Improved Vertical Handover Decision Algorithm for UMTS-WLAN

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Abstract

Next generation wireless systems consist of heterogeneous wireless networks. Wireless LAN (WLAN) and cellular mobile radio systems will be important part of heterogeneous networks. Universal mobile telecommunication system (UMTS) provides wide-area coverage, high mobility but relatively low data rate. WLAN is designed for low-range, high/medium data rate access, low mobility and can be used as a complement to larger cellular mobile radio systems. In this paper, we consider a simple heterogeneous system of WLAN and UMTS cell. Vertical handover plays a vital role in ensuring quality of service in heterogeneous networks. In this paper, we proposed a vertical handover algorithm for an integrated cellular/wireless LAN system. The design goal is to provide the user the best available quality of service (QoS) at any time. Moreover, connections are handed over independently between UMTS and WLAN, aiming at seamless service continuity. Here we have taken handover rate, probability of outage and probability of handover as the performance metrics. Simulation results show that adaptive vertical handover algorithm improves the performance.

Keywords: *Vertical handover algorithm, Heterogeneous wireless network, Probability of handover and probability of outage*

1. Introduction

In recent years, wireless networks have emerged and played key roles in modern telecommunications. General Packet Radio Service (GPRS) enables Global System for Mobile Communications (GSM) users to access IP networks, such as the internet, and third-generation (3G) cellular systems, such as Universal Mobile Telecommunications System (UMTS) and cdma2000. In the evolution of cellular networks, one problem is that the data rates in these networks are limited. The data rate in GPRS is up to 144 kb/s, in UMTS it is from 384 kb/s to 2 Mb/s. One widely acceptable way to deal with this limitation is the complementary use of wireless local area network (WLAN) [1,2] technology in hot spot areas (e.g., business centers, airports, hotels, and campuses) since WLAN can provide up to 54 Mb/s data rate with coverage of a few thousand square meters around a single access point. Numerous interworking architectures between 3G cellular and WLAN systems have been proposed in the technical literature. The most important objective is to enable 3GPP cellular network subscribers to access WLAN service. A WLAN terminal equipped with a 3GPP subscriber identity module (SIM)/universal SIM (USIM) smart card can access both the 3GPP subscriber database and WLAN. In this article, we focus on handover between cellular system and WLAN. The major challenge in selecting a network is to decide the most favorable trade-off among user preference, service application, and network condition. Network selection is typically carried out in three steps. The first step is collecting the necessary information that has some impact on the final decision. The information might be user preference, service application, and network condition. The second step is using the collected information as inputs to a certain handover algorithm that aims to keep the user always best connected (ABC) [3]. The meaning of ABC is that the user is not only connected but also enjoys the best achievable QoS at any time and any place. The last step is making a decision according to the algorithm's output. A number of researchers proposed network selection algorithms in the literature [4, 5]. The most important is received signal strength (RSS) based algorithm that uses the threshold and hysteresis values as input parameters [6-10]. ABC is the design goal, which means the best network is always selected. One of the major challenges for seamless mobility is the availability of simple and efficient vertical handover scheme, which is the decision for a mobile node to handover between different types of networks, cellular wireless network and wireless local area networks (WLANs). Vertical handover schemes will play a main role in the IEEE 802.21 standard and shall pave the road for emergence of 4G overlay multi-network atmosphere.

In this article, we consider UMTS and WLAN as network alternatives. The proposed technique would, however, be applicable to systems with more heterogeneity (e.g., cdma2000-WLAN, GPRS, WLAN), and this will be the subject of future work.

The remainder of this paper is organized as follows: In Sect. 2, we briefly introduce the vertical handover. System model for UMTS-WLAN Handover is given in Sect. 3. The proposed handover decision algorithm is given in Sect. 4 followed by performance metrics in sect.5 and result and discussion in Sect. 6. Finally, we draw our conclusions in Sect. 7.

