Call Admission Control in CDMA2000/WLAN Network Based on User Position Information

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Abstract—In this paper, a call admission control scheme based on user position information is proposed in the context of CDMA2000 and WLAN heterogeneous networks with voice and data traffic. The user position based call admission (UPBAC) scheme is composed of a parameter measurer, an admission controller and a decision executer. When a new call or a handoff call arrives, the parameter measurer first obtains channel and load conditions of available subnetworks as well as the position and mobility information for the admission controller. The admission controller then decides whether to admit or reject the call considering both QoS and load balancing. The decision executer carries out the final actions at last. Simulation results show that UPBAC can always reduce pingpang effect while maintaining the QoS requirements in that it can appropriately admit or reject the users’ admission requests. Also, the UPBAC can achieve lower blocking rate than conventional algorithms such as RSS based algorithm or WLAN first algorithm and can significantly reduce the handoff dropping rate by effective load balancing.

Index Terms—Call Admission Control, Position Information, Heterogeneous Networks, Pingpang Effect

I. INTRODUCTION

Call admission control (CAC) is one of the most important parts of radio resource management (RRM) [1], aiming at reducing network congestion while supporting the required Quality of Service (QoS). It is also a key technology to 3G and WLAN networks convergence.

Although individual CAC schemes can be tuned to optimally perform within their respective radio access network (RAN), they may not efficiently perform in heterogeneous networks if different schemes are not properly managed. Hence, a major issue is how to jointly utilize the resources of the different RANs in an efficient manner while simultaneously achieving the desired QoS and minimizing the service cost from both the user and service provider perspectives [2,3]. This issue of joint RRM forms the focus of this paper.

In recent years, with the fast development of the positioning Technology, 3G networks such as WCDMA and CDMA2000 are able to provide positioning service. WLAN network positioning technology is also becoming more and more mature at the same time. As a result, position information has become the focus of many researchers’ concern. Many studies revealed that it can significantly help solving the pingpang effect and load balancing, thus improving the performance of CAC [4-7].

In this paper, a call admission control scheme based on user position information is proposed in the context of CDMA2000/WLAN heterogeneous networks. As shown in Fig.1, it not only considers the position information of the user side to solve the so-called pingpang effect, but also takes the load balancing into consideration to reduce new call blocking rate and the handoff call dropping rate, thus improving performance of the whole heterogeneous networks. The proposed UPBAC scheme concludes the following innovative points:

1) UPBAC proposed a novel channel condition evaluation method specific to CDMA2000 and WLAN heterogeneous networks.
2) UPBAC proposed a novel network load condition evaluation method specific to CDMA2000 and WLAN heterogeneous networks.
3) UPBAC considers the user position information combining the channel and load condition to propose an effective CAC algorithm.

The remainder of this paper is organized as follows: Section II brings up the system model and the essential system measures are selected. Section III presents the proposed UPBAC scheme and then describes its operation in details. The performance criteria to evaluate the proposed UPBAC scheme are also described. Section IV presents simulation results and discussions. Also, final concludes are given in section V.
II. SYSTEM MODEL AND EVALUATION

Fig. 2 shows the CDMA2000/WLAN heterogeneous networks equipped with UPBAC system in packet data serving node (PDSN). Parameters of each subnetwork are reported to UPBAC by base station (BS) or access point (AP). Realtime position information of a mobile station (MS) is saved in home location register (HLR).

Whenever a call request arrives, BS and AP will report the measured parameters set in each available subnetwork which are presented by \( P = (X, Y, v, \theta) \). Where SNR denotes the received signal to noise ratio of the traffic channel, \( \eta \) is the load of the subnetwork, \( (X, Y) \) is the coordinates of MS and \( (v, \theta) \) denotes the speed and direction angle respectively.

A. Channel Evaluation

In CDMA2000, there’re fundamental channels (FCH, 9.6kbps) and supplemental channels (SCH, 19.2kbps, 38.4kbps etc.) to carry voice and data traffic[8-9]. While in WLAN IEEE 802.11b protocol, there’re 4 modes with different data rate, namely 1Mbps, 2Mbps, 5Mbps and 11Mbps [10]. Fig. 3 is the simulation results of bit error rate (BER) versus the received SNR for the two networks.

Traditional methods use the received signal strength (RSS) to trigger a handoff. While in the UPBACA scheme, RSS is mapped into BER of QoS. The standard maximum BER requirement of voice and data traffic is \( 10^{-2} \) and \( 10^{-6} \) respectively. Thus, it can be obviously concluded from Fig. 3 that the minimum SNR which meets the QOS requirements, as shown in Table I, where \( \sigma \) is the variance of the fast fading.

