Combined SINR Based Vertical Handoff Algorithm for Next Generation Heterogeneous Wireless Networks

Conference or Workshop Item

How to cite:

Yang, Kemeng; Gondal, Iqbal; Qiu, Bin and Dooley, Laurence (2007). Combined SINR Based Vertical Handoff Algorithm for Next Generation Heterogeneous Wireless Networks. In: Global Telecommunications Conference (GLOBECOM '07), 26-30 Nov 2007, Washington DC.

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.1109/GLOCOM.2007.852

Combined SINR Based Vertical Handoff Algorithm for Next Generation Heterogeneous Wireless Networks

Kemeng Yang, Iqbal Gondal, Bin Qiu and Laurence S. Dooley
Faculty of Information Technology
Monash University
Melbourne, Australia

***Abstract*—Next generation heterogeneous wireless networks offer the end users with assurance of QoS inside each access network as well as during vertical handoff between them. For guaranteed QoS, the vertical handoff algorithm must be QoS aware, which cannot be achieved with the use of traditional RSS as the vertical handoff criteria. In this paper, we propose a novel vertical handoff algorithm which uses received SINR from various access networks as the handoff criteria. This algorithm consider the combined effects of SINR from different access networks with SINR value from one network being converted to equivalent SINR value to the target network, so the handoff algorithm can have the knowledge of achievable bandwidths from both access networks to make handoff decisions with QoS consideration. Analytical results confirm that the new SINR based vertical handoff algorithm can consistently offer the end user with maximum available bandwidth during vertical handoff contrary to the RSS based vertical handoff, whose performance differs under different network conditions. System level simulations also reveal the improvement of overall system throughputs using SINR based vertical handoff, comparing with the RSS based vertical handoff.**

***Keywords*—Vertcal handoff, SINR, heterogeneous wireless networks**

I. INTRODUCTION

For seamless communication, the integration of WLAN and third generation (3G) cellular networks such as WCDMA system should be error free to achieve the next generation multimedia wireless networks. The seamless and efficient handoff between different access technologies known as vertical handoff is essential and remains a challenging problem.

All previous studies on vertical handoff [1-6] are using *Received Signal Strength* (RSS) as the basic handoff decision indicator, in which handoff decisions are made by comparing the RSS with the preset threshold values. However, the achievable data rate of a mobile device is a function of received *Signal to Interference and Noise Ratio* (SINR), which is proportional to the distance between Access Point (AP) or Base Station (BS) to the mobile user, as well as the current interference level in the network. Using RSS based vertical handoff, a mobile device will handoff to another network, when it can not receive the pre-established minimum receiving power from the original network. Use of RSS based vertical handoff in integrated WLAN and WCDMA networks to support multimedia services cannot provide the user with the multimedia QoS throughout, as the vertical handoff algorithm itself is not QoS aware. This may result in premature handoff from a WLAN to WCDMA, even though the user achievable data rate from WLAN is still much higher than it may get from WCDMA.

Using the RSS as the handoff indicator, we are not achieving the best possible performance of the integrated wireless networks. To provide seamless handover between WLAN and WCDMA, a SINR based vertical handoff that can support multimedia QoS with adaptive data rate is desirable. The new vertical handoff algorithm not only can support the user with multimedia QoS and allow them achieving the maximum throughputs during vertical handoff, but also makes the load balancing between WLAN and WCDMA systems practical. Moreover, since the SINR based horizontal handoff [7] is already being used within WCDMA systems, in order to have a unified radio resource management strategy for the heterogeneous wireless network, it is essential to also have a SINR based vertical handoff. By having a SINR based vertical handoff residing in Radio Network Controller (RNC) together with the SINR based horizontal handoff, we can apply the unified radio resource management strategy to provide seamless mobility, multimedia QoS provision and load balancing.

In this paper, we propose a novel vertical handoff algorithm using SINR instead of RSS as the handoff criterion. Combined effects of both SINR from WLAN and WCDMA are being considered to decide on the handoff. Analysis results show that SINR based vertical handoff provides higher average throughput for end users comparing with the RSS based vertical handoff with various thresholds settings, and also can adapt to different network conditions, such as different noise level and load factor. Simulation results further confirm that the SINR based vertical handoff improves the overall system throughputs. The paper is organized as follows. The SINR based vertical handoff strategy is presented in Section II, while Section III describes the system model. Section IV analyses and discusses the user end performance of different vertical handoff algorithms, while the system level simulation and results are presented in Section V, with some conclusions being provided in Section VI.