2. Overview of Vertical Handover

For ubiquitous coverage, trend is to integrate complementary wireless technologies with overlapping coverage. The state of the art mobile devices in beyond third generation (B3G) networks will be equipped with multiple network interfaces for accessing different networks. Users will expect to continue their connections without any disruption when they move across networks using different technologies. This process in wireless technology is known as vertical handover. In heterogeneous wireless networks, cellular networks using one access technology and WLANs using different technology will coexist. In such situation, transfer of ongoing connection from base station (BS) of cellular network to access point (AP) of WLAN is possible only by vertical handover mechanism. Vertical handover is more complex process than horizontal handover due to additional parameters. A decision for vertical handover may depend on several factors (such as network bandwidth, load, coverage, cost, security, price, speed, power consumption and QoS) related to the network to which the mobile node is already connected and to the one that it is going to handover. Handover is needed or not is indicated by handover metrics. New handover metrics should be considered along with signal strength for next generation heterogeneous wireless environment.

Several parameters have been proposed in the research literature for use in the vertical handover algorithms. Some of them have been briefly explained below [11, 12, 13, 14, 15, and 16].

Received Signal Strength (RSS) is generally used for handover because it is easy to measure and is directly related to the quality of service. RSS is directly associated with the distance between mobile station (MS) and its point of attachment. Nearly all horizontal handover algorithms use RSS as the main decision criterion, and RSS is an important criterion for vertical handover decision (VHD) algorithms.

Network Conditions related parameters like traffic, available bandwidth, network latency, and packet loss may need to be considered for effective network usage. Networks information can be useful for load balancing across different networks.

Data Rate is a measure of quality of service of the network. It is a good indicator of the traffic conditions in the access network and is especially important for delay-sensitive applications.

Power Consumption is very important criterion because wireless devices operate on limited battery power. In such situations, it would be preferable to hand over to a point of attachment with low power consumption. If battery of MS is low then it is advisable to hand over to UMTS from WLAN.

Cost of Service: For different networks, there would be different charging policies; therefore, the cost of a network service will probably influence the handover decisions.

Security: Confidentiality or integrity of the transmitted data is very important for some applications. Therefore, a network with higher security level may be chosen over another one, which would provide lower level of data security.

User Preferences: A user's personal preference is one of the most essential criteria in vertical handover algorithm. For high data rate application, user will like to handover to the network with high data rate and if user can not afford high cost then certainly user will move to the cheaper network.

3. System Model

We consider a UMTS and WLAN cells adjacent to each other as shown in fig.1. The simplest mobility model is the user traveling in a straight line at a constant speed have been considered and assumed that MS moves with constant speed from the UMTS BS along a straight line towards WLAN access point. D is the distance between the BS and AP. MS samples the pilot signal strength measurements at regular distance intervals $d = kd$s, where ds is the sampling distance (ds = 1m) and k, an integer with $k \in [0, D/d\text{s}]$. Both, base station and access point are assumed located in the center of the respective cell and operating at the different transmitting powers.

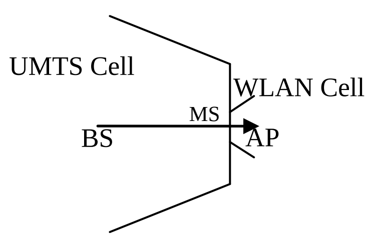

Fig. 1 Vertical Handover

Received Signal Strength (RSS) at MS consists of path loss attenuation with respect to distance, Shadow fading, and fast fading [17, 18]. The propagation attenuation can be expressed as the product of the η^{th} power of distance and a lognormal component representing shadow fading losses [19]. These represent slowly varying variations even for users in motion and apply to both reverse and forward links. For MS at a distance d from BS or AP, attenuation can be expressed as.

