International Conference on Network Applications, Protocols and Services 2008 (NetApps2008)
21 - 22 November 2008
Executive Development Center, Universiti Utara Malaysia

A Survey of Cellular IP in the Next Generation of Network Protocol

Ahmad Hanis Mohd Shabli, Hasbullah Omar and Suhaidi Hassan
Internetworks Research Group, Graduate Department of Computer Science, College of Arts and Sciences,
Universiti Utara Malaysia
Email: {ahmadhanis,hasbullah,suhaidi} @uum.edu.my

***Abstract*—The main objective of mobility management in wireless data communication is to allows networks to search and locate (location management) mobile users while maintaining it's connections (handoff management) whenever users move into a new network. Management of location and handoff divided into macromobility (for managing inter-domain network) and micromobility (for managing intra-domain network). For macromobility management, IETF has adopted Mobile IP and had perform very well for managing inter-domain mobility. However Mobile IP suffer from handover performance in intra-domain network which is inefficient for mobile user with frequent handoff. For this defect, cellular IP protocol has been considered for managing intra-domain network for it's fast handoff and interoperability with Mobile IP. This paper we present a review of different micro-mobility management protocols available to date. We also discuss various issues and challenges regarding mobility management for the next generation network protocol.**

***Index Terms*—Mobile IP, IPv6, Cellular IP, HIPv6**

I. Introduction

Cheaper production rate, new services/applications available by the service provider at affordable price contribute to some of the factors why mobile devices are ever becoming more popular in the recent years. The number of mobile user are expected to increase due to advancement of the mobile device. Instead of the traditional use of mobile phone for just sms and calls, user start to expect more features from their mobile phone. Smartphone and Pocket PC such as iPhone and HTC TYTN II offer features that almost comparable to mobile computer enable platform for many advance mobile application such as voice-over-IP, push mail, online messenger, video streaming.

Always on connectivity with high speed connection to the Internet through mobile devices is a dream comes true for all active Internet user. Real time information and entertainment will always be available anywhere at anytime. With such ability, applications such as voice-over-IP, video streaming, push mail, can widely utilize. Currently there are few technologies available that can provide such service. General Packet Radio Service (GPRS a.k.a 2G), Universal Mobile Telecommunications System (UMTS a.k.a 3G) and High Speed Downlink Packet Access (HSPDA a.k.a 3.5G) are the some of technologies that able to demonstrate of the said capability.

Unfortunately the available technology are inefficient for small mobile devices (such as pocket PC, mobile phone) which has quite limited resources (processing speed, memory and particularly battery life)[12]. For example; in 3G network, user first needs to establish connection which is a process of creating a "virtual connection" between mobile device and the Internet. During the connection mobile devices will constantly update it's routing update packet (RUP) to base station for location and routing management. It is also constantly update it location even during idle connection. This will lead to inefficient power consumption due to radio activities that consume much power. With the concept of "dialing up to the Internet" this will loosen the idea of always on connectivity such as what cellular phone user has enjoyed. User will lose connection once the connection terminated and no real-time data can be push in to the mobile devices.

Even though 3G network do have idle and active states to save battery consumption, the use of network address translator (NAT) is addressing & routing but in other way it also introduce complexity to the system. NAT require for idle mobile host to wake-up to updates it's location due to change in NAT configuration. Frequent wake-up will consume much power. NAT also increases complexity of the network and cause many applications such as peer-to-peer which has complicated problem handling different private network access behind NAT.

Nevertheless 3G network employ Mobile IP framework which has severe technical limitation for handling local mobility (micro-mobility) resulted in high handoff latency for fast moving mobile user [7], [5]. In mobile IP after each MN migration, a local address must be obtained from foreign network (FN) and to a possibly distant location directory or home agent (HA) [12] thus increases it's complexity and overhead processing. This involves a lot of signaling and processing, and requires a lot of resources. Furthermore, although it is not necessary for external hosts to be updated when a mobile node moves locally, these updates occur for both local and global moves. With the increase in complexity and processing overhead makes Mobile IP inappropriate for small mobile devices.

A number of protocol has been proposed to overcome the problem in Mobile IP such as Hierarchical Mobile IP, Handoff-Aware Wireless Wireless Access Internet Infrastructure (HAWAII), and cellular IP. All protocols designed to reduce the amount of signaling required and to improve handoff speed and packet lost for mobile connections.

Micromobility support in cellular IP network is more important than the other micro-mobility protocols, due to it's simplicity [1]. It combine the best features from both cellular network and IP based network. The integration seems able to provide good framework for “always-on” Internet connectivity. Features such as mobility with multimedia-rich content, high bit rate, and IP transport with support for quality of service (QoS) management and authentication, authorization, and accounting (AAA) security [10]. With such rich features, cellular IP is no doubt will be able to fullfill all the 4G network requirement.

