

GPS ASSISTED FAST-HANDOFF MECHANISM FOR REAL-TIME COMMUNICATION

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Abstract

Reducing transient data loss during a mobile's frequent subnet handoff depends upon several factors such as layer 2 handoff detection, faster IP address discovery, and registration and media re-direction. We present a new methodology that can provide faster IP address discovery using GPS coordinate of the mobile. This mechanism provides a suitable approach for high-speed vehicular users. It discusses several issues involved with this handoff process such as layer 2 detection, IP address assignment, and duplicate address detection. It also describes the experiment carried out in an external testbed.

Index Terms— Fast-handoff, Real-time communication, IP address acquisition

I. INTRODUCTION

There are several components at different communication layers that contribute to the overall delay of multimedia stream delivery during a mobile's handoff. Figure 1 shows details of a handoff latency. As the mobile moves from one cell to another it is subjected to delays at various layers. In the beginning it experiences a layer 2 handoff denoted as Δ_1 , where the mobile decides to connect to a different access point after listening to the new beacon. However in the case of soft-handoff procedure such as observed in CDMA, the mobile binds to more than one base station at the same time. If the base stations in the adjacent cells belong to the same subnet, the delay due to L2 handoff will approximate to the beacon interval which is about 100 ms for 802.11 environment. After

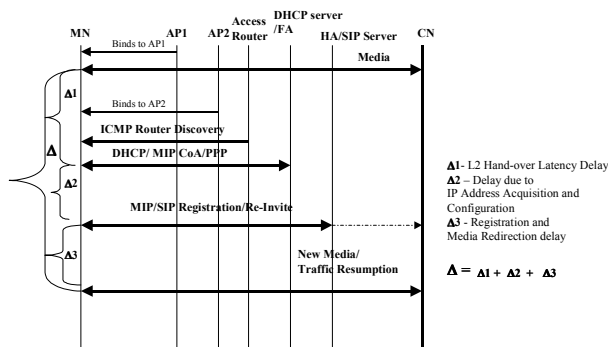


Figure 1: Handover Latency Analysis

a layer 2 handoff is complete and the mobile connects to the adjacent Access Point it needs to determine that it is in a different subnet.

This is achieved by listening to the ICMP router advertisement, FA (Foreign Agent) advertisement or any other server advertisement. During this process the client also configures itself with a new IP address or FA (Foreign Agent) COA. In short this process can be described as IP address discovery phase and is mostly denoted as Δ_2 . This delay component will vary based on the IP address acquisition method such as DHCP, DRCP [8], PPP, or MIP FA-COA [9] and operating system involved such as Linux or Windows. Besides static IP address provisioning and Auto-IP configuration using zero-conf approach, existing IP address discovery process can either be stateful and stateless. A stateful IP address assignment involves a server interaction where the server keeps a state of all the IP addresses assigned. Example of a stateful server can be a DHCP server or relay agent, PPP server or MIP server using FA COA. A stateless IP address configuration is mostly used in IPv6 scenario where an IP address is determined by using subnet prefix being advertised by the router and the link local prefix. After a client is reconfigured either with a new IP address or FA COA, based on the type of mobility management, it will send SIP Re-invite [10], MIP register or MIP update so that the media will get redirected to the mobile's new location. Thus delay incurred between the IP address discovery (client's reconfiguration) and the arrival of new media is denoted as Δ_3 . This factor will evidently depend upon the number of signaling messages traversed between MH, CH and Home Agent, distance between the mobile and the correspondent host.

Rest of the paper is organized as follows. Section II describes the related work. Section III describes the key principles behind the GPS-IP based fast-handoff and its applicability to both IPv4 and IPv6. Section IV describes the implementation details in an outdoor testbed. We conclude the paper in Section V.

II. RELATED WORK

There have been some previous works that attempt to reduce these components that contribute to the handoff delay [2], [3],[4],and [5]. While IPv6 provides allocation for geographic addresses, Geocast [1] on the other hand explains several mechanisms by which IP address space can be augmented with the geographic address space using GPS coordinates. It proposes three different ways of achieving geographically-

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routed messages such as 1) geographically-aware router solution, 2) a multicast solution and 3) an extended Domain Name Service (DNS) solution. Geographically-aware router solution method has components like geohost, geonode and georouter. In this mechanism virtual network that uses geographic addresses for routing will be overlaid onto current IP network. Ergen et al. [6] provides a methodology where by one can leverage the information of the mobile and base station positions, obtained via the GPS and improve the performance of ad hoc routing. It helps adaptively to determine the appropriate base station capacity to be reserved strictly for handoffs, to inform mobiles about the prospective future location. Geopriv working group within IETF defines ways of obtaining coordinates of the IP address by providing GPS coordinates as the DHCP option. However this specific mechanism described here differs from the related work as it provides a new approach of reducing the delay associated with IP address acquisition due to frequent hand-off between heterogeneous (802.11, CDMA 1XRTT) networks.