$$\alpha(d,\zeta) = d^{\eta} 10^{\frac{\zeta}{10}} \quad (1)$$

Where ζ is the dB attenuation due to shadowing, with zero mean and standard deviation σ. Alternatively, the losses in dB are

$$\alpha(d,\zeta)[dB] = 10\eta \log d + \zeta \quad (2)$$

Where, η (eta) is path loss exponent and d represents BS to MS or AP to MS separation in kilometers. The autocorrelation function between two adjacent shadow-fading samples is shown in [20]. Let the transmitted power of BS or AP is P_t, the signal strength received by MS can be written as

$$S(d) = P_t - \alpha(d_i,\zeta) \quad (3)$$

The rectangular averaging window can be used to alleviate the effect of shadow fading according to the following formula [21, 22]

$$\hat{S}(k) = \frac{1}{N_w} \sum_{n=0}^{N-1} S(k-n) W_n \quad (4)$$

Where $\hat{s}_i$ is the averaged signal strength and s_i is the signal strength before averaging process. W_n is the weight assigned to the sample taken at the end of $(k - n)^{th}$ interval. N is the number of samples in the averaging window

$N_w = \sum_{n=0}^{N-1} W_n$. In the case of rectangular window $W_n = 1$ for all n.

Shadow fading in the present work is modeled as follows [23, 24]

$$\zeta(k) = \rho\zeta(k-1) + \sigma_i \sqrt{(1-\rho^2)} W(0,1) \quad (5)$$

Where ρ (rho) is correlation coefficient, σ is standard deviation of shadow fading and $W(0,1)$ represents truncated normal random variable.

Shannon's Theorem gives an upper bound to the data rate of a link, in bits per second (bps), as a function of the available bandwidth and the signal-to-noise ratio of the link. The Theorem can be stated as [25]:

$$D = W * \log_2 \left(1 + \frac{S}{N}\right) \quad (6)$$

Where D is the maximum theoretical channel data rate, W is the bandwidth of the link, $\frac{S}{N}$ is the ratio of average signal power to average noise power.

4. Vertical Handover Algorithm

The integration of cellular network and WLAN is the trend of the beyond 3G mobile communication systems, and mobile station will handover between the two kinds of networks. The received signal strength (RSS) is the dominant factor considered in the case of handover. However, signal power level of different network is dissimilar. Therefore, in the case of vertical handover signals from different networks can not be compared like horizontal handover. Hence, horizontal handover algorithms can not be used in heterogeneous network. In this paper, new vertical handover algorithm based upon normalized power has been proposed. MS will be handed over to WLAN if S_{W_n} exceeds S_{U_n} in following way.

$$S_{W_n} \rangle S_{U_n} \tag{7}$$

Where, S_{U_n} and S_{W_n} are the normalized signal power received by the MS from the UMTS and the WLAN respectively.

Handover to UMTS will be made if S_{U_n} exceeds S_{W_n} in the following way.

$$S_{U_n} \rangle S_{W_n} + hys \text{ margin} \tag{8}$$

Performance of vertical handover can be enhanced by using distance based adaptive hysteresis margin shown below.

$$hys \text{ margin} = \max\left\{20\left(1-\left(\frac{X}{R}\right)^4\right), 0\right\} \tag{9}$$

Where X is the distance of MS from WLAN access point and R is the radius of WLAN cell.

In heterogeneous networks, data rate is very important factor for selection of network. So depending upon user preference UMTS to WLAN handover may take place if D_{WLAN} exceeds D_{UMTS} in following way.

$$D_{WLAN} \rangle D_{UMTS} \tag{10}$$

Where D_{WLAN} and D_{UMTS} are the maximum achievable theoretical data rate in WLAN and UMTS respectively.

Vertical handover decision is shown in given in Fig.2

5. Performance Metrics

This section discusses performance metrics used to evaluate soft handover algorithm:

Handover rate: Reducing the number of handovers is usually preferred, as frequent handovers would cause wastage of network resources. Ping-pong effect in handovers should be minimized.

Probability of Handover: Probability of handover at the boundary should be very high for improving the performance of the system. In ideal case, probability of handover should be one at the boundary and handover area should be small.

Probability of outage: Here probability of outage refers to the fact that MS is not connected to any network. Probability of outage is used to describe the quality of service.

