www.ijraset.com

Vol. 2 Issue V, May 2014

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Analysis of IP Micro Mobility Protocols: A Review

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Abstract- Node mobility between distinct subnets inside domain or between distinct domains is manged by IP mobility management protocols which are of two types: IP Macro Mobility protocols and IP Micro Mobility protocols. IP Macro Mobility protocols are used to manage mobile nodes between two domains without any disconnection whereas IP Micro Mobility protocols are used to manage the mobile nodes which change their access points between two subnets in the same domain and providing fast and seamless handoff such as, HAWAII, EMA, TelMIP, Cellular IP, HMIP and so on. This paper aims at the analysis of the different IP Micro Mobility Protocols having common and different characteristics.

Keywords-IP Mobility Management protocols , IP Macro Mobility protocols, IP Micro Mobility protocol, HAWAII, EMA, TelMIP, Cellular IP and HMIP.

1. INTRODUCTION

The movement of mobile nodes between two subnets within same domain is known as Micro Mobility, and they changes their access points in the accessing network frequently. IP Micro Mobility protocols are designed so far to manage mobile nodes in the environment, provides fast and seamless handoff like HAWAII, EMA, TelMIP, Cellular IP, HMIP and likewise.

HAWAII is based on IP Micro-Mobility protocol implementing the mobility of nodes within the domain. It is connected to the Internet via a Domain Root Router(DRR). Every mobile node has its constituent IP address and home domain. This mobile node when changes its domain to a foreign domain, Mobile IP handoff mechanism is applied. The mobile node is allocated a new Care of Address(CoA) which remains fixed during the movement between the Foreign Agents(FAs) in the same domain. Figure 1 demonstrates the HAWAII architecture and its constituents. It illustrates the intradomain(managed by HAWAII) and interdomain(managed by Mobile IP) mobility of mobile nodes.

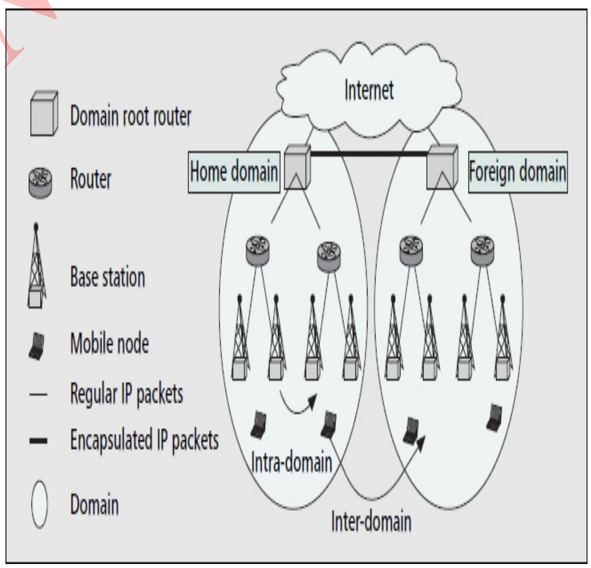

Figure 1: HAWAII architecture

The extension of basic Mobile IP is known as Hierarchical Foreign Agent(HFA) ,which deals to address the drawback of Mobile IP Via handling the IP micro-mobility of the mobile node under a single domain. Figure 2 demonstrates the basic network components.

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

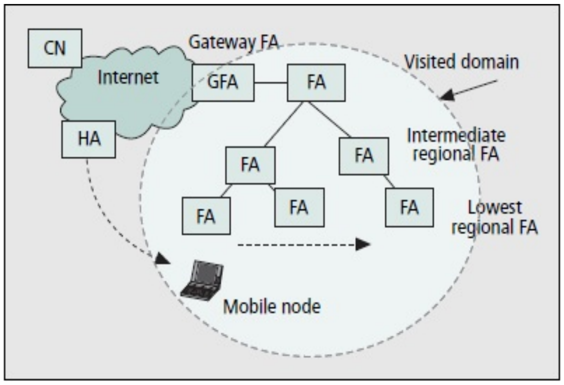

Figure 2: HFA Network.

