Human Health and Velocity Aware Network Selection Scheme for WLAN/WiMAX Integrated Networks with QoS

S. Chandra Sekaran, V. Saravanan, Rudra Kalyan Nayak, Ramamani Tripathy, S. Siva Shankar

Abstract*: The objective of this paper is to propose a human health aware network selection scheme for integrated WLAN and WiMAX networks by considering the velocity of the mobile device, achievable SAR value, network condition and required bandwidth. This paper investigates the handoff-related issues in WLAN/WiMAX integrated overlay network, proposed handoff algorithms for two different scenarios, and evaluated the performance of the proposed scheme with respect to both fixed and mobile devices. Also, our handoff algorithm considers the parameters like bandwidth requirement, available bandwidth, the speed of the mobile terminal, and SAR value at the time of selecting the target point of attachment. This SAR based handoff helps the mobile users in saving battery power and in reducing the biological effects such as sleep disturbance, brain tumor, depression and cancer caused by EM signals on the human body. Thus our proposed handoff scheme improves the QoS and it protects the human health.

***Keywords* : Absorption Rate , Human Health, Vertical Handoff, WiMAX, WLAN.**

I. INTRODUCTION

The objective of the 4G networks is to offer high-speed connectivity to the mobile and fixed devices. The new standard such as LTE (Long Term Evaluation), WiFi, WiMAX offers high-speed connectivity for both the mobile and fixed users. Most of the recent mobiles and few of the fixed devices come with multiple interfaces today, which is helpful in accessing multiple wireless networks using a single device. For accessing network services without any interruption and with seamless connectivity with QoS, both the mobile and fixed devices have to perform seamless switching from one network to another network. The process of transferring the ongoing connection from one access point or base station to another access point or base station belong to different network standard is called as vertical handoff (VHA). This VHA process will consider many network parameters such as RSS, velocity of the mobile device, power consumption, network connection time, bandwidth and so on. The VHA process can be split into three phases or stages namely initiation, network selection, and handover execution.

Generally, the VHA initiation phase is responsible for deciding when the handoff is required based on the RSS or other parameters. If the RSS or other parameter goes below the required minimum level, then this phase will trigger the handoff process. The network selection phase is responsible for selecting the best access point or base station among the available access points or base stations. The execution phase is responsible for complete the handoff process. The widely used network parameter for handoff decision is RSS in which the QoS of a network is directly related. The RSS method for performing handoff leads to serious problems such as 1) most of the mobile devices may get connected to the same access point which causes overload, 2) network with poor QoS, 3) high handover delay, and 4) frequent unbeneficial handoff in the case of smaller cells. The WiFi access point offers very small coverage up to few meters and when a mobile device moves with high velocity may result in frequent handoffs. In order to avoid such frequent handoffs, a number of works have been proposed in the literature but no work have provided a generic solution for transferring the ongoing session from one network to another network. Hence it is necessary to develop a dynamic network selection mechanism to provide a mobile device with seamless connectivity and QoS. In the last few years, many network selection schemes were proposed by various works but no scheme considers the current network context and user preferences. Also, most of these schemes consider single parameter for handoff decision where multiple parameter consideration may result in two-dimensional cost functions. The first dimension specifies the services that can be requested by the users and the second dimension represents the cost for each service. Furthermore, the cost based network selection can be classified into weighting parameters, network priority parameters, and QoS parameters. All these three parameters could vary based on the network availability and situation. On other hands, the researchers are trying to propose an effective algorithm for handling multimedia traffic such video from one network to another network. The high performance adaptive deblocking filters [1] are used for moving multimedia traffic during the handoff process and in the future generation of networks the motion estimation techniques will be used for transferring the minimum amount of data in video traffic over the Internet.

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With respect to the Internet of Things (IoT) and Cyber-Physical System (CPS), it is very challenging to transfer data with fast handover support. Hence, an effective handoff scheme is required for transferring data without breaking of connections which are possible only if the handoff is assisted by the network. In the past, many schemes were developed to select optimal network during the handoff process which can be classified into weight product method (WPM), Simple Additive Weighting (SAW), Multiplicative Exponent Weighting (MEW), and GRA [3]. All these schemes use parameters like bandwidth, delay, packet loss rate, and cost for selecting the best network. Out of these four classes of schemes, GRA offers good throughput and reduced delay. The majority of the traditional handoff system was based on RSS and cost but later the researchers identified that other related parameters that affect the network selection strategy directly.

