# An Efficient Vertical Handoff Technique for Two-Tier Heterogeneous Networks

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***Abstract***— Integration of cellular networks and Wireless local area networks (WLANs) will be very useful for development of fourth generation communication technologies. The integration of two or more networks would be done by employing techniques of vertical handoff across different radio access networks. Internetworking system can offer users with ubiquitous connectivity as well as high-speed data access in high user density locations known as "Hotspots". We propose a simple vertical handoff technique using these interface switching mechanisms to enable transparent roaming across these two complementary access networks. Simulation studies show that our proposed approach results in a better vertical handoff experience as compared to existing techniques.

***Keywords***-- Two tier Heterogeneous networks, WLAN, UMTS, MN and vertical handoff.

## I. INTRODUCTION

Two-tier Heterogeneous [1] networks are an attractive means of increasing mobile network capacity and providing Quality of Service [2]. A heterogeneous network is mainly consists of two or more radio access technologies, architectures, transmission solutions and transmitting base station (BS) antennas of varying transmission power. For the end users this heterogeneity could result in being always best connected [3]. UMTS networks provide ubiquitous connectivity [4] with relatively low data rates but the mobility is relatively high. WLAN networks can offer higher data rates compared to UMTS network but they cover very small areas with low mobility. Heterogeneity might also be a way for network operators to reduce capital expenses. Deploying different access technologies in specific locations can avoid expensive large scale deployment operators and service providers can build new service models by combining different radio access technologies such as UMTS/WLAN interworking [4]. The main objective regarding the interworking network stems from the fact that these technologies are complementary. Any access technology or service provider cannot provide ubiquitous coverage and required services to the users anytime and anywhere. The integration of complementary wireless technologies with overlapping coverage can provide the ubiquitous coverage and achieve always best connected. In a two-tier heterogeneous access network, low tier [1] consist wireless IEEE 802.11 LAN. High tier [1] is comprised of a packet cellular network, such as UMTS. WLAN can provide high data rate at low cost. However, its coverage is limited to a small geographical area. UMTS networks can provide wide area coverage. However, cost of utilization is high and the provided data rate can not sufficient for the requirements of bandwidth intensive applications like HD video streaming. By integrating these two complementary technologies; UMTS and WLAN several benefits can be achieved, i.e., load balancing, extension of coverage area, better quality of service (QoS), improved security features, etc.

