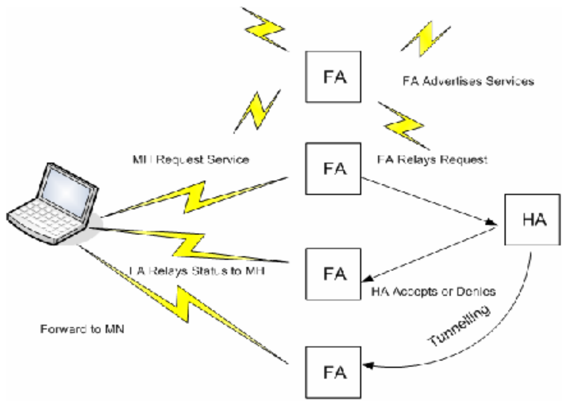

Figure 3. MobileIP

Registration with the home agent. Once a mobile node has received a care-of address, it must register it to its' home agent. This can be done directly by the mobile node itself or via the foreign agent. When registration is complete, the mobile node can receive datagram's sent to its permanent address.

Tunnelling. Tunnelling refers to the process of enclosing the original datagram, as data, inside another datagram with a new IP address. At the receiver, original datagram can be recovered by removing the outer header before sending it to the mobile node. There are several mechanisms for tunnelling but the default one is called IP-within-IP. Other mechanism include Minimal Encapsulation and Generic Routing Encapsulation (GRE).

3.3 Deficiencies in mobile IP

Mobile IP serves well in solving the IP addressing problem; however there are some deficiencies in Mobile IP protocol that need to be addressed. First, Mobile IP protocol treats all forms of mobility uniformly (Ramjee,2000), meaning that users moving short distances, perhaps between two base station, will involve the same mechanism as other user registering from a remote domain. That is, changing mobile node's IP care-of address as well as notifying the home agent of the movement. When these movements become frequent, which will be the norm in future wireless data network, these notifications will create a significant overheads in the traffic. Also, the routing usually goes through very long and inefficient routes thus placing more burdens on the network. An attempt to optimize routing in Mobile IP (Perkins, 2000) results in significant disruption to user traffic every time handoff occurs.

Secondly, in Mobile IP the mobile node is expected to update the network with every move which results in excessive power consumption. One way around this, is to use a *paging* scheme that provides the network with the approximate MN's location information and not the exact location.

Therefore, while Mobile IP is a suitable enough candidate for mobility protocol in wide-area wireless network that is in addressing *macro-mobility*, it suffers several limitations when applied to an environment with high mobility users since it was not designed to manage *micro-mobility*.

3.4 Micromobility

There are several proposals that extend mobile IP to address these limitations such as HAWAII (Ramjee, 2000) and Cellular IP (Campbell, et.al., 2002).

These protocols use a hierarchical model of routers within a domain. Figure 5 shows the hierarchy or routers in the HAWAII and Cellular IP architectures. Access Points are in the first level of hierarchy and communicate directly with mobile nodes. Uplink there are Access Router (AR) which are interior router within the domain. At the edge of the wireless networks, there is the access network gateway (ANG) that acts as the interface between wireless domain and wired IP network (Murthy & Manoj, 2004). These protocols rely purely on Mobile IP to support *macromobility* while complement it in providing fast and seamless *micromobility*.

HAWAII

In this protocol from Lucent Technology, a mobile node enters a foreign network is given care-of address which remains the same as long as it only moves within that domain (Ramjee, 2000). HA will not need to be involved unless MN is moving to a new domain. To do this, HAWAII uses a so called *path setup scheme*. This scheme is used to update selected routers to form a path from the root router to MN. HAWAII uses paging scheme to locate an idle MN by identifying a set of base stations that belong to the same *paging area*.

CellularIP

Cellular IP minimize control messaging by refreshing host location information on a hop-by-hop basis using regular data packets transmitted by MN. It maintains Routing Cache and Paging Cache (Campbell, et.al., 2002). Routing Cache is used to map the location of currently active nodes, whereas a paging cache is used for an idle host. Cellular IP requires neither new packet format or encapsulations.

3.5 Mobility Management in Cellular Networks

The term cellular refers to the fact that geographical areas are divided into a number of coverage area called cells (Ross & Kurose, 2004). The earlier generation of cellular network was designed for voice communication, whereas the later generation supports Internet access as well as voice. Currently, communication providers are implementing a third generation also known as 3G and moving towards the fourth (4G). 3G systems are mandated to provide 144kbps at driving speed, 384 kbps for stationary and walking speed users and 2Mbps for indoors (Maniatis et. al., 2005). The following are a description of mobility management used in two of the most prominent 3G systems i.e. UMTS and CDMA.

