Improving Throughput and Delay by Signaling Modification in Integrated 802.11 and 3G Heterogeneous Wireless Network

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***Abstract*—Current trends show that UMTS network and WLAN will co-exist and work together to support more users with higher data rate services over a wider area. However, this integration invokes many challenges such as mobility management and handoff decision making. Vertical handoff is switching process between heterogeneous wireless networks in a 3G/WLAN network. Vertical handoffs often fail due to the abrupt degrade of the WLAN signal strength. In this paper, proposed a new vertical handoff method for to decrease the number of signaling and registration processes, to examine the Special conditions such as WLAN black holes and to eliminate disconnecting effects. By estimating user locations related to WLAN position, interface on-times will be reduced which makes the power consuming of the system decreased. To indicate the efficiency of proposed approach the performance and the delay results are simulated.**

Keywords—Registration; WLAN; 3G network; Vertical handover

I. Introduction

Non-homogenous networks are integrated of several networks with various technologies. Vertical handover in these networks are unavoidable because of transparent services to end users. The two wireless networks categories are low bandwidth services over a large geographical region such as 3G and 2.5G and high bandwidth services over a small geographical area like WLANs. Universal Mobile Telecommunications System (UMTS) is a common 3G technology. Quality of service QoS) is one of the most important challenges in these networks which should not experience remarkable changes when handover process is being done. Therefore an efficient algorithm must be employed in order to initialize and complete handovers [1, 2].

Vertical handover are either upward or downward cases. In the downward case the mobile node (MN) enters from a large cell like 3G to a smaller one like WLAN while in the upward case the MN enters from a smaller cell like WLAN to a larger one like 3G [1, 3]. In the upward handover, since the mobile node switches to a cellular network before disconnecting from the WLAN, delay is an important problem while in the downward case delay sensitivity is low. However, in the upward handover, the mobile node should keep its connection with the WLAN to achieve more effective QoS and lower cost. Identifying the decline in signal strength is of high importance when the MN departs a WLAN. In this case, before disconnecting from the WLAN, the mobile node has to take decision when to start the handover to a 3G network. In the downward case, handover is often done in order to promote QoS, but the mobile node should not start handover too soon because it might depart the WLAN quickly and disconnect from UMTS as a consequence of inappropriate handover [4, 5].

The handover process is fundamentally dependent to the network architecture and its software and hardware elements. Various protocols and algorithms have been suggested for this process. They could be classified based on the existing network layers like the application, transport, and network layer. MIP (Mobile IP), which is a handover protocol in the network layer, represents the FA (Foreign Agent) and HA (Home Agent) to address mobility difficulties [7,8]. Synchronization, authorization and updating of user connections and CoA (Care of Address) of the foreign networks are provided by FA and HA.

The most important mobility management protocol in the transport layer is Stream Control Transmission Protocol (SCTP). It was designed to control the signaling in voice over IP (VoIP) networks. SCTP was improved by the Internet Engineering Task Force (IETF) in order to support dynamic address reconfiguration during connections. Reliability (as with TCP) and Multi-Homing providing one SCTP session on various interfaces with distinct addresses are supported by this protocol. In SCTP, the primary IP is set as the source address of the transmitted packet if this IP is available, while the secondary IP is set as the source address in situations where the primary IP is unavailable. Therefore SCTP hosts can use primary addresses for primary routing and secondary addresses for alternative routing [10]. In the original version of SCTP, end peers exchanged all IP addresses before starting the connection. Thus it was impossible to change one of these addresses during a session in a non-homogeneous network such as UMTS. In a WLAN, a host may have a fixed and known IP address, so this version of SCTP cannot be employed for vertical handover. However, Dynamic Address Reconfiguration (DAR) in newer versions of SCTP allows IP addresses to be modified during a session via mobile SCTP (mSCTP). Session Initiation Protocol (SIP) is the most pivotal protocol in mobility management through the application layer. As vertical handover (as opposed to horizontal handover), is between different networks with different capabilities, applications must be aware of these changes. Thus application requirements must be considered in the handover process [11].

II. None-Homogeneous Integrated Networks

The European Telecommunications Standards Institute (ETSI) suggested two approaches for connecting 3G networks and WLANs, tight and loose, as shown in Fig. 1. The GPRS network and the packet switched network are connected by the Gateway GPRS Support Node (GGSN). When connection is loose, a distinct path is supplied for 3G traffic, therefore WLAN traffic is not passed through the 3G network and routing to the Internet is through the WLAN gateway. Thus, various protocols for accounting and authentication might be employed by WLANs and 3G networks [12, 13]. When connection is tight, a WLAN is linked to the 3G network in the same way as other radio access networks. It becomes a part of the 3G core and all WLAN traffic is passed through 3G networks. Thus, WLAN gateways use 3G protocols and both the WLAN and 3G network employ similar Authentication, Authorization Accounting (AAA) mechanism. The pivotal merit of the procedure is that security, QoS and 3G mobility mechanisms could be employed in the WLAN. Loose connection is preferred over tight connections Due to the fact that it demands fewer reconfigurations and a simpler structure. Yet tight connections are more desirable in terms of security, performance and QoS. [14].