It has been noted in the literature that continuous exposure of radio signals from mobile devices and various wireless access points or base stations causes the health disorders like sleep disturbance, brain tumor, depression and cancer [8]. These impact caused by the EM radiation depends on the SAR value that depends on the frequency and intensity of the EM signal. The WHO groups the radio frequency EM fields into "possible group 2B carcinogen" but the safety standards are not too away from the calculable SAR values [10]. The SAR value can be calculated by the equation

$$SAR = \frac{\sigma E^2}{\rho} \quad (1)$$

Where ρ and σ are the mass density and electrical conductivity of the human tissue respectively, and E is the root mean square of the EM field. The EM signal from various networks could vary in both intensity and frequency. Similarly, the transmitting power and frequency of the signals from the multi homed mobile devices will vary based on the network interface used and access point or base station connected.

The power usages of the mobile devices are controlled by the access point or base station connected. Based on the distance between the mobile node and BS, the power usage may change. The mobile which is too near to the BS could use lesser power than the mobile which is far away. If the user is in a car or some other place where the signal penetration is tough, then the uplink power should be increased even though the distance between the BS and mobile is too low. The transmitting power differs based on the distance between the mobile and access point or base station. To minimize the impact of EM signals generated by the mobile device the network selection algorithm has to consider the SAR value as handoff decision parameter.

Nowadays, the deployment of WLAN is very familiar in every office/organization throughout the world due to the easy installation, higher bandwidth, and low cost. The primary disadvantage of WLAN is its cell size which is very small in radius. The network with almost equal characteristics of WLAN is WiMAX. The WiMAX network has very big coverage up to few kilometers. Hence the integrated WiMAX/WLAN network seems to be good in many aspects. Today most of the mobile applications demand large bandwidth, particularly the application related to video streaming. In this situation for maintaining the QoS, the available bandwidth of the current and target network must be calculated before processing the handoff.

Our primary contribution in this work is, we have proposed a mobile terminal's speed based handoff algorithm with QoS support for WiMAX/WLAN overlay networks. Our proposed handoff algorithm considers network condition, the speed of the mobile terminal, bandwidth requirement, and SAR value.

II. RELATED WORKS

The works in [4] propose various techniques to enhance the function of handover triggering, avoid the issues such as too early/too late/wrong cell handoff, and to reduce the false handoff. The too early handoff could result in inefficient resource utilization and could fail in connecting the target network. The too late handoff the mobile device may move far away from the currently serving access point or base station which could cause disconnection of the current point of attachment before performing the handoff process. In literature, the commonly used parameter for triggering handoff is RSS which could result in these three types of issues. To avoid such situation, the researchers use other parameters like SINR, location of mobile devices, and network status for deciding the handoff but no works provide expected result in the case of false handoff indications. Few other works [5] uses periodical scanning method for comparing the RSS level of the current point of attachment with the nearby access points or base stations. If any access point or base station is detected with better RSS then handoff will occur but this method introduces two new problems: 1) ping pong effect, and 2) no network will be selected due to insufficient RSS level even after the RSS level of the current point of attachment goes below the threshold. Also, these handoff schemes do not consider the handover dropping rate.

In the recent years few works have been tried to enhance the QoS in the multimedia traffic specifically for video streaming. The work in [6] uses analytic hierarchy process (AHP) method for enabling QoS for various applications running in the mobiles and to ignore frequent handoff. In [11], the work did is not suitable for real-time implementation since it uses adaptive scanning method that adjusts the scanning time inside a particular network using its velocity. They used fixed speed inside a particular network which is not possible in real networks. The work in [12] uses broadcasting for sharing the information about available access points inside the current WiMAX base station. This information is used by the mobiles to decide whether to scan the available networks or not. All the above handoff or network selection schemes use few parameters for handoff decision those are good in some aspects and not suitable for choosing the generic point of attachment selection in heterogeneous wireless networks. For the next generation networks, the current network selection scheme may not be enough since the networks are growing rapidly.