Another excitement added to cellular IP is the new network layer protocol that has been widely introduced. IPv6 added more functionality and capability towards cellular IP. Limitless IP address with pure end-to-end application layer communication plus with added security, simplified header, auto-address configuration, and many more. With such features, cellular IPv6 being able to offer top-notch services to mobile user. But how far this features stood to the truth still far fetch. This paper intended to provide some literature background on the capabilities of cellular IPv6.

The paper is structured as follows. In Section 2, we discuss the concept of an Mobile IP which provides macro-mobility support. Following this in Section 3 we present an overview of the Cellular IP design issues such as in routing, handover and paging mechanism. In Section 4 we discuss our research direction and at the end some concluding remarks.

II. Mobile IP

The Internet Protocol was first engineered for stationary environment with no mobility function in mind. Hence it was optimized to work efficiently in wired network. Then when wireless was first introduced, this was major problem for IP based network because of the new wireless environment user has a tendency to move from one network to another. Moving host in multiple networks will require change in IP address thus will break any transport layer communication or even worst restarting the device while doing so [5]. IP network needs a new mechanism to enable mobile host to move freely in wireless IP network without breaking up communication hence the Mobile IP was born.

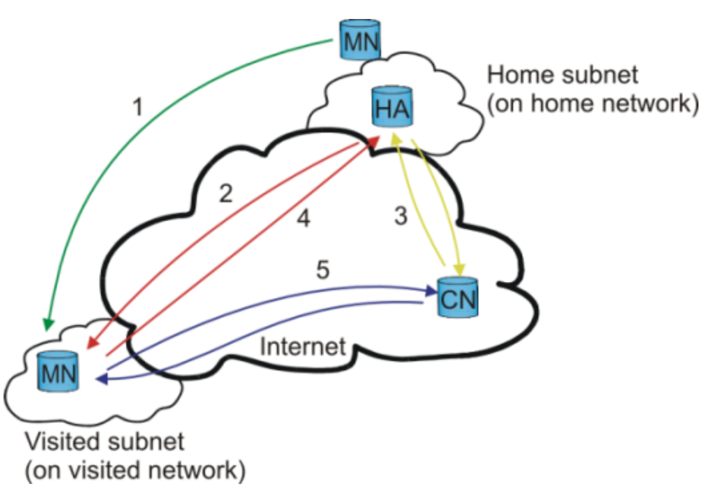

Figure 1. Mobile IP [3]

Mobile IP has been proposed by Internet Engineering Task Force (IETF) as an extension to IP infrastructure to overcome the limitation of wired IP functionality. It allows mobile node (MN) to move from one network to another while maintaining a permanent IP address (refer to figure 1). Mobile IPv4 works by using two IP addresses; one home IP address (HoA) and the others Correspondent IP address (CoA) instead of single IP based network. The HoA stays with MN through out the connection eventhough MN change places. When MN moves to a new network, a process called handover took place. MN then request for care-of-address (CoA) from foreign network (FN) and update it’s CoA at home agent (HA). Any packets from correspondent node (CN) that destine for previous point-of-attachment will be tunnelled based on the information from HA routing table. Detail description on MIPv4 can be found in RFC 3344 (Obsoleting both RFC 3220 and RFC 2002), and updates are added in RFC 4721.

Later development on IP technology was the introduction of IPv6 that foresees replacing IPv4 in the near future. IPv6 provide solutions to the depleted number of IP addresses in IPv4. With almost unlimited number of IP address, the possibility of uninterrupted end-to-end connection can finally be realized (which the concept the Internet was originally built on). Each devices can be addressed with unique global IPv6 address without the needs of any IP translator thus decreasing network complexity and single point of failure. Thus the extension for mobility function provided by the introduction of mobile IPv6 (MIPv6). MIPv6 was develop based on the success of MIPv4 but with many major new improvement due to new improvement of IPv6. Nevertheless MIPv6 provides transport layer connection survivability when a MN moves from one network to another by performing address autoconfiguration for mobile nodes at the Internet layer thus resulted in more stable connection. For more discussion on mobility support for IPv6 can be found in IETF RFC 3775 and IETF RFC 3776.