III. The Proposed Method

Consider the system as shown in Fig. 2. In the proposed method, when the MN gets closer to the WLAN the locations of the MN in the UMTS network are approximated. In a suitable time, the MN gets a message to turn on its WLAN interface. With this technique, the WLAN APs in each SGSN are mentioned as Node Bs for that SGSN, and the UMTS Service GPRS Support Nodes (SGSNs) are mentioned as FAs. Meanwhile the MN enters a WLAN of a UMTS network; the MN is given a new IP address from the WLAN. When the new IP address is allocated, all packets from the Corresponding Node (CN) with the old valid IP address are to be tunneled to the MN by using this new IP address. On the other hand, all packets from the MN should be sent to the CN by using the old IP address, routed to the AP, afterwards via the UMTS network, and eventually forwarded to the MN. First, the process of turning on the WLAN interfaces is discussed and then the protocol will be explained in detail. The black holes influences are also mentioned. Black Holes (BH) are defined as tiny areas where the RSS at an MN declines suddenly so that the link to AP will be broken very quickly. When a BH occurs, in case the MN does not change the connection into the 3G network, it cannot maintain connectivity. By using 3GPP methods categorized into four major groups (cell identifier, Observed Time Difference of Arrival (OTDOA), Uplink Time Difference of Arrival (UTDOA), and Global Positioning System (GPS)) the location of the MN is approximated [16]. Environmental conditions play a critical role in the accuracy of every approach and in the optimum case is as little as 10 meters. Any of these approaches or a combination of them can be applied. During connecting to the MN, the CN demands the MN location from the SRNC through the Iu interface regardless of the employed method. The Iu Interface connects the Radio Network Controller (RNC) with the 3G SGSN. The demanded information from the Location Measurement Unit (LMU) will be gathered by the serving RNC (SRNC) and then the MN location will be assessed. Eventually LMU responds to the CN [16]. Denoted the WUD to RNC unit, a database of user and WLAN information is employed in proposed scheme. The geographical location and general characteristic of the networks like delay, bandwidth and cost are kept in The WUD while for users store an access and priority list of those WLANs they can connect to. When a CN requests the location of a MN from the SRNC, the SRNC calculates the approximate location of the MN and compares it with the stored one in the WUD. In case the difference is lower than a threshold (S_{th}), a message will be sent to the MN in order to turn its interface on. The evaluation is performed according to the following inequality:

$$(x-x_0)^2+(y-y_0)^2<(R-R_{th})^2 \quad (1)$$

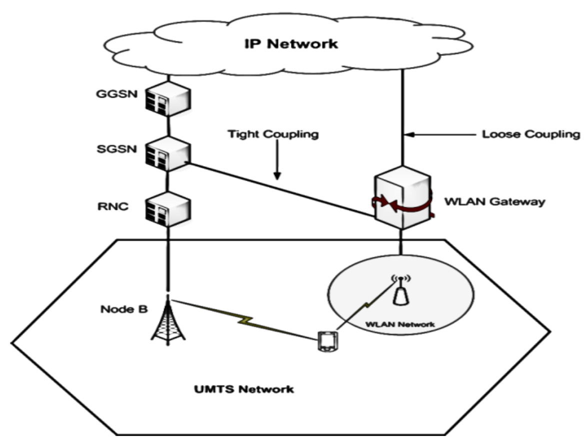

Fig. 1. None-homogeneous networks architecture

Where (x, y) , (x_0, y_0) are the last MN location, WLAN center, and *R* is WLAN radius. Since it is impossible to apply 3GPP estimation when the MN is in a WLAN network, upward and downward handovers have to use different approaches. Therefore in this paper employ two strategies for turning on the UMTS interface, always keep it on, or turning it on while the RSS falls lower a threshold. With the first approach, there is no problem with black holes. With the second approach, black holes cannot be overcome because of increasing handover delay. In the following sections the upward and downward handover techniques are explained.

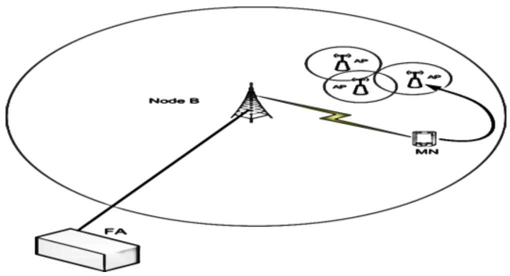

Fig. 2. locating, approximating and turning the WLAN interface on

IV. Downward Handover

It is supposed that the MN is linked to the CN through NODE B and is within the UMTS network. The MN location is assessed periodically by the SRNC and the data will be relayed to the CN. In case the MN gets closer to a WLAN boundary, the MN will be signaled by the SRNC. The MN turns its WLAN interface on and seeks for advertisement messages from closest WLAN APs. Afterwards, the MN determines whether there is any better quality AP than the UMTS network based on a weighted function of the AP parameters. Thus, a network cost function is to be defined. It is noted that the cost function given in [17] is appropriate for proposed protocol which is described as:

$$f^n = W_n = \sum_s \left[\prod_i E^n_{s,i} \right] \sum_j f_{s,j}(w_{s,j}) N(Q^n_{s,j}) \quad (2)$$

where $N(Q^n_{s,i})$ is the normalized QoS, $Q^n_{s,i}$ illustrates the cost in the *j*th network parameter to carry out service "*s"* on network *n*, $f_{s,j}(w_{s,j})$ is the *j*th weighting function for service s and $E^n_{s,i}$ is the *i*th network eradication parameter for service s. The elimination parameter is either one or infinity to show if the current network situations are appropriate for the services which are demanded by the MN. The multiplication over *i* eliminates networks that are not qualified for service *s*, while the summation over *s* considers all services carried by one user. Eventually, the summation over j provides the total cost to network n.

In case the MN cannot find an appropriate AP with a cost function more effective than UTMS it neglects the handover process and keeps the current connection. Otherwise, the shown handover process in Fig. 3 is commenced. The registration request that involves the new CoA address to the FA is sent by AP, and then the FA registers the MN and responds to the AP. Furthermore, the FA sends an update message of binding to NODE B to clean up the dedicated resources. Then, new IP address of the MN that is valid in the AP domain informs the FA. The gained packets of the CN that have the previous MN IP address (that is valid in the UMTS domain) are tunneled to the new IP address by the FA. Since the source address of the packets from the MN to the CN is the previous MN address, these packets should first be routed to the AP through the new IP address and then forwarded to the CN. This process is shown in Fig. 3where W_{ON} is the previous network weight and W_{NN} is the new network, and Fig. 4 indicates the corresponding signal flow where P: 4 is Target network information sending, P: 5 is MN signaling flow, P: 11 to P: 13 are Data path for the neighboring WLAN, and P: 14 to P: 15 are Data path from the MN to CN.