In [7], the work reviews various epidemiological and experimental studies and stated that the wireless network standards cause biological effects such as brain tumor, muscle spasms, and depression. The work in [8] identifies that the microwaves reduce the reproduction rate of the micro organism such as bacteria and fungi. The wireless systems cause EM pollution on the environment due to the usage of mobile devices and cell phones [9]. Also the elder people, children, baby and pregnant women are at high risk if they live very near to the cell phone towers than the normal peoples. We have the sufficient number of papers [2] in the literature to find the biological effect on humans by EMRs. Similarly, we have the handful of papers in the literature focusing on the vertical handoff.

III. INTERWORKING ARCHITECTURE

The work in [12] presents the issues to be considered in integration of WLAN and WiMAX networks. The integration of WLAN and WiMAX seems to be a promising approach since it offers consistent Internet connectivity and higher data rate with very low cost. The interworking of WLAN and WiMAX can be done in three ways: 1) openly coupling, 2) loosely coupling, and 3) tightly coupling. In open coupling the networks are implemented independently with each other which will introduce several disadvantages. The primary disadvantages of open coupled network architecture are: 1) reduced handover performance, and 2) subscriber database and billing is not common between the networks with different standards. Although the open coupling has several disadvantages it has few advantages. The important advantage is, both the networks can be implemented without any changes to the existing standards.

A better network integration architecture than the open coupling is the loosely coupling in which the handover performance is far better than the open coupling. The reason for improved handover performance is, it uses Internet to integrate the WiMAX and WLAN networks. Another advantage in loosely coupling is, both the networks can be deployed independently without considerable changes to the WiMAX or WLAN standards. This loosely coupling architecture is suitable for non real-time applications in which the QoS requirement is less important. For the real-time-application this loosely coupling architecture is not suitable since the signaling overhead to transfer the current connection during the handoff decision cannot be neglected. Moreover, our proposed system is developed for tightly coupled interworking architecture and not for loosely coupled architecture. The details about tightly coupling architecture are given below.

A. Tightly Coupling

In this tightly coupled WiMAX and WLAN architecture, both the access point of WLAN and base station of WiMAX networks are mixed to provide the coverage based on the requirement. As shown in figure 1 entire network can be split in to two parts namely access service network (ASN) and Connectivity Service Network (CSN). To provide the wireless coverage over the service area, both the access points and base stations can be used just by connection it to a gateway called ASN gateway (ASNGW). The network components of the CS networks can be utilized by the WLAN through the ASNGW via data traffic. This will reduce the deployment cost while comparing with the open coupling and loosely coupling. The communication between the ASNGW and the WLAN AP can be achieved by the protocol stack proposed by the work in [12]. Both the 802.11 and 802.16 architectures are very similar to each other and developed to work just like the Ethernet. So, connecting both the networks can be done easily by utilizing the Ethernet based architecture.

