HANDOVERS IN WIRELESS OVERLAY NETWORKS BASED ON MOBILE IPV6

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Abstract—**By the integration of heterogeneous wireless networks, mobile nodes can move freely among different wireless overlay networks and still stay connected. However, the latency and packet losses faced during handovers degrade the quality of seamless connection significantly. Therefore, minimizing handover latency and the number of lost packets during a handover is usually critical. In this article, we analyze horizontal and vertical handovers in Wireless Overlay Networks (WONs). Then, we present and evaluate the basic handover system. Finally, we propose a new mobility management scheme based on Mobile Internet Protocol version 6 (MIPv6) to handle the movements of mobile nodes (MN) among different WONs in order to reduce data loss and maintain uniform connectivity. Relying on the simulation results, we show that the proposed model profoundly decreases latency at the expense of slightly increased data traffic.**

Index Terms—**Horizontal Handover, Vertical Handover, Wireless Overlay Network, Mobile IPv6**

I. INTRODUCTION

WIRELESS networking is becoming an increasingly important and popular way to provide global information access for users regardless of time and location. However, there is no unified wireless technology that fits all the user requirements at all times. Instead, using several overlaying wireless networks can provide the best possible data delivery service. Therefore, extensions to a traditional cellular handover (handoff) system are made in order to handle the simultaneous operation of multiple wireless network interfaces. This new system allows mobile users to roam in a "Wireless Overlay Network (WON)" structure consisting of different layers of wireless networks of different sizes, coverage and performance. In spite of the advantage of global connectivity, users may experience some disturbance in service during a horizontal handover between cells of the same ireless network or a vertical handover between different overlay networks. Data packets may be lost during these handover periods. Therefore, minimizing handover latency is crucial for critical wireless applications. In this paper, we focus on how to reduce the latency and disruption as much as possible when the mobile user roams both inside a particular wireless network and among multiple wireless networks. In the case of horizontal handover, we propose a new scheme that decreases handover latency significantly especially when there are a lot of users in a cell. We also present a simulation model in order to evaluate the performance of our proposed scheme. In the case of vertical handover, we design a handover scheme that allows a mobile user to roam among multiple wireless networks in a manner that is completely transparent to applications and that disrupts the connectivity as little as possible. Moreover, in this article, the basic handover schemes used in WONs are presented, their drawbacks are discussed, and the new mobility management scheme, which decreases handover latency, and the basic models are compared. The proposed handover models are determined to provide a seamless service to roaming end-users.

The rest of this paper is organized as follows. Section II presents wireless overlay network architecture. Section III describes the concept of Mobile IPv6 in more detail. Section IV includes the proposed models for horizontal and vertical handovers with the basic schemes. Finally, Section V concludes this work.

II. WIRELESS OVERLAY NETWORK

A. The Wireless Overlay Network Structure

Different network technologies, which are overlaid to form larger networks, construct the Wireless Overlay Network model (WON). WON has a hierarchical structure with different levels. These levels differ from each other with their coverage areas and bandwidths. Higher levels have a larger coverage area but a lower bandwidth. Conversely, lower levels consist of high-bandwidth cells that cover a smaller area. Users should operate in lower layers as long as possible since they provide a greater bandwidth. However, providing high bandwidth to all users all the time is not possible. Therefore, low-mobility users are served by lower layers and benefit from a greater bandwidth while high-mobility users are served by upper layers and benefit from a greater coverage.

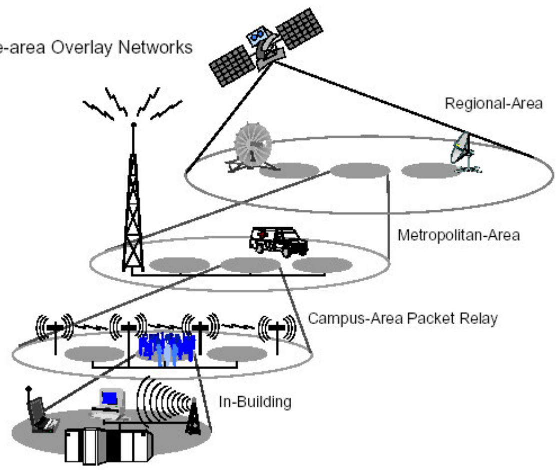

Fig. 1. Hierarchical structure of WONs

Fig. 1 is an example of WON structure [1]. In this figure, the Regional-Area has a larger coverage area but a lower bandwidth than all the lower layers.

In a WON structure, the MN travels within or between the different levels of network. Therefore, it must have a switching ability as well as the necessary network interfaces which are used interchangeably after switching between different networks.

B. Handover issues in WON

There are two types of handovers in WONs: horizontal and vertical.

1) Horizontal Handover

Horizontal (or standard) handovers are the conventional handovers which take place while the MN switches between cells of the same network. Therefore, the MN does not need to change the network interface it is using. Fig. 2 shows how a horizontal handover occurs [2]. There is a handover from the old base station (BS) to the new BS; both of them having the same wireless network interface. The beacons, which are generated by the BSs, help the MN to determine if a horizontal handover is necessary. The MN checks the signal strengths of all beacons. If a new BS sends stronger signals than the old one, the handover mechanism is triggered by the MN. The MN sends the handover request to the new BS and receives an acknowledgement. The new BS also sends a notification to the old BS and waits for an acknowledgement from the old BS. Meanwhile, the old BS buffers the packets coming to MN until getting the notification from the new BS. These packets are sent to the new BS after the notification acknowledgement. Therefore, MN's packets, which arrive during the handover operation, are not lost. As depicted in Fig. 2, handover latency is the time between the moment when the MN instructs the new BS for a handover start and the moment when the new BS sends the first data packet to the MN.