Two or more tree like levels of FA constitutes HFA network. The topmost FA hierarchy is known as Gateway Foreign Agent(GFA), which connects domain to internet via publicly routable address. The hierarchy bottom of FAs allows the mobile node to access the domain and connected to Internet. Edge Mobility Architecture(EMA) is a illustration of architecture of domain based routing and addressing support. It does not specify the creation and modification of IP routing. TelMIP is a two level IP based architecture. As compared to Mobile IP it is more scalable and results in small handoff latency and overhead signalling. The ability of FAs to connect to more than one GFAs is considered to be the main advantage of TelMIP.

Columbia University and Ericsson proposed Cellular IP for handling mobility under a single domain. Cellular IP supports fast handoff, passive connectivity and paging mechanism. To provide Macro Mobility between domains it can interwork with Mobile IP. Figure 3 shows the Cellular IP architecture and its various components.

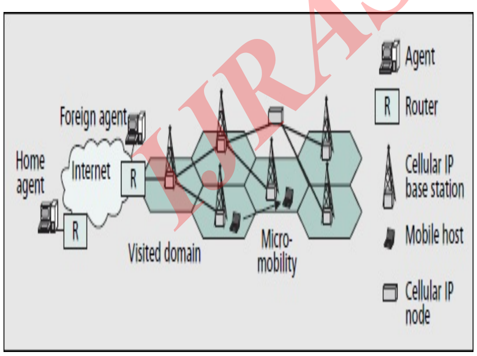

Figure 3: Architecture of Cellular IP.

2. ISSUES

Micro Mobility protocols aims at fast handoff control with least packet loss and minimize signalling with the use of paging techniques, hence registration is reduced to minimum value.

Fast Handoff: Delay and packet loss is minimized during handoff with fast handoff. Issues like handoff control buffering and forwarding techniques, radio behavior movement detection and prediction and coupling and synchronizing between IP and radio layers affects handoff performance. Handoff performance is primarily affected by Layer three movement detection(Such as Eager cell switching). The delay involved in recognizing and registering at a new access point can have a quite a impact on mobility and delivery. Layer two event triggers Layer three hand off control in this situation. The wide diversity of wireless devices make its difficult to describe operation and interaction of these radios in a global mobility network without falling into link specific dynasty. A need arises to illustrate an open radio API, which extracts the wireless technology's essence avoiding complex link specific description. It allows Layer two " Triggered " handoff in between distinct radio technologies.

Paging: In the case of mobile network, network location information is maintained by mobile hosts to easily reachable would need frequent updates consuming bandwidth and battery power. Paging reduce the overhead signalling.[2]

Fast Security/AAA: The support of Fast Handoff control for mobile host is one of the major goals of Micro Mobility Protocols. Authentication and authorization at user and at network location level should be implemented with handoff to implement Fast Security access.

3. CHARACTERISTICS

Hierarchical Mobility: It manages to reduce the performance impact of mobility by managing the local movement locally and privatizing from Home Agent. The IP address cannot be used to identify mobile host's exact location, rather it depicts the address of gateway that is common to large number of network access points. The Home Agent need not to be informed when mobile host migrates. The Micro Mobility protocol checks whether packets arriving at the gateway are forwarded to their allocated access points or not. For this purpose of mapping it maintains the "location database". To perform routing two different types of mobility is supported

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

by hierarchical mobility such as, "hierarchical tunneling" and "mobile specific routing".