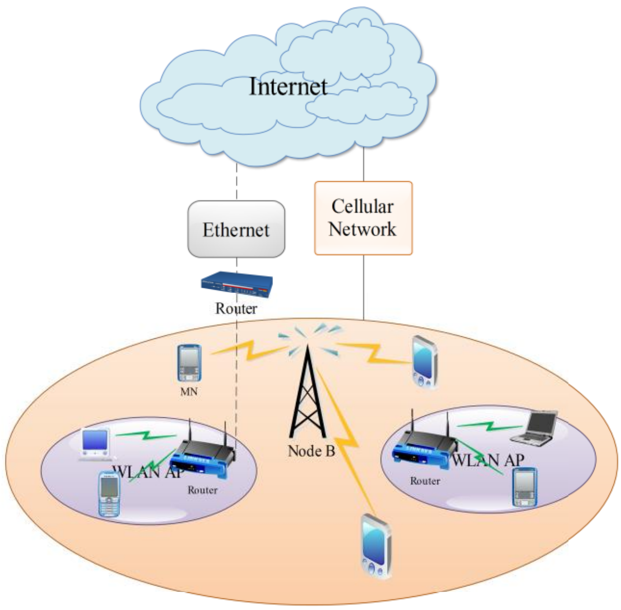



Fig. 1 Two-tier Heterogeneous Network

When a Mobile Node (MN) is under coverage of both networks in integrated UMTS-WLAN system the problem arises is which network should access and when it should switch from one network to other network. In Fourth generation networks, the Mobile Node (MN) will try to connect to a network which has strongest Received Signal Strength (RSS) among the available networks [5]. The MN may desire to switch to a network that is offering best services for the applications running on their MNs. The process of switching in wireless networks is referred as handoff (HO). The switching from serving access network to other access network is referred as vertical HO (VHO) [6]. When the HO is triggered on the basis of RSS, it is known as imperative VHO [7] and when it is triggered to satisfy QoS requirements of the user, it is known as alternative VHO [7]. An imperative VHO occurs due to weak RSS from any network and to keep connectivity to either of network. An alternative VHO initiates when a user require better performance i.e. more bandwidth connection. VHOs are generally of two types namely, upward VHO (UVHO) [1] and downward VHO (DVHO)[1] see Fig. 2. An UVHO is a HO to a wireless overlay with a larger cell size and generally lower bandwidth per unit area. So, an UVHO makes a mobile device disconnect from a network providing faster but smaller coverage to a new network providing slower but broader coverage. A DVHO is a HO to a wireless overlay with a smaller cell size, and generally higher bandwidth per unit area. A MN performing a DVHO disconnects from a cell proving broader coverage to one providing limited coverage, but higher access speed. In a heterogeneous network environment the challenge of choosing the best network is a major issue [4]. VHO process consists of three phases. They are system discovery, HO decision and HO execution [6]. The HO decision is most important step in the VHO process, based best access point which can support QoS of ongoing calls. This paper is organized as follows. Review of related work presented in section II. Section III presents the system description of integrated network architecture. Section IV contains the path loss models for UMTS and WLAN. Section V presents the vertical handoff decision algorithm. Simulation results presented in section VI and section VII concludes the paper.

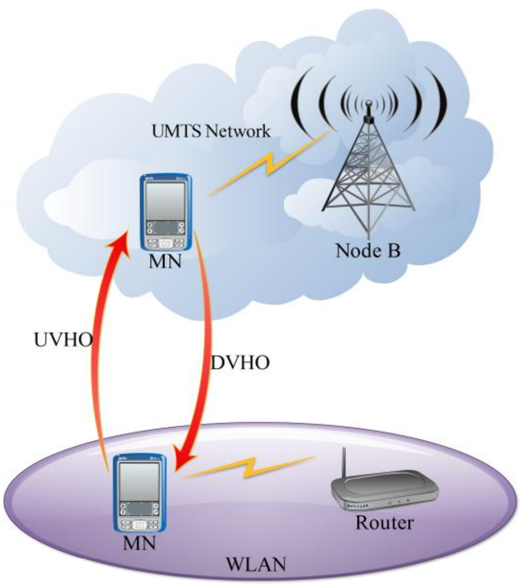



Fig. 2 Upward and Downward VHO

## II. REVIEW OF RELATED WORK

The studies in [4], proposed a WLAN first based HO in which HO decision based mainly on RSS value. In [5], VHO in heterogeneous networks is investigated and an optimal algorithm based on fuzzy logic is presented. Dwell timer based algorithm is proposed in [6], the HO scheme is maximizing mean throughput and minimizing HO delay. In [13], proposed two layer architecture in order to dedicate different layers to different types of subscribers according to their speed and the type of call (new or HO) in the same geographical area. In [8], proposed HO algorithm using threshold and hysteresis, as well as a HO algorithm based on distance and RSS measurements. The paper [9] proposes the signal strength model of MN and presents a new vertical handoff decision algorithm. The algorithm can adapt to the change of MN velocity and improve the handoff efficiency significantly. In [3], discusses an efficient network selection mechanism for next generation networks to guarantee mobile users being always best connected. Networks discover analysis was proposed in [10]. Then the MN decides whether to initiate handoff or not. We adopt a WLAN first based VHO algorithm decision algorithm that uses inputs as RSS values, signal thresholds and available radio resources. In [11] presents the effect of velocity on handoff delay and velocity has no significance on handoff delay experienced by user if the handoff is initiated based radio signal measurement. A time adaptive vertical handoff decision scheme for overlapping wireless networks is proposed in [12]. This scheme discovers all the available networks and then selects the most suitable network based on user preferences and service requirements.

## III. SYSTEM DESCRIPTION

The deployment schemes for wireless heterogeneous networks can be classified into two types; they are competitive and cooperative networking schemes [16]. For competitive scheme, different access technologies are provided by different network service providers. Each operator provides one access network. i.e., UMTS access provide by one network operator and WLAN service provided by another operator. For interworking of these two technologies, coordination of operations such as radio resource management [4] among service providers is mandatory. But it is very difficult in practical situations. The cooperative scheme is developed by mutual investments and ownership of different access technologies, opening up the possibilities for centralized coordination between them to optimize the design and performance of the integrated heterogeneous network. In this paper, we considered cooperative networking scheme.