6. Results and Discussion

In this section, handover rate, probability of outage and probability of handover have been computed as the function of different system parameters and characteristic parameters of radio propagation environment. Numerical results for this performance metric are obtained via computer simulation for the system parameters indicated in Table 1. System simulation is performed in Matlab 7.0. To obtain probability of outage for each system parameter setting, 10000 runs of the simulation program are performed.

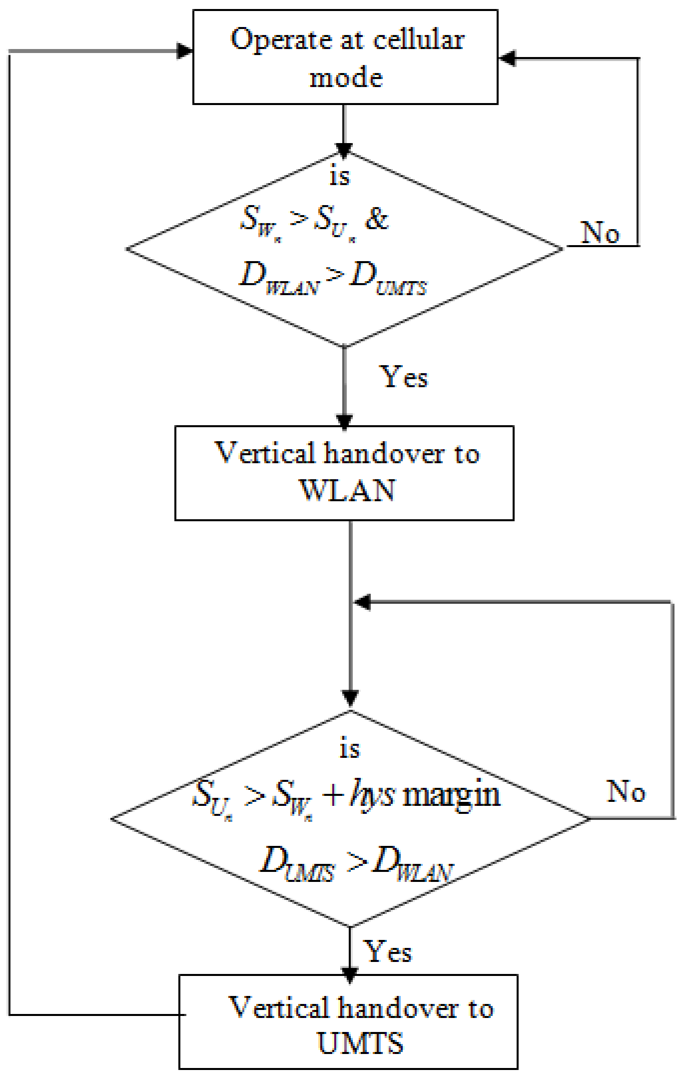

Fig.2 Vertical Handover between UMTS and WLAN

Fig. 3 shows the plot of received signal strength from UMTS base station and WLAN access point with respect to distance. Here same environmental condition has been considered for both networks.

Fig. 4 shows the handover rate versus hysteresis margin plot. This plot shows that handover rate decreases with the increase of hysteresis margin. Unnecessary handovers can be reduced by increasing hysteresis margin. Nevertheless, large hysteresis margin increases the probability of outage and handover delay. Handover delay refers to the duration between the initiation and completion of the handover process. Handover delay is related to the hysteresis margin, and reduction of the handover delay is especially important for delay sensitive voice or multimedia sessions.

Therefore, hysteresis margin should not be very high nor it should be very low. Simulation with adaptive handover margin shows handover rate equal to 2.26. This value is neither very low nor very high. This result shows the advantage of adaptive hysteresis margin over fixed hysteresis margin.