2) Vertical Handover

Vertical handovers are a result of the trade off between coverage and bandwidth. They take place when the MN moves from a cell in one level to a cell in a different level in WON. Moving from an IEEE 802.11 WLAN cell to a GSM cell is an example for vertical handover. After vertical handovers, the MN's network interface changes because the MN travels between different wireless communication architectures [3].

Vertical handovers are either upwards or downwards. An upward vertical handover occurs when the MN moves to an upper WON layer with larger coverage area but lower bandwidth. This happens as the MN becomes highly mobile and the lower layer becomes unreachable. On the other hand, a downward vertical handover occurs when the MN moves to a

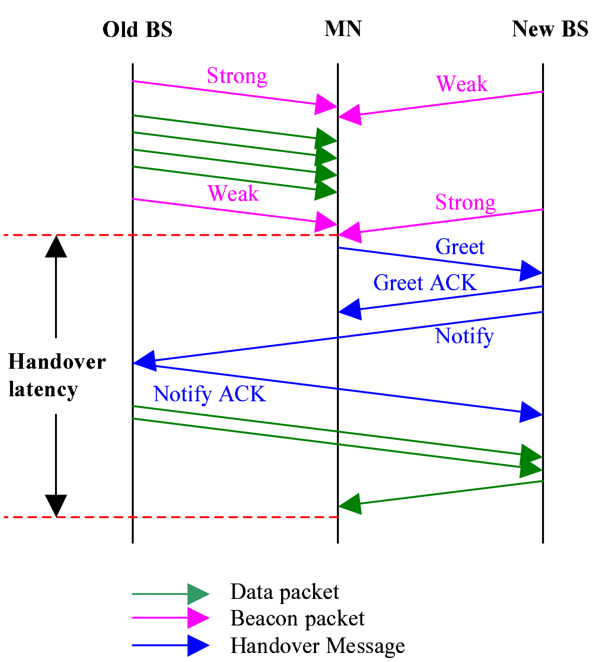

Fig. 2. Horizontal handover

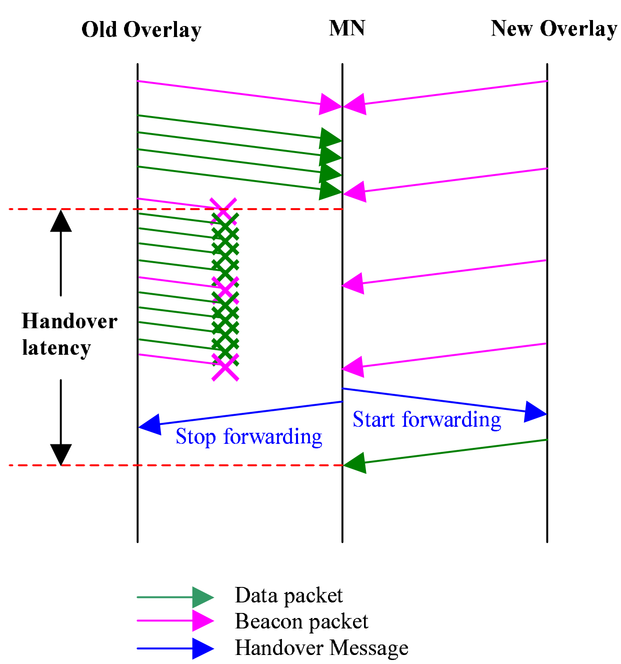

Fig. 3. Upward vertical handover

lower WON layer with greater bandwidth but smaller coverage area. This happens as the lower layer becomes reachable.

Fig. 3 shows how an upward vertical handover occurs [2]. It starts when the MN senses that the current level is not reachable anymore. The MN sends "start forwarding" handover message to the upper level. Then it sends "stop forwarding" handover message to the current/old level via the new overlay. Handover ends when the first packet is received from the new overlay.

III. Mobile IPv6

A MIPv6 node can continuously change its location on an IPv6 network and still be connected. The connectivity of the node is maintained by various messages going back and forth between the MIPv6 components [4]. This section discusses the MIPv6 components and how they communicate [5].

A. *Components of Mobile IPv6*

1) *Nodes*

The mobile node (MN) is the node that travels between IPv6 subnets. It acquires new temporary addresses as it roams into new subnets and maintains its connectivity by using its unchanging home address. The Correspondent Node (CN) is the node that wants to exchange data with the MN. The Home Agent (HA) is the router on the MN's home subnet and provides communication between MN and CN. If the MN is away from its home, it registers its current temporary address with the HA and the HA forwards data, which come to the MN's home address, to the MN's temporary address. The Foreign Agent (FA) is the Home Agent of the foreign subnet the MN roams. HA and FA are both Access Routers (AR) or Access Points (AP).

2) *Links*

Home Link is established between MN and HA. The MN obtains its home address from this link. Foreign Link is between the MN and the FA. The MN obtains its temporary address from this link.

3) *Addresses*

Home Address always identifies the MN even if it is outside the home subnet. It is used on Home Link. Care-of address is the temporary address assigned to the MN when it is attached to a foreign link and provides information about the MN's current location. It is used on Foreign Link.

