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Fast Handover Between WiMAX and WiFi Networks in Vehicular Environment

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Abstract

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FAST HANDOVER BETWEEN WiMAX AND WiFi NETWORKS IN VEHICULAR ENVIRONMENT

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ABSTRACT

Fast handover is crucial to provide the best services to mobile users in vehicular environment. WiMAX and WiFi support mobility in vehicular speed. However, WiMAX and WiFi network entry processes may take seconds to complete. In this paper, we propose the fast handover techniques between WiMAX and WiFi networks to speed up handover process. A link layer fast handover approach is proposed to realize fast link layer connectivity. An IP layer fast handover mechanism is proposed to achieve the high speed IP layer connectivity. The proposed fast handover protocols can be utilized to accomplish the seamless handover in vehicular communications.

KEYWORDS: Vehicular communications, WiMAX network, WiFi network, Fast link layer handover, Fast IP layer handover, Seamless handover.

INTRODUCTION

A handover protocol may sit at a single layer of communication protocol stack or across several layers. SIP [1] is an application layer handover solution. Cellular SCTP [2] is a handover approach at transport layer. Mobile IP [3] has been proposed as a handover solution at network layer. Fast BS Switch [4] has been proposed as link layer handover protocol in WiMAX networks. Cross-layer handover schemes have been proposed in [5] and [6]. In this paper, we propose fast handover protocols between WiMAX and WiFi networks to reduce link layer handover time and IP layer handover time in vehicular communication environment. As shown in [7] and [8], link layer handover time and IP layer handover time may take seconds, respectively. To achieve seamless handover, the total delay must be less a few hundred milliseconds [9].

WiMAX (IEEE802.16) and WiFi (IEEE802.11) are two wireless communication technologies that support mobility in vehicular environment [4], [10]. Fast BS Switching and Macro Diversity Handover [4] are homogeneous handover protocols proposed for WiMAX network. WiFi [11] defines Fast BSS Transition and Fast BSS Transition Resource Request as homogeneous handover protocols. To complement WiMAX and WiFi's homogeneous handover protocols, this paper proposes fast heterogeneous handover protocols between WiMAX and WiFi networks.

We assume that neighbor WiMAX Base Station (BS) and WiFi Access Point (AP) are connected via a backbone network, and WiMAX BS/WiFi AP is capable of verifying the identity of neighbor WiFi AP/WiMAX BS. In the proposed fast handover mechanisms, a WiMAX BS or WiFi AP periodically broadcast neighbor network information to all nodes connected to it. This reduces target network detection time. In WiFi networks, detection takes about 800 milliseconds [12].

FAST LINK LAYER HANDOVER BETWEEN WiMAX AND WiFi NETWORKS

There are several operations to be performed before a node establishes link layer connectivity to a WiMAX network or WiFi network [13], [14]. However, authentication operation is the most time-consuming operation in network entry due to the fact that authentication server may be connected to network through many hops in the backbone network. Authentication may take seconds to complete [7]. To realize fast link layer handover, key is to minimize amount of time for authentication process. This paper proposes fast link layer handover protocols to achieve fast authentication based on authentication schemes supported in WiMAX and WiFi networks.

Fast Link Layer Handover from WiMAX Network to WiFi Network

WiFi supports two authentication schemes, EAP and PSK. The EAP is invoked so that a Master Session Key is generated and distributed to the network node and AP by an authentication server. This master session key is used to derive other keys for data communications. PSK is installed into network node and AP manually by the network administrator. The pre-installed PSK is employed to generate other keys for data communications. It is noticed that PSK is not suitable for authentication in vehicular communication environment due to its Ad Hoc nature.

We have proposed a fast link handover protocols from WiMAX network to WiFi network based on EAP authentication schemes. Figure 1 shows the proposed fast handover protocol with WiFi network using EAP authentication. Node currently connects to a WiMAX network and is to be handled over to a WiFi Mobility Domain (MD), which is a set of WiFi Basic Service Sets that support WiFi homogeneous handover protocols between them. R0KH is the first level master key holder. We assume that AP_0 is one access point in WiFi MD connected to WiMAX BS, AP_1 is another access point in same WiFi MD, to which the node is to be handed over. AS is the authentication server for the WiFi MD.