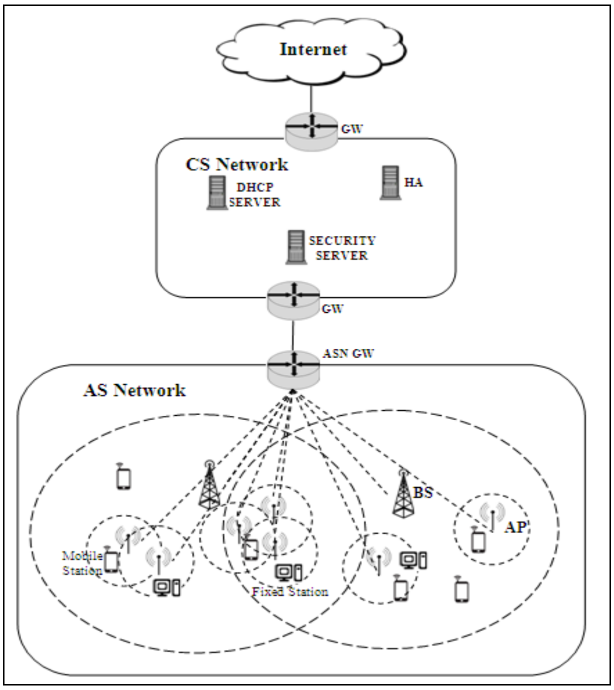

Fig. 1. Tightly Coupled Interworking Architecture

Apart from the connectivity issue, combining security services is an important issue which has to be resolved in tightly coupling architecture. The WLAN uses extensible authentication protocol for providing the security based on authentication, accounting, and authorization (AAA) architecture. The WLAN access point uses the extensible authentication protocol to exchange extensible authentication messages with stations and it acts as an authenticator for AAA server. After the successful authentication, the AAA sever will generate a key called pair wise master key and send the same to access point. The access point will generate one more key based on this key to use between the access point and stations. Similarly, in 802.16e the base station work as the authenticator for AAA server and the AAA server will generate the master key and it will be sent to ASN gateway. The ASN gateway will generate further keys. This similarity between the 802.11 and 802.16 with respect to security, the security issue in the tightly coupled WLAN and WiMAX architecture will be resolved easily by incorporation a small change in the WLAN network that is the authentication function of 802.11 access point has to be shifted to ASN gateway.

By doing his change both the 802.11 access point and 80.16 base stations could work as an extensible authentication protocol proxy and all the operations could transparent to the AAA server.

The tightly coupled 802.11/802.16 architecture will have several advantages such as seamless mobility, reduced implementation cost, reduced packet loss, reduced signaling cost during vertical handoff and minimized service degradation.

IV. PROPOSED HANDOFF SCHEME

Most of the existing handoff algorithm triggers handoff only by mobility which is not suitable for fixed stations. Instead of initiating handoff only by mobility the handoff should be initiated based on the current network condition. If the current network condition is bad and it cannot satisfy the requirements of the ongoing UL or DL application, then handoff process has to be initiated. This network condition based handoff initiation will help the ongoing applications to sustain the QoS.

In our proposed handoff system, a handoff decision manage is designed which could sit in the MAC layer of both WLAN and WiMAX interfaces. This handoff decision manager will keep on tracking the application's transmission direction and status. In the UL or DL application continuously violates the QoS requirements up to a predefined duration (time T) then the handoff initiation should be initiated. The reason for bad traffic could be due to two factors: 1) the performance anomaly caused by the local access point or base station and 2) the performance anomaly caused by other networks on the path between the source and destination of the communication. Hence the handoff decision manager has to check the presently connected network's condition and ensure that the current network condition is bad enough before initiating the handoff. After initiating the handoff process, the mobile node has to scan for the available access points or base station based on the velocity and then it has to select a better access point or base station. If there no access point or base station is detected with good network condition then the handoff process should be dropped to avoid unbeneficial handoff.

We propose handoff algorithms for two different scenarios: 1). WiMAX originating handoff and 2) WLAN originating handoff. Both the algorithms are described below.

A. WiMAX Originating Handoff Algorithm

If the uplink or downlink application continuously losses the QoS for a predefined time T, then the handoff decision manager has to check for the current base station's condition to ensure that the current base station's condition is bad enough. Once the handoff decision manager identifies that the current base station is bad enough then, it will initiate the handoff process. If the speed of the mobile terminal is high, then it will scan for the available WiMAX base station. If one or more base station detected, then the condition of those base station has to be calculated. If anyone or number of base stations could able to satisfy the ongoing application's QoS requirements, then, it has to be grouped in a set Bi. if the set Bi contains more than one base station then based on the expected SAR value the target base station will be selected (with minimum SAR value). If there is no base station satisfies the QoS requirements of the ongoing application and if the speed of the mobile is slow then the WLAN interface will be turned on for scanning the available access points. If many number of access points are detected then an access point with minimum SAR value will be selected for handoff.