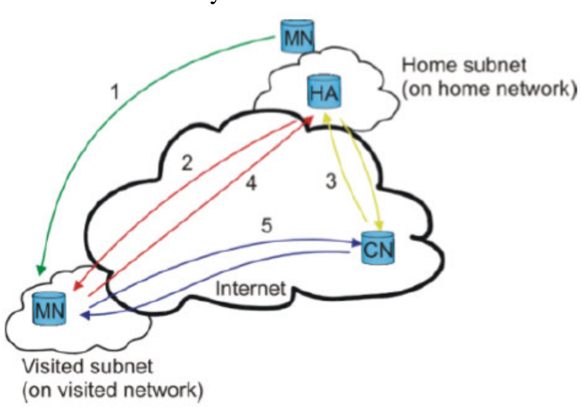

Fig. 4. Communication of MIPv6 components

B. *Communication Between MIPv6 Components*

Fig. 4 illustrates the communication lines between the components of MIPv6 [6]. In this figure, the MN travels from its home subnet to the foreign subnet, registers with the foreign subnet and gets a new address called the care-of address (1). Then, the MN transmits this address to the HA (4) and sometimes to the CN (5) if the CN is MIPv6 capable. This message, which enables a mapping between the MN's home address and care-of-address, is called a "binding update". Then, HA sends a "binding acknowledgment" (2) to the MN. If the CN is not MIPv6 capable, it sends data to the MN's home-address and HA collects the data to deliver it to the MN's care-of address (3). The MN sends its response to the CN over HA but this type of communication increases the burden of routing at HA. On the other hand, if the CN is MIPv6 capable, it may directly send data to and receive data from the MN's care-of address (5). As a result of binding, it can be said that there is a dynamic tunnel between home address and care-of address at any time.

Moreover, it is worthy to note that the FA periodically sends a message called the "Router Advertisement". This contains the globally unique routing prefix that is used to formulate a care-of address by the MN. As soon as the MN switches its network, it can send a "Router Solicitation" message to the FA before receiving the periodic Router Advertisement message.

IV. Proposed Models For Horizontal And Vertical Handovers

As explained in the previous sections, in order to minimize any disruption in connectivity, a proper mobility management scheme for WONs must take both horizontal and vertical handovers into account. Therefore, this section discusses the present solutions and then proposes better solutions for decreasing handover latency both for horizontal and vertical handovers.

A. *Horizontal Handover*

1) *Present Solution in Mobile IPv6*

Previously, it has been explained that MN registers with the foreign subnet and gets a new care-of address as soon as it enters a new foreign subnet. Fig. 5 shows this registration process. As explained in [7], first, MN creates its own care-of address by making use of "Router Advertisement" messages sent from FA. Then, MN sends a request to FA to check the uniqueness of the care-of address it has just created (1). FA performs Duplicate Address Detection (DAD), which takes a considerable amount of time, and sends the result back to MN (2). Finally, if everything is OK, i.e. if the newly created care-of address is unique, the MN registers with the foreign subnet

(3 and 4). Otherwise, MN has to create another care-of address and the same procedure starts all over again.

One of the major drawbacks of this model is certainly starting the handover process *after* the MN enters the new subnet. No matter how fast the signals are transmitted or how fast the DAD operation is done, it is impossible to get rid of the handover latency. If the handover process could start *before* the MN actually enters the new subnet, then the handover latency can be decreased to some extent.

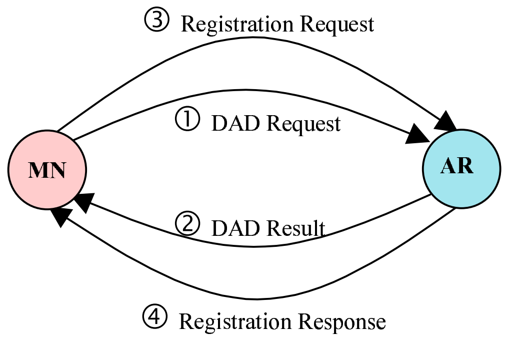

Fig. 5. Present solution for horizontal handover

Secondly, DAD takes a very long time. If the AR could keep track of all the care-of addresses in its coverage area and could generate a new care-of address for the MN, then time would not be wasted for the DAD operation.

2) *Proposed Model For Horizontal Handover*

The horizontal handover model proposed in this paper focuses on the two major drawbacks of the present system described above. First, it reduces the handover latency significantly since the MN's handover process starts before the MN physically enters a new subnet. Moreover, since the care-of addresses are generated by the ARs instead of the MNs, the amount of time wasted for DAD is also gotten rid of.

According to the proposed model depicted in Fig. 6, all the ARs know each other in advance. As the MN moves far away from its current AR (approximately 90% of the subnet's coverage radius), it sends a handover signal to its current AR noting that it is about to perform a handover (1). The handover signal also contains the MAC address of the MN and necessary information that identifies the target AR. Then, the current AR requests a care-of address for the MN from the target AR (2) by sending the MAC address of the MN. The target AR generates a new care-of address and sends it to the current AR (3). The target AR also reserves the generated address for a certain amount of time so that the address is not generated for other new comer MNs. The current AR informs the MN of its new care-of address (4). Having obtained its new care-of address, the MN registers to the new subnet (5, 6).

Although this model decreases the horizontal handover latency considerably, it has some hidden costs. First, all the ARs have to be aware of each other in advance. Second, the messaging traffic is considerably increased since there is more signaling done in this model.

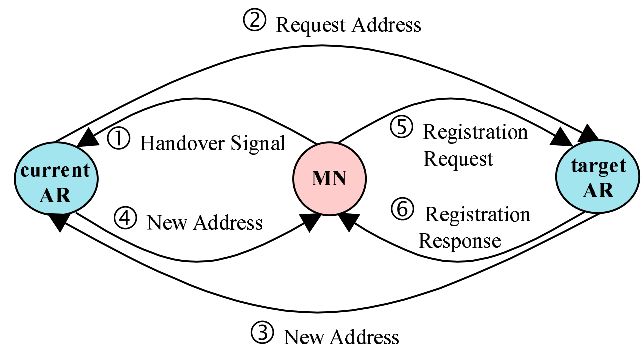

Fig. 6. Proposed solution for horizontal handover

3) *Simulation and Its Results*

In order to compare the performances of the two horizontal handover schemes explained above, a Java simulation is implemented. In the simulation, the ARs are assumed to be base stations whose radius of coverage is approximately 500 meters. The base stations are assumed to support 50 MNs at most. The handover latencies are measured separately for each model as the MN moves from one base station to another. The simulation of the proposed model is performed for two different MN velocities: 80 km/hour (approximate velocity of an automobile) and 8 km/hour (approximate walking velocity).