HO decision mechanisms are categorised into three types. They are Mobile Controlled HO (MCHO), Network Controlled HO (NCHO) and Mobile Assisted HO (MAHO) [6]. In MCHO, MN is responsible for detecting HO. The MN continuously monitors the signal strength from neighbouring BSs and identifies if a HO is necessary. In NCHO scheme, MN does not involve in HO decision process. The BS monitors the signal strength used by MNs and if it falls below a threshold value then BS initiates HO. In MAHO scheme, every MN continuously measured the signal strength from surrounding BSs and notifies the strength data to the serving BS. The strength of these signals is analyzed, and a HO is initiated when the strength of a neighbouring BS exceeds the strength of the serving BS. In this paper, we used MAHO scenario.

An integrated network consists of different access technologies and a single MN should be capable of access both technologies. A dual mode MN [13] can able to communicate with both UMTS and WLAN. While the dual mode MN can access both WLAN and UMTS systems, it connects with only one access network at a time. A dual mode MN can easily measures the RSS values and able to switch between these networks when roaming in heterogeneous network. These measured RSS values are given as inputs to the VHO decision algorithm. The VHO algorithm is implements in VHO decision controller (VHDC) [5] for this entity. VHDC utilizes the media independent handover function (MIHF) [5] and the standard being developed by IEEE 802.11 to enable the handoff of IP sessions from one network to another. The MIHF facilitates standards based message exchange between the various access networks to share information about the current network conditions and available RRs, between itself and both types of access networks (APs and Node B).

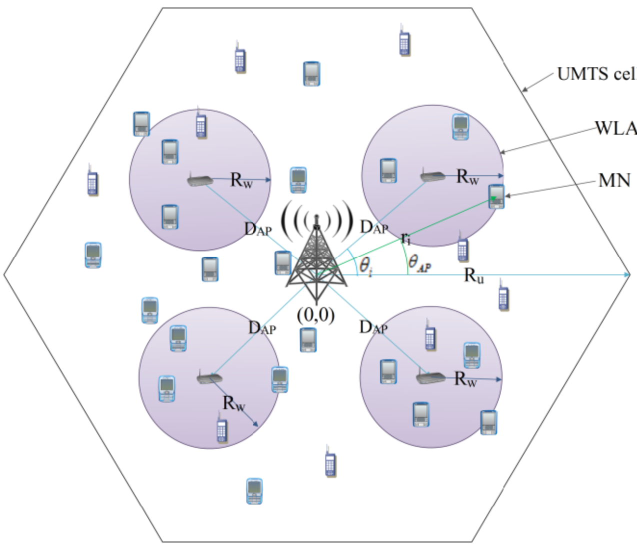



Fig 3. 3G-WLAN Heterogeneous Network Topology

### A. UMTS Node B

In cellular system a land area is divided into regular shaped cells, which can be any shape but hexagonal shape cells are conventional. Hexagonal shape cells have similar coverage of circular radiation pattern. Each UMTS cell is serving with one BS antenna is referred as Node B. Node B is located at the center of the cell and the position of Node B is taken as origin (0, 0) for calculations. The radius of cell is represented by $R_u$. Here, we considered only one cell. So, there is no neighbouring cell to make Horizontal HO. In this scenario, only vertical handoffs between Node B and WLAN AP are considered.

### B. WLAN APs

AP coverage limited to very few metres. The area of coverage is very less when compared to UMTS cellular coverage. We can deploy number of APs within a single UMTS cell coverage area. Each AP coverage area is referred as Hotspot. Each hotspot is served by an Omni directional antenna which is situated in the center of the hotspot. The antenna position can be calculated with reference to Node B. The two parameters are radial coordinate and angular coordinate. The radial distance is distance between Node B and the hotspot antenna and it is denoted by $D_{APi}$. The angular coordinate is the angle making with Node B and is represented by $\theta_{APi}$. The radius of coverage is given by $R_{wi}$. In our proposed architecture we made the following assumptions. All hotspots have the same coverage area, with radius equal $R_w$, Four APs having the same angular spacing and four APs have the same distance i.e., $D_{AP}$ from the origin Node B.