Node receives neighbour WiFi network information through its current serving WiMAX BS and selects target WiFi MD for handover. It communicates with target WiFi MD via serving WiMAX BS. Node first negotiates the security parameters with AP_0. It then sends AP_0 its MAC address, which is broadcasted to all APs in the WiFi MD and serves as S0KH-ID and S1KH-ID. Node initiates the EAP authentication process with AS. By the end of authentication exchange, AS generates and sends the MSK to the node. AS also derives a PMK from MSK and sends PMK to R0KH. The PMK is used by R0KH to derive the first level key, PMK-R0. Since R0KH knows the MAC addresses of all APs in WiFi MD, it proceeds to generate and sends the second level master keys, PMK-R1s, to all APs (R1KHs) in WiFi MD. Especially for AP_0 and AP_1, the second level master keys are PMK-$R1_0$ and PMK-$R1_1$, respectively

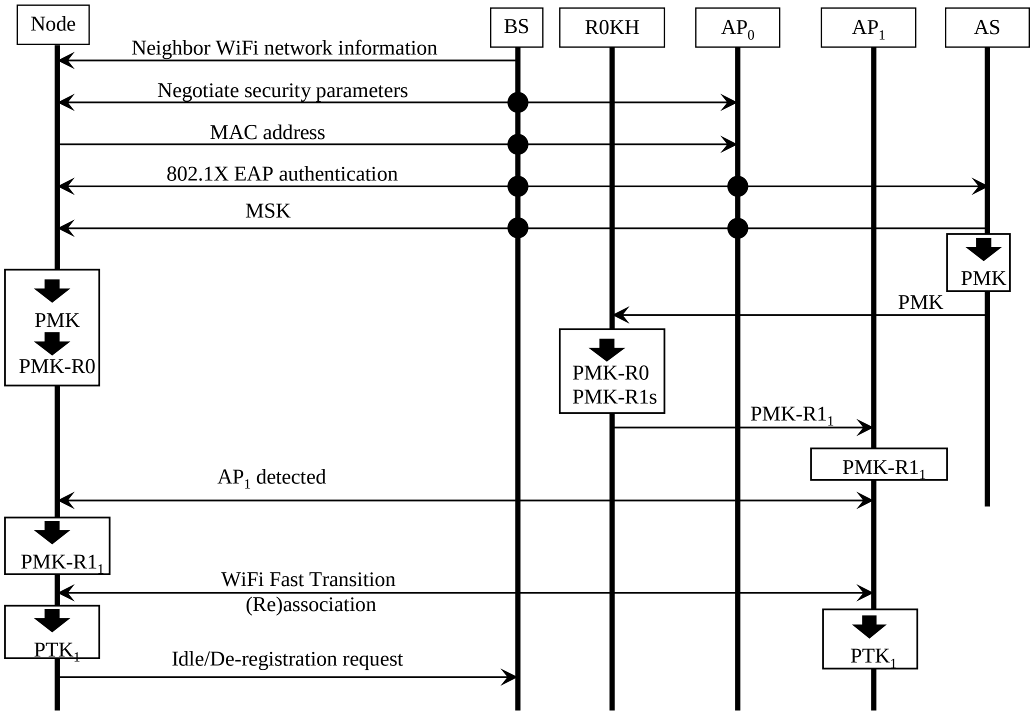

Figure 1- Fast handover protocol from WiMAX network to WiFi network

Upon receipt of PMK from AS, the node has sufficient information to generate PMK-R0. However, it does not have the R1KH-IDs to generate PMK-R1s keys for the APs in WiFi MD. We assume that the node first detects AP_1 in WiFi MD. From AP_1's beacon, it then obtains R1KH-ID_1, the MAC address of AP_1, and AP_1's MDID. At this point, node has all information needed to generate the second level master key PMK-$R1_1$ for AP_1. Once PMK-$R1_1$ is ready, the node associates with AP_1 using WiFi Fast Transition protocol.