Fig. 7 presents the performance of present solution and proposed solution for horizontal handover. Note that no value for MN's velocity is given for the present model. The handover latency of the present model is independent of the MN's velocity because the handover process starts after the MN enters the subnet. However, the MN's velocity plays an important role in the proposed model because the handover process starts as the MN's distance from the old AR approaches 90% of the AR's total coverage radius. Therefore, if the MN is not highly mobile, i.e. walking, it can be registered to the new subnet before even stepping into it and in such a case there is no handover latency.

As depicted in Fig. 7, the handover latency of the present solution increases as the number of nodes in the subnet increase. As the subnet approaches its limit (30-50 MNs), the

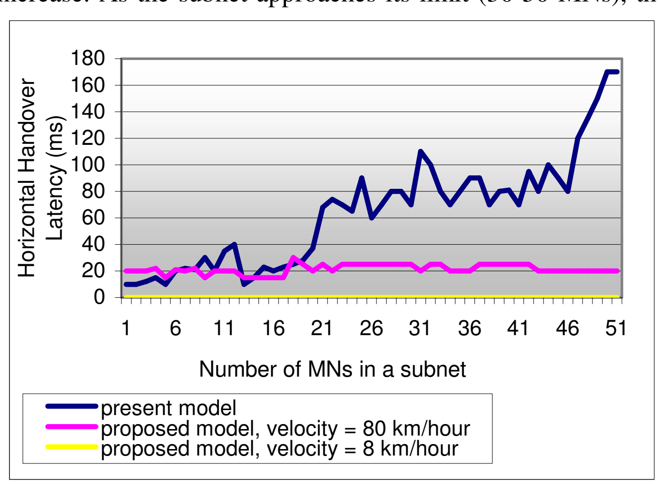

Fig. 7. Horizontal handover latency vs. number of MN

probability of the MN's generating a unique care-of address decreases significantly. As a result, the MN tries to generate another care-of address and the DAD procedure starts all over again for that newly generated address.

However, in the proposed model, the time for generating a care-of address is independent of the number of MN in a subnet. Therefore, the handover latency of the proposed model is almost constant.

Finally, note that if the number of MNs in a subnet is between 0 and 10, the present model's performance is better than that of the proposed model for MN's velocity = 80 km/hour. Therefore, one can conclude that the present model is more appropriate if the subnet does not contain many MNs whereas the model proposed in this paper is more appropriate for highly crowded subnets.

B. Vertical Handover

1) Primary Challenges in Vertical Handover

In the case of vertical handover, one faces the following challenges:

- In a wireless overlay network, there is no comparable signal strength available to aid the decision of the 'best' network to make vertical handover, because the networks have such varying characteristics. For example, an in-building RF network with a low signal strength may still yield better performance than a wide-area data network with a high signal strength [8]. Thus; discovering the right time to perform handovers in a wireless channel is difficult to predict and characterize.
- During a handover procedure, upper-layer applications are interested in network conditions such as available bandwidth, delay and user preferences rather than the physical layer parameters such as received signal strength and signal-to-interference ratio.
- The main goal of the wireless overlay networking is to allow a user to use fully-interactive multimedia communication tools across all of these different network interfaces even though the networks provide different levels of service. For example, the infrared network may support full-motion video and high-quality audio, the RF network may support a lower frame-rate video and lower quality audio, and the wide-area network may support only audio. Therefore, making the switch between networks as seamless as possible for disruption intolerant applications and with as little data loss as possible means that achieving 'low latency handover" is really a difficult issue.
- The simplest approach to managing multiple wireless network interfaces is to keep all of them on all of the time. Measurements of commercially available wireless network interfaces [8] show that keeping an IBM Infrared and WaveLan RF interface on all of the time consumes approximately 1.5 watts. Therefore, another challenge is "power saving" in the case of vertical handover. The aim is to minimize the power drain due to simultaneously active multiple network interfaces.
- Designing vertical handovers in wireless overlays requires bandwidth overheads in the form of beacon packets and handover messages that are necessary to provide service to roaming users, and the cost of this additional network traffic should be minimized while also providing minimal disruption for transitions between networks.

2) The Basic Vertical Handover Model

In [8], a model of handovers which is built on top of the mobile routing capabilities of Mobile IP is proposed. This model is based on the infrastructure that is described in [9] and the Mobile IP specification that is described in [10]. The architecture of the basic handover scheme is shown in Fig. 8.