B. Upward handover

Two various cases for upward handover are considered. In the first case, in the WLAN network the MN is linked to the CN. In the second case, the connection is in the UMTS network. Just one upward handover is demanded in the first case whereas two handovers (downward from UMTS to WLAN and upward from WLAN to UMTS) are obligatory in the second case. Afterwards, the handover process is described in detail.

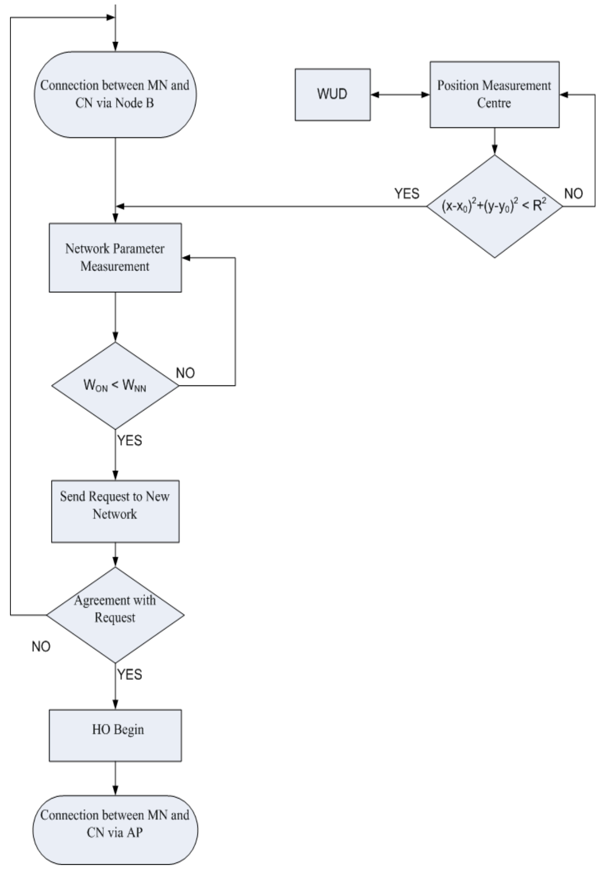

Fig. 3. The handover process of UMTS to WLAN

1) Upward handover process while the link starts in the WLAN

It is an obligation to continuously assess the RSS and compare it to the threshold S_{th} when the MN is in the WLAN network and linked to the CN through the AP. In case the measured strength is under S_{th} for at least a threshold interval (T_{th}), the MN will send a handover request to NODE B. In case the request is not accepted by the system, the MN is to find another network, otherwise it will be disconnected. Initiating the process, NODE B forwards the request to the FA, which registers the MN and then informs NODE B. Afterwards, all packets sent between the MN and CN are transmitted via NODE B. In addition, the FA sends a binding update message to the AP to clean the dedicated resources up. Fig. 5 indicates the process and the Fig. 6 shows the corresponding signal flow where P: 1 to P: 4 are Data path between the MN and the CN before handover.