Table-I: WiMAX originating handoff algorithm

if *ul* or *dl* application is loosing *QoS* for time > T
    get the required *ul* bandwidth $\hat{U}_{req}$ and *dl* bandwidth $Đ_{req}$;
    if the condition of current BS $\beta \in B$ is bad enough
        scan the nearby BS β;
        for each $\beta \in B$ detected by scanning
            estimate AULBW $\hat{U}_{\beta}$ and ADLBW $Đ_{\beta}$;
            if $\hat{U}_{\beta} > \hat{U}_{req}$ & $Đ_{\beta} > Đ_{req}$
                add BS β to subset B_i;
            end if
        end for
        if $|B_i| > 0$
            $b = \min \beta \{SAR_{i,\beta} \mid \beta \in B_i\}$;
            perform horizontal handoff for client *i* with *b*;
        else if Speed of MT is slow
            turn on the WLAN interface parallely;
            scan for available $\alpha \in A$;
            for each AP $\alpha \in A$
                if client $i \in N$ detects α
                    get the $\hat{U}_{\alpha}$, and $Đ_{\alpha}$ of α;
                    if $\hat{U}_{\alpha} > \hat{U}_{req}$ and $Đ_{\alpha} > Đ_{req}$
                        add AP α to subset A_i;
                    end if
                end if
            end for
            if $|A_i| > 0$
                $b = \min \alpha\{SAR_{i,\alpha} \mid \alpha \in A_i\}$;
                perform vertical handoff for client *i* with *b*;
            else
                stay back in current BS
            end if
        else
            avoid unbeneficial handoff and stay in the current BS
        end if
    end if
end if

B. WLAN Originating Handoff Algorithm

If the uplink or downlink application continuously losses the QoS for a predefined time T, then the handoff decision manager has to check for the current access point's condition to ensure that the current access point's condition is bad enough. Once the handoff decision manager identifies that the current access point is bad enough then, it will initiate the handoff process. If the speed of the mobile terminal is low (slow) then it will scan for the available access points. If more than one access point is detected then the access points that satisfy the requirement of ongoing application are filtered and added to the set Ai. If the set Ai contains more than one access points then the best access point with minimum SAR value will be selected as a target to perform a horizontal handoff. Else if the set Ai is empty or the speed of the mobile is high then, the WiMAX interface will be turned on and scanned for available WiMAX base stations.

If one or more base station detected then the condition of those base station has to be calculated. If anyone or number of base stations could able to satisfy the ongoing application's QoS requirements, then, it has to be grouped in a set Bi. if the set Bi contains more than one base station then based on the expected SAR value the target base station will be selected (with minimum SAR value).

Table-II: WLAN originating handoff algorithm

```
if ul or dl application is losing QoS for time > T
    get the required ul bandwidth Û_req
    get dl bandwidth Đ_req;
    if the condition of current AP α ϵ A is bad enough
        if the speed of the mobile terminal is slow
          scan for available AP α ϵ A;
          for each AP α ϵ A
             if client i ϵ N detects α
                 get the AULBW Û_α
                 get AULBW  Đ_α of α;
                 if Û_α > Û_req and Đ_α > Đ_req
                     add AP α to subset A_i;
                 end if
             end if
          end for
          if |A_i| > 0
             b = min α{SAR_i,α| α ϵ A_i };
             perform horizontal handoff for client i with b;
          else
             goto abc:
          end if
        else
          abc: turn on the WiMAX interface in parallel;
          scan for available β ϵ B;
          for each BS β ϵ B
             estimate AULBW Û_β and AULBW Đ_β of β;
             if Û_β > Û_req & Đ_β > Đ_req
                add BS β to subset B_i;
             end if
          end for
          if |B_i| > 0
             b = max β {RSS_i,β | β ϵ B_i };
             perform vertical handoff for client i with b;
          end if
        end if
    else
        stay back in current AP
    end if
end if
```

In our algorithms, the priority is given to horizontal handoff than the vertical handoff. The speed of the mobile terminal is used to give priority to either WLAN or WiMAX. Also based on the SAR value to be generated by the mobile device for communicating with the access point or base station the target is selected. Thus our work contributes in minimizing the impact of EM signal on the human body.

V. NETWORK CONDITION ESTIMATION

Before These section present numerical methods for estimating the network condition of both IEEE 802.16 WiMAX and IEEE 802.11 WLAN networks. The clients can estimate the network condition of WiMAX network by itself with the help of HDM installed in it since the coverage area of WiMAX BS is large enough and the mobile devices can stay connected for a long duration. In case of WLAN the mobile device may not able to stay connected for a long duration since the coverage area of WLAN AP is too small when comparing to the WiMAX BS. So the WLAN AP has to estimate the network condition and it has to update the network status information to all its clients periodically via beacon message.