Hierarchical Tunneling: FAs in the access network maintains the distributed form location database. The original destination address is read by each FA of incoming packet and searches the visitor list in database for the respective entry, which is maintained by registration messages transmitted by mobile hosts. FAs tree like structure affects all these proposals which encapsulates the traffic from home agent by decapsulating and rencapsulating the data packets as they are forwarded across the network which is known as tunneling while changing the access locations.[5]

Mobile–Specific Routing: Mobile-Specific routing prevents from the overhead resulted from decapsulation and reencapsulation techniques. These schemes typically introduce implicit (e.g., based on snooping data) or explicit signaling to update mobile-specific routes or they are aware that a routing protocol is in use. In the case of Cellular IP mobile hosts attached to an access network use the IP address of the gateway as their Mobile IP care-of address. The gateway decapsulates packets and forwards them toward a base station. Inside the access network, mobile hosts are identified by their home address and data packets are routed using mobile-specific routing without tunneling or address conversion. The routing protocol ensures that packets are delivered to the host's actual location. Examples of micro-mobility protocols that use mobile-specific routing include Cellular IP and Hawaii.

4. PROTOCOLS

In what follows, we provide an overview of a number of micro-mobility proposals. Each protocol is identified as having one or more of the following protocol design attributes: (h) fast handoff, (p) paging, (s) fast security, (m) hierarchical mobility, (t) hierarchical tunneling and (r) mobile-specific routing. We use these design attribute to present a simple taxonomy.

Cellular IP (h,p,s,m,r): The Cellular IP[2] (CIP) proposal from Columbia University and Ericsson supports fast handoff and paging techniques. Location management and handoff support are integrated with routing in Cellular IP access networks. To minimize control messaging, regular data packets transmitted by mobile hosts are used to refresh host location information. Cellular IP uses mobile originated data packets to maintain reverse path routes. Nodes in a Cellular IP access network monitor (i.e., "snoop") mobile originated packets and maintain a distributed, hop by-hop location data base that is used to route packets to mobile hosts. Cellular IP uses IP addresses to identify mobile hosts. The loss of downlink packets when a mobile host moves between access points is reduced by customized handoff procedures. Cellular IP supports two types of handoff scheme. Cellular IP hard handoff is based on simple approach that trades off some packet loss in exchange for minimizing handoff signaling rather than trying to guarantee zero packet loss. Cellular IP semisoft handoff exploits the notion that some mobile hosts can simultaneously receive packets from the new and old base stations during handoff. Semisoft handoff minimizes packet loss providing improved TCP and UDP performance over hard handoff. Distinguishing idle and active mobile hosts reduces power consumption at the terminal side. The location of idle hosts is tracked only approximately by Cellular IP Therefore, mobile hosts do not have to update their location after each handoff. This extends battery life and reduces air interface traffic. When packets need to be sent to an idle mobile host, the host is paged using a limited scope broadcast. A mobile host becomes active upon reception of a paging packet and starts updating its location until it moves to an idle state again. Cellular IP also supports a fast security model that is suitable for micro-mobility environments based on fast session key management. Rather than defining new signaling, Cellular IP access networks use special support of session key management, which would inevitably add additional delay to the handoff process.

Hawaii (h,p,m,r): The Hawaii[3] protocol from Lucent Technologies proposes a separate routing protocol to handle intra-domain mobility. Hawaii relies on Mobile IP to provide wide-area inter-domain mobility. A mobile host entering a new foreign agent domain it is assigned a collocated care-of address. The mobile node retains its care-off address unchanged while moving within the foreign domain, thus the home agent does not need to be involved unless the mobile node moves to a new domain. Nodes in a Hawaii network execute a generic IP routing protocol and maintain mobility specific routing information as per host routes added to legacy routing tables. In this sense Hawaii nodes can be considered as enhanced IP routers, where the existing packet forwarding function is reused. Location information (i.e., mobile-specific routing entries) is created, updated and modified by explicit signalling messages sent by mobile hosts. Hawaii defines fore alternative path setup schemes that control handoff between

ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

access points. An appropriate path setup scheme is selected depending oil the operator's priorities between eliminating packet loss, minimizing handoff latency and maintaining packet ordering. Hawaii uses IP multicasting to page mobile hosts when incoming data packets arrive at an access network and no recent routing information is available.