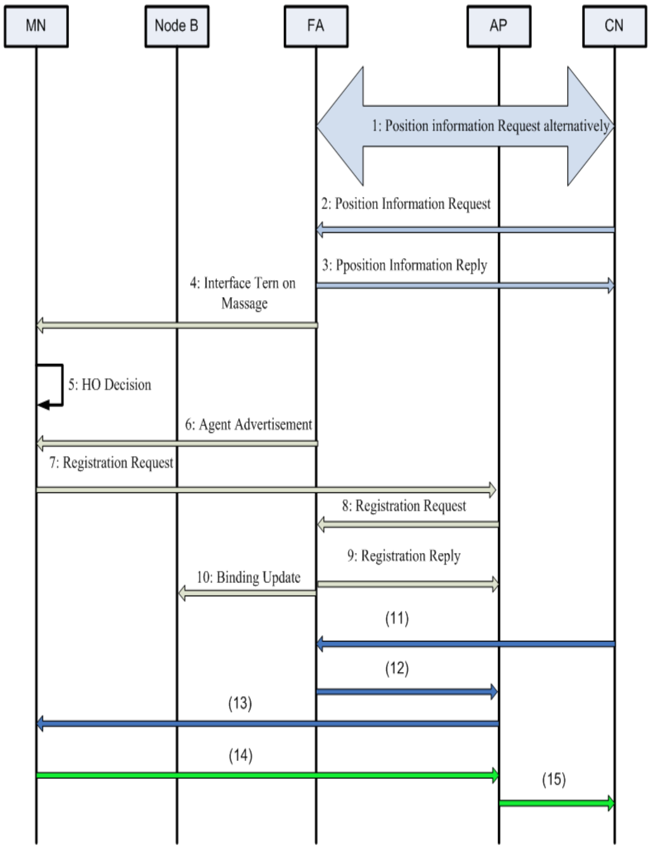

Fig. 4. Signal flow in the proposed downward handover

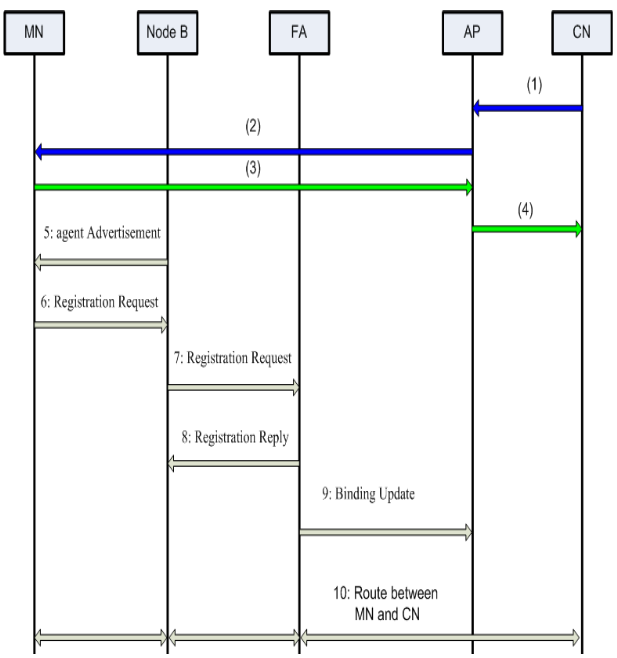

Fig. 6. Signal flow in upward handover while the link starts in the WLAN

2) Upward handover process while the link starts in the UMTS network

In contrast to the previous section, the MN does not require a new IP address and thus the MN is able to resume its connection with the CN applying the old IP address that is valid in the network of UMTS. Two various methods might be used to clean up the resource. After the downward stage the resources might be released instantly, or they might be retained for a particular time to reuse in the following upward handover. This creates a tradeoff between dedicated resources and handover delay. There should be a determination for an appropriate interval for resource reservation in relation to effective reuse by an MN and releasing through an acceptable time for a user who terminates the CN connection in the WLAN. Fig. 7 indicates the signal flow where P: 1 to P: 4 are data path through the CN and the MN before handover.

The above process is held for a WLAN network with a CN connection through the AP as the MN always assesses the RSS and compares it to S_{th}. In case the evaluated strength is under S_{th} for at least a threshold interval (T_{th}), the MN will send a re-association request to NODE B. Handover has the lowest delay in the second method because resources are reserved for the MN whereas there is no significant difference in situation for resource releasing as in Section B.1 Besides, a binding update message is sent to the AP for de-allocation the MN resources by the FA.

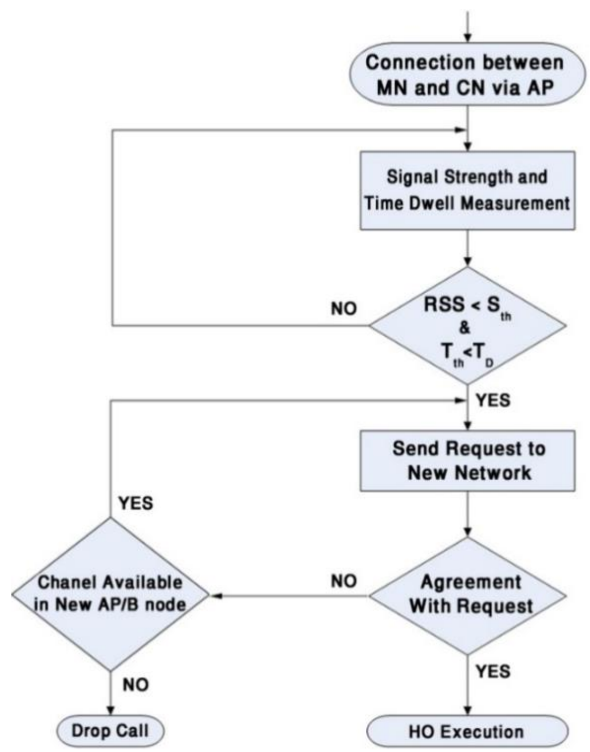

Fig. 5. The WLAN to UMTS handover process

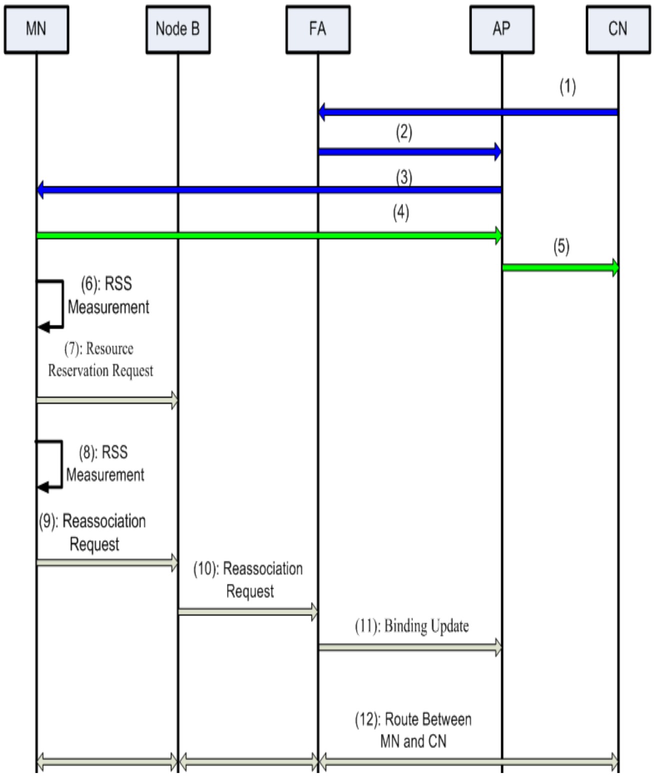

Fig. 7. Signal flow in upward handover while the link starts in the UMTS network

V. INVESTIGATING BOUNDARY CONDITIONS

We have supposed the case that the WLAN is not covered by only one NODE B. When two NODE Bs cover the WLAN two cases are identified according to the number of FAs related to these NODE Bs. These cases are divided based on this issue that the NODE Bs might have a common FA or different FAs. For both cases, downward handover and upward handover when the connection initiates in the WLAN are the same as in section **Ш-B** and **IV-A** section respectively. Yet when the connection initiates in a UMTS network the handover process is different. These cases are discussed in detail in the following sections.