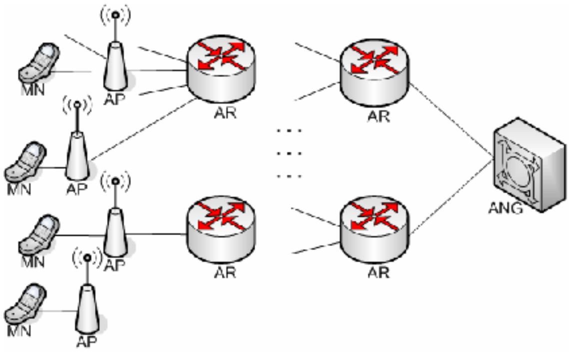

Figure 4. Hierarchical routers

UMTS

The Universal Mobile Telecommunication System (UMTS) has been defined by International Telecommunication Union (ITU). The system has resulted from the evolution of previous generations i.e. 2G (General System for Mobile Communications, GSM) and 2.5G (General Packet Radio Services, GPRS). UMTS is currently on standardization process conducted by 3G Partnership Project (3GPP).

An architecture of UMTS as set by 3GPP is shown in Figure 6 below. It consists of a core network (CN) and access network (AN). Core network is divided into circuit-switched domain for voice related services and packet-switched domain for data-related user traffic. Since we are only concerned with IP mobility, then this section will only focus on the packet-switched domain of UMTS. Essentially UMTS uses GPRS as core packet network (Maniatis, 2005). This domain consist of two fundamental GPRS nodes: the serving GPRS support node (SGSN) and gateway GPRS support node (GGSN). The SGSN is the connection point between CN and AN (which consist of radio access network, RAN and mobile stations), whereas GGSN is the gateway to the external IP network such as the Internet. Both SGSN and GGSN are IP enable nodes. These nodes are assisted by the GPRS Home Location Register (HLR) which holds information for each user on its' database. Integration of the above components forms a fully integrated system owned by a cellular provider called Public Land Mobile Network (PLMN).

A mobile node registers itself to SGSN using a procedure called *GPRS attach*. IP address for the mobile node is given and managed by GGSN, therefore limits the mobility of the mobile node within a particular GPRS network. If a mobile node is moving towards another network, then the communication session will either be torn down or a macro-mobility mechanism such as Mobile IP will need to be implemented in GGSN.

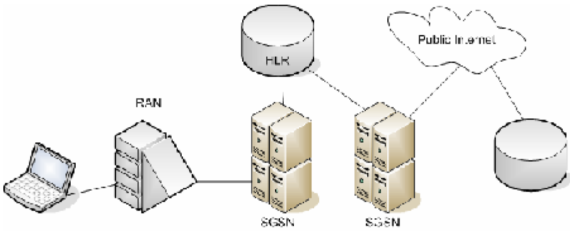

Figure 5. UMTS architecture

CDMA

CDMA system evolved from the North American Standard, IS-95 and is being standardized by 3GPP2 forum. 3GPP2 has taken the advantages of 3G high data rates and made use of Mobile IP to enhance the network in providing IP capabilities. Figure 7 shows 3GPP2 architecture of CDMA. It uses a combination of link layer mobility and Mobile IP to manage mobility. The network protocol defined by CDMA data networks are based on IP.

In 3GPP2, a mobile node identifies itself using Mobile IP protocol. BTS and BSC is contained within the RAN which is essentially an IP based router with some radio control functions. There is a Packet Data Serving Node (PDSN) that connects the CDMA IP-manage network to the external networks such as Internet or PSTN.

In addition, being the IP gateway, PDSN also serves as a Foreign Agent (FA). When a mobile node comes within or attaches itself to the FA, FA sends a registration message to the Home Agent (HA) using Mobile IP tunnel. The IP address of the mobile node is now anchored in HA for the duration of data session. Thus mobility within CDMA network is also done using Mobile IP, and therefore creating the same problem faced by Mobile IP. Again micro-mobility scheme could be employed to address this issue.

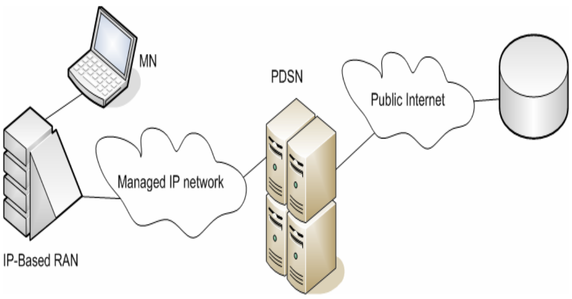

Figure 6. CDMA architecture

3.6 Integration of WLAN with 3G Cellular Network

Having examined how mobility is managed within WLAN and 3G Cellular Networks (WWAN), we can now turn our attention to the integration of the two systems. As mentioned before, there are currently two 3G cellular technologies in use, UMTS and CDMA. Our discussion however, will only focus on the integration between UMTS and WLAN since it is a more mature technology than CDMA. However the principles discussed could similarly be applied to CDMA.

According to the literature, there are five ways that can be used to integrate WLAN and UMTS (Ahson, 2004) namely using UMTS entities (BSS and SGSN) emulators within WLAN, Virtual AP, mobility gateway (proxy) and Mobile IP. Due to the deficiencies suffered by the first four, which will be described later, we will only discuss the fifth architecture in detail.

By using BSS (1) or SGSN (2) emulators within WLAN, the network will appear as UMTS network, thereby WLAN will be regarded as a cell or coverage area within UMTS (Pahlavan, 2000). In this case UMTS will be the *master* network whereas WLAN is the *slave*, thus mobility will be handled in accordance to UMTS mobility scheme.