II. SINR BASED VERTICAL HANDOFF STRATEGY

Maximum achievable data rate for the given carrier bandwidth and SINR can be determined with the help of Shannon capacity formula, the maximum achievable data rate R is given by:

$$R = W \log_2(1+\frac{\gamma}{\Gamma}) \qquad (1)$$

Where:

- W is the carrier bandwidth
- γ is SINR received at user end when associated with WLAN or WCDMA
- Γ is the dB gap between uncoded QAM and channel capacity, minus the coding gain.

Let R_{AP} and R_{BS} be the maximum achievable downlink data rate while user connected with WLAN and WCDMA. From Shannon capacity, we have:

$$R_{AP} = W_{AP} \log_2(1+\frac{\gamma_{AP}}{\Gamma_{AP}}) \qquad (2)$$

$$R_{BS} = W_{BS} \log_2(1+\frac{\gamma_{BS}}{\Gamma_{BS}}) \qquad (3)$$

Where, γ_{AP} and γ_{BS} are the receiving SINR from WLAN and WCDMA respectively. We are interested in the relationship between required γ_{AP} and γ_{BS} while offering the same downlink data rate to the user by WLAN and WCDMA.

Letting $R_{AP} = R_{BS}$, we can solve the equation and get the relationship between γ_{AP} and γ_{BS} as:

$$\gamma_{AP} = \Gamma_{AP}((1+\frac{\gamma_{BS}}{\Gamma_{BS}})^{\frac{W_{BS}}{W_{AP}}} - 1) \qquad (4)$$

The parameters in (4) are:

- The carrier bandwidth for WLAN W_{AP} is 1MHz [8], and 5MHz for WCDMA W_{BS} [7].
- Γ_{AP} equals to 3dB for WLAN [8], and Γ_{BS} equals to 16dB for WCDMA [7].

Having the relationship between the maximum achievable data rate and the receiving SINR from both WLAN and WCDMA makes the SINR based vertical handoff method applicable, in which the receiving SINR from WCDMA γ_{BS} is being converted to the equivalent γ_{AP} required to achieve the same data rate in WLAN, and compared with the actual receiving SINR from WLAN. With the combined effects of both SINR being considered, handoff is triggered while the user is getting higher equivalent SINR from another access network. It means that given the receiver end SINR measurements of both WLAN and WCDMA channel, the handoff mechanism now has the knowledge of the estimated maximum possible receiving data rates a user can get from either WLAN or WCDMA at the same time within the handover zone, where both WLAN and WCDMA signal are available. This gives the vertical handoff mechanism the ability to make handoff decision with multimedia QoS consideration, such as offer the user maximum downlink throughput from the integrated network, or guarantee the minimum user required data rate during vertical handoff.

Our model is based on the WLAN and WCDMA integration architecture using very tight coupling [9, 10], in which WLAN is directly connected to RNC via the Inter-Working Unit (IWU), as shown in Figure 1. The SINR based vertical handoff can operate under active mode or passive mode. In active mode, the user is continuously seeking for maximum available bandwidth from the integrated networks. The user keeps measuring receiving SINR for WLAN and WCDMA, conducting the γ_{AP} to γ_{BS} conversion and sending the handoff request to the RNC based on the SINR comparison results. In the passive mode, the measurements of user receiving SINR from both WLAN and WCDMA are periodically sent to RNC directly, in which the handoff decisions are made according to the SINR values, the user specific QoS requirements, as well as the cell congestion conditions. Obviously, the passive mode is preferable from the network operator's point of view, because of the comprehensive handoff strategies with the ability of traffic and load control for both WLAN and WCDMA. However, the active mode has the advantage of self detection, and resulting in less handoff delays, and also can be deployed for cells under low load condition.