<table>
<thead>
<tr>
<th>Networks</th>
<th>Voice</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMA2000</td>
<td>-17+( \sigma ) dBm</td>
<td>-11.5+( \sigma ) dBm</td>
</tr>
<tr>
<td>IEEE802.11b</td>
<td>11+( \sigma ) dBm</td>
<td>11+( \sigma ) dBm</td>
</tr>
</tbody>
</table>

B. Load Evaluation

In CDMA2000 network, the Rise Over Thermal (ROT) is related to the load based on interference \( \eta_c \) [11]:

\[
ROT = \frac{I_{\text{total}}}{P_N} = \frac{1}{1 - \sum_{j} L_j} \leq 1 - \eta_c. \tag{1}
\]

Where \( I_{\text{total}} \) is the total interference, \( P_N \) is the thermal noise power, \( L_j \) is the load factor between user \( j \) and BS. It is known that CDMA2000 is a self-interference system and ROT will rise sharply when \( \eta_c \geq 0.75 \) as deduced from (1). So the aim of load control is designed as

\[
\eta_c = 1 - \frac{1}{ROT} \leq \eta_{b,c} = 0.75. \tag{2}
\]

As to CDMA2000 cells with both voice and data traffic, define \( \eta_i \) as the load based on bandwidth of user \( i \), then sum of each user’s load must satisfy

\[
\eta_i = \sum_{i=1}^{N_i} \eta_i = \sum_{i=1}^{N_i} \frac{b_i}{B_i} \leq 1. \tag{3}
\]

As to IEEE 802.11b, let \( \eta_{wi} \) denotes the load of user \( i \)

\[
\eta_{wi} = \frac{b_{wi}}{B_w}. \tag{4}
\]

Where \( b_{wi} \) is the band width of user \( i \), \( B_w \) is the actual whole band width that the system can provide. So the band width sum of \( N_w \) users can be expressed by

\[
\eta_w = \sum_{i=1}^{N_w} \eta_{wi} = \sum_{i=1}^{N_w} \frac{b_{wi}}{B_w}. \tag{5}
\]

However, actual maximum band width is given by

\[
B_w = \frac{B_u \times \eta}{2 \times N_w \times \eta_{\text{user}}}. \tag{6}
\]

Where \( B_u \) is 11Mbps usually, \( \eta \) is the transmission efficiency due to RTS/CTS mode which is approximately 0.51 in practice, \( \eta_{\text{user}} \) is the user efficiency which is set 1 here. Important parameters in load balancing are shown in Table II. UPBAC controls the load of each subnetwork. When the load of some subnetwork is up to a threshold which is set in advance, new calls should be rejected.
TABLE II. IMPORTANT PARAMETERS IN LOAD BALANCING

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( B_W )</td>
<td>2.8Mbps</td>
<td>Bandwidth of 802.11b</td>
</tr>
<tr>
<td>( \eta_W )</td>
<td>0.8</td>
<td>Load threshold in 802.11b</td>
</tr>
<tr>
<td>( B_C )</td>
<td>2Mbps</td>
<td>Bandwidth of CDMA2000</td>
</tr>
<tr>
<td>( \eta_C )</td>
<td>0.75</td>
<td>Load threshold in CDMA2000</td>
</tr>
</tbody>
</table>

C. Estimation of MS’s Position and Dwell Time

The coordination of a MS is denoted by \((X, Y)\) as shown in Fig.4, where \(r\) is the radius of a hot-spot with WLAN, \(v\) is the speed of the MS, \(\theta\) is the angle of the moving direction and the horizontal axis.

![Moving into Hotspot](image)

![Moving out of Hotspot](image)

The dwell time \(\tilde{t}\) in the hot-spot of MS is estimated by

\[
\tilde{t} = \frac{2 \cdot r \cdot \cos \theta}{v}. \tag{8}
\]

D. Bandwidth Resources Reservation

UPBCA detects and updates the real time position information of MS and estimate coordinates \((X_{i+1}, Y_{i+1})\) of the next time \(t+1\) is estimated by

\[
\begin{align*}
X_{i+1} &= X_i + \Delta t \cdot v_x, \\
Y_{i+1} &= Y_i + \Delta t \cdot v_y.
\end{align*} \tag{7}
\]

III. PROPOSED UPBCA SCHEME

The UPBCA functionality is dependent on the position of MS, which can be either in the hot-spot area or out of the hot-spot area. UPBAC consists of two algorithms: new call admission algorithm and vertical handoff algorithm, both of which consider the channel condition, network load condition and mobility information of MS.

A. New Call Admission Algorithm

As shown in Fig.5, UPBAC scheme for new calls is depicted as follows:

1) When a new call arrives, QOS of the traffic and the parameter set \(M\) measured in each available subnetwork is reported to parameter measurer of UPBAC by BS or AP.