Hierarchical Mobile IP (h,p,s,m,t): The Hierarchical Mobile IP (HMIP) proposal from Ericsson and Nokia[5]employs a hierarchy of foreign agents to locally handle Mobile IP registration. In this protocol mobile hosts send mobile IP registration messages (with appropriate extensions) to update their respective location information. Registration messages establish tunnels between neighboring foreign agents along the path from the mobile host to a gateway foreign agent. Packets addressed to mobile hosts travel in this network of tunnels, which can be viewed as a separate routing network overlay on top of IR The use of tunnels makes it possible to employ the protocol in an IP network that carries non-mobile traffic as well. Typically one level of hierarchy is considered where all foreign agents are connected to the gateway foreign agent. In this case, direct tunnels connect the gateway foreign agent to foreign agents that are located at access points. Paging extensions for Hierarchical Mobile IP are presented in allowing idle mobile nodes to operate in a power saving mode while located within a paging area. The location of mobile hosts is known to home agents and is represented by paging areas. After receiving a packet addressed to a mobile host located in a foreign network, the home agent tunnels that packet to the paging foreign agent, which then pages the mobile host to re-establishes a path toward the current point of attachment. Paging a mobile node can take place using a specific communication time-slot in the paging area similar to the paging channel in second generation cellular systems. Paging schemes increase the amount of time a mobile host can remain in a power saving mode. In this case, the mobile host only needs to wake up at predefined time intervals to check for incoming paging requests. Table 1 shows a simple comparison of CIR Hawaii and HMIR

Intra-Domain Mobility Management Protocol (h,p,m,r): The Intra-Domain Mobility Management Protocol (IDMP) from Telcordia and University of Texas reduces handoff latency and signaling overhead of frequently roaming hosts by localizing mobility-related management within a wireless access, Number domain. IDMP supports fast handoff with minimal packet losses and paging fbr reduced signaling. IDMP uses a hierarchical structure with a mobility agent at the top of the hierarchy with several child sub-network foreign agents interconnected to it. The top-level mobility agent functions as a gateway to the Internet. No global registration is necessary as long as hosts move within the agent's administrative domain. The home agent only needs to be updated when the mobile host changes administrative domains. Global and local addresses handle mobility. The global address points toward the current administrative top-level mobility agent. This address remains unchanged as long as the mobile host remains in the domain. In contrast, the local address is a pointer toward the visiting foreign agent and changes every time a mobile host hands off to a different child foreign agent.

IntraDomain Mobility Management Protocol (h,p,m,r):[10]The Intra-Domain Mobility Management Protocol (IDMP) from Telcordia and University of Texas reduces handoff latency and signaling overhead of frequently roaming hosts by localizing mobility-related management within a wireless domain. IDMP supports fast handoff with minimal packet losses and paging fbr reduced signaling. IDMP uses a hierarchical structure with a mobility agent at the top of the hierarchy with several child sub-network foreign agents interconnected to it. The top-level mobility agent functions as a gateway to the Internet. No global registration is necessary as long as hosts move within the agent's administrative domain. The home agent only needs to be updated when the mobile host changes administrative domains. Global and local addresses handle mobility. The global address points toward the current administrative top-level mobility agent. This address remains unchanged as long as the mobile host remains in the domain. In contrast, the local address is a pointer toward the visiting foreign agent and changes every time a mobile host hands off to a different child foreign agent.

3G Wireless (h): [13]The 3G wireless proposal from members of the 3GPP2 consortium describes a Mobile IP based micro-mobility management protocol for third generation cdma2000 wireless networks. Enhancements to Mobile IP include mobility management support between radio access networks and the Internet. The work focuses on the connectivity between mobile hosts and foreign agents at the link layer. A feature of cdma200 networks is that the physical layer terminates at a radio network node while the administrative foreign agent resides at a separate serving node. The serving node is responsible for controlling the link layer operations of mobile hosts. This includes establishing, maintaining, and

ISSN: 2321-9653

terminating connections to and from mobile hosts. The 3G wireless proposal also minimizes the disruption experienced by mobile hosts during handoffs between radio access network.