A. Case 1: Two NODE Bs are covered by one FA

As shown in Fig. 8, the MN links to the CN through the first NODE B. Afterwards, it enters to the WLAN by a downward handover and connects to the CN via the AP. Then the MN leaves the WLAN and enters the second NODE B domain. Despite the existence of two NODE Bs, the procedure is the same as the case that there are two FAs. Besides, it is not necessary to have the new IP address of the MN because the protocol is fully transparent to the HA and CN. The signal flow for this protocol is shown in Fig. 9, where P: 1 to P: 5 are Data path through the CN and MN before handover. It should be noted that the simulation results for this part of the protocol illustrate a progress for handover delay which increases the probability of avoiding black holes. The increased success in handover to the 3G network is because of decrease in upward handover delay.

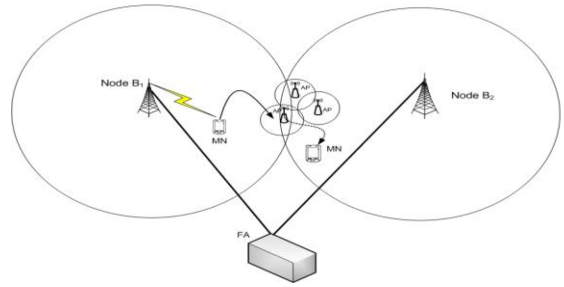

Fig. 8. Handover architecture while the destination and source are covered by one FA

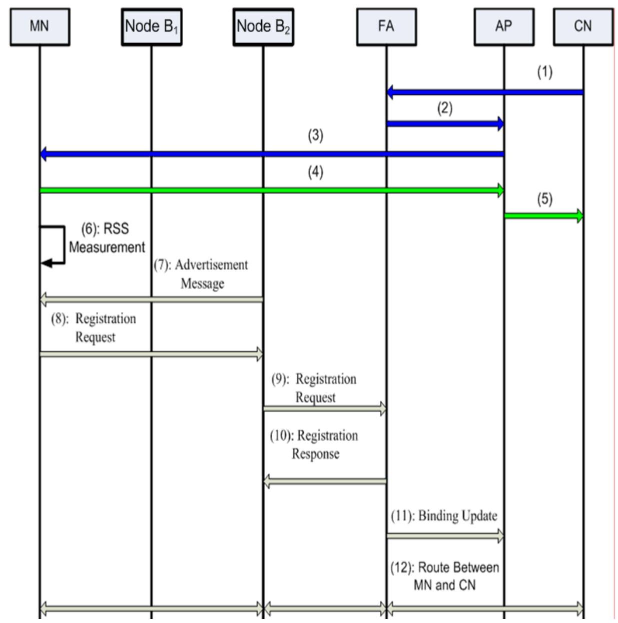

Fig. 9. Flow of signal in an upward handover while the destination and source are covered by one FA

B. Case 2: Two NODE Bs are covered by two different FA

As shown in Fig. 10, MN is covered by FA_1 before starting handover whereas MN is covered by FA_2 after handover process. When the MN is in the WLAN and its RSS is under S_{th}, the MN gets an advertisement message from NODE B_2 and afterward responses a handover request to NODE B_2. It is nessecary that the message be forwarded along a path NODE B_2-FA_2-FA_1. Since the mentioned process needs a registration in CN, delay is much more than the previous handovers. Therefore, in order to reduce packet loss and increase delivery rate, it is proposed that FA_1 routes the packets with the MN as the destination through NODE B_1 and then a copy of packets is sent to FA_2 and the packets are stored until new connection is fully established. In case the RSS received from AP goes under the threshold, a registration request is sent by the MN to NODE B_2 which in turn forwards to FA_2, and then forwards to the HA. After registration in the HA, the HA returns the responses to FA_2 and then FA_2 forwards them to NODE B_2. At the same time in order to correct the MN address in packets transferred from the CN, the HA is to send an update message to the CN. After getting this message, the FA_2 Node get the new MN address. Next, an update message is sent to the FA_1

by the FA_2 which in turn forwards it to NODE B_1 in order to disallocate the assigned resources of the MN in NODE B_1. After receiving the update message, the FA_1 sends packets with the MN as the destination to FA_2 until the CN registers the new MN address. In order to avoid packet loss due to handover process delay, a message containing the ID of the last received packet is sent to the FA_2 through NODE B_2 which enables the FA_2 to forward packets to the MN. The corresponding signal flow is shown in Fig. 11, Where P: 1 to P: 5 are data path between the CN and the MN before handover process.

VI. BLACK HOLES

As mentioned previously, two strategies are possible for turning on the UMTS interface, always have it on or turning it on when the RSS is under a threshold. In the former case, the challenge is power consumption while in the latter power is saved in favor of accepting the black holes problem (greater packet loss and possible disconnection from the CN). In WLANs, there are often blind spots as a result of obstacles such as elevators and walls which can greatly attenuate signals. This causes packet loss and disconnections during the handover process. Thus by turning the interface on in proposed protocol during the connection, found that the negative effects of black holes are greatly reduced during the handover process.