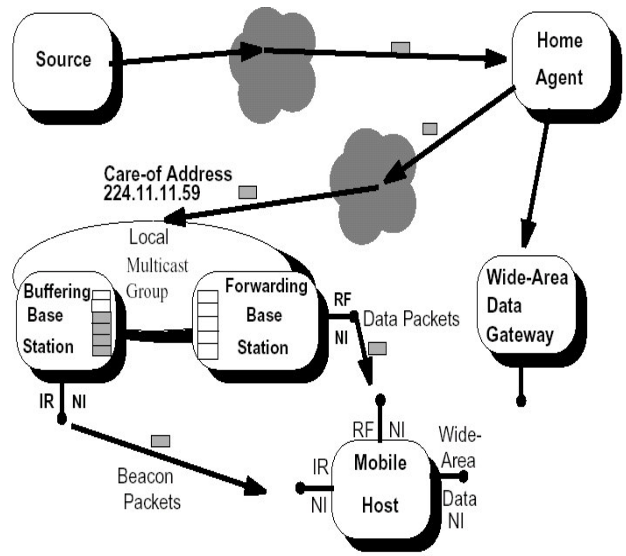

Fig. 8. Overview of the basic handover system

In this structure, MNs connect to a wired infrastructure via Base Stations (BSs). An HA performs the same functions as in Mobile IP. The difference is that the care-of address is not a unicast address but an encapsulating multicast address. The MN is responsible for initiating handovers between BSs and between different network interfaces. A small group of BSs are selected by the MN to listen on this multicast address for packets encapsulated and sent by the HA. One of the BSs is selected by the MN to be a forwarding BS; it decapsulates and forwards the packets it receives on the multicast address to the MN. The other BSs are buffering BSs; they hold a small number of packets from the HA in a circular buffer. When the MN initiates a handover, it informs the old BS to switch from forwarding to buffering mode. The new BS then forwards the buffered packets that the MN has not received yet. For networks where the BS infrastructure is not under control, the HA acts as the BS for the MN; the HA sends separate unicast packets to the care-of address of the MN's wide-area data interface [8].

The BSs send out periodic beacons similar to Mobile IP foreign agent advertisements. The MN listens to these packets and decides which BS should be forwarding packets and which BSs should be buffering packets in anticipation of a handover, and which BSs should be members of the multicast group assigned for a single MN. The signal strengths of these beacon packets are compared and the BS with the highest signal strength is chosen as the forwarding BS.

Upward vertical handovers are initiated when several beacons on the currently connected network are not received. Then, the MN decides that the current network is not reachable and is handed over to the upper overlay network. Downward vertical handovers are initiated when several beacons in a row are heard from a lower overlay's network interface (NI). The MN decides that the MN is now within the range of the lower overlay's NI and switches to the lower overlay [8].

3) Proposed Model For Vertical Handover

In WON, we come across with an important term "Vertical Handover", that is, the procedure of utilizing high-bandwidth wireless local area networks (WLANs) such as IEEE 802.11 in hotspots and switching to wireless wide area networks (WWANs) such as General Packet Radio Service/Universal Mobile Telecommunications System (GPRS/UMTS) networks when the coverage of WLAN is not available or the network condition in WLAN is not good enough.

In order to achieve seamless vertical handover and maintain continuity of connection, we propose a novel vertical handover management system that integrates a Handover Decision Manager (HDM) to detect network condition changes in a timely and accurate manner, and a Subnet Agent (SA) architecture with a Billboard Manager (BM) that uses an end-to-end principle to maintain a connection without additional network infrastructure support. We propose a completely IP based approach to overcome the mentioned primary challenges of vertical handover to provide an efficient roaming service to end users.

a) Architecture of Wireless Overlay Network Interconnection

To interconnect WWAN and WLAN, we introduce an IP-centric architecture using MIPv6, as shown in Fig. 9. Each overlay level has a Subnet Agent (SA). All Access Points (APs) of a specified region are linked to the SA of this level, that is, the Lower Overlay Subnet Agent (LOSA) and all Base Stations (BSs) of a wide-area are connected to the SA of this overlay, that is, the Upper Overlay Subnet Agent (UOSA). These SAs are also connected to Mobile Agent (MA) in addition to HA in order to support mobility management.

The SAs are newly designed for three purposes. First, they manage the handover process to reduce handover latency and to prevent data loss during roaming of the MN between different overlays. Second, they contain user/service preferences and technical parameters, such as access delay, available bandwidth, threshold values and capabilities of terminal which help the newly introduced HDM to make an appropriate handover decision. Finally, they are responsible for maintaining the connection transparently and achieving the best possible communication quality.

There are two cases in which handovers occur in this architecture are as follows: First, the upward vertical handover case that is illustrated in case 1 of Fig. 9, in which the MN serviced in the WLAN moves to another area that is covered by WWAN. Second, the downward vertical handover case that is shown in case 2 of Fig. 9, in which the MN moves from WWAN into the WLAN.

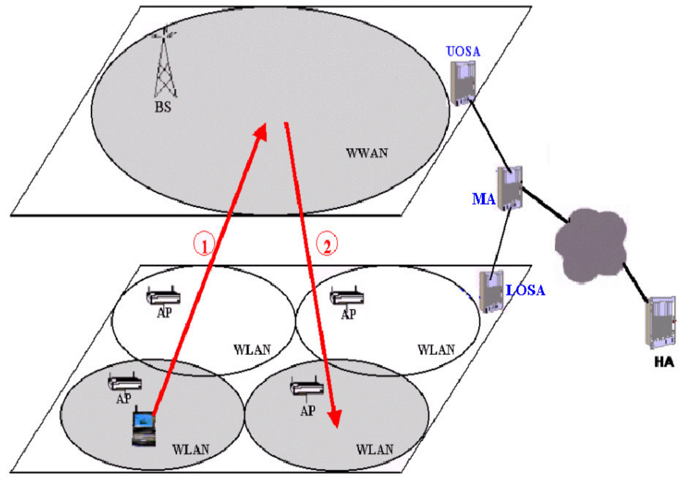

Fig. 9. WLAN-WWAN Interconnection Architecture based on IP

b) Vertical Handover Phases

(1) Vertical Handover Decision Phase

Some work on handover decision suggests different techniques. In [11] a roaming scheme that considers the relative bandwidth of WLAN and GPRS was proposed. However, no information on how to obtain the available bandwidth is given. In [12] a detailed vertical handover signaling procedure was presented but no details on a handover decision algorithm were provided.