Mobile IP (in general) technology allows MN to switch from one network to another with little or no intervention of ongoing data request or transfer. However Mobile IP operational energy consumption for staying alive through “keep-alive” message is significantly high [6]. Thus application such as push-mail, instant messaging which require a very long-lived connection inadvertently consume very large amount of energy which is inefficient if these applications running on mobile devices. Furthermore mobile IP lacking with the paging concept such as available in cellular phone which allow mobile phone to stay connected with minimum energy consumption. Paging allow mobile device to stay alive during idle connection and can still be reach at anytime. Other than that Mobile IP was not appropriate for fast moving host with frequent handoff event. Mobile IP was design for macro-mobility switching between different networks and not optimize for handoff within networks (micro-mobility).

In conclusion although Mobile IP provide a robust global mobility solution but is not appropriate to support on local scale (micro level). Current cellular technology which are built on complex networking infrastructure which lacking the flexibility offered by IP-based solutions. A hybrid technology called cellular IP which has been proposed represents another way of merging the goods of both IP based and cellular based architecture. Cellular IP combines the capability of cellular networks that being able to provide smooth fast handover and efficient location management for active and passive mobile users with the inherent exibility, robustness and scalability found in IP networks [4].

III. Cellular IP

Cellular IP protocol has been developed by Columbia University joined research with Ericsson Research Lab. It represents a novel mobile host protocol that is optimized to provide access to a Mobile IP enabled Internet in support of fast moving wireless hosts. It's includes a number of important cellular principles but remain it's root based on IP design philosophy which allowing the technology to scale. It also able to provide fast handoff mechanism due to distributed nature of it's routing mechanism. All these features are critical for providing always-on connectivity services to mobile user.

A Cellular IP network (refer to figure 2) based on a group of radio signal cells split in a geographical area. Each cells controlled by a base station which transmit and receive radio signal. Mobile node within coverage of cellular network can send and receive data through each cell and data is routing and maintain through a distributed, hop-by-hop location database that is used to route packets to mobile hosts and finally to the gateway router (GR) before moving to the Internet through Mobile IP network. In other words Cellular IP is a distributed in nature. Each node will decide and maintain it's own routing and locations database updates thus simplified the overall operational process and reduces loads for each nodes. Simplified process allowed Cellular IP to operate on much lower power consumption make it feasible for small mobile device.

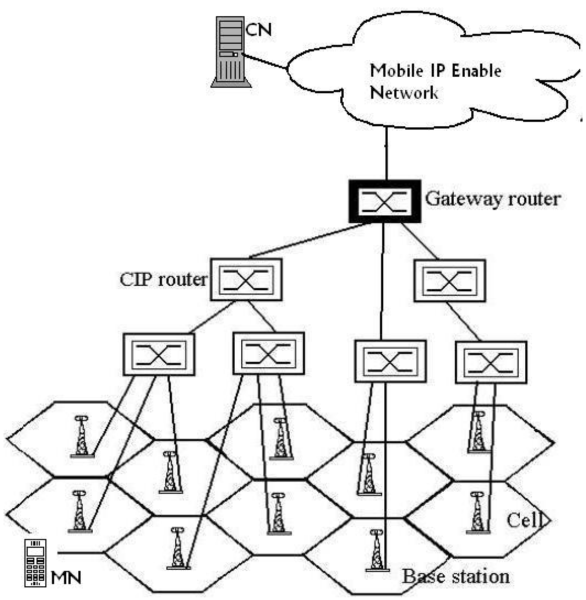

Figure 2. Basic Cellular IP Network

The integration of Internet Protocol version 6 (IPv6) to Cellular IP was first envisioned by [11]. IPv6 provide solution to the most prominent issues in IP based network which is lack of global IP address. With abundance of global IP, end-to-end connectivity finally can be realized without the used of any IP translation tools mechanism such as network address translator (NAT). Application such as voice-over-IP, text messaging, push mail and many more can finally benefit from the end-to-end connection. Other than that, IPv6 also provide significant services upgrade such as improved security, autoconfiguration, routing efficiency, and many more. More details can be found regarding IPv6 features in RFC2460. We will elaborate more details on cellular IPv6 in the following section.

Cellular IPv6

In the following section, we present an overview of the operation of Cellular IPv6. The description of the operation is base on the figure 2. Base Stations in cellular IP network will from time to time emit beacon signals. Mobile hosts use these beacon signals to locate the nearest Base Station. A mobile host can transmit a packet by relaying it signal to the nearest Base Station base on base station propagation delay. By default all IP packets transmitted by a mobile host are routed from the Base Station to the Gateway by hop-by-hop through shortest path routing, regardless of the destination address.

IP packets addressed to a mobile host are routed by the chain of cached mappings associated with mobile host. The use of IPv6 within cellular networks implies an implementation of the IPv6 protocol stack within a wide range of cellular base station. Such base station may vary significantly in terms of capacity, task orientation and processing power. For instance, the smallest handheld terminals can have a very limited amount of memory, computational power, and battery capacity and operate over low bandwidth wireless links with limited throughput.