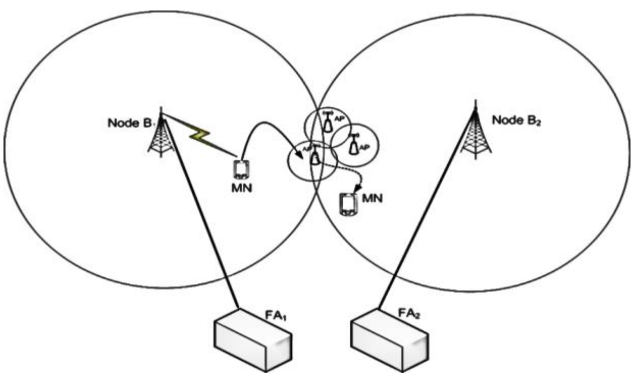

Fig. 10. Handover architecture while the destination and source are covered by two different FA

VII. PERFORMANCE EVALUATION

For simulation the Multi-interface Crass Layer Extension for NS2 (NS-MIRACLE) is employed [18]. For the WLAN network IEEE 802.11b is chosen. A different number of MNs were used in each simulation trial. For each MN, an initial and a final position were randomly selected, and the MN moves along a path between these points with a random speed between 0 to 10 m/s. Every 100 ms, the speed and final position are updated. In order to evaluate delay, 50 MNs were used in the UMTS network and 50 MNs were used in the WLAN network. The S_{th} was set to -75 dBm. Computation of handover delay is the differentiation in time among last packet receipt in the former network and the first packet in the new network.

In figures 13 to 20 simulate proposed scheme handover and Traditional MIP handover and then a comparison is done for them. In all the figures the proposed handover results are shown by green colure and the result of traditional MIP are shown by red colure.

Figs. 13 and 14 illustrate the downward handover delay. Fig.13 is for a tight architecture between the SGSN and AP. There has been a decline in the number of signaling and registration processes because there has been a reduction in utilization of home agents and correspondent nodes. In addition, for mobile users the handover delay and processing time were declined, with a significant improvement relative to the MIP protocol. As the number of MNs increases, utilization of home agents and correspondent nodes, the number of signaling and registration processes will be increased. Fig. 14 indicates the case in which there is no direct wired connection between FA and AP; thus packets among them will be routed via the Internet. Now, a random Internet delay from 0 to 55 ms was applied.

Both loose and tight connections were considered for upward handover. In the first case suppose that when the MN is in WLAN, it connects to CN, afterwards it enters to the UMTS network. Figs. 15 and 16 show the results of simulation for loose and tight connections. In the second case, suppose that the MN connects to the CN through the SGSN address and enters to the WLAN. Then it starts handover to UMTS while there is a connection with the CN. In this case, registration is not necessary and it is sufficient to send a request of re-connection to the SGSN. Fig. 17 shows the results in the case of tight connections and Fig.18 indicates the results in the case of loose connections, respectively.

The results in Figs. 15-18 are for a WLAN that is completely situated within a UMTS network. Fig. 19 indicates the results of simulation when the WLAN is situated between two NODE Bs under one FA for tight connection whereas Fig. 20 shows the results of simulation when the WLAN is situated between two NODE Bs under one FA for loose connection. The maximum WLAN data rate with 802.11b is about 11Mbps which is not accessible by the end users due to overhead such as packet payload and checksum fields. Fig. 21 shows the network throughput for 50 MNs during a 500 ms period.

For the case of black holes, in this paper consider two scenarios when a black hole is passed as indicated in Fig. 12. First, the MN is in the WLAN and passes a black hole which initiates an upward handover to UMTS. This requires registration and obtaining a new address, so the handover delay is greater and network throughput lower than previously, as shown in Fig. 22. Second, the MN connects to the CN through NODE B, and then the MN enters the WLAN via a downward handover. The MN maintains its connection with the CN before entering the black hole, so once the signal strength decreases sufficiently, the MN immediately returns to the UMTS network. This is shown in Fig. 23.

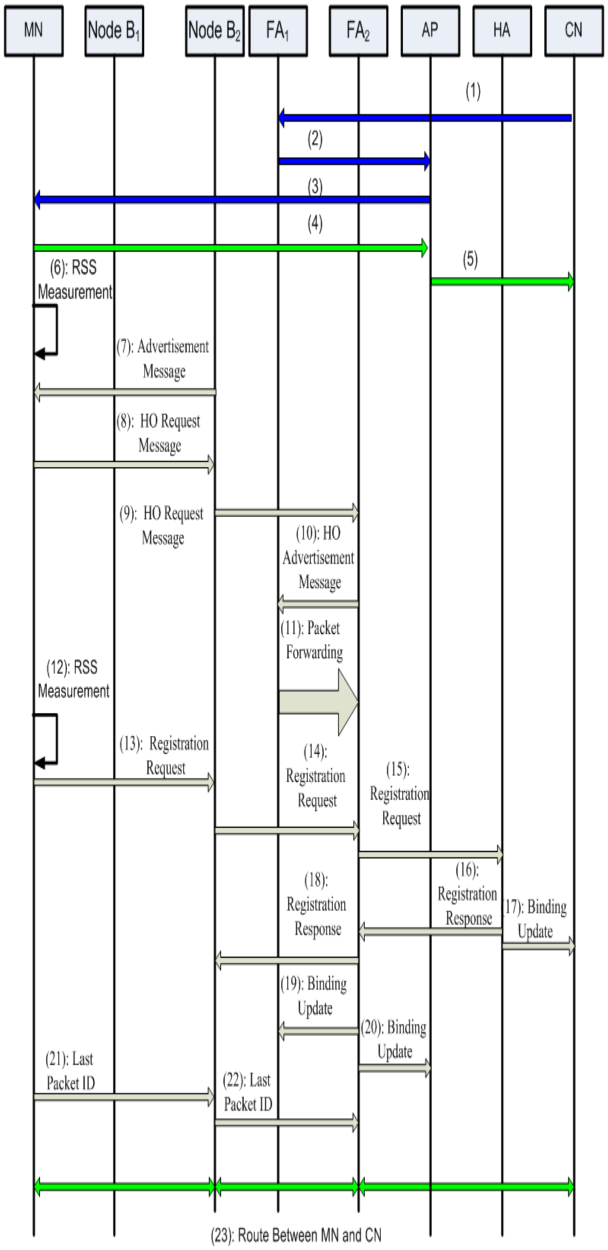

Fig. 11. Upward handover signal flow while the destination and source are covered by two different FA