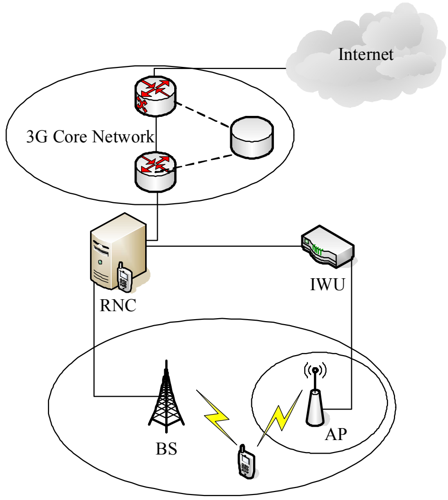

Figure 1: WLAN and WCDMA Integration Architecture

III. SYSTEM MODEL

In this research, we concentrate on the downlink traffic, as they normally require higher bandwidth than uplink, especially for multimedia services such as video streaming using the HSDPA channel while connected with WCDMA.

The SINR $\gamma_{APj,i}$ received by user i from WLAN AP_j can be represented as:

$$\gamma_{APj,i} = \frac{G_{APj,i}P_{APj}}{P_B + \sum_{\substack{k\in AP \\ k\neq j}} G_{APk,i}P_{APk}} \tag{5}$$

Where:

- P_{APj} is the transmitting power of AP_j
- $G_{APj,i}$ is the channel gain between user i and AP_j
- P_B is the background noise power at user receiver end.

The SINR $\gamma_{BSj,i}$ received by user i from WCDMA BS_j can be represented as:

$$\gamma_{BSj,i} = \frac{G_{BSj,i}P_{BSj,i}}{P_B + \sum_{k\in BS}(G_{BSk,i}P_{BSk}) - G_{BSj,i}P_{BSj,i}} \tag{6}$$

Where:

- P_{BSk} is the total transmitting power of BS_k
- $P_{BSj,i}$ is the transmitting power of BS_j to user i
- $G_{BSj,i}$ is the channel gain between user i and BS_j

A macro-cell propagation model for urban and suburban areas [11] is used, and for a antenna height of 15 metres, the path loss is:

$$Pathloss\,(dB) = 58.8 + 21\log_{10}(f) + 37.6\log_{10}(R) + \log(F)$$

Where f is the carrier frequency (2GHz for WCDMA, 2.4GHz for WLAN), R is the distance in metres between the user and the BS or AP, and log(F) is the log-normal distribution shadowing with standard deviation σ=10dB.

The following common conditions and assumptions [7, 12, 13] are used:

For WCDMA HSDPA:

- BS transmits to only one user via HSDPA channel at a time, with maximum available power to achieve the optimal physical rate.
- Maximum BS transmitting power is 40dBm.
- The total of pilot channel and other common channels combined power is 33dBm.
- The ratio of total allocated BS transmits power to HSDPA channel is 50%.
- The ratio of received power of target-cell to own-cell base station by the user is 65%.
- Average downlink load factor is 75% in all cells, with the total transmitting power of BS equals to 75% of the maximum BS transmitting power.
- User end background noise power equals to $7.66*10^{-14}$W.

For WLAN:

- Distributed Coordination Function (DCF) is used and only one station can transmit at one time.
- Maximum AP transmitting power is 20dBm.
- Background noise power equals to -96dBm.

IV. USER-END PERFORMANCE ANALYSIS

In the user end performance analysis, we consider a point to point model, in which a user is moving at speed v from AP (X_1) to BS (X_2), as shown in Figure 2. The vertical handoff is taken place at handoff point X_h.

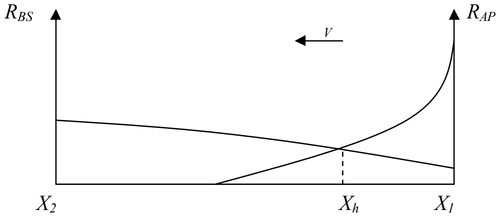

Figure 2: Point to Point Model

The total downlink throughputs θ can be represented as:

$$\theta = \int_{X_1}^{X_h} R_{AP}(x)\times CRT_{AP} + \int_{X_h}^{X_2} R_{BS}(x)\times CRT_{BS} \tag{7}$$

Where CRT_{AP} and CRT_{BS} is the cell residence time inside WLAN and WCDMA. R_{AP} and R_{BS} is the maximum bit rate received from WLAN and WCDMA. To offer the user maximum downlink throughput max(θ), we are aiming at finding the optimum handoff point X_h. For the RSS based vertical handoff, the X_h for user i is constrained by the receiving power $G_{APj,i}P_{APj}$ from AP_j. In SINR based vertical handoff, the X_h for user i depends on the relationship between receiving SINR $\gamma_{APj,i}$ from AP_j and $\gamma_{BSj,i}$ from BS_j. Therefore, we should be able to compare the average throughputs for different vertical handoff algorithm with different X_h.