2) HLR reports the position and mobility information of MS to the parameter measurer of UPBAC.

3) The admission controller choose the appropriate network for the new call with following steps:

a) If the position of MS is out of the hot-spot, then try to access CDMA2000.

b) If the position of MS is in the hot-spot and the traffic type is voice, then UPBAC estimate the dwell time in hot-spot \(\tilde{t}\). If \(\tilde{t}\) is less than pingpong time interval \(t_{pp}\), then try to access CDMA2000 to reduce possible call drops and time delay that may caused by frequent handoffs. Else, try to access WLAN.

c) If the position of MS is in the hot-spot and the traffic type is data, then UPBAC estimate the MS’s coordinations of the next time slot. If MS tends to remain in the hot-spot, then try to access WLAN considering its high bandwidth and the QOS of the traffic. Else, if MS tends to move out of the hot-spot, then try to access CDMA2000 subnetwork.

B. Vertical Handoff Call Admission Algorithm

As shown in Fig.6, call admission control algorithm for vertical handoff calls is depicted as follows:

1) UPBPCA detects and updates the real time position information of MS and estimate the next time coordinates \((X_{i+1}, Y_{i+1})\).
2) If the coordinates of MS changes:
   a) If MS is moving out of the hot-spot, then try to handoff to CDMA2000.
   b) If MS is moving into the hot-spot, then consider its traffic type:
      If the traffic type is data and the MS will move out of hot-spot, then remain in CDMA2000 to
      avoid unnecessary handoffs and reduce the signaling cost. Else, try to handoff to WLAN
      to achieve higher bandwidth.
      If the traffic type is voice, then UPBAC estimate the dwell time in the hot-spot \( t_i \). If \( t_i \)
      is less than \( t_{pp} \), then remain in CDMA2000.
      Else, try to handoff to WLAN.
   3) UPBAC also detects and updates the real time position information of MS and estimate the next
      time coordinates \((X_{t_i+1}, Y_{t_i+1})\) to make bandwidth reservation. Consider the following scenarios:
      a) If MS is going to move out of hot-spot, then make a reservation in CDMA2000.
      b) If MS is going to move into hot-spot, then make a reservation in WLAN.

IV. SIMULATION RESULTS

A. Simulation Environment

As shown in Fig.7, without loss of generality, the simulation Environment is within a heterogeneous
network which consists of a CDMA2000 and a WLAN subnetwork which are tightly coupled. The coordinates
of BS is (0,0) with a coverage radius of 800m. The coordinates of AP is (200,0) with a coverage radius of
150m. The sampling interval \( \Delta t \) is set 0.1s.

The heterogeneous wireless networks system model and the associated assumptions are listed below:

1) The arrival of new calls is modeled as a poisson process with a mean arrival rate \( \lambda \). There are two
   types of traffic in the CDMA2000/WLAN heterogeneous network: voice and data. In the
   simulation, a new call could be a voice call or a data call with the possibility of 80 and 20 percent
   respectively while the mean service time of the two services are 120s and 180s respectively
   following the negative exponential distribution. In the CDMA2000 network, typical data rates of
   voice and data traffic are 9.6kpbs and 38.4kpbs respectively. In WLAN network, they are 24kpbs
   (coded by G.729) and 48kpbs respectively in this simulation.

2) Users are assumed to be uniformly distributed in cells, and a random-walk model is used to simulate
   the mobility of every user with a speed varies from 0 to 20m/s.

3) 75% of the traffic arrives in the hot-spot area.

4) Okumura-Hata propagation model is used to simulate propagation environment of CDMA2000
   while attenuation factor model is used specifics to WLAN subnetwork.

5) Ignore cases that the collision probability in WLAN with CSMA protocol increases when
   there’re too many users, that is to say channel utilization rate is assumed to 1 in this simulation.

In order to evaluate UPBAC algorithm in a more comprehensive way, metrics like pingpong times, new call
blocking rate, handoff call dropping rate, load balancing rate are used. Load balancing rate \( \mu \) is defined as

\[
\mu = 1 - \frac{\eta_c - \eta_w}{\eta_c + \eta_w}, \quad \eta_c \neq 0 \lor \eta_w \neq 0. \tag{10}
\]

Where \( \eta_c \) and \( \eta_w \) are the load of CDMA2000 and WLAN respectively. What’s more, another two classical
algorithms which are very commonly used in actual systems, namely RSS based algorithm [12] and WLAN
first algorithm [13], are also simulated to compare with UPBAC. All the three algorithms mentioned above use
the following traffic priority: voice handoff call > data handoff call > voice new call > data new call.