Edge Mobility Architecture (h,m,r): The Edge Mobility Architecture proposed by British Telecom, Ansible-Systems and the University of Maryland presents a general framework that supports host mobility in wireless access networks. The authors argue that edge based routing protocols need to be more responsive to host mobility and further conjecture that exist routing protocols developed for highly dynamic environments (e.g., mobile ad hoc networks) are very applicable. The edge proposal discusses the use of the TORA routing protocol in this context. However, the approach supports a generic framework where other fast routing algorithms could support micro mobility. Edge mobility supports transparent handoff between access routers using different wireless technologies through information exchanged between access routers. Edge mobility does not advocate any specific layer two functions. Rather, it presents a common interface to hide the details of different wireless technologies from the higher layers. A mobile host acquires an IP address within an address block allocated to the access router. An access muter advertises the IP address prefix associated with an address block using an intra-domain routing protocol. Here the intra-domain routing protocol uses longest prefix match to overrule or overwrite the standard prefix routing of allocating access routers. During handoff a host redirect route is introduced to forward packets from the old to the new access router.

Proactive Handoff (h,m,t): The foreign agent assisted hand-off proposal from Sun Microsystems and the University of Illinois allows one or more foreign agents to forward packets prior to receiving a Mobile IP registration request from a mobile host. After detecting that a mobile host is about to perform a handoff to a different location, the mobile node's serving foreign agent sends a binding update request to the "new" foreign agent prior to handoff. This proactive binding update contains the mobile host's home address, security related information, as well as the serving gateway foreign agent's address. The proposal assumes that foreign agents can detect the direction of movement of mobile hosts by taking advantage of link layer and radio specific information. Upon reception of the binding update, the new foreign agent sends a handoff request toward the gateway foreign agent, which in turn towards packets to all foreign agents registered by the mobile host. The proactive protocol completes the layer two handoff and forward data to the mobile host before the Mobile IP registration proceeds. In essence, proactive handoff delivers IP packets to the mobile host via the new base station before Mobile IP can "handoff".

Anchor Handoff (h,s,m,t): Anchor handoff proposes a number of enhancements to ease local registration and global indirect registration. A mobile host authenticates with its home agent during global registration and establishes a secure tunnel between the home agent and foreign agent. The foreign agent then acts as anchor foreign agent for future registrations. This proposal assumes mobile hosts and foreign agents can establish a shared key through a mechanism that can be used to authenticate a mobile host with a foreign agent. In this scheme, only a local registration is necessary after handoff. This rule holds as long as the mobile host moves within the same domain between the visiting foreign agent and the anchor foreign agent.

Fast Handoff (h,m,t): The fast handoff proposal assumes that the serving foreign agent anticipates the movement of mobile hosts by sending multiple copies of the traffic to potential neighbor foreign agents. "Bicasting" is used to support data forwarding to the previous and new foreign agents while the mobile host is moving between the old and new access points. Fast handoff predicts the movement of mobile hosts through coupling with layer two functionality that, it is argued, is dependent on the type of access technology used. Bicasting uses simultaneous bindings, where the mobile hosts sets the "S" bit in the registration request. Depending on the networking model (i.e., fiat or hierarchical model) the receiving agent (home agent, gateway foreign agent or regional foreign agent) will add a new binding for the mobile host. As in the case of proactive handoff, the fast handoff proposal also assumes that it can anticipate the movement of mobile hosts in advance of handoff. Fast handoff completes the Mobile IP handoff prior to establishing layer two connectivity or forwarding data. The total delay for fast handoff is limited to the time needed to perform a layer two handoff.