In our approach, a handover decision manager (HDM) is introduced to intelligently detect the conditions of the different types of networks and the availability of multiple networks. In the HDM, we consider two handover scenarios. Fig. 10 shows the flow chart of these two handover cases. When moving from WWAN to WLAN, since WLAN is optional, the objective of the handover is to improve the quality of service (QoS). When moving out of WLAN, we need to have a timely and accurate handover decision to maintain the connectivity before the loss of WLAN access. When a user in a WWAN moves into a WLAN, medium access control MAC-layer sensing and traditional physical-layer sensing for the WLAN is performed to improve QoS. On the other hand, when the user moves out of a WLAN area, we should immediately detect the unavailability of the WLAN and switch the connection from WLAN to WWAN seamlessly. Therein a received signal decay detection scheme is used to indicate the distance from the AP and prolong the time the user stays in WLAN.

(a) Handover from WWAN to WLAN

When a user who is connected to a WWAN system steps into a WLAN area, he would like to change the connection to WLAN to obtain possible larger bandwidth and less cost. We need to perform the sensing in both the physical and MAC layers of WLAN to ensure better QoS. More specifically, physical layer sensing is used to detect the availability of the stable WLAN signal, while MAC layer sensing is used to detect the network conditions of the WLAN system, such as access delay and available bandwidth [13]. Since physical layer sensing is well defined in literature, we only present MAC layer sensing next.

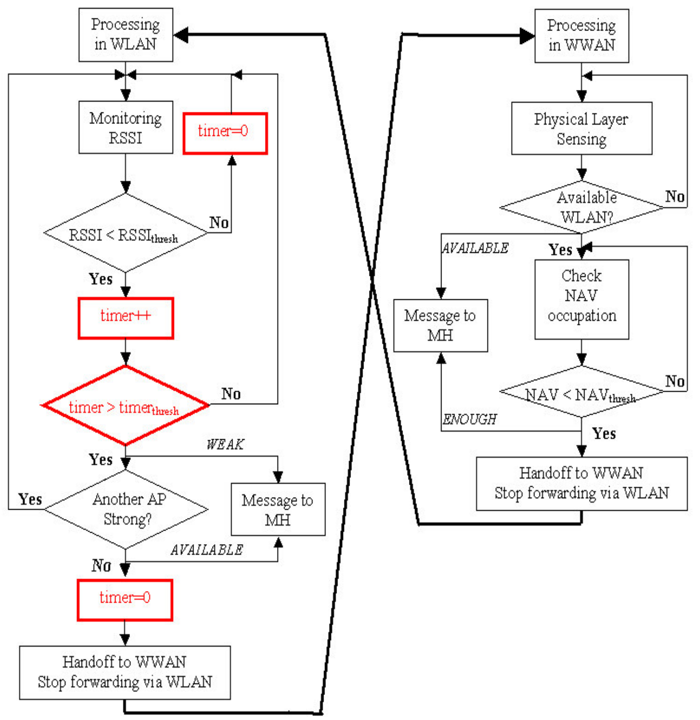

Fig. 10. Vertical Handover Decision Algorithm

(i) MAC Layer Sensing

In this work, we suggest to listen and collect the network allocation vector (NAV) in the MAC layer to estimate network conditions (e.g., available bandwidth and access delay). As explained in [13] and [14], NAV is the major mechanism in the MAC layer of the IEEE 802.11 WLAN to avoid collision. Once a station hears other stations' transmission, it will set the NAV to busy state and keep silent for a time duration equal to the duration ID in the packet header. From the above description, we can see that the NAV busy state can well reflect the media's busy state or traffic load. The higher the traffic, the larger the NAV busy occupation will be, and vice versa. We can defend that there is a fixed relationship between NAV and the available bandwidth and access delay. Large values for NAV occupation show that available bandwidth of WLAN is not enough for the MN to roam into WLAN. Also, we can say that access delay increases while NAV busy occupation increases. Fig. 10 shows the NAV occupation checking for handover decision from WWAN to WLAN.

In summary, the MAC sensing scheme has several advantages [13]. First, handover is achieved by being aware of network conditions. Second, among multiple APs, the one with the best QoS can be selected. Third, the QoS information can easily be adapted to upper network layers.

(b) Handover from WLAN to WWAN

Since WLAN has a smaller coverage range, when the user steps out of a WLAN area, we should quickly detect the unavailability of the WLAN and switch the connection to WWAN seamlessly. Therefore, the aim of upward handover is to switch to WWAN before the WLAN link breaks, while staying in the WLAN as long as possible due to lower cost and better QoS. There are two key issues in detecting the WLAN unavailability. First, how to accurately detect the signal decay. On average the mean received signal strength indication (RSSI) will decrease when a user leaves from WLAN. Second, how to determine if the signal is weak. The standard defines a lower bound for WLAN signal receiver sensitivity.

To address these two problems, a received signal (RS) decay detection approach, that is a well known scheme, is used with a novel control mechanism called timer to detect signal decay. We use the following variables to determine the upward vertical handover :

RSSI : Received signal strength indication of the received beacon signals

$RSSI_{thresh}$: Predefined threshold value of RSSI when the handover transition region begins

timer : The number of continuous beacon signals that are received from the WLAN with below $RSSI_{thresh}$

$timer_{thresh}$: Predefined threshold value for timer

(i) RS-Based Decay Detection

To detect signal decay accurately, we propose a new timer mechanism for RSSI. During the periodic checks of the HDM for the RSSI of the received beacon signals, if the RSSI falls below $RSSI_{thresh}$, timer is increased by one. The HDM determines whether the handover should take place or not by comparing $timer_{thresh}$ with the exact timer value. The $timer_{thresh}$ depends on the type of application traffic. We can simply classify the traffic as real-time and non-real time. In the case of delay sensitive real-time services, handover should be performed as rapidly as possible in order to minimize the delay due to frequent handovers. For non-real time services, the amount of transmission data is more important than the delay; therefore, the connection to the WLAN should be maintained as long as possible. Thus, the $timer_{thresh}$ for real-time services should be much more smaller than that of non-real time services.