### C. MNs

In cellular networks, the RSS value depends on mobility of MN. When a MN moves away from a base station the signal level degrades and there is a need to switch to another base station. The MNs are generated in the simulation capable of access both network technologies. The location of MN is calculated by polar coordinates of the MN with reference to the UMTS Node B. The distance between Node B and MN is denoted by $r_j$ and angular coordinate is represented by $\theta_j$. Using the polar coordinates, the distance from Node B to MN and distance between WLAN AP and MN can be calculated. Then the RSS of both UMTS and WLAN at each MN can be measured. In simulation, the MNs are generated using two types of distribution schemes; normal distribution and random distribution schemes. In random distribution scheme, randomly distribute the radial and angular coordinates. Normally distribute the radial coordinate while keeping the angular coordinate random in the normal distribution scheme. We assumed that each MN uses data services in simulation and the data rate of all MNs is a constant of 64Kbps.

## IV. PATH LOSS MODELS

The path loss model for the 3G network cell in this simulation is the COST 231 (Walfisch-Ikegami) Non Line of Sight (NLOS) model [20] is given by

$$L_{uNLOS}[dB] = L_{FS} + L_{rts} + L_{MSD} \tag{1}$$

Here, $L_{FS}$ represents Free Space loss, $L_{RTS}$ is Roof-to-Street loss and $L_{MSD}$ is Multi Scale Diffraction loss

$$L_{FS} = 32.44 + 20\log_{10}^{f} + 20\log_{10}^{d} \tag{2}$$

$$L_{RTS} = -16.9 - 10\log_{10}^{sw} + 10\log_{10}^{f} + 20\log_{10}^{(h_{roof}-h_{rx})} + L_{or} \quad (3)$$

$$L_{MSD} = L_{bsh} + k_a + k_d \log_{10}^{d} + k_f \log_{10}^{f} - 9\log_{10}^{bu} \quad (4)$$

Where, $f$ = the frequency of network in MHz
$d$ = distance between cellular BS and MN in km.

$h_{roof}$ = height of the building roof

$sw$ = street width

$h_{rx}$ = height of the MN antenna

$h_{tx}$ = height of the BS antenna

$k_f$ = The increase of the path loss for BSs below the roof

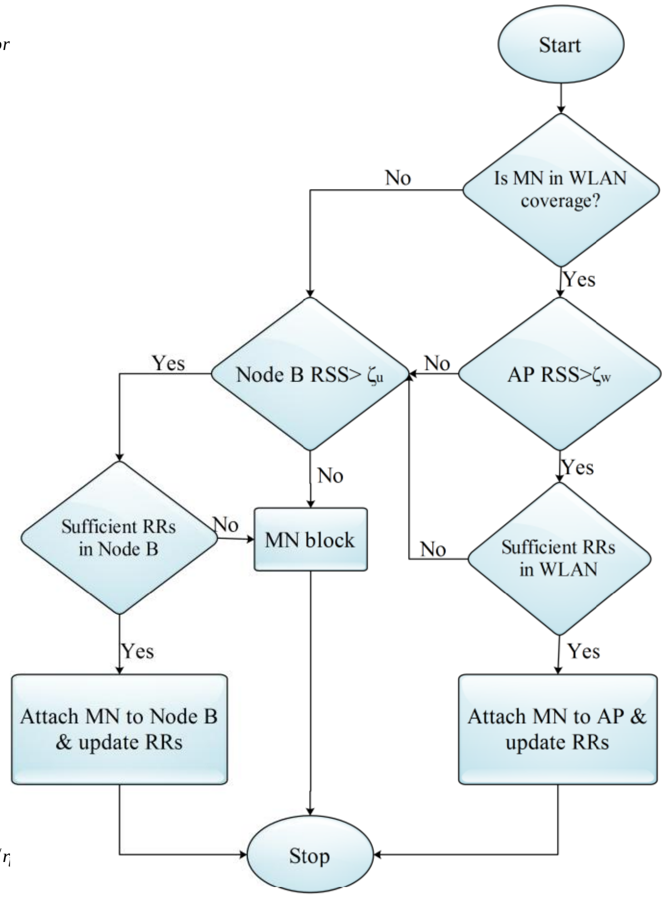
$k_a$ = 54 if $h_{tx}>h_{roof}$

$k_d$ = 18 if $h_{tx}>h_{roof}$

For the WLAN hotspots, the adopted path loss model for each hotspot in the simulation is the dual slope model [21] is given by

$$L_W[dB] = L_{ref} + 10n_1 \log_{10}^{(r_{i,j})} + 10(n_2 - n_1)\log_{10}^{(1+r_{i,j}/r_{i}} \quad (5)$$

Where, $r_{i,j}$ is the distance from the $MN_j$ to $AP_i$, $L_{ref}$ represents the reference path loss at $r_{i,j}$ = 1m and it is equal to 40dB and $n_1$ and $n_2$ are the path loss exponents before and after the breakpoint distance $r_b$ and are taken to be equal to 2 and 4 respectively.