Cellular IPv6 design and implementation is based on the original implementation of the Columbia University. The main design specifications and functionality for Cellular IPv6 are:

- the use of IPv6 extension headers to carry control information
- authentication transactions based on IPv6 authentication headers
- deployment of IPv6 stateless address autoconfiguration to obtain a care-of address, and
- the use of IPv6 care-of address to identify Mobile Hosts.

Mobile-IPv6-capable hosts, use their IPv6 care-of address as the source of every packet they send and carry their permanent Home IPv6 address into a Home address destination options header. In order to be interoperable with Mobile IPv6 specification, the Cellular IPv6 control packets (route-updates and paging-updates) are sent uplink with source address of the Mobile Host's IPv6 care-of address. On the reverse direction, IPv6 packets destined to upper level in Mobile Host network reach the Cellular IPv6 Gateway through two alternative methods:

IPv6-encapsulation

The sender is not aware of the recipient Mobile host's current CoA, and sends the packet with destination its Home

IPv6 address. This packet is normally routed to the Mobile Host's Home Network, where it is intercepted by the local Home Agent which next encapsulates and sends the packet to the Mobile host's current care-of address.

Carrying an IPv6 routing header.

The sender has a fresh binding for the recipient Mobile Host and sends the packet directly to its current care-of address. In this case, the sender maps the Mobile Host's Home IPv6 address as the last entry in the routing header, while the Mobile Host's current care-of address is mapped as second-to-last. Packets addressed to a Mobile Host will be routed towards the Cellular IPv6 Gateway/Router using prefix-based routing. Next, Cellular IPv6 host-based routing into the Cellular IPv6 Access Network will forward packets to the Mobile Host, through the Base Station that it is currently attached to.

IV. Design issues

A. Location Management and Routing

The use of cache system in cellular IP is very significant since MN location management and routing depends on two parallel type of caching system to function. Cellular IP user can be either in active state or in idle state. In active state user are busy with transferring and receiving data through their mobile device. In this active-state user might be moving from one base station to another. It is very important for the network to keep track the location of MN so that any handoff of active user to new base station is known to the network. The task for updating handoff and location in the network manage by MN to so the network will be able to track the MN location without having to searching. MN will update it's route cache from time to time to the network. During active mode the location for MN is very important to the network so the network will know where to direct packets.

In passive mode, MN will not involve in any data transmission but always want to be reachable for any incoming packets. Route Cache mappings time out during passive mode will be over but MN is maintain a different cache called Paging Cahce mappings. Paging cache help MN keep connected to the network with the minimal communication as possible to save battery life. Unlike Mobile IP where MN has to send route-update-packet to router for location updates all the time which will consume more battery power thus reduce the ability to stay-alive in network. Thus by separating the caches for active and idle mobile hosts only a smaller cache needs to be searched for most of the packets. This results in faster lookups and better scalability [11].

All packets transmitted in cellular IP network are routed from the Base Station to the Gateway through shortest path hop-by-hop routing. Cellular IP nodes maintain a Route Cache in distributed manner. Packets that has been transmitted by the MN at the same time create and update entries in each node's cache. This entry maps the MN IP address to the neighbor like a chain from which the packet arrived to the node. The chain of cached mappings referring to a single mobile host it is also being used as a reverse path for any replied packets addressed back to the same mobile host. As the MN moves to a new base station, this chain of mappings will always pointing to its current location because every-time request made from MN, its uplink packets will create a new and modified the old mappings.

The Cellular IP network is connected to the Internet via a gateway router. However mobility between gateways is managed by Mobile IP while mobility within access networks is handled by Cellular IP. MN attached to the network use the IP address of the gateway as their Mobile IP CoA. Inside a Cellular IP network, mobile hosts are identified by their home addresses and data packets are routed without tunneling or address conversion. Cellular IP routing protocol ensures that packets are delivered to the host's actual location. Packets transmitted by mobile hosts are routed to the gateway and from there on to the Internet.

In Cellular IP, location management and handoff support are integrated with routing to minimized complexity. Unlike mobile IP which regularly send control messaging packet to update it's location, cellular IP minimize control messaging by using a regular data packets transmitted by MN to establish host location information. Uplink packets are routed from mobile to the gateway on a hop-by-hop basis. The path taken by these packets is cached in base stations. To route downlink packets addressed to a mobile host the path used by recent packets transmitted by the host is reversed. When the mobile host has no data to transmit then it periodically sends empty IP packets to the gateway to maintain its downlink routing state. Following the principle of passive connectivity mobile hosts that have not received packets for a certain period of time allow their downlink soft-state routes to timeout and be cleared from the routing cache. In order to route packets to idle hosts a Cellular IP mechanism called paging is used.