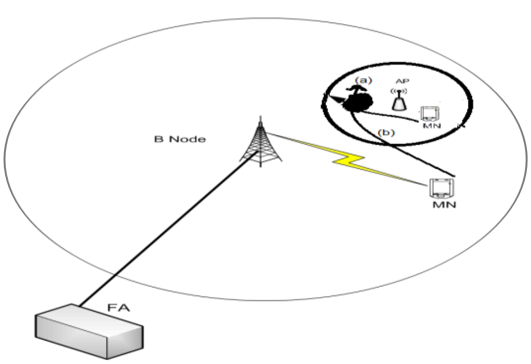

Fig. 12. (a) and (b) Black hole conditions

Fig. 13. Delay of downward handover in tight coupling

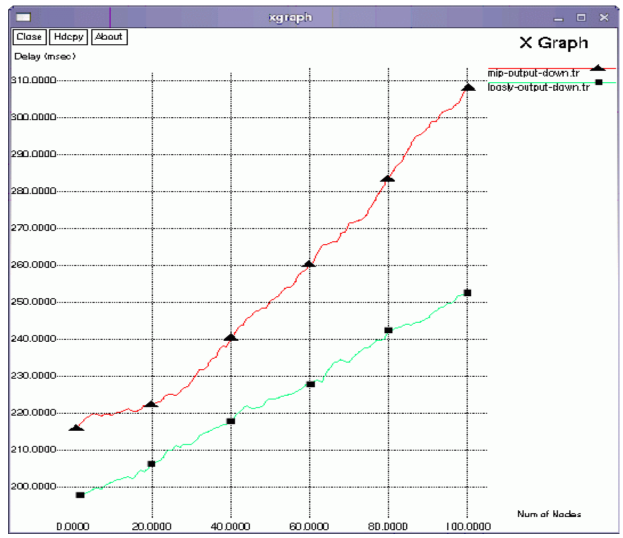

Fig. 14. Delay of downward handover in loose coupling

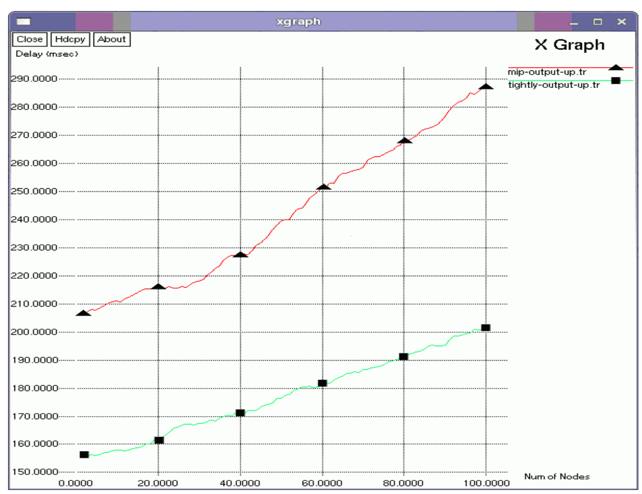

Fig. 15. Delay of upward handover by tight coupling while the connection commences in WLAN

Fig. 16. Delay of upward handover by loose coupling while the connection commences in WLAN

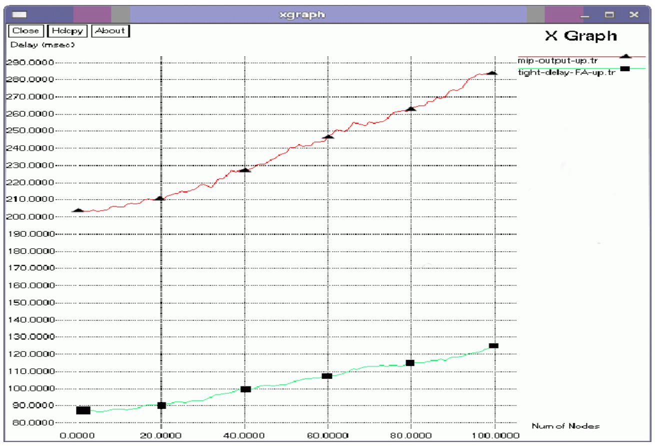

Fig. 17. Delay of upward handover by tight coupling while the connection commences in UMTS

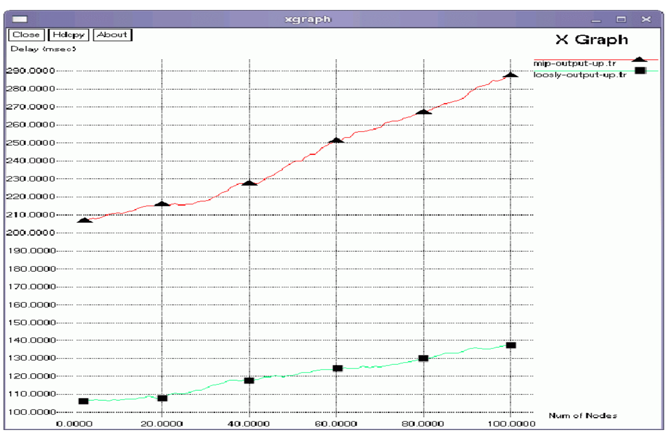

Fig. 18. Delay of upward handover by loose coupling while the connection commences in UMTS

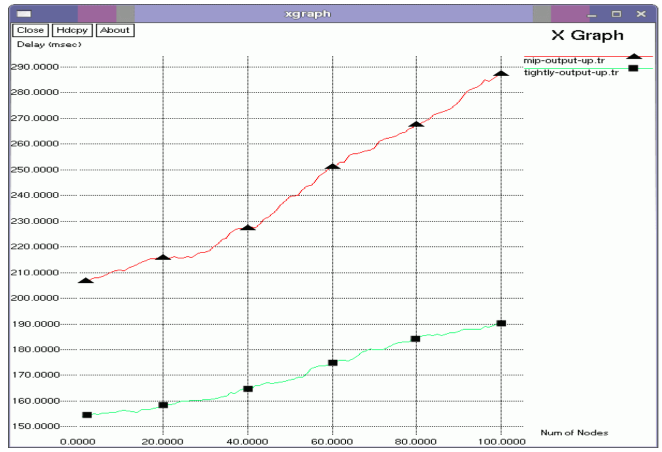

Fig. 19. Upward handover delay with tight coupling and Two NODE Bs are covered by one FA