Session Initiation Protocol Mobility (h,m,t): The

[8]Session Initiation Protocol (SIP) mobility proposal is to support multimedia sessions for mobile devices in wireless access networks. SIP is gaining widespread use as a signaling protocol for handling multimedia applications and telephony

ISSN: 2321-9653

in the wired Internet. The proposal covers roaming support to both real-time and non-real-time applications. Similar to most micro-mobility protocols, SIP mobility considers partitioning the network along the lines of other micro-mobility proposals. Mobility management encompasses domain handoff and sub-network handoff leaving the link layer to deal with cell-to-cell handoff. The proposed SIP mobility framework can support TCP applications by spoofing addresses through the use proxy servers. General support for authentication, accounting, quality of service management and SIP registrations for mobile users is also discussed.

Unified Hierarchical Mobility (h,m): [9]The Unified Hierarchical Mobility model (UHM) presents a framework for interoperability between different types of micro-mobility protocols. The different micro-mobility protocols will be implemented in the Internet and that there will be a need for mobile hosts to handoff between access networks running different micro-mobility protocols (e.g., Cellular IP and Hawaii). UHM decomposes mobility management into three protocol components. An access protocol specifies a standard approach to registration between mobile hosts and domains. A micro-mobility protocol manages local mobility that can vary from one domain to another depending on which protocol is supported (e.g., Hawaii, IDMR HMP, etc). A macro-mobility protocol based on Mobile IP manages mobility between domains. Mobile node registration is independent of the micro mobility protocol operating within a specific domain. The nature of the mobility support is therefore very much dependent on which micro-mobility protocols are deployed.

Paging Extensions for Mobile IP (p): [12]The paging extensions for Mobile IP is designed to reduce signaling load in the core Internet and power consumption of mobile hosts. Active mobile nodes operate in exactly the same manner as in Mobile IR When a mobile host changes its point of attachment, it registers with a new foreign agent. In contrast, idle mobile hosts do not register when they move in a same paging area. An idle mobile host is forced to register only when it moves to a new paging area. When packets are destined to mobile hosts then home agents forward data packets to registered foreign agents. A registered foreign agent first checks if it has the mobile host's information on record. If it has a record, then it checks if the mobile host supports paging or not. If paging is supported then the registered foreign agent checks the mobile host's state. If the mobile node is in active mode then the registered foreign agent decapsulates and forwards packets to the mobile host, as in the case of Mobile IR In contrast, if the mobile node is in idle mode, the registered foreign agent sends a paging request message to other foreign agents in the same paging area as well as transmitting the message on its own access network. When a mobile host receives a paging request, it registers through the current foreign agent to its home agent. After receiving a registration request, the mobile node sends a paging reply back to its registered foreign agent through its current foreign agent to inform the register foreign agent of its current location. When the registered foreign agent receives a paging reply, it forwards any buffered packets to the mobile host.

Hierarchical Mobile IPv6 (h,m): There has been a number of recent Internet drafts addressing fast handoff and paging issues for MIPv6. The Hierarchical Mobile IPv6 (HMIPv6) proposal uses the IPv6 address space and neighbor discovery mechanisms to support flexible, scalable and robust mobility management. HMIPv6 uses anchor points called mobility servers and supports two or more levels of hierarchy. The simplest implementation of HMIPv6 supports two levels of hierarchy (e.g., a micro-mobility protocol and Mobile IP). The micromobility protocol in HMIPv6 is based on one or more mobility servers. When a mobile host moves into a new domain it acquires a global and a local address. Mobile hosts only need to change their local address while moving within a domain, their global address remains unchanged. Packets addressed to a mobile host's global address are routed to the domain, intercepted by the mobile server and encapsulated and tunneled toward the mobile host's actual location, as defined by its local address. The global address does not represent the address of the mobile server. Rather, it is an address associated with the mobile server's subnetwork. This operation allows HMiPv6 to dynamically change the mobile server without changing the global address. This feature supports load balancing and robustness.