Some issues related to cellular IP routing includes triangle routing and delay. Triangle routing occur when 2 hosts are in different access networks request for each other. This will lead to triangle routing where packets having problem to route with A possible delay for host moving into another access network

B. Paging

Paging in cellular IP operate the same way as it's routing except paging is for idle user who want to stay connected. Cellular IP defines an idle mobile host that has not received data packets for a system specific time and exceed it's time out value. In idle state mobile user intentionally leave their mobile device unused but still connected to network. Any incoming data from CN will be push in to MN in real time, a features that is laking in Mobile IP. In mobile IP network leaving the mobile device in connected mode will unimaginably consume battery life since it will constantly transmit packet to updates its location.

Cellular IP hosts transmit paging-update packets at preset regular intervals which is defined by paging-update-time. Paging-update packets are sent to the base station that offers the best signal quality. As mentioned before paging-update packets are also routed on a hop-by-hop basis to the gateway the same way as route-update packets does. Although both has

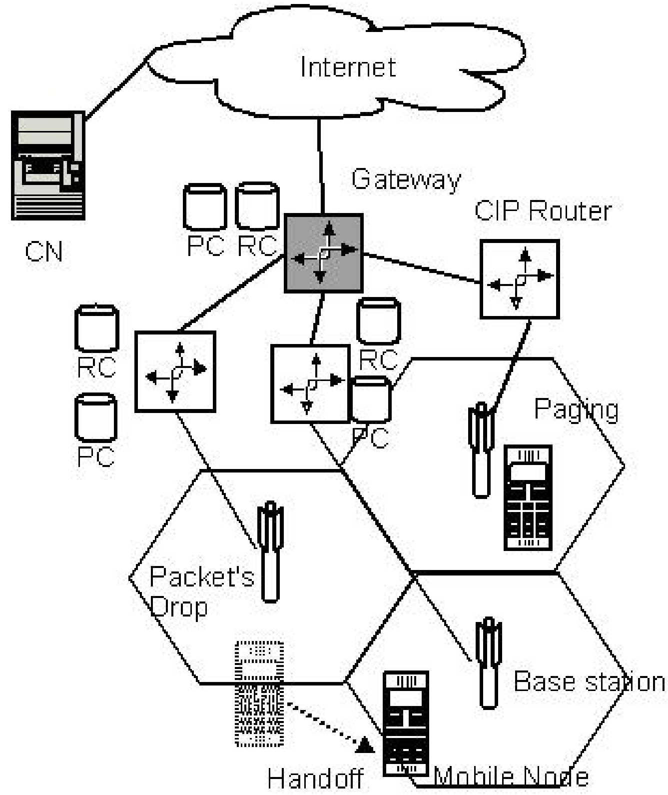

Figure 3. Routing and Paging

the same routing preference, paging cache mappings have a longer timeout and it's updated by any packet sent by mobile hosts including paging-update packets.

In addition, active mobile hosts have mappings for both routing and paging cache. Packets addressed to a mobile host are normally routed by routing cache mappings. Paging cache occurs when a packet is addressed to an idle mobile host and the gateway or base stations find no valid routing cache mapping for the destination address. In case of the base station has no paging cache, it will broadcast the packet to all its outgoing ports except for the port where the packet came in. By using paging cache, broadcast search such as available in cellular network can be avoided which can reduce the burden of the network with multipath request. Base stations with paging cache will forward the paging packet if the destination that has a correct paging cache mapping and only to the destined output ports. Without any paging cache the first packet addressed to an idle mobile host is broadcast in the access network. While the packet does not experience extra delay it does, however, load the access network. Idle mobile hosts that receive a packet move from idle to active state, start their active-state-timer and immediately transmit a route-update packet. This ensures that routing cache mappings are established quickly potentially limiting any further flooding of messages to the mobile host.

C. Handoff

A change of access point by mobile host during active data transmission or reception is called a handoff or handover. During the handoff process, packet losses may occur due to the transition of communication management to the new base station. However these losses should be minimized in order to avoid a degradation of service quality as handoff become more frequent.

Cellular IP supports two types of handoff scheme; hard handoff and semi-soft handoff. Cellular IP hard handoff is based on a simple approach that trades off some packet loss for minimizing handoff signaling rather than trying to guarantee zero packet loss. On the other hand, semi-soft handoff exploits the notion that some mobile hosts can simultaneously receive packets from the new and old base stations during handoff. Semi-soft handoff minimizes packet loss, providing improved performance over hard handoff but with the cost of complexity for reliability.