Fast Link Layer Handover from WiFi Network to WiMAX Network

WiMAX allows RSA authorization and EAP authentication. For RSA authorization, the BS verifies the node's identity by its manufacturer-issued X.509 digital certificate. Once verified, the BS sends the node a pre-Primary Authorization Key (pre-PAK) encrypted with node's public key. Node uses pre-PAK to derive a Primary Authorization Key (PAK) that is in turn used to generate the Authorization Key (AK). The product of the EAP authentication process is the MSK, which is transferred by authentication sever to BS and node. The BS and node derive a PMK from MSK. The PMK is used to generate the AK. The AK is a shared secret used to secure further transactions.

We proposed two fast link layer handover protocols from WiFi network to WiMAX network based on RSA authorization and EAP authentication, respectively. Due to the limited space, only fast handover protocol with WiMAX network employing the RSA authorization is demonstrated in Figure 2.

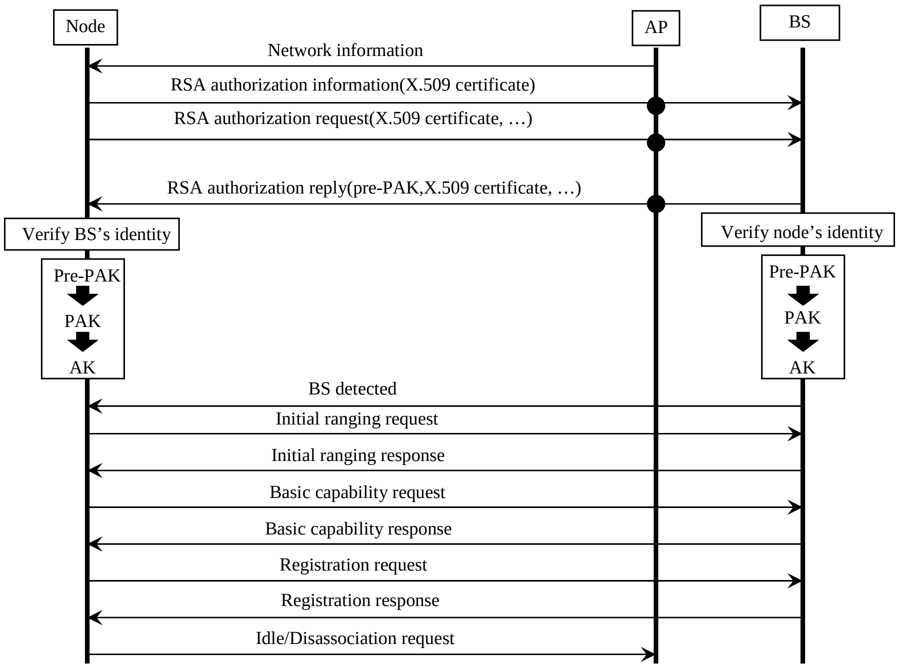

Figure 2 – Fast handover from WiFi network to WiMAX network

Node is currently connected to WiFi network and receives neighbor WiMAX network information via WiFi network. It communicates with target WiMAX BS via WiFi AP. The node first sends an authorization information message, which contains its manufactory-issued X.509 digital certificate, to BS. Immediately, node sends an authorization request message, which also contains node's X.509 digital certificate and other parameters, to BS. The X.509 certificate contains sender's public key and MAC address. BS then verifies node's identity and sends an authorization response message, which contains an encrypted pre-PAK (using node's public key) and BS's X.509 digital certificate as well as other parameters, to the node. The node verifies BS's identity and derives a PAK from pre-PAK, its MAC address and BSID. BS also derives a PAK from pre-PAK, node's MAC address and its own BSID. The node and BS then generate a shared secret, AK, from PAK, node's MAC address and BSID. Before the node enters BS's coverage, it needs to refresh the AK with BS via WiFi AP. When the node discovers the BS, it proceeds with the normal network entry procedure. However, it does not perform RSA authorization and key distribution process. The rest of the network entry procedure remains the same.