III. GPS-IP HANDOFF DESIGN

In this section we provide the GPS-IP handoff design and describe different mechanisms associated with the process.

A. GPS assisted Handoff Scenario

As it is analyzed, IP address discovery process is one of the components that contributes to the delay associated with the handoff. The following sections describe a scenario where GPS coordinates can be used to obtain IP address in a faster way thus providing further reduction in $\Delta 2$. Figure 2 shows an example scenario where a mobile has obtained an IP address IP₁ from the cellular network A using different means such as DHCP [2] or PPP (Point-to-Point Protocol) and it has a GPS coordinate (x_1, y_1, z_1) .

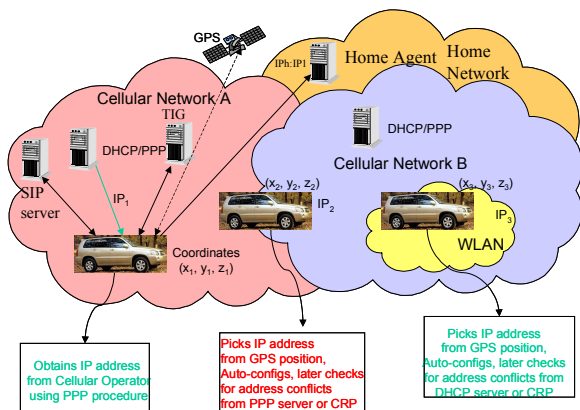


Figure 2: GPS assisted fast-handoff scenario

As the client moves away, the mobile may experience two different kinds of movement scenario. It may move to a new cellular network B or may make a move to a new 802.11b network. Depending upon the types of network it is planning to make a move to, the mobile connects to a DHCP server or

PPP server to obtain an IP address or may do stateless auto-configuration. In the process it may experience a delay because of the associated protocol exchange between the client and the server. Key motivation behind this approach is to assign a globally routable IP address almost instantly based on the GPS coordinate. After the GPS-IP address has been assigned it is an interesting design decision to implement as to if the mobile will continue with the IP address it has obtained via GPS-IP procedure or it will go through another cycle of obtaining an IP address using PPP or DHCP. During the first transition as shown in Figure 2, the mobile has made a move to a cellular network, thus IP₂ actually belongs to a broadcast domain controlled by the NAS server in cellular network B. In this scenario, during the transition the client obtains the GPS coordinate $\{x_2, y_2, z_2\}$. Thus combination of GPS coordinate, a unique ID such as vehicle ID and MAC address on the mobile will map to a unique IP address. This IP address can be obtained from the GPS-IP table ahead of time available from a local server such as TIG (Toyota Information Server). IP address acquisition obtained this way does not involve any signaling transaction it will take a little processing time to assign the IP address (IP₂). As the IP₂ is globally routable IP address, the mobile can continue to communicate with the CH with a very little interruption in service. At this point it is a design decision as to if it should proceed with another PPP transaction or continue with the same address (IP₂). As part of the second transition the mobile makes a move into a LAN environment moving away from the cellular network B. During the transition to LAN when its GPS coordinate is $\{x_3, y_3, z_3\}$ it assigns a new IP address IP₃, using the similar procedure as above. This time IP₃ is in the same broadcast domain as the LAN and is considered to be unique that is verified by using a Conflict Resolution Protocol or ARP type mechanism. We provide the mechanism behind Conflict Resolution Protocol in the following paragraph.

B. Duplicate Address Detection

It is important to make sure that the mobile has obtained the unique address within a subnet. There are many approaches based on ARP (Address Resolution Protocol) that provide duplicate address detection mechanism but add few seconds of delay as a result [12]. We provide here a novel duplicate address detection mechanism using a combination of ARP cache, SNMP and localized multicast address. It has been verified that DHCP server and the respective router keep the ARP cache entries of the mobiles in the respective subnets. Thus it is assumed that at any particular point of time a router has the ARP cache entries of all the mobiles in its own subnet irrespective. It is also possible that a local server can use SNMP monitoring agents such as HP Open-view or SNMP-walk to extract the ARP cache information from the routers for its respective clients within the subnets. Thus the server has an instantaneous ARP cache information of all the mobiles in the subnet at any particular point of time. Any GPS-IP equipped mobile client, during the boot-strap process will point to a localized multicast address within its specific zone. As it points to a specific multicast address (M1) within