1) Hard Handoff : Hard handoff mechanism uses very simple mechanism where Mobile hosts listen to beacons signal from a base stations and start initiate handoff depend on signal strength. Mobile node will switch to whichever base station that has the higher signal strenght. Hard handoff initiated when a mobile host tunes its radio to a new base station and sends a route-update packet (1) to the new base station (refer to figure 4). Then the new base station will send the message to the gateway to updates mapping to the new route (2,3). All new packet into the gateway will be redirected to new base station. Any incoming packet that before the gateway updates will be considered as lost (4). This is a brute method of handing over mobile host to the new base station. The advantage of this method was low handoff latency where mobile host can quickly tune to new base station.

Since hard handoff employ such simple mechanism performance and reliability issues such as quality of service needed to be address. One of the issues is handoff latency. Handoff latency define as the time taken between handoff initiation by the mobile host and the arrival of the first packet from the new route. We define the crossover base station as the common branch node between the old and new base stations, an example of which is illustrated in the figure 4. In the worst case the crossover point is the gateway. During this interval, downlink packets may be lost. Mappings associated with the old base station are not cleared when handoff is initiated. Rather, mappings between the crossover node and the old base station timeout and are removed. No packets are transmitted along the old path once the route-update message has created a new mapping at the crossover base station that points toward the new base station [2].

Hard handoff procedure packet may get lost during handover but still considered shorter than Mobile IP handoff latency. This is due to the fact that only a local node has to be notified rather than a possibly distant HA in the case of Mobile IP [2]. However hard handoff is not suitable for certain applications that require reliability of packet transfer. There are several ways to reduce packet loss during handoff. One approach relies on notification system between the old and