FAST IP LAYER HANDOVER BETWEEN WiMAX AND WiFi NETWORKS

In IP networks, if a node changes its access point to a new network, its communications will be lost. In this case, either new network must reconfigure its list of available IP addresses to accommodate this newly attached node or this newly attached node must acquire a new IP address from the new network. The network reconfiguration is a costly process and impractical. The conventional IP address acquisition process is time-consuming. Therefore, the new approaches are needed for high speed IP layer handover. Several technologies such as Mobile IP and Cellular IP have been proposed as handover solutions at IP layer. However, it is noted that these legacy handover mechanisms proposed for homogeneous handover could not directly used for heterogeneous handover.

This paper proposes high speed IP layer handover protocols for both IPv4 network and IPv6 network. The proposed handover protocols apply to both homogeneous handover such as handover between WiMAX networks and heterogeneous handover such as handover between WiMAX and WiFi networks. The proposed high speed IP layer handover protocols speed up new IP address acquisition during the handover without modifying IP layer characteristics. The IP address acquisition is performed by the link layer of the node with collaboration of the wireless network access points.

Fast IP Layer Handover in IPv4 Networks

The proposed fast handover protocol for IPv4 networks allows target AP (WiMAX BS or WiFi AP) to perform IP address acquisition process on behalf of the node as shown in Figure 3. Once a node is pre-authenticated or sends a handover request to the target AP, target AP knows the MAC address of the node. The target AP acquires an IPv4 address from a DHCPv4 server within local network. Target AP transmits DHCPOFFER and DHCPACK messages received from DHCPv4 server to the node through node's current AP. The DHCPOFFER and DHCPACK messages are stored at link layer of the node.

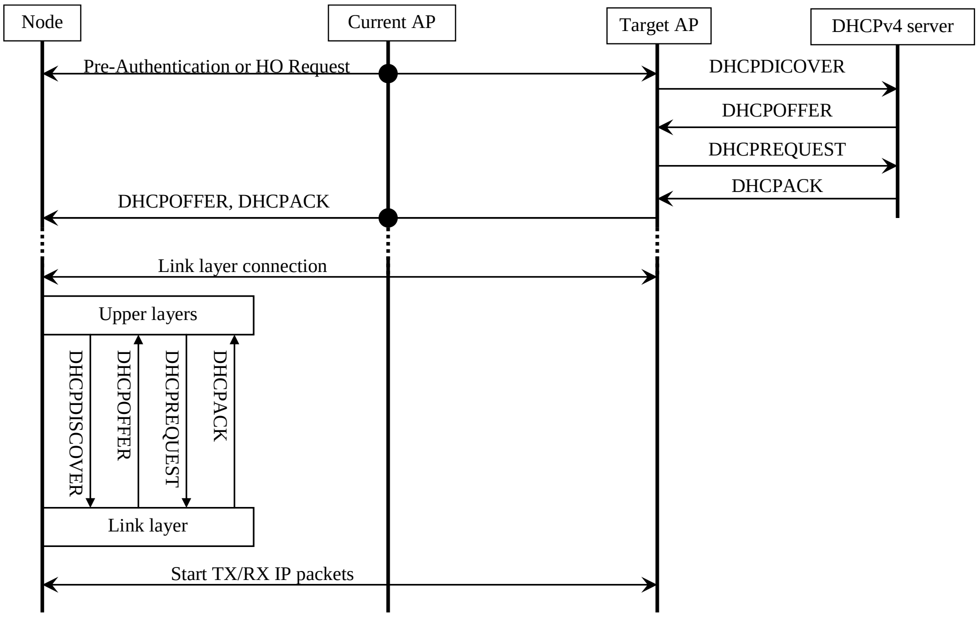

Figure 3 – Fast handover in IPv4 networks

During actual handover process, node's link layer to process the IPv4 address acquisition packets sent from upper layer. Once a node completes the link layer connection with the target AP, the link layer starts interpreting the upper layer packets and responding to the upper layer's IPv4 address acquisition packets on behalf of a DHCPv4 server so that high speed IPv4 address acquisition is performed by the node without actual DHCPv4 server involved. The link layer responds upper layer's DHCPDISCOVER packet with DHCPOFFER packet and DHCPREQUEST packet with DHCPACH packet, respectively. Link layer may stop interpreting the upper layer packets when the upper layer starts sending data packets.