Flowchart 1. VHO decision algorithm

TABLE 1. NETWORK PARAMETERS USED IN SIMULATION

| **Parameters** | **Values** |
|---|---|
| **UMTS Parameters** | |
| Cell range | 0-10km |
| Node B transmit power | 15dB |
| Bandwidth capacity | 12Mbps |
| Threshold | -149dB |
| Frequency | 2100 MHz |
| Height of BS | 25m |
| **WLAN Parameters** | |
| WLAN range | 50-250m |
| RF band | ISM 2.4 GHz |
| AP transmit power | -15dB |
| Bandwidth capacity | 2 Mbps |
| AP sensitivity | -110dB |
| AP antenna height | 2m |
| Breakpoint distance | 72m |
| **MN Parameters** | |
| MN required data rate | 64kbps |
| Average MN height | 2m |
| Number of MNs | 240 |

## V. VERTICAL HANDOFF DECISION ALGORITHM

In our proposed VHO decision algorithm (Flowchart 1), the VHDC maintains a list of all candidate service nodes available in its coverage area. In general, if an MN's connection can be supported by an available BS and an available AP, then the AP would be the preferred attachment point for that MN. This is due to higher data rate and lower bandwidth cost associated with an AP, compared to those associated with a BS. If the MN service at an AP, the RSS for the MN has dropped below a specified threshold, then the VHDC tried to search for other networks for connection handoff. In this case there exist multiple choices of APs for handoff, the VHDC evaluates the APs and then directs a handoff operation to the network with optimal performance/cost [2]. On the other hand, if no other APs are found for a possible handoff, then the cellular network would then be considered the best available wireless network. Even though the RSS from the Node B is usually greater than WLAN, HO is done with high priority since connecting to WLAN is more desirable because it provides more bandwidth and is cost effective. But when WLAN has heavy traffic or the channels are busy [17], it's better to not make HO to WLAN and MN remains connected to UMTS. Hence, VHDC consists of available radio resources information obtained from the MNs, and this available information is given as inputs to the VHO decision algorithm. Furthermore, VHDC periodically updates the available radio resources, which represents the current service node of each MN in the integrated network. The updated information and RSS values are given as input to algorithm. Two different predefined thresholds are used for making decision. The RSS threshold of WLAN and UMTS is denoted $\zeta_w$ and $\zeta_u$ respectively. Here we proposed WLAN fist based HO, in which if both are exist then first it checks for WLAN threshold. On the other hand, The MN will blocked due to HO failure may be occurring in any of the following three cases.

1. MN is accessing 3G network, but its RSS dropped below $\zeta_u$ but the MN is not in the coverage of any of the WLAN APs.
2. The current serving network is WLAN and its RSS dropped below $\zeta_w$, and there is no free channel in 3G network.
3. The MN connected to WLAN, but its RSS dropped below $\zeta_w$ and RSS of 3G network is also below $\zeta_u$. This case occurs for MNs close to or on the 3G cell boundaries.

## VI. SIMULATION RESULTS AND DISCUSSION

Simulation results are obtained by the measured RSS values and available RRS are given as input to the VHO algorithm. These results are used to determine the optimum radial distance between the Node B and WLAN AP ($D_{AP}$) and Relative size of WLAN AP with respect to UMTS cell ($R_w/R_u$) to minimize the HO failure probability. The Network parameters used in this simulation listed in Table 1.

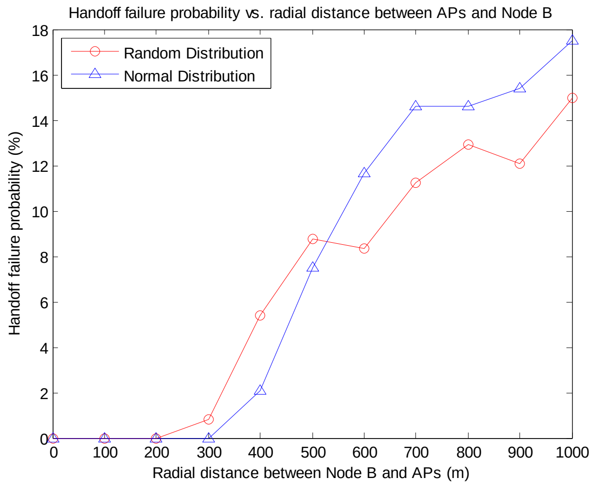



Figure 4 HO failures probability vs. radial distance between APs and Node B ($D_{AP}$)