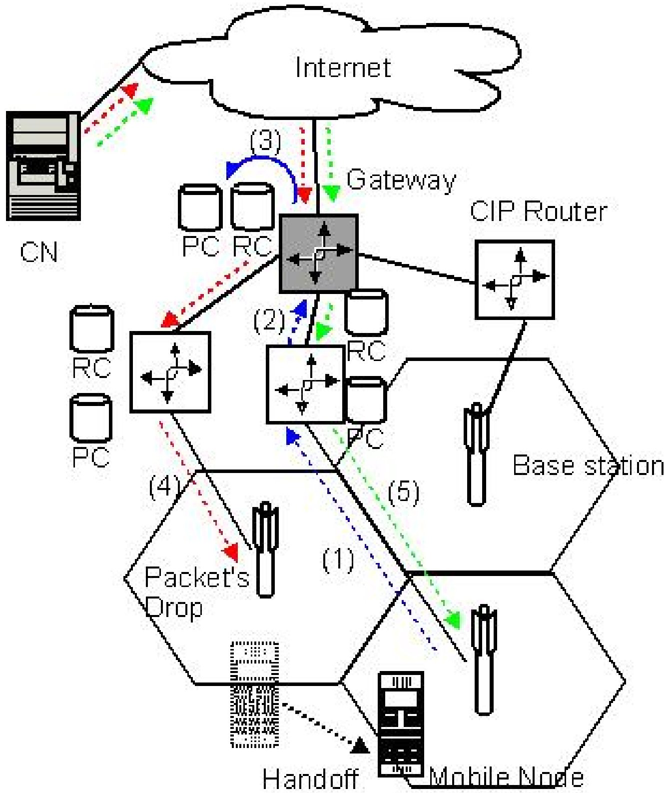

Figure 4. Hard Handoff

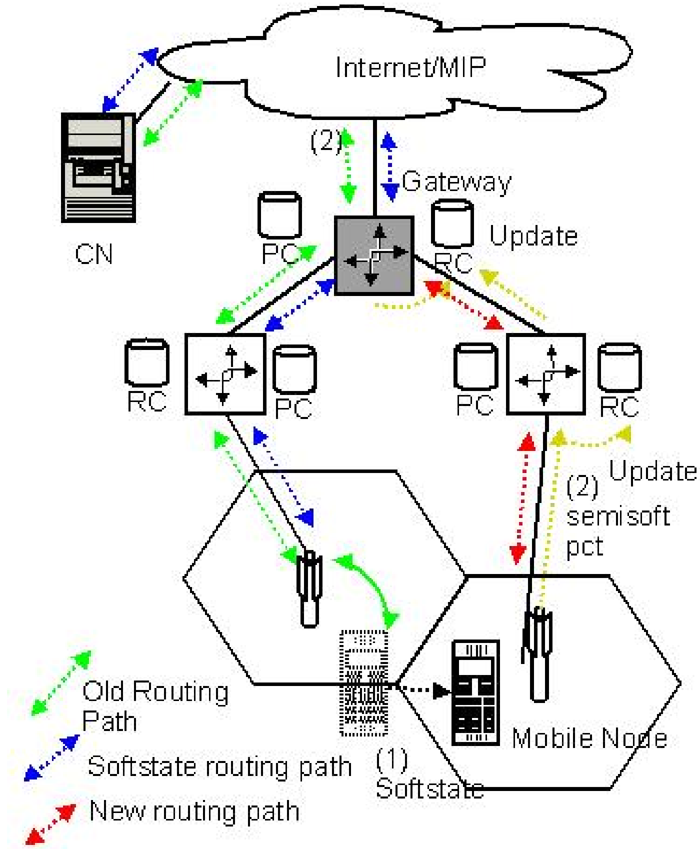

Figure 5. Semi-soft handoff

new base stations. During handoff the new base station notifies the old base station of the pending handoff. Packets that arrive at the old base station after notification of handoff are rerouted to the new base station and onto the mobile host. In contrast, packets that arrive at the old base station before notification is complete will be lost. If the notification time (i.e., the round-trip time between the new and old base stations) is not smaller than handoff duration (i.e., the round-trip time between the new and cross-over base stations), this approach does not significantly improve handoff latency. An additional cost of these schemes is that communications, signaling, and information state exchange are required between base stations for this approach to work. To preserve the simplicity of hard handoff, Cellular IP employs a different approach to counter the problem of packet loss with the semi-soft handoff.

2) Semi soft Handoff: Semi-soft handoff improve packet transfer reliability by allowing both old and new base station to work in parallel until mobile host really cut off from the old base station. This will ensure cellular IP routers and gateway has enough time to update it's routing cache and form a new path to the mobile host. Semi-soft handoff works between a period when both the old and new routes are valid and packets are delivered through both base stations. This feature is used in the Cellular IP semi-soft handoff algorithm that able to improves handoff performance but still suits the maintain as it's simple architecture. However it doesn't fully eliminates the packet loss but only provide some guarantees.

Basically semi-soft handoff procedure has two main process. The first feature is routing cache mappings associated with the new base station must be created before the actual handoff takes place. When the mobile host start to initiates a semi-soft handoff, it start by sending a semi-soft packet to the new base station and then immediately returns to listening to the old base station. While the host is still in contact with the old base station, the semi-soft packet start to initiate new route for the mobile host by configuring routing cache mappings associated with the new base station. After the initiation procedure, then can mobile host perform a regular handoff with the old base station.

The semi-soft delay determined by mobile host to gateway round-trip time and the route-timeout value for the cellular IP network routing. During the delay it's self semi-soft process take place to ensures that by the time the host tunes its radio to the new base station, all the packets can go through both both the old and new base stations. Depending on the network topology and traffic conditions, the time to transmit packets from the cross-over point to the old and new base stations may be different and the packet streams transmitted through the two base stations will typically not be synchronized at the mobile host.

During the semi-soft process, both old and new stream will coexist but synchronization of the two streams is not necessary. It can be avoided by using a delay device which will intelligently know that semi-soft process is taken place. The mapping created by the semi-soft packet has a flag to indicate that downlink packets routed by this mapping must be cleared before transmission. These packets have the impact of clearing the flag causing all packets in the delay device to be forwarded to the mobile host. Base stations only need a small pool of delay buffers to resolve this issue. Packets that cannot sustain additional delay can be forwarded without passing through the delay device. This differentiation can be made on a per-packet basis, using, say, differentiated service or transport (e.g., TCP, UDP, or RTP) codepoints. After handoff, the mobile host will send data or route-update packets along the new path which will clear this flag and cause all packets in the delay device to be forwarded to the mobile host. After the hard handoff, the old routing cache path to the old base station still remains in place until the soft-state cache mappings time out.

On the other hand, the Cellular IP semi handoff scheme requires that the handoff take place within the area where the new and old base stations overlap [8]. However, if the mobile node is temporarily out of radio contact with its old base station during the handoff, then the packets cannot be diverted to both base stations. This results in data loss and communication interruption. In other words, the semi handoff scheme works well when the mobile host is in the overlap area.

V. Research Direction

Our work mainly focus on handoff mechanism which we're looking for a better way reducing handoff latency and packet lost. Although cellular IP handoff mechanism are able to provide quite reliable and fast handoff compared to Mobile IP, further research in these area are able to explore different mechanism or at-lease provide some improvement or alternative or hybrid methods that can significantly improved cellular IP performance interm of packet lost or further reduce handoff latency. It is feasible for cellular IP to reduce more signalling load from mobile user this reducing power consumption in idle or active mode. Any method that we found through out the research process will focus towards this realizing this vision.