Fast IP Layer Handover in IPv6 Networks

This paper proposes fast IP layer handover protocols using DHCPv6 approach and IPv6 stateless autoconfiguration approach. To perform the fast IP layer handover, target AP monitors periodic Router Advertisement messages. As pointed in [15], a router may broadcast Router Advertisement every few seconds. Once a node is pre-authenticated or sends a handover request to target AP, target AP forwards the latest Router Advertisement message to the node via node's current AP so that node knows which approach is used for IPv6 configuration.

In order to speed up the process of IPv6 configuration, target AP performs Duplicate Address Detection procedure on behalf of the nodes. The DupAddrdetectTransmits flag is set to zero so that node does not perform Duplicate Address Detection. Once a node receives the Router Advertisement message forwarded by the target AP, it sends its interface identifier to the target AP via its current AP. The target AP uses node's interface identifier to generate necessary addresses and perform Duplicate Address Detection on behalf of the node.

Figure 4 shows fast IPv6 address acquisition with DHCPv6 mechanism. Target AP acquires an IPv6 address from a DHCPv6 server on behalf of the node. To do so, a node sends its DHCP Unique Identifier (DUID) together with interface identifier to the target AP. Target AP generates a link-local address by using node's interface identifier and performs Duplicate Address Detection on node's link-local address. If the link-local address is unique on the link, target AP uses the link-local address to acquire an IPv6 address for node. If the link-local address is a duplicate, it can not be used for communication on the link. In this case, target AP re-generates an interface identifier for the node so that the link-local address is unique on the link. New link-local address is used to acquire IPv6 address from DHCPv6 server. Advertise and Reply messages received from DHCPv6 server are sent to the node via its current AP. If a new interface identifier is generated, new interface identifier is also sent to the node. All messages from DHCPv6 server and new interface identifier are stored at link layer of the node.

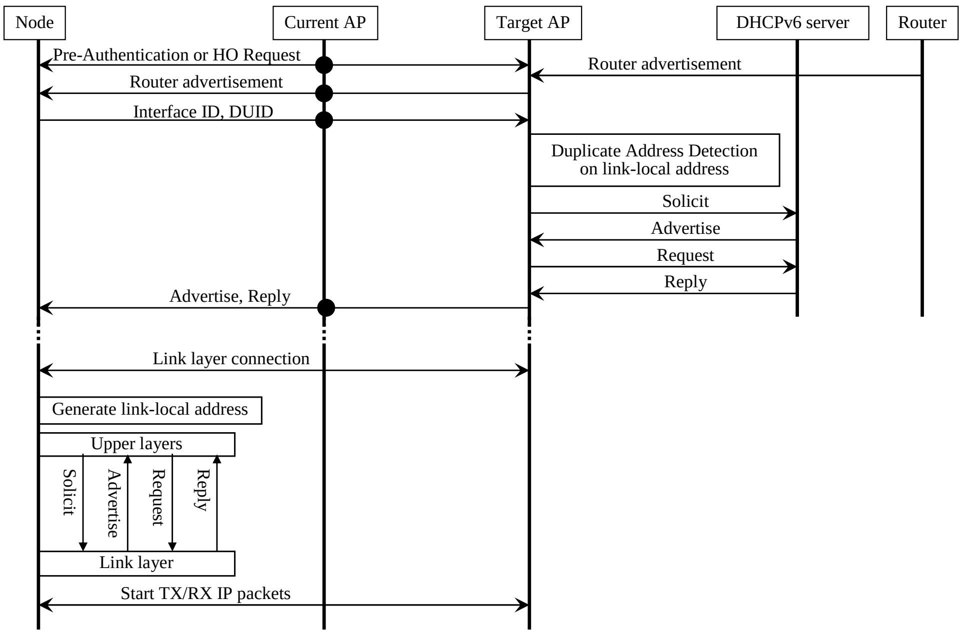

Figure 4 – Fast IPv6 address acquisition with DHCPv6 server

During the handover, link layer to process the IPv6 address acquisition packets sent from the upper layer. Once a node completes the link layer connection with the target AP the link layer starts interpreting the upper layer packets and responds to the upper layer's IPv6 address acquisition packets on behalf of a DHCPv6 server so that the IPv6 address acquisition is performed by the node without actual DHCPv6 server involved. Link layer may stop interpreting the upper layer packets when the upper layer starts sending data packets. If a new interface identifier is received, the link layer will replace the original interface identifier with new interface identifier in the outgoing messages, and replace the new interface identifier with original interface identifier in the incoming messages.