A. Calculating the Available Bandwidth of WiMAX

In the proposed method of work, the network condition estimation of WiMAX BS is carried out fully by the clients (derived from the work [18]). So, the existing WiMAX standard require no changes for enabling the facility of estimating the network condition since the estimation work is carried out by the HDM installed in the clients. The IEEE 802.16e supports both the time division duplex (TDD) and the frequency division duplex (FDD). In our proposed work we have taken FDD for available bandwidth estimation process. The IEEE 802.16e supports two types of frame structure split between downlink and uplink traffic; 1) frame structure with adapting split, and 2) frame structure with fixed split. The adaptive split is quite complex in estimating the available uplink and downlink bandwidth so we took fixed split case for estimating the available uplink and downlink bandwidth of WiMAX BS.

In orthogonal frequency division multiple access (OFDMA), the WiMAX BS assigns the bandwidth in the form of data burst which contains fixed number of slots. The WiMAX BS will keep on broadcasting the uplink MAP and downlink map messages to all of its clients. This message contains the information such as the number of uplink and downlink slots assigned to a client in one frame. Using this message any client can estimate the available bandwidth of a BS by subtracting the utilized bandwidth form the maximum bandwidth. The maximum uplink bandwidth can be calculated by the equation

$$MUB = \frac{UBR.TUS}{FD} \quad (1)$$

Where, MUB is the maximum uplink bandwidth, UBR is the uplink bitrate (number of bits in the uplink slot and it differs based on the coding scheme applied), TUS is the total number of uplink link slots of the uplink subframe and FD is the frame duration.

The allocated or utilized uplink bandwidth can be computed using the below equation as follows:

$$UUB = \frac{AUS \cdot UBR}{FD} \quad (2)$$

Where, UUB is the utilized uplink bandwidth, UBR is the uplink bitrate (number of bits in the uplink slot), AUS is the number of allocated uplink slots of the subframe and FD is the frame duration.

From (1) and (2) the available uplink bandwidth $\bar{A}$ can be calculated as

$$\bar{A} = MUB - UUB \quad (3)$$

Similarly, the available downlink bandwidth Đ can be calculated by the equation

$$MDB = \frac{DBR.TDS}{FD} \quad (4)$$

Where, MDB is the maximum downlink bandwidth, DBR is the downlink bit rate (number of bits in the downlink slot and it differs based on the coding scheme applied), TDS is the total number of downlink link slots of the downlink subframe and FD is the frame duration.

The allocated or utilized downlink bandwidth can be computed using the below equation as follows:

$$UDB = \frac{ADS \cdot DBR}{FD} \quad (5)$$

Where, UDB is the utilized downlink bandwidth, DBR is the downlink bitrate (number of bits in the downlink slot), ADS is the number of allocated downlink slots of the subframe and FD is the frame duration.

From (4) and (5) the available downlink bandwidth Đ can be calculated as

$$Đ = MDB - UDB \quad (6)$$

B. Calculating Available UL/DL Bandwidth in WLAN

The available uplink bandwidth and available downlink bandwidth of a WLAN AP could be estimated by finding the sum of every attached client's uplink and downlink throughput and subtracting it with the maximum uplink and downlink bandwidth respectively [13]. We calculate the uplink and downlink throughput of individual client by utilizing the frame collision and transmission probability along with the transmission duration. The transmission probability (TP) and collision probability (CP) of every client can be calculated using the Markov model described in [14], [15] and [16]. Let N be the number of clients connected to an access point and for every individual client i, the uplink throughput can be computed as

$$ULT_i = \frac{STP_i \cdot LSTP_i}{ATS} \quad (7)$$

Where, $LSTP_i$ is the length of the successfully transmitted payload of client i, STP_i is the probability of client i's successful transmission, and ATS is the access point's average time slot which can be estimated by adding the expected duration of an idle time slot, successful frame transmission and transmission failure due to collisions.

The STP_i can be estimated simply as

$$STP_i = TP_i \cdot (1 - TP_a) \cdot \prod_{j \epsilon N} (1 - TP_j)$$

Where, TP_i is the transmission probability of client i, TP_a is the transmission probability of AP_a and TP_j is the transmission probability of client j ϵ N.