the specific zone's scope, it can get a listing of all the addresses (instantaneous mapping) being used in this zone. As the mobile moves from one subnet to another within its zone it will still have the same information available ahead of time. Figure 2 shows stepwise execution of GPS-IP-based fast-handoff. As an initialization procedure mobile node configures itself by a DHCP or PPP server based on if it is operating within a LAN or WAN environment. If the client is being configured using stateless auto-configuration process in an IPv6 environment, it will be configured by an IPv6 router. At this point it discovers the serving TIG (Toyota Information Gateway) and downloads the GPS-IP database that provides a one-to-one mapping between IP address and GPS coordinate. It also downloads the ARP-cache entry from the associated routers in the neighborhood that will help in performing the conflict resolution. Step 1 shows all the processes involved as the mobile moves to a new location. As the GPS coordinates vary or based L2 and L3 advertisement it will decide to switch to a new network and the GPS-IP triggering process will be initiated. At this point the GPS-IP database will be consulted, combination of GPS-IP, MAC and machine ID will determine a specific IP address meant for this client. Since this GPS-IP database is local, it will not experience the delay due to signal traversal as in the case of DHCP. Before the IP address is assigned the client goes through the CRP process. In case of MIP with FA-COA, corresponding FA's address is provided to the mobile client as the COA. Once the IP address is obtained or FA-COA assigned, the mobile sends either SIP Re-Invite message or MIP registration message so that the media gets redirected to the mobile client again. It is important to note that the range of IP addresses is different for each GPS location. When the GPS coordinate is G1 it consults particular part of the IP table compared to the location Gn+1, when it consults to another set of IP addresses. Similar things take place as the mobile make another move to a different GPS zone and obtains a new GPS id, in this particular case it is Gn+1. After obtaining this GPS Id, it consults the local GPS-IP database to obtain the correct IP address from the local GPS-IP table.

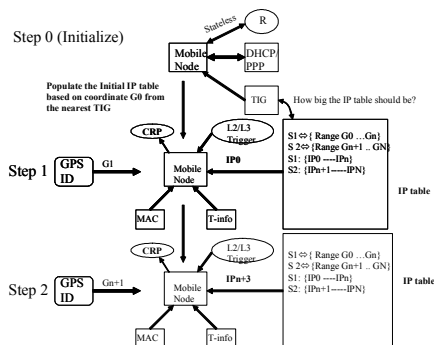


Figure 3: Flow diagram of GPS-IP handoff

C. GPS-IP for IPv6 Networks

It is to be noted that GPS-IP address acquisition is also possible in case of IPv6 networking environment. IP address acquisition can be both stateful and stateless. Stateful address acquisition is very similar to DHCPv4, and the mobile goes through the whole process of obtaining an IP address from a server that dispenses IP address. On the other hand since IPv6 provides stateless auto-configuration it is possible to obtain a unique IP address based on the link-local address and router's prefix. In both the cases (stateless and stateful) configuration there is still a need for suitable duplicate address detection mechanism. In case of a stateless auto-configuration process GPS-IP database does not need to be complete with set of IP addresses. In this case GPS-IP database can just consist of the router prefix based on the GPS coordinates. Thus instead of waiting for the router advertisement to obtain the router prefix, it can look up in its database for the proper router prefix and then configure its IP address based on it. This will dramatically decrease the time associated with IP address configuration on the client itself. Once a new IP address is obtained using a GPS-IP procedure, any form of mobility management procedure such as MIPv6 or SIP based mobility [10] can be initiated to take care of the mobility of the multimedia stream.

IV. IMPLEMENTATION

We describe the implementation details of the GPS-IP-based fast handoff that was conducted in an external testbed. In the beginning when the client comes up, it uses DHCP or PPP process to obtain an IP address. During the initial stage it will download GPS-IP database specific to that zone from the centralized server. This database will contain the list of all the IP addresses that can be assigned and are globally routable within that subnet. This will also provide the information of GPS address range and the subset of IP addresses that can be assigned from that range. As the mobile moves from one subnet to another within its zone it will still have the same information available ahead of time.

We have implemented GPS coordinate based fast-handoff scenario using Linux 2.4.7-10 kernel, Orinoco Access Points, GARMIN GPS 72 receivers spanning over three zones. Freeware version of GPSMAN has been customized to provide online coordinates of the mobile as it moves along. Localized Multicast and SNMP agent in Cisco router have been integrated to implement the Conflict Resolution Protocol. Experiments while transitioning from WLAN to wide area network such as PPP revealed some of the issues such as inability of PPP link to support broadcast ARP and ingress filtering on the network access server. Alternate mechanisms were developed to take care of these issues. IPTABLES based NAT approach was applied to change the source address to avoid the ingress filtering problem.

Figure 3 shows the trajectory of the path during the