Figure 5 demonstrates fast IPv6 stateless autoconfiguration, which includes generating a link-local address, generating global IPv6 address, and verifying the uniqueness of the address on a link. A global IPv6 address is created by appending the interface identifier to a subnet prefix of the appropriate length. The subnet prefix is obtained from Prefix Information option contained in Router Advertisements. In the proposed protocol, target AP forms link-local address and global IPv6 address for the node and performs Duplicate Address Detection on node's link-local address and global IPv6 address. If the link-local address and global IPv6 address are unique on the link, target AP forwards the latest Router Advertisement to the node as soon as the link layer connection process is completed. Node obtains the global address prefix and other network configuration information from the forwarded Router Advertisement, forms the link-local address and Global IPv6 address to start communication on IPv6 networks. If the link-local address or global IPv6 address is a duplicate, it can not be used for communication. In this case, target AP re-generates an interface identifier for node so that both link-local address and global IPv6 address are unique on the link. New interface identifier and the latest Router Advertisement are forwarded to the node once node completes the link layer connectivity with target AP. Node then obtains the global address prefix and other network configuration information from the forwarded Router Advertisement, forms the link-local address and global IP6 address to start communication on IPv6 networks. New interface identifier is transferred to node and stored at link layer of the mobile node. The link layer will replace the original interface identifier with new interface identifier in the outgoing messages, and replace the new interface identifier with original interface identifier in the incoming messages.

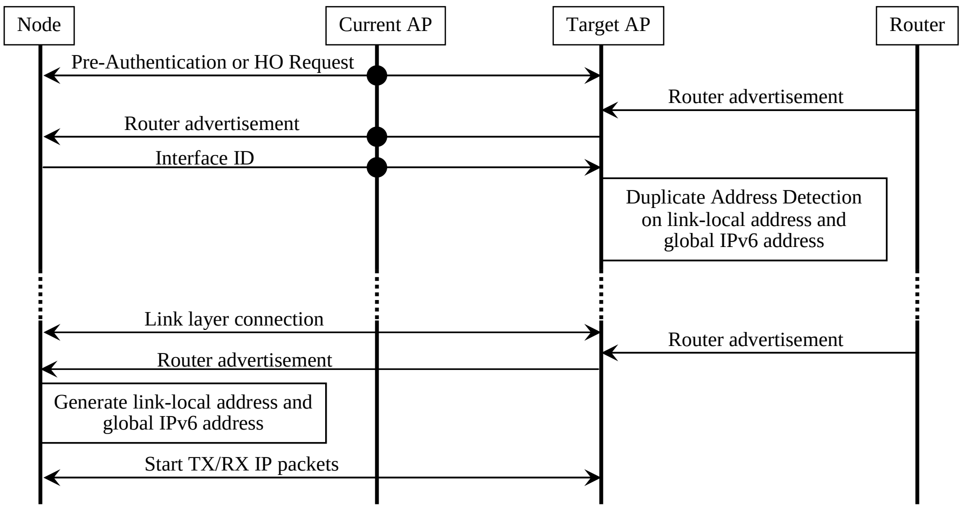

Figure 5 – Fast IPv6 stateless autoconfiguration

CONCLUSIONS

Due to the varieties of communication technologies, handover is needed for many reasons including mobility, network availability, service availability, etc. Both WiMAX and WiFi support the high mobility in vehicular speed. Vehicular communications have been attracting a lot attention from both academia and industry. To provide the best service to mobile user in vehicular environment, fast handover mechanisms between WiMAX and WiFi networks are crucial. IEEE 802.21 standard defines heterogeneous handover framework without defining handover protocols. This paper proposes several fast handover protocols between WiMAX and WiFi networks. The proposed protocols focus on fast link layer and IP layer handover. These protocols can be used to achieve seamless handover in WiMAX and WiFi networks and provide better services to mobile users in vehicular environment.

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