Then, the available uplink bandwidth Ā can be calculated as

$$\bar{A} = MUB - UUB \quad (8)$$

Where, MUB is the maximum uplink bandwidth of an access point and UUL is the utilized uplink bandwidth of an access point. The UUB can be calculated by (7) as

$$UUB = \sum_{i \epsilon N} ULT_i$$

Similarly the downlink throughput for any client i can be calculated as

$$DLT_i = \frac{DTP_i}{DLT_a \cdot \sum_{x \epsilon N} DTP_x} \quad (9)$$

Where, DLT_i is the estimated downlink throughput of client i, DLT_a is the estimated downlink of the access point, DTP_x is the down link traffic probability of client x where x belongs to N. DLT_a can be estimated as

$$DLT_a = \frac{TP_a \cdot \prod_{i \epsilon N} (1 - TP_i) \cdot \sum_{i \epsilon N} DTP_i \cdot LP_i}{\sum_{i \epsilon N} DTP_i \cdot AT}$$

Where, TP_a is the transmission probability of an AP *a* while none the other clients transmit, DTP_i is the down link traffic probability of client i. Similarly, the available downlink bandwidth Đ can be calculated as

$$Đ = MDB - UDB \quad (10)$$

Where, MDB is the maximum downlink bandwidth of the access point, UDB is the utilized bandwidth of access point. The UUB can be calculated by (9) as

$$UUB = \sum_{i \epsilon N} DLT_i$$

In most of the WLAN deployment, the estimated AUB and ADB of an access point seem to be equal. The WLAN deployment which uses controllable resource-allocation [16]-[17] method between uplink and downlink traffic, could have difference in the AUB and ADL, based on the required utilization ratio (RUR).

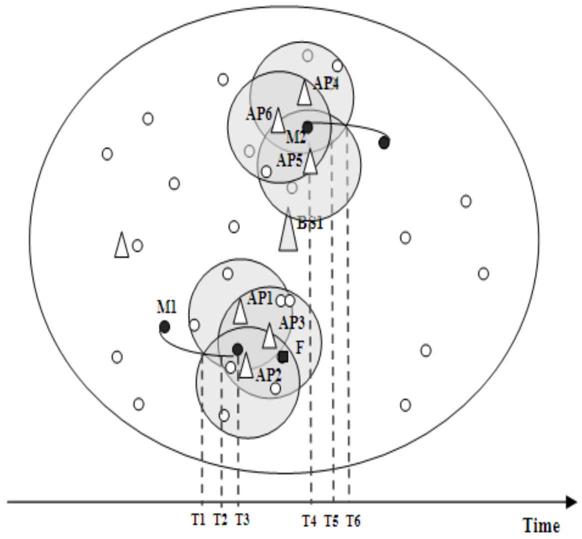

Fig. 2.Simulation Topology

VI. SIMULATION RESULTS

This section compares the performance of our proposed handoff algorithm with the existing RSS based and WLAN preferred handoff of schemes.

The RSS-based algorithms always select the access point or base station based on the highest RSS level where the WLAN preferred scheme always give priority to the WLAN than WiMAX.

Also, this section validates the performance of the proposed algorithm for both mobile devices and fixed devices with respect to the throughput separately. The achieved SAR value is not measured since it is not possible to measure it using network simulation tools. But the SAR value is estimated numerically and the Access point /Base station with minimum estimated SAR value will be preferred for handoff which will logically minimize the SAR value achieved by the human body.

A. For Mobile Stations

The performance for both the scenarios (WLAN originate and WiMAX originated) are evaluated. As shown in figure 2 a mobile device M1 initially got connected with a base station B1 in which a UL connection was running with the throughput requirement of 800 Kbps. Initially, the mobile device found that the average throughput goes below the threshold 700kbps but there is no other base station or access point found at that point. Here the mobile moves slowly towards the point T1 and at the point T1, it detects access points AP1 and AP2. The WLAN preferred handoff scheme performs handoff with AP1 immediately. Our proposed algorithm estimates the condition of the access points and identified that the access point's condition is bad enough. At the point T3, it finds that the condition of the access point AP3 is good enough. At point T2 the RSS based algorithm performs handoff with AP1. The simulation results for WiMAX originated handoff is depicted in figure 3.