The above approach is also known as *tightly coupled* architecture since they include one network within the other. *Tightly coupled* architectures have several advantages including firm coupling between WLAN and UMTS and reuse of UMTS resources. However, since these architectures were designed for WLANs owned by cellular operators, they can not support third party WLANs (Ahson, 2005. Furthermore, throughput capacity of UMTS might not be sufficient to support concurrent high-bit-rate WLAN terminals (nodes).

The third approach, on the other hand, is the reverse of the previous method, whereby a virtual access point is used within UMTS network. The network will then appear only as WLAN and accordingly, mobility will be managed by WLAN using a protocol such as IAPP (Moelard and Trompower, 1998). This approach might not be visible as the coverage of UMTS is larger than WLAN.

The latter two architectures are known as *loosely coupled* architecture where one network acts as a peer network to another. The advantage of loosely coupled architecture is that it imposes minimal requirements on both networks as well as supporting third party LANs, thus more scalable (Ahson, 2005).

The fourth architecture is designed by placing a mobile *proxy* in either WLAN network or UMTS. The mobility gateway will be responsible for routing of packets and mobility management. This architecture is highly scalable as a number of mobility gateways can co-exist. However, this scheme suffers from lack of standardization of the proxy architecture (Ahson, 2005) thus it can not handle *intertech* roaming and has poor performance since a significant latency is added to the client-server communication path (Pahlavan, 2000).

Perhaps, the most efficient solution in integrating WLAN and UMTS is using one of IETF most popular protocol, Mobile IP (Pahlavan, 2000). Mobile IP is used for forwarding IP datagram when a mobile user roams from one network to another. Each mobile node is identified by fixed IP addresses and should have both 3G UMTS and IEEE 802.11 WLAN protocol stacks. Both networks, UMTS and

WLAN will act as peer networks connected through their own gateway routers. Each of these gateway router will have Mobile IP entities i.e. HA and FA.

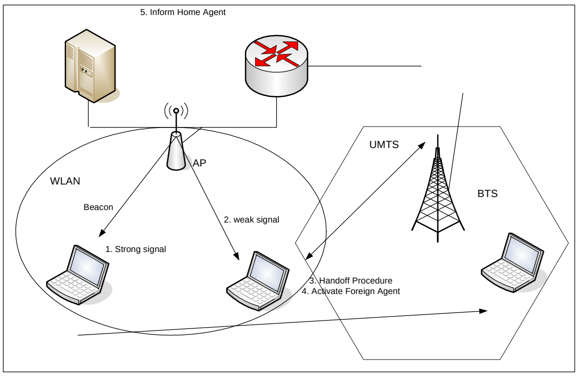

Figure 7. Integration of WLAN and UMTS using Mobile IP

As an example, let us consider a mobile node within its *home* WLAN network (Figure 8). When a mobile node powers up, it registers with its home agent. The node can initiate a handover when it is moving out of WLAN. The UMTS network in this case will be considered as a Foreign Network. When the node roams into the foreign network, it registers with FA then obtains a care-of address. Then the mobile node informs the HA of its care-of address. The mobile node's home agent then captures all the packets destined to the mobile node and uses IP-in-IP encapsulation to tunnel the packet to a foreign agent which will deliver them to the mobile node.

Because of the nature of Mobile IP, this scheme will also suffer from triangular routing. However, this problem can be solved by implementing route optimization (Perkins, 2000) which will create some latency. But because handover between WLAN and UMTS will not happen as frequently as movement within the network itself, this problem will not be of too much concerned.

4. CONCLUSION

The notion of having internet access anywhere, anytime can become a reality by seamlessly combining the many wireless heterogeneous networks technologies. This report has identified two of the most prominent technologies used in todays wireless network i.e. IEEE 802.11 WLAN and Cellular Networks. IEEE 802.11. WLAN has the advantage of having a high data rate but suffers from smaller coverage whereas Cellular Network can provide a much larger coverage but limited data rate. Therefore, integration between the two system would allow users to have the best of both systems.

Furthermore, this report has describe how mobility is manage within WLANs and cellular networks and the protocol used for mobility management. IETF standard Mobile IP can be used to handle mobility in WLAN but in an environment with highly mobile users and smaller cells, Mobile IP suffers from overheads and inefficient routing. It has been shown that domain-based micro-mobility protocols such as HAWAII (Handoff Aware Wireless Access Internet Infrastructure) and Cellular IP has would be able to solve the problem. Eventhough mobility in Cellular Network is handled mostly using link layer technology, it also adopt Mobile IP type mechanism for movement between subnet entities.

The integration between WLAN and UMTS has been discussed by presenting five different integration architectures. A *Loosely coupled* architecture such as Mobile IP would be the most efficient scheme to handle movement between one network to another.

In conclusion, this report has demonstrated that to have the anytime, anywhere internet access, WLAN and Cellular Network provider could adopt micromobility protocol within the wireless network domain and use macromobility protocol such as MobileIP to integrate between domain and different wireless network technologies.

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