The idea of inter-working of protocols is one of our interest in improving cellular IP handoff mechanism. As discussed in [9], inter-working of protocol is having two different protocol to merge together and solve problem with more efficient result. The semi handoff in Cellular IP protocol can achieve fast and smooth handoff, but it does not work properly when the mobile node suddenly loses contact with its previous base station [8]. Semi-soft handoff also unable to deal with frequent handoffs within their areas. Under such scenarios, the communication efficiency of the mobile host decreases and the load on the network increases.

[9] proposed by combining hierarchical approach and fast handover mechanism the overall performance of handover can be further decreased. The fast handover mechanism minimize the detection time during the handover and router advertisement. By reducing handover detection time combine with less router advertisement [9] believe that overall handover latency can be reduces.

One interesting fact that the introduction of cellular IP with the new network layer protocol (IPv6) certainly will provide us more interesting result and methods. The new features of IPv6 will greatly enhance the service provided at network layer towards cellular IP. Feature such as better security, more IP addresses for end-to-end connection, better routing mechanism, simplicity, and many more. However at the moment only cellular IPv4 will be used for 4G networks. Realizing the potential of IPv6, cellular IPv6 will surely leads the way for the future. The significant of the research will then will become greater.

VI. Conclusion

We can see that the future for cellular IP is there. The selection of cellular IP as one of the protocol to coexist with mobile IP in future high speed 4G network was the right move taken by IETF. The important of cellular IP will be more significant once the protocol is being inserted into working 4G network. IPv6 on the other hand will provide a big leap for cellular IP realizing the vision of "always connected" to the Internet with low cost and power consumption. Application such as voice-over-IP, email, on-line multimedia messaging open up more to it's current potential once such services can be provided. The Internet will become more connected than ever before.

References

[1] Fekri M. A Abduljalil and Shrikant. K. Bodhe. Forward-based handoff mechanism in cellular ip access networks. In *Auswireless 2006 Conference Papers*, 2007.

[2] A. Campbell, J. Gomez, S. Kim, A. Valko, C. Wan, and Z. Turanyi. Design, implementation, and evaluation of cellular ip, 2000.

[3] A. T. Campbell, J. Gomez, Sanghyo Kim, Chieh-Yih Wan, Z. R. Turanyi, and A. G. Valko. Comparison of IP micromobility protocols. *IEEE [see also IEEE Personal Communications] Wireless Communications*, 9(1):72–82, February 2002.

[4] Andrew T. Campbell, Javier Gomez, and András G. Valkó. An overview of cellular IP. *IEEE Wireless Communications and Networks Conferance 1999 (WCNC'99)*, 2:606–611, 1999.

[5] G. Edwards and N. Suryakumar. Cellular IP performance. *2003. WCNC 2003. 2003 IEEE Wireless Communications and Networking*, 3:2081–2085, March 2003.

[6] Pasi Eronen. Tcp wake-up: Reducing keep-alive traffic in mobile ipv4 and ipsec nat traversal traffic in mobile ipv4 and ipsec nat traversal. Nokia Technical Report (NRC-TR-2008-002), January 2008.

[7] Isidro Vicente H. and Ernesto E. Quiroz M. Performance analysis of the cellular IP mobility protocol. In *Electronics, Robotics and Automotive Mechanics Conference, 2006*, volume 1, pages 43–48, Cuernavaca,, September 2006.

[8] Y. Liang, A. G. Jost, and A. N. Zincir-Heywood. Support micro-mobility with multiprotocol handoff mechanism. In *Electrical and Computer Engineering, 2003. IEEE CCECE 2003. Canadian Conference on*, volume 3, pages 1621–1624, May 2003.

[9] Bi-Lynn Ong and Suhaidi Hassan. Interworking of protocols in IPv6 mobility management. In *Telecommunications and Malaysia International Conference on Communications, 2007. ICT-MICC 2007. IEEE International Conference on*, pages 599–604, Penang, Malaysia, May 14–17, 2007.

[10] D. Saha, A. Mukherjee, I. S. Misra, M. Chakraborty, and N. Subhash. Mobility support in IP: a survey of related protocols. *IEEE Network*, 18(6):34–40, November/December 2004.

[11] Zach D. Shelby, Dionisios Gatzounas, Andrew Campbell, and Chieh-Yih Wan. Cellular ipv6. Internet Draft, 2000.

[12] András G. Valkó. Cellular ip: a new approach to internet host mobility. *SIGCOMM Comput. Commun. Rev.*, 29(1):50–65, 1999.