The handover decision procedure from WLAN to WWAN is depicted in Fig. 10, which has two stages. When the user is in WLAN, the RSSI is sampled periodically. Once the RSSI is less than $RSSI_{thresh}$, intensive sampling that is the timer mechanism will begin. If the RSSI is consistently less than $RSSI_{thresh}$ for a period of time, it means the currently associated AP is weak and will lose connection. We send the $WEAK_{WLAN}$ message to the MN. Then we will check if there are other strong APs nearby. If yes, we will simply wait for an horizontal handover. Otherwise, we need to pass the $AVAILABLE_{WLAN}$ message to the MN to make it switching to WWAN.

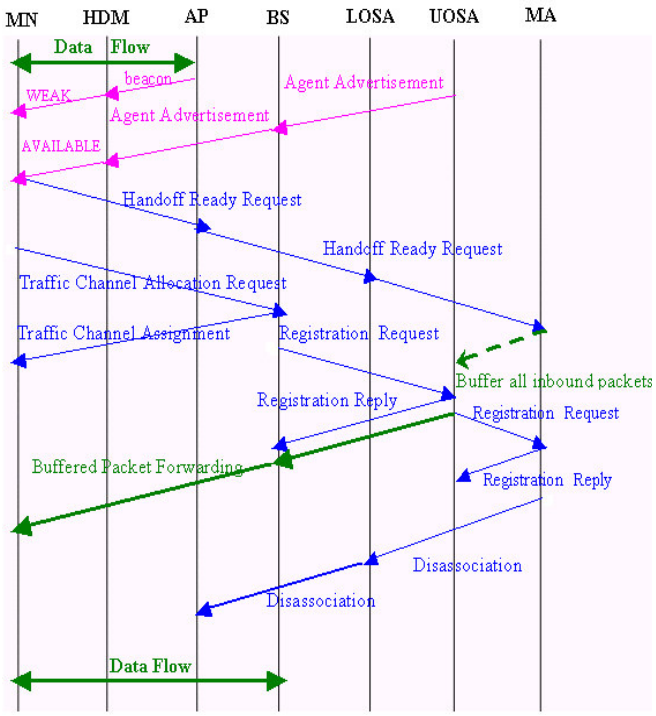

Fig. 11. Upward vertical handover signaling flow

(2) Vertical Handover Execution Phase

The process of which a MN, which is in the WLAN service area, leaves the area and connects to the WWAN is called the upward vertical handover. We propose a handover execution flow with HDM as shown in Fig. 11 to move from WLAN to WWAN. As the MN leaves the WLAN AP, the strength of the beacon signal that is received from the AP periodically weakens. If its strength decreases below the threshold value, then the WWAN card is activated and starts to make signaling with the system to prepare the handover. When the HDM receives continuous beacon signals below the threshold value, which is sensed by timer mechanism of HDM, the handover execution process is performed. The MN is warned by HDM, then it sends a Handover Ready Request Message to the MA through the serving AP when it receives an Agent Advertisement Message from the UOSA. The MA also sends in-bound packets to the Subnet Agent of the upper overlay that is configured with the overlay network, and then the UOSA buffers the received packets. The UOSA will send the buffered packets when it receives a Registration Message from the BS. This process is designed to prevent the in-bound packets from being lost during the handover period. After handover, the MN sends a Request message to the BS to demand traffic channel allocation. Then, it performs Registration to the SA and MA. The packet that was buffered in the SA is sent to the BS as soon as the MN registers to the SA. Afterwards, the MA sends a disassociation message to the AP. From now on, the MN communicates with the WWAN.

When the MN serving in WWAN region enters the WLAN service region, it connects to the WLAN. This is called the downward vertical handover. Its signal flow is shown in Fig. 12. In this case, power saving can be achieved by determining the time of the physical layer sensing in the handover transition region, and the time to activate the WLAN card in the MN. For instance, position information can be used. For the seamless handover service, the handover point in the downward vertical handover flow is not a critical factor, because the WWAN covers the WLAN region with an overlaid network. In Fig. 12, the HDM performs physical layer sensing to detect availability of any WLAN. If there is an available WLAN, WLAN card is activated. After that, the condition of WLAN is checked by HDM in order to determine whether to handover or not. If the conditions for the handover are satisfied, MN is informed by HDM, then the handover procedure is performed. When the MN receives an Agent Advertisement message with enough conditions from the LOSA, it sends a Handover Ready Request message to the MA through the currently serving BS. Then the MA transmits in-bound packets to the LOSA of the WLAN. The MN requests the release of the channel that is allocated to the WWAN and transmits a Re-association Request message to the AP in the WLAN. After registration to the SA of WLAN and MA, all buffered packets are sent to MN. Finally, the MN communicates with the WLAN.