Other parameters are set as shown in Table III.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_{pp} )</td>
<td>8s</td>
<td>Pangpang interval</td>
</tr>
<tr>
<td>( P_{BS} )</td>
<td>43dBm</td>
<td>BS transmission power</td>
</tr>
<tr>
<td>( P_{AP} )</td>
<td>23dBm</td>
<td>AP transmission power</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>3dB</td>
<td>Variance of the fast fading</td>
</tr>
</tbody>
</table>
B. Simulation Results

Fig. 8 depicts the average pingpong times per second of voice and data calls versus the new call arrival rate $\lambda$. It can be found that UPBAC has the least number of pingpong times for both voice and data calls. It is because UPBAC scheme takes an adequate consideration of user mobility information by introduction of position predictor and dwell time estimator. It makes MS who will go out of hot-spot or has a short expected dwell time access to CDMA2000 network. In that way, it can reduce pingpong effect and system overhead significantly while maintaining the QoS requirements at the same time.

Fig. 9 depicts the new call blocking rates versus the new call arrival rate $\lambda$. It can be seen that UPBAC scheme has a very obvious advantage but it is shown in Fig.9 that simulation curves become very steep especially for data calls. This denotes that the system begins to reject some call requests in order to maintain the QoS requirements of other active calls. Moreover, due to the traffic priority, data calls have a larger blocking rate.

On the contrary, the RSS based algorithm and WLAN first algorithm, both of which take no consideration of MS position and mobility information, try to handoff once MS finds a better link or a higher bandwidth, thus leading to more pingpong times, more system overhead and larger delay of services. In addition, when the call intensity is too heavy, pingpong times of data calls will decrease slightly because both new call blocking rate and handoff call dropping rate increased, especially for data services, thus decreasing the data users.

Fig. 10 depicts the voice and data handoff call dropping rate versus the new call arrival rate $\lambda$. It can be seen that UPBAC has lower dropping rate than the other two algorithms. In actual systems, to end an active call forcibly is harder for users to bear than to reject a new call, so it’s very important for a good admission control system to keep call dropping rate lower than blocking rate. Due to the consideration of traffic priorities, all of the three algorithms achieved this point. However, UPBAC considers load control, so the system will reserve a certain bandwidth in each subnetwork appropriately used for satisfy the handoff calls. When the load of some subnetwork exceeds a predetermined threshold, new call requests will be rejected so that the QoS of the handoff calls can be guaranteed effectively.

Fig. 11 shows the average load balancing rate versus the new call arrival rate $\lambda$. As can be seen from the simulation results, UPBAC has the highest load balancing rate in the three algorithms. This is because UPBAC scheme fully considers load balancing. Before some subnetwork congestion, UPBAC makes MS access to an underloading subnetwork while maintaining the QoS requirements. This macro-control is significative. When $\lambda$ becomes larger, UPBAC scheme has a very obvious advantage.
subnetwork congestion, UPBAC could balance the loads among subnetworks in advance while maintaining the QoS of the users to avoid situations that one subnetwork is congested while the other is underloading, thus fully using the whole resource of the heterogeneous network.

Fig. 12 shows the average number of active users in the network versus the new call arrival rate \( \lambda \). As can be seen from the simulation results, UPBAC scheme is able to access the largest number of users. This denotes that the system can serve for more users at the same time while maintaining the QoS requirements. It is more obvious especially when \( \lambda \) becomes larger. This is because UPBAC improves system resource utilization significantly by load balancing and it maintains the QoS requirement assisted by position and mobility information. The RSS based algorithm and the WLAN first algorithm failed in taking consideration of these factors. Moreover, WLAN first algorithm performs a little better than RSS based algorithm.

V. CONCLUSION

In this paper, a call admission control scheme based on user position information is proposed in the context CDMA2000/WLAN heterogeneous networks with voice and data traffic. Firstly, from the network perspective, it improves the resource utilization effectively by load balancing while providing reliable and stable service for more users with the same resources. At the same time, from the user perspective, it takes MS position and mobile information into account, thus effectively reducing the pingpong effect, the system overhead and signaling overhead.

The main Innovation of this paper is that UPBAC not only proposed a novel channel and load condition evaluation method specific to CDMA2000 and WLAN heterogeneous networks but also combined them with the user position information, bringing up the effective CAC algorithm. According to the simulation results, UPBAC can always reduce pingpong effect while maintaining the QoS requirements in that it can appropriately admit or reject the users’ admission requests. Also, the UPBAC can achieve lower blocking rate than conventional algorithms such as RSS based algorithm or WLAN first algorithm and can significantly reduce the handoff rate by effective load balancing.

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