USING SINR AS VERTICAL HANDOFF CRITERIA IN MULTIMEDIA WIRELESS NETWORKS

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ABSTRACT

In the next generation multimedia wireless network environment that consists of heterogeneous access technologies, we need to offer the end user with multimedia QoS inside each access network as well as during vertical handoff between them. The vertical handoff algorithm have to be QoS aware, which cannot be achieved by using the traditional RSS as the vertical handoff criteria. In this paper, we propose a new vertical handoff algorithm using the receiving SINR from various access networks as the handoff criteria. By converting the different receiving SINR values, the handoff algorithm can have the knowledge of achievable bandwidths from both access networks, and make handoff decisions with multimedia QoS consideration. Analysis results confirms that the new SINR based vertical handoff algorithm is able to consistently offer the end user with maximum available bandwidth during vertical handoff comparing with the RSS based vertical handoff, whose performance differs under different network conditions.

1. INTRODUCTION

Large amount of research shows the integration of WLAN and third generation (3G) cellular networks such as WCDMA system has been a trend towards 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 physical 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 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 cannot receive the given minimum receiving power from the original network. In case of WLAN and WCDMA integrated networks supporting multimedia services, this means that we are not providing the user with the multimedia QoS throughout the integrated networks, as we the vertical handoff algorithm is not QoS aware. This may results in a mobile user earlier handoff from a WLAN to WCDMA, even though the achievable data rate from WLAN is still much higher than it will 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 rate is desirable. The new vertical handoff algorithm not only can support user with multimedia QoS and be capable of allowing the user achieving the maximum throughputs during vertical handoff, but also makes the load balancing between WLAN and WCDMA systems practical. Moreover, since the SINR based handover is already being used in WCDMA system, 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 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 new vertical handoff algorithm using SINR instead of RSS as the handoff criterion. Analyses results shows that SINR based vertical handoff provides higher average throughputs for end users comparing with the RSS based vertical handoff with various thresholds settings, and is better adaptive to different network conditions, such as different noise level and load factor. The paper is organized as follows. The SINR based vertical handoff strategy is presented in Section 2. Section 3 describes analytical model used to evaluate the performance of different vertical handoff algorithms, while the results and discussions are presented in Section 4, with some conclusions being provided in Section 5.

2. SINR BASED VERTICAL HANDOFF STRATEGY

According to Shannon capacity, the maximum achievable rate R_{ij} is given by:

$$R_{ij} = W \log_2(1 + \frac{\gamma_{ij}}{\Gamma}) \quad (1)$$

Where:

- W is the bandwidth,
- γ_{ij} is SINR received at user i when associated with AP_j or BS_j
- Γ is the gap between uncoded M-QAM and capacity, minus the coding gain.

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

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

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

Where, γ_{AP} is the receiving SINR from WLAN, and γ_{BS} is the receiving SINR from WCDMA on High Speed Downlink Packet Access (HSDPA) channel. We are interested in the relationship between required γ_{AP} and γ_{BS} while offering the same downlink bandwidth to 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:

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

The parameters in (4) are:

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

Having the relationship between available bit rate and 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 bit rate, and compared with the receiving SINR from WLAN. 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 bit rates a user can get from either WLAN or WCDMA at the same time within the handover zone, inside 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 bit rate during vertical handoff.

Our design 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, conduct the γ_{AP} to γ_{BS} converting and send the handoff request to the RNC based on the SINR comparison results. In the passive mode, the SINR measurements of both WLAN and WCDMA are periodically sent to RNC directly, in which the handoff decisions are made according 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 detectable with less handoff delays, which can be deployed for cells under low load condition.

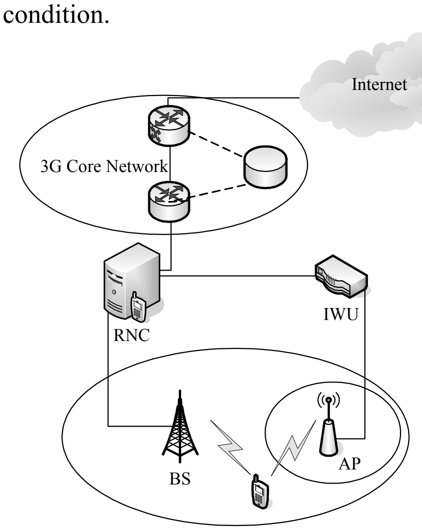

Figure 1. WLAN and WCDMA Integration Architecture

3. ANALYSIS 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 γ_{ij} received by user i from WLAN AP_j can be represented as:

$$\gamma_{ij} = \frac{G_{ij} P_j}{P_B + \sum_{\substack{k \in AP \\ k \neq j}} G_{ik} P_k} \quad (5)$$

Where:

- P_j is the transmitting power of AP_{j}
- G_{ij} is the channel gain between user i and AP_j
- P_B is the background noise power at user receiver end.

The SINR γ_{ij} received by user i from WCDMA BS_{j} can be represented as:

$$\gamma_{ij} = \frac{G_{ij} P_{ij}}{P_B + \sum_{k \in BS} (G_{ik} P_k) - G_{ij} P_{ij}} \quad (6)$$

Where:

- P_k is the total transmitting power of BS_k
- P_{ij} is the transmitting power of BS_j to user j
- G_{ij} is the channel gain between user i and BS_j

In our analysis, we consider a point to point model, in which a user 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 .