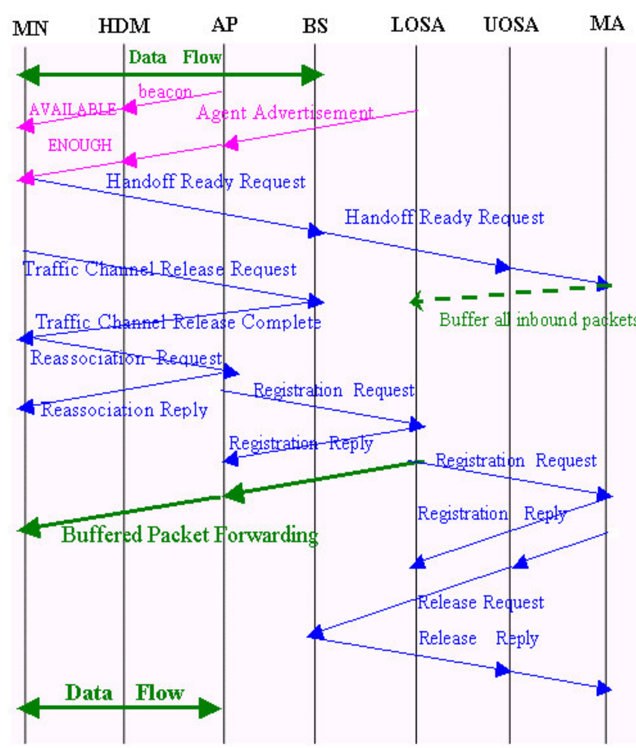

Fig. 12. Downward vertical handover signaling flow

(3) Improvements in Connection Quality

Once the vertical handover decision has been made, the other key issue for a roaming system is the mobility management scheme, which can maintain a connection's continuity after a vertical handover. As explained in [15] and [16], Mobile IP (MIP) is the most widely studied approach to mobility handling, where packets from and to the mobile node are tunneled through a HA at its home network, so the corresponding node that communicates with the MN can be shielded from the mobility of the MN. Several new schemes such as [17] have been proposed to improve the routing performance and resolve certain scalability problems associated with MIP. All of these solutions, including MIP, completely rely on newly introduced network infrastructures such as the HA. Although these techniques have useful characteristics, they have a major problem: Since a MN notifies its peer directly of the IP address change, this scheme may not make mobility transparent to applications. By transparency to application, we mean that an upper layer application should be unaware of changes of address, port, and routing-related information. Transparency to application is very important, especially for those UDP applications that use the IP address and port number of the received packet to identify to which user this packet belongs. We use the following example to illustrate this problem. Suppose mobile node A is communicating with its peer B; the IP address of A is IP_A. The node B buffers the address and port of A and uses it as the identity of A. When A moves to a new place and gets a new IP address, say, IP_A', the following two things happen:

- When A sends a packet to B using the new IP address IP_A', B cannot know that it is a packet from A; thus, the packet cannot be processed correctly.
- When B sends a packet to A, it still uses the old IP address IP_A. Therefore, the packet will be delivered to the wrong receiver.

Meanwhile, a *Billboard Manager* (BM) is proposed to maintain connection's continuity using an end-to-end argument when handover occurs. By utilizing the information provided by the HDM, the BM not only maintains the connection, but also achieves the best possible communication quality. In order to address the aforementioned problem faced by end-to-end schemes, we introduce a connection translation mechanism, that is, a billboard mechanism. The BM maintains a map between the original connection information and the current connection information. Therefore, mobility becomes transparent to upper applications.

(a) Billboard Manager

The new simple idea to overcome the transparency problem is to maintain a mapping relationship between the original connection information (e.g., IP address and port number) and the current connection information for each active connection, as illustrated in Fig. 13. The original connection information does not change during the connection's lifetime, while the current connection information changes each time the MN or its peer gets a new IP address. The upper layer applications only see the original connection information. The SAs give BM service to their linked APs and BSs .Therefore, mobility is made transparent to the upper-layer applications. The following actions are performed by the BM when the MN sends and receives packets:

- *Packet sending*. When an application sends a packet, the BM looks up the billboard to substitute the original connection information for the current information, and then delivers the packet to the lower layer (Fig. 13 (b)).
- *Packet receiving*. When the BM receives a packet from outside, it also looks up the billboard to substitute the current connection information of the packet for the original packet information, and then delivers the packet to the upper layer (Fig. 13 (c)).

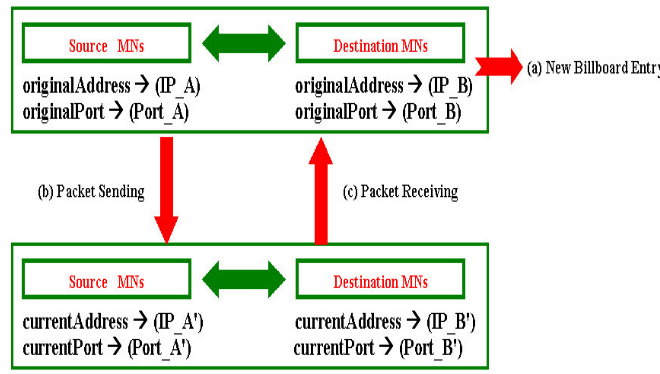

Fig. 13 Billboard Manager

The new entry of billboard is created when a new connection is established (Fig. 13 (a)), and the entry is linked with the current connection information when the source or destination nodes move to new a wireless network interface.

V. CONCLUSION

In this paper, we investigated handovers in Wireless Overlay Networks (WON) based on Mobile IPV6. We proposed a new mobility management scheme which decreases the handover latency and hence data loss. The proposed scheme provides solutions both for horizontal and vertical handovers. We showed that the proposed horizontal handover model decreases latency significantly at the expense of slightly increased traffic.

A new mobility management with HDM using MA and SA was also designed to minimize the handover delay in WLAN-WWAN interconnection architecture. In the handover decision algorithm we used the number of continuous beacon signals whose signal strength from the WLAN falls below the predefined threshold value. We adopted a timer metric to reflect the difference between real-time service and non real-time service. Finally, we suggested a Billboard Manager (BM) to provide the connection's continuity in a transparency manner.

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