We compare our SINR based vertical handoff algorithm with the RSS based vertical handoff algorithm in terms of the maximum downlink throughputs the user can achieve while traveling through the integrated network. Studies have used various thresholds setting for RSS based vertical handoff: -90dBm, -85dBm and -80dBm along with the proposed SINR based vertical handoff.

The user's mean throughputs under different noise power of WLAN are shown in Figure 3. As it can be seen, the mean throughput becomes lower with higher noise power, also the maximum bit rate from WLAN decrease as the interference level increases. The performance of RSS based vertical handoff using different thresholds values varies under different network conditions. RSS based vertical handoff with lower threshold values perform better in low noise conditions than higher thresholds values, as they allow the user to stay connected with WLAN longer, from which higher bandwidth is still available because of lower interference level at the WLAN carrier frequency band, as compared to WCDMA HSDPA channel. The same reason is true for the improved performance of higher threshold over the lower threshold while the noise power increases. Comparing with the performance variations of RSS based vertical handoff using different thresholds values (Figure 3), the SINR based vertical handoff consistently offers the end-user with the highest mean throughput under any noise level.

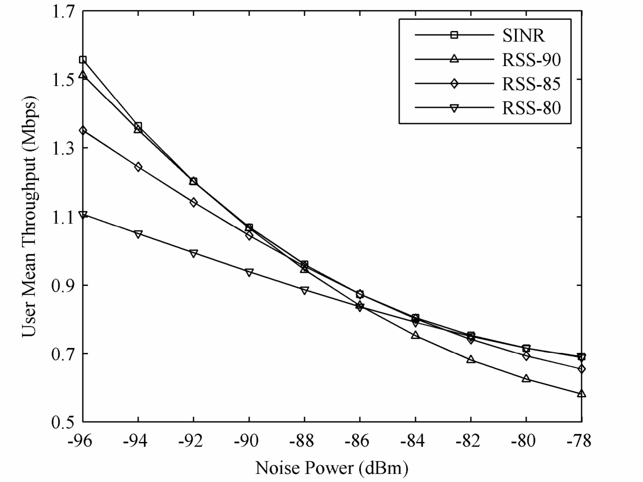

Figure 3: User Mean Throughput vs Noise Power

In real networks, interference power will depend on the user location as well as the density of the users. Therefore, only the SINR based vertical handoff can guarantee multimedia QoS specifying the achieved date rate for end user inside vertical handover zone. This is also another important reason that our SINR based vertical handoff can adapt to the network conditions and can provide consistently maximum available throughputs to the end user, which RSS based handoff cannot achieve.

Studies were also conducted on WCDMA network by varying the average cells' downlink load factor and the performance of different algorithms are shown in Figure 4. In this comparison, the noise power of WLAN is fixed at its minimum value of -96dBm, which allows the maximum available data rate in WLAN. As the load factor of WCDMA network increases, the downlink radio resources becomes scarce and as a result decreases the maximum achievable data rate of the HSDPA channel. Therefore, the overall user throughput becomes lower under higher load factor, and the variation in the performance of different RSS thresholds settings become more apparent. The advantage of SINR based vertical handoff has again been confirmed by its highest user mean throughputs over various WCDMA networks conditions.