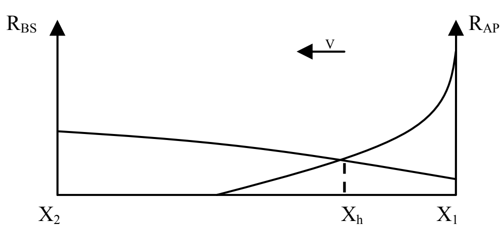

Figure 2. Point to Point Model

The total downlink throughputs θ can be represented as:

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

Where CRT is cell residence time, and R_{AP} and R_{BS} is the maximum bit rate received from WLAN and WCDMA. To offer the user maximum downlink throughput $\max(\theta)$, we are aiming at finding the optimum handoff point X_h . For the RSS based vertical handoff, the X_h is constrained by the minimum required receiving power P_j from WLAN AP_j. In SINR based vertical handoff, the X_h is calculated based on the receiving SINR from WLAN and WCDMA. Therefore, we be able to compare the average throughputs for different vertical handoff algorithm with different X_h .

4. RESULTS AND DISCUSSION

We compare our SINR based vertical handoff algorithm with the RSS based vertical handoff algorithm in terms of user's mean downlink throughputs while traveling through the integrated network. Various thresholds setting for RSS based vertical handoff: -90dBm, -85dBm and -80dBm are all tested together with the proposed SINR based vertical handoff. The following common conditions and assumptions [8, 11, 12] are used in the performance analysis:

For WCDMA HSDPA:

- The ratio of total BS transmit power is allocated to HSDPA channel is 50%.
- The ratio of other cell to own cell base station power received by user is 65%.
- BS transmits to only one user via HSDPA channel at a time, with maximum available power to achieve the optimal physical rate.
- Average downlink load factor is 75% in all cells, with the total transmitting power of BS equals to $0.75 * P_{max}$, where P_{max} is the BS maximum transmitting power that equals to 20W.
- User end background noise power equals to $7.66 * 10^{-14}$W.

For WLAN:

- Distributed Coordination Function (DCF) is used. Only one station can transmit at one time.
- Background noise power equals to -96dBm.

The mean throughputs under different noise power of WLAN are shown in Figure 3. As it can be seen, the overall mean throughput becomes lower with higher noise power, since the maximum bit rate the user is getting from WLAN decrease while 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 comparing with WCDMA HSDPA channel due to lower interference level currently at the WLAN carrier frequency band. The same reason is behind why the performance of higher thresholds setting start to overtake the lower one while the noise power increases. Comparing with the performance variations of RSS based vertical handoff using different thresholds values, the SINR based vertical handoff consistently offers the highest mean throughput under any noise level.

In real networks, interference power will be various depend on the user location as well as the density of 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 why our SINR based vertical handoff can adaptive to the network conditions and be able to consistently provide the maximum available throughputs for end user, while the RSS based can hardly achieve.

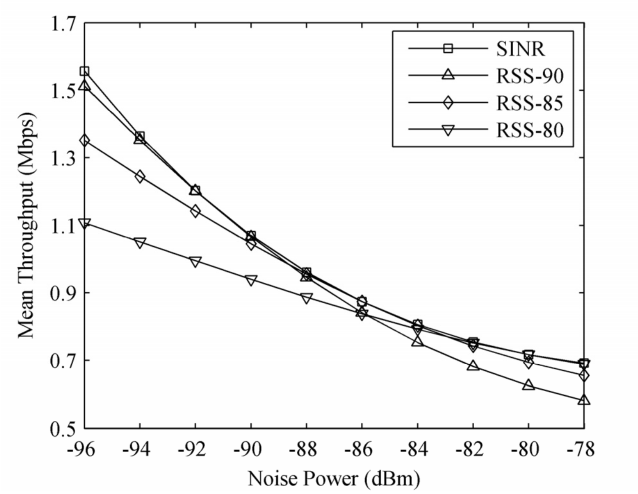

Figure 3. Mean Throughput vs Noise Power

We also vary the average cells' downlink load factor of WCDMA networks 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 bit rate came from WLAN side. As the load factor of WCDMA networks increases, the downlink radio resource is getting scarce and decreases the maximum achievable bit rate of the HSDPA channel. Therefore, the overall throughput becomes lower under higher load factor, with the performance variations of different RSS thresholds settings become more apparent. The advantage of SINR based vertical handoff has again been confirmed by its highest mean throughputs over various WCDMA networks conditions.

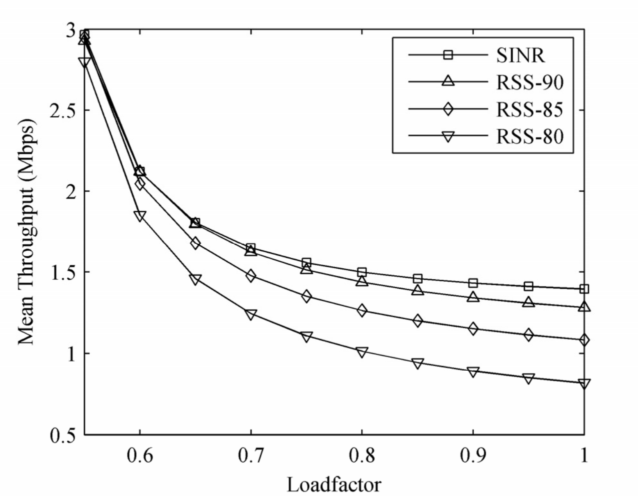

Figure 4. Mean Throughput vs Load Factor

5. CONCLUSIONS

Seamless vertical handoff between different access networks in the next generation multimedia wireless networks remains a challenging problem. In order to provide multimedia QoS as well as load balancing inside the integrated network environment, the vertical handoff algorithm needs also to be QoS aware, which is hardly to achieve by using RSS as the handoff criteria. The new vertical handoff algorithm proposed in this paper using the 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 differs under different network conditions, for different thresholds setting. In contrast, the new SINR based vertical handoff algorithm is able to consistently offer the end user with maximum available throughputs during vertical handoff. Future research includes extending the analysis model and simulations to a large scale environment with more cells and various user moving patterns.

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