Mobile IPv6 Handoff (h,m): The Mobile IPv6 handoff proposal addresses latency and packet losses issues associated with MIPv6 handoff. This proposal allows mobile hosts to send IPv6 binding updates with multiple care of-addresses. These include the care-of-address of the mobile node's current location as well as the care-of address of other access points in the neighborhood that the mobile node may handoff to. This "neighborhood" is established on a per mobile basis and is based on the network layout and the direction the mobile host in moving in. A new routing header extension allows home agents and corresponding hosts to route packets toward a

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mobile node's last known recorded position, and if not there, to the other care of-addresses defined by the binding update. To some extent this proposal leverages ideas used in paging where the location of mobile host is approximately tracked via paging areas.

5. CONCLUSION

In the above paper I have given a brief overview of micro mobility protocols as discussed in Mobile IP working Group previous decade. IETF working group is in process packing all advancements and contributions in a one standard fast handoff. As a part filtering processes many proposals were eliminated which did not meet or support the processes for tunneling and mobile IP messaging. A new team was formed to discuss four proposals. After the design team had made assessments and necessary additions they were left with proactive and fast handoff as discussed above. There are many similarities between the fast and proactive handoff proposals. Both proposals aim to limit handoff delay to the time needed to perform a layer two handoff. While neither proposal advocates a particular link layer technology each proposal couples layer three and two to minimize handoff delay. Both proposals predict the movement of mobile hosts anticipating new points of attachment. Differences ex- ist, however. The proactive proposal first completes layer two handoff, then starts to forward data to the mobile host, and finally, allows layer three registration to proceed. Handoff control is driven by the net- work as opposed to mobile hosts. The fast handoff proposal anticipates the movement of a mobile host allowing the mobile host to register with the "new" foreign agent or gateway foreign agent prior to layer two connectivity being established. This allows packets to be forwarded by the receiving agent to the old and new foreign agents prior to, or synchronized with, establishing connectivity at layer two. Some form of synchronization is required so that layer three registration completes before the mobile host is instructed to perform layer two handoff. A number of open issues remain. What is the minimal coupling between the IP and radio layers to facilitate fast handoff? Here the challenge is to keep the "interface" as simple and radio independent as possible. Both proposals call for some degree of coupling and synchronization. However, this is not clearly spelt out in the proactive and fast handoff Internet drafts. Both the proactive and fast handoff proposals rely on predicting new access points in advance. Is this assumption reasonable? What styles of handoff control should be supported? The proactive proposal advocates network-controlled handoff while fast handoff is mobile initiated. The proactive draft requires some extra support from the network elements but allows for vanilla MIP client implementation, which may be an issue with the fast handoff proposal.

In summary, the proactive and fast handoff proposals being discussed by the working group make a number of assumptions regarding handoff control, radio behavior, movement prediction, layer coupling and protocol synchronization. Any limitations associated with these design choices need to be understood to determine if there is any hidden cost or lack of generality of the two schemes. The process of consolidating these two proposals has recently resulted in a single proposal for fast and low latency handoff for Mobile IPv4 networks. A similar consolidation has also resulted in an Internet-Draft for Mobile IPv6 fast handoff and paging.

Other recent developments in the area of micro- mobility in IETF include the formation of a new working group to look at solutions that possibly adopt per- host routing techniques in support of fast and localized handoff. The Seamoby Working Group is formulating problem statements for IP paging, context transfer (including QOS state) and micro-mobility.

Finally, there is a growing need to best understand the differences between many of the micro-mobility proposals discussed in this article in terms of, complexity of the design choice and performance differ- ences. As part of that process, we have recently made available the Columbia Micro-mobility Suite (CMS). The CMS software is freely available from the web (comet.columbia.edu/micro mobility) and includes ns source code extensions for Cellular IP, Hawaii and HMIR

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