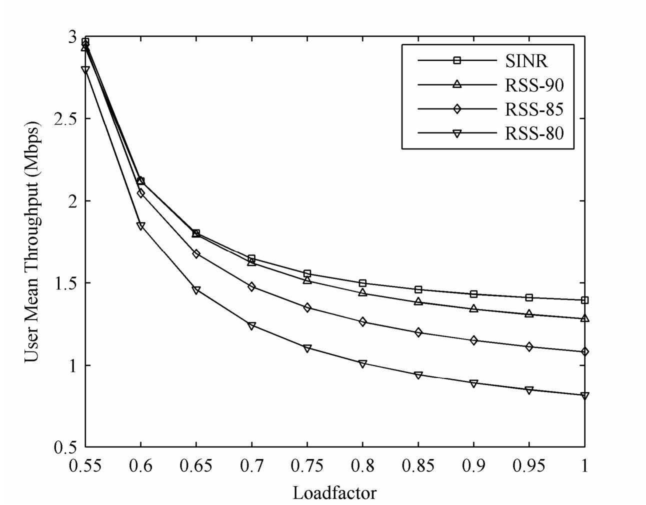

Figure 4: User Mean Throughput vs Load Factor

V. SYSTEM LEVEL SIMULATION AND RESULTS

To evaluate the performance of different vertical handoff algorithms at the system level, a MATLAB-based simulator has been developed, which is suitable for investigating the heterogeneous wireless network performance under different radio resource management strategies.

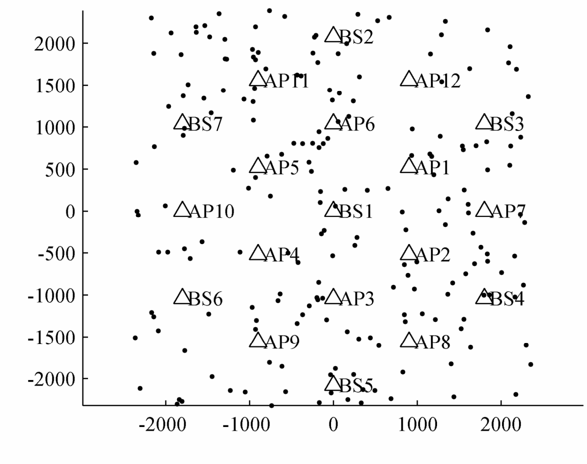

Figure 5: Simulation Scenario

The performance of the proposed SINR based vertical handoff algorithm and the RSS based vertical handoff algorithm have been evaluated with the scenario shown in Figure 5, in which there are 7 BS and 12 AP placed at each WCDMA cell boundary. The WCDMA cell radium is 1200 meter. 200 randomly generated UEs are used inside the simulation area, whose position changes every time interval, depending on their moving speed and direction, which are randomly chosen with mean direction and speed changing rate of 5 changes per 100 seconds. The maximum user moving speed is 80km/hour. In traffic generator module, for a mean session duration of 60 seconds and certain given mean session arrival rate, user traffic is randomly generated with a Poisson arrival distribution.

Using a typical user data rate for video traffic of 384kbps, the overall system throughput for different session arrival rates are shown in Figure 6, which shows that SINR based handoff has out performed the RSS based handoff techniques in providing higher system throughput, and the increment becomes more prominent at higher session arrival rate.

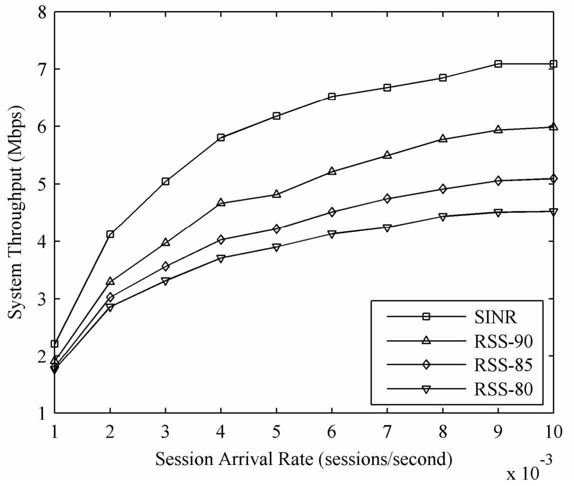

Figure 6: System Throughput vs Session Arrival Rate

To further study the performance of different algorithms at lower session arrival rate, investigations were also conducted by varying the user data rate with a fixed session arrival rate of 0.001 sessions/second, as shown in Figure 7. The advantage of SINR based handoff algorithm again been proved by absolute highest overall system throughput at any data rate.