Table 1.System Parameters for System Simulation

D = 1100 m	Distance between UMTS base station and WLAN access point
S_{min}=-90dBm	Minimum acceptable signal to maintain the call
d_s = 1m	Sampling distance
P_{tUMTS} = 30dBm	UMTS Base station transmitter power
P_{tWLAN} = 0dBm	WLAN access point transmitter power
R_{UMTS}=1000m	Radius of UMTS cell
R_W=100m	Radius of WLAN cell
W_{UMTS}=5MHz	Bandwidth of UMTS
W_w=20MHz	Bandwidth of WLAN

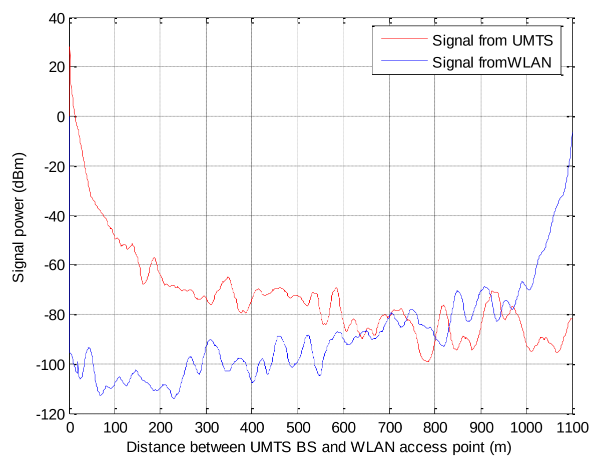

Fig.3 Received Signal Power versus Distance for given $\rho = 0.5, \sigma = 8dB, \eta = 3.6$

Probability of handover is very important factor for seamless handover. Fig. 5 shows the probability of handover for different hysteresis margin in the case of MS moving from UMTS to WLAN. Handover should occur near the boundary for better performance of network. Ideally, Probability of handover should be one at the boundary and zero when MS is away from the boundary for given simulation model. However, practically it is not possible. Hence vertical handover should be designed in such a way that rate of increase of probability of handover should be very high near the boundary. Plot shows that adaptive hysteresis margin gives best performance compared to fixed hysteresis margin. Adaptive handover algorithm will decrease unnecessary handover when MS is away prom boundary and handover will take place only when MS is very near to boundary.

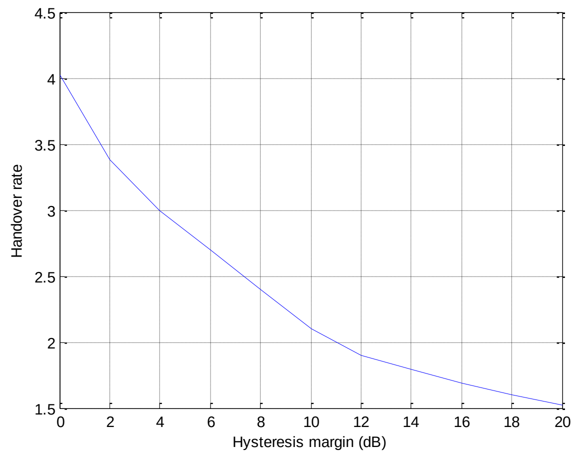

Fig.4 Handover Rate versus Hysteresis Margin for given $\rho = 0.5, \sigma = 8dB, \eta = 3.6$.

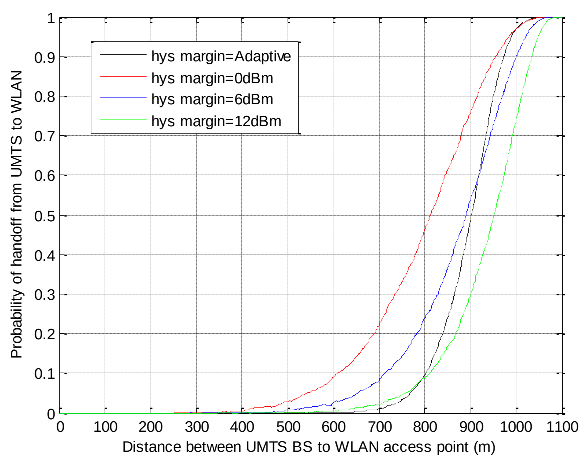

Fig.5 Probability of Handover from UMTS to WLAN versus Distance for given $\rho = 0.5, \sigma = 8dB, \eta = 3.6$

Fig. 6 shows the probability of outage versus distance plot. This plot shows that probability of outage increases with the increase of hysteresis margin. With large hysteresis margin, probability of outage is high but at the same time, probability of handover is very high near the boundary. In the case of adaptive handover algorithm, probability of outage is not very high but probability of handover at boundary is high. Therefore, it is better to use adaptive handover algorithm for enhancing vertical handover performance.