The relation between the radial distances $D_{AP}$ and the HO failure probability with the two distinct mobile distribution schemes shown in Fig. 4. The radius of coverage of WLAN AP ($R_w$) is taken as 100m. The graph shows that below 500m, the HO failure probability for the random MNs distribution is greater than that of the normal MNs distribution. Because MNs density near Node B is greater than in normal distribution compared to random distribution. Above 500m the HO failure probability for normal distribution is greater than random distribution due to some of the MNs near the UMTS cell boundaries, previously blocked due to weak RSS, become coved by the APs, where as the normal distribution case MNs suffers insufficient radio resources near the origin Node B. So, the number of HO failure increases.

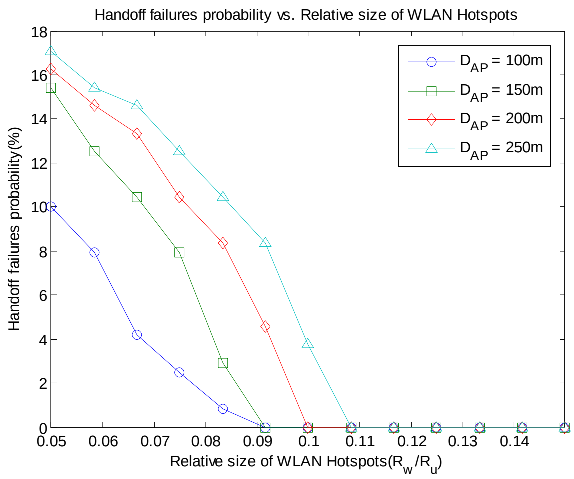



Figure 5 HO failures probability vs. Relative size of WLAN Hotspots ($R_w/R_u$)

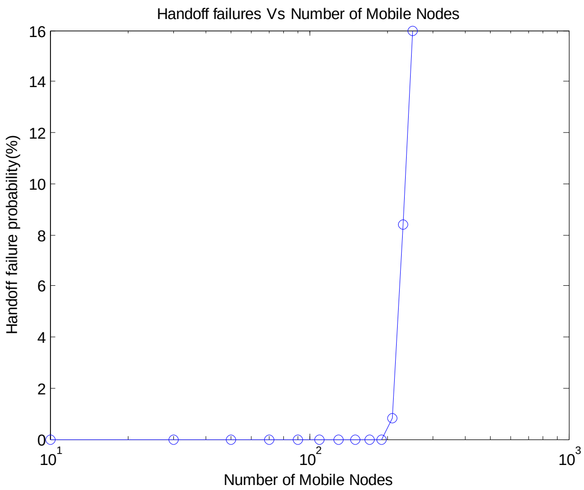



Figure 6. HO failures probability vs. number of MNs

In Fig. 5, the relation between the relative size of the WLAN hotspots ($R_w/R_u$) and the UMTS cell is shown. In this case, we used normal distribution scheme. We calculated the HO failure probability at different values of $D_{AP}$ while AP coverage is varying. From The figure we can say that the minimum HO failure probability occurs when $D_{AP}$ is greater than 100m. For each value of $D_{AP}$, when the relative size of hotspot increases the number of HO failure decreases. From Fig.4 and Fig. 5 we can say that minimum HO failure in our proposed internetworking architecture is obtained when $D_{AP}$ is 100m and $R_w/R_u$ is set to be 0.1. Fig.5 shows our proposed interworking architecture, $D_{AP}$ and $R_w/R_u$ is set to 100m and 0.1 respectively, and mobiles nodes are distributed using normal distribution scheme. The figure illustrates that the blocking probability increases as the number of MNs increase. Because the available radio resources are limited. So, the increase in HO requests will increase the HO failure.

## VII. Conclusion

Heterogeneous wireless networks with a hierarchical two-tier structure is a possible solutions for the next generation wireless systems have attracted a lot of research attention in recent years. This paper presents a simple vertical handoff algorithm for UMTS/WLAN integrated architecture to provide ubiquitous connectivity with less number of HO failures. The algorithm is WLAN first HO and HO initiation based on RSS values and available radio resources in the existing networks.

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