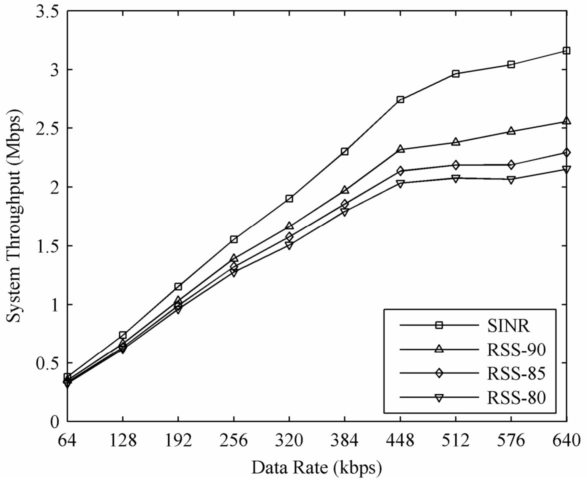

Figure 7: System Throughput vs Data Rate

VI. CONCLUSTIONS

Seamless vertical handoff between different access networks in the next generation multimedia wireless networks remains a challenging problem. In order to provide multimedia QoS inside the integrated network environment, the vertical handoff algorithm needs to be QoS aware, which cannot be achieved by RSS based handoff criteria. The new vertical handoff algorithm has been proposed in this paper using the combined receiving SINR from WLAN and WCDMA networks as the handoff criteria, which provides the knowledge of the achievable bandwidth from both access networks. Analysis results show that the performance of RSS based vertical handoff with different thresholds setting differs under different network conditions. In contrast, the new SINR based vertical handoff algorithm is able to consistently offer the end user with maximum available throughput during vertical handoff. Simulation results also confirm that SINR based vertical handoff provides higher overall system throughput comparing with the RSS based vertical handoff algorithm.

REFERENCES

[1] A. H. Zahran, B. Liang and A. Saleh, "Signal Thresholds Adaptation for Vertical Handoff in Heterogenous Wireless Networks", *Mobile Networks and Applications*, Springer Netherlands, Volume 11, Number 4, 625-640, August 2006.

[2] W. Shen and Q.-A. Zeng, "A Novel Decision Strategy of Vertical Handoff in Overlay Wireless Networks", *Fifth IEEE International Symposium on Network Computing and Applications (NCA'06)*, 2006.

[3] K.-S. Jang, J.-S. Kim, H.-J. Shin and D.-R. Shin, "A Novel Vertical Handoff Strategy for Intergrated IEEE802.11 WLAN/CDMA Networks", *ICIS'05*, 2005.

[4] Y. Nkansah-Gyekye and J. I. Agbinya, "Vertical Handoff between WWAN and WLAN", *ICNICONSMCL'06*, 2006.

[5] J. McNair and F. Zhu, "Vertical Handoffs In Fourth-Generation Multinetworks Environments", *IEEE Wireless Communications*, June 2004.

[6] M. Ylianttila, M. Pande, J. Makela and P. Mahonen, "Optimization Scheme for Mobile Users Performing Vertical Handoffs between IEEE802.11 and GPRS/EDGE Networks", *Globecom'01*, 2001.

[7] H. Holma and A. Toskala, "WCDMA for UMTS", *John Wiley*, New York, 2004.

[8] S. Toumpis and A. J. Goldsmith, "Capacity Regions for Wireless Ad Hoc Networks", *IEEE Transactions on Wireless Communications*, Volume 2, No. 4, July 2003.

[9] G. Cristache, K. David and M. Hildebrand, "Aspects for the integration of ad-hoc and cellular networks", *3rd Scandinavian Workshop on Wireless Ad-hoc Networks*, Stockholm, 2003.

[10] R. Samarasinghe, V. Friderikos and A. H. Aghvami, "Analysis of Intersystem Handover: UMTS FDD &WLAN", *IEE Proceedings of London Communications Symposium 2003*, London, UK, 2003.

[11] "RF System Scenario (Release 6)", 3GPP TR 25.942 V6.4.0, March 2005.

[12] K. Premkumar and A. Kumar, "Optimum Association of Mobile Wireless Devices with a WLAN-3G Access Network", *ICC'06*, Istanbul, Turkey, June 2006.

[13] E. L. Aguilera, J. Casademont and J. Cotrina, "Outdoor IEEE 802.11g Cellular Network Performance", *Globecom '04*, 2004.