Fig. 7 shows the variation of maximum theoretical data rate with distance for both networks UMTS and WLAN. This plot shows that data rate of WLAN is very high near the access point and decreases with distance. Data rate in UMTS is low compared to WLAN but coverage area is more. Hence, for low data rate application and high mobility user UMTS is better network. High mobility user will not like to be connected with WLAN due to its low coverage area and frequent handover will increase network load. 4G networks will use multimodal MS and in such case, handover will be based upon user preference. Hence, for high data rate application and low cost MS will handover to WLAN.

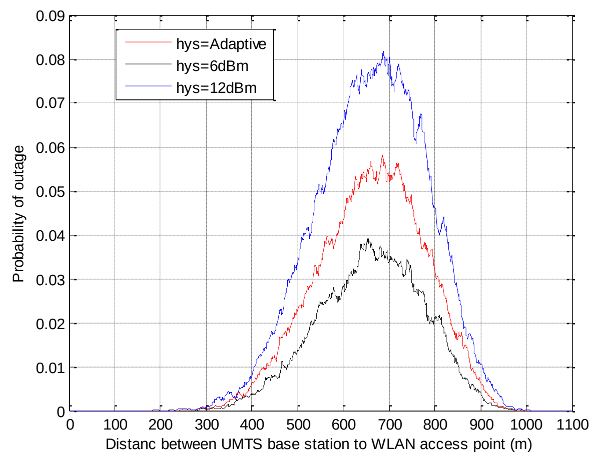

Fig.6 Probability of Outage versus Distance. $\rho = 0.5, \sigma = 8dB, N = 20$

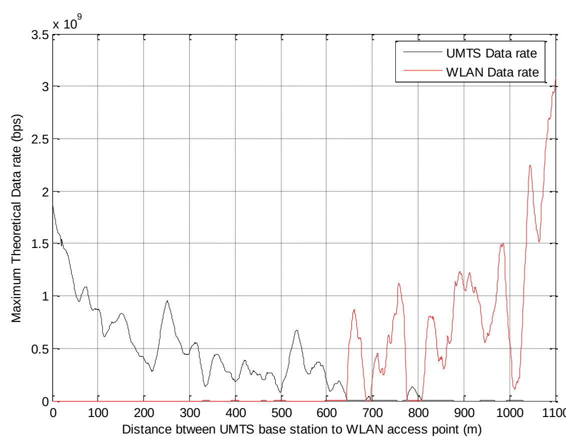

Fig.7 Data Rates of UMTS and WLAN versus Distance

7. Conclusion

In this paper, a novel handover scheme has been presented for the vertical handoff between UMTS and WLAN for guaranteeing the best QoS by selecting the most suitable network whereas preventing frequent handovers. It is based on absolute signal strength, distance and data rate. Results show that proposed algorithm outperforms the conventional algorithm based on signal strength measurements. Simulation result shows that adaptive handover algorithm outperforms the handover algorithms with fixed hysteresis margin. The present study may be significant in enabling the deployment of seamless networks. The approach presented in this paper may be applied for traffic load sharing between UMTS and WLAN. This can be achieved by adapting the threshold parameter settings on distance and signal strength measurements as functions of traffic load conditions. The MS can be directed from serving network to another if the first network becomes heavily loaded and vice -versa. This will increase the overall traffic carrying capacity of the integrated network. Simultaneously, it will improve the QoS by making more radio and network resources available to the users irrespective of the network, it is initially associated with. Another issue deserving further explanation is the adaptation of the algorithm design parameters to varying system parameters and their optimization.

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