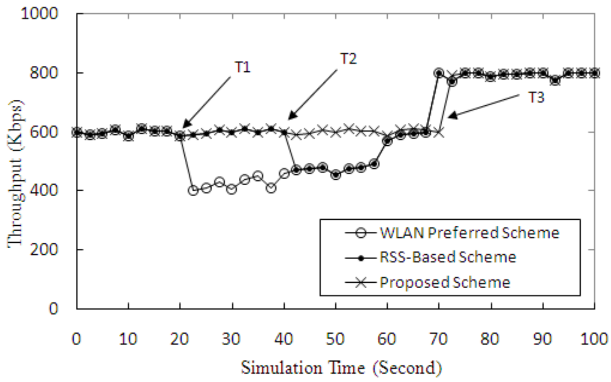

Fig. 3. Throughput Comparison for WiMAX Originated Mobile Scenario

Similarly, in WLAN originated scenario, the mobile M2 was initially connected with AP6 with same application of M1. At the point T4, handoff decision manager found that the QoS goes below the accepted threshold and the mobile terminal moves towards the point T6 with high speed. The proposed handoff algorithm performs handoff and it connects the mobile M2 with the base station since the estimated condition of WiMAX base station is good enough. The other reference scheme connects the mobile with AP4 and AP5 respectively at point T5. Finally, WLAN preferred scheme connects the M2 with WiMAX base station at point T6 just after the RSS based scheme. The simulation results for WLAN originated handoff is depicted in figure 4. From simulation, it is known that the proposed algorithm always selects the best access point or base station.

B. For Fixed Stations

A fixed device F was added to the simulation environment in overlapped cells as shown in figure 2. The F was initially served by AP3 with 700 kbps speed. Latter handoff decision manager found that the connection speed goes below the threshold 550kbps. It starts estimating the condition of the nearby access points. But no access point satisfies the bandwidth requirement of the ongoing application. After few seconds it found that the base station B1's condition is good enough and it performs handoff with B1. Other reference schemes have not performed handoff until the end of the simulation. The simulation result for fixed scenario is depicted in figure 5.

The average throughput achieves by the mobile and fixed devices, the number of unbeneficial handoffs, the number of beneficial handoffs are compared with the other two reference schemes. It is found that our proposed handoff scheme always performs well in all aspects.

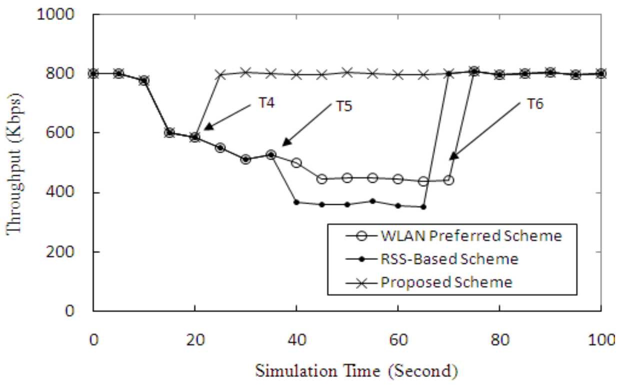

Fig. 4. Throughput Comparison for WLAN Originated Mobile Scenario

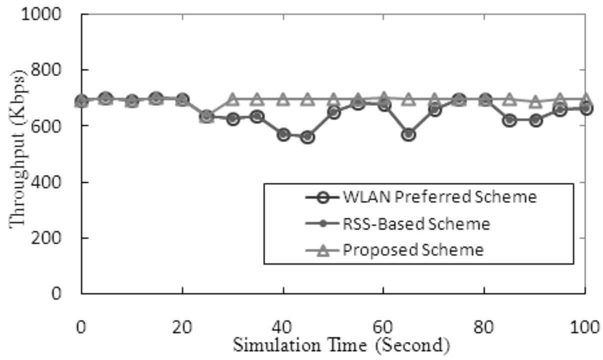

Fig. 5.Throughput Comparison in Fixed Scenario.

VII. CONCLUSION

This paper investigates the handoff-related issues in WLAN/WiMAX integrated overlay network. The handoff algorithms proposed for two different scenarios are evaluated and found that it perform always best for both fixed and mobile devices.

Also, our handoff algorithm considers the parameters like bandwidth requirement, available bandwidth, the speed of the mobile terminal, and SAR value. This SAR based handoff helps the mobile users in saving battery power and in reducing the biological effects of EM signal on the human body. Thus our proposed handoff scheme improves the QoS and it protects the human health.

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