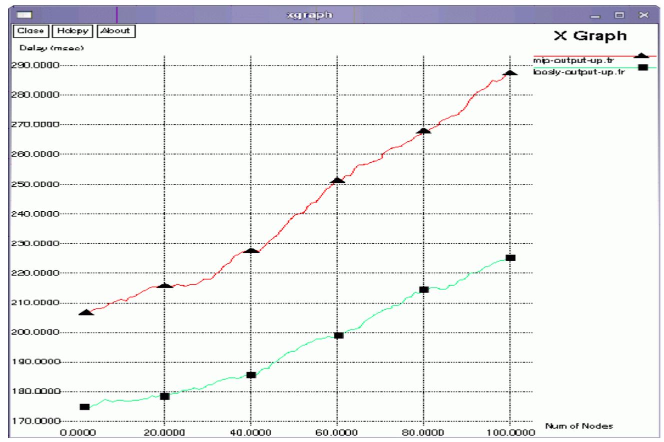

Fig. 20. Upward handover delay with loose coupling and two NODE Bs with one FA

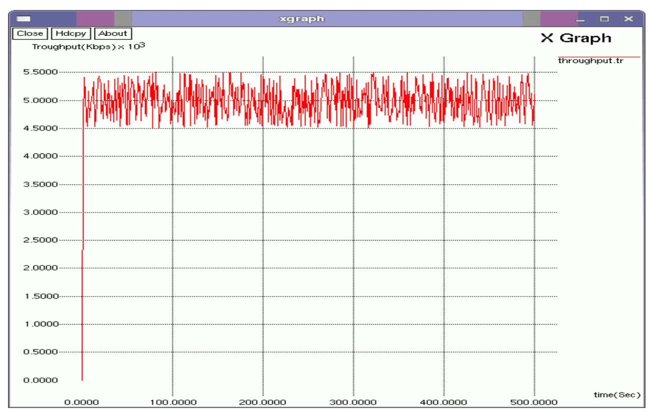

Fig. 21. Throughput with a combination of UMTS and WLAN networks

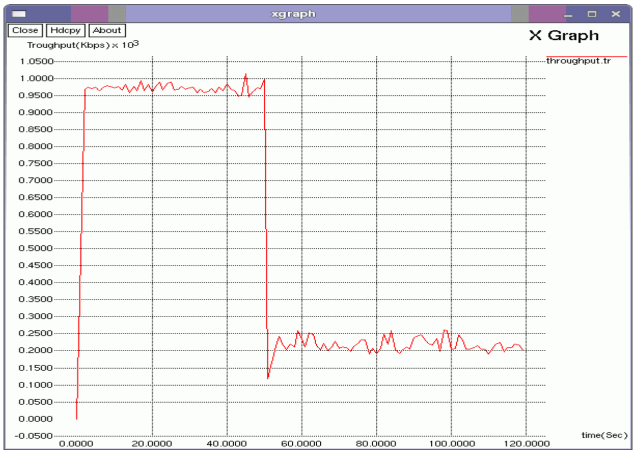

Fig. 22. Blackhole throughput during the existence of WLAN connection

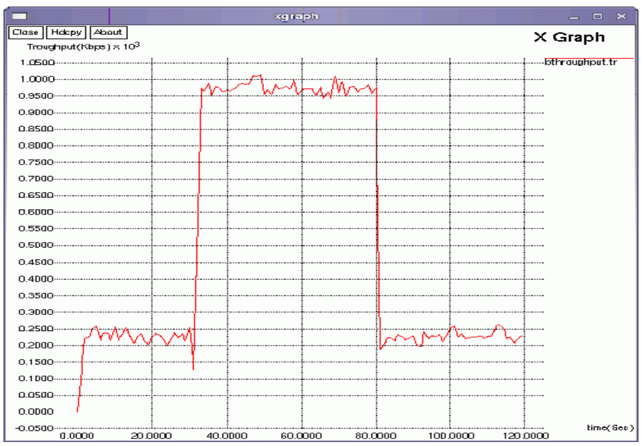

Fig. 23. Black hole throughput during the existence of UMTS connection

VIII. Conclusion

An innovative vertical handover method is proposed that there is no need to modify the WLAN structure. There is just a slight change in UMTS where the SGSN has to tunnel packets to the MN after receiving the new MN address. In the WLAN two MN addresses are used: the first address is assigned to UMTS address that is employed as the source and destination of the transmitted packets and the second one is assigned to CoA address belonging to the WLAN that is employed for routing packets to the CN through the AP during being in the WLAN. The interaction between the HN and CN is declined by this approach. For loose and tight coupling the processing time and delay of handover were declined. There has been a significant reduction in the case of tight coupling where there is a direct wired connection between AP and SGSN. This reduction has led to 38.45% improvement network throughput.

Two general cases were considered for upward handover. In the first case, UMTS keeps turning on while the MN is in a WLAN network. This prevents disconnection due to black holes, but also increases power consumptions, so this approach is not suitable when power is low. In the second case, UMTS turns on only when the WLAN signal strength falls below a given threshold. In this case, there is a higher probability of disconnection due to black holes, but the energy consumption is lower. Reducing energy consumption is one of the most important design criteria of in mobile nodes. Energy of the mobile nodes is supplied from battery. Since, the battery capacity is limited.

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