A Probabilistic Call Admission Control Algorithm for WLAN in Heterogeneous Wireless Environment

SuKyoung Lee, Kyungsoo Kim, Kunho Hong, David Griffith, YoonHyuk Kim, and Nada Golmie

***Abstract*—In an integrated WLAN and cellular network, if all mobile users whose connections originate in the cellular network migrate to the WLAN whenever they enter the double coverage area, the WLAN will be severely congested and its users will suffer from performance degradation. Therefore, we propose a Call Admission Control (CAC) algorithm that allows the WLAN to limit downward Vertical Handovers (VHOs) from the cellular network to reduce unnecessary VHO processing. Numerical and simulation results demonstrate that our CAC scheme reduces the unnecessary VHO processing while keeping the DVHO blocking rate within acceptable limits and maintaining reasonable throughput in the WLAN.**

***Index Terms*—CAC, DVHO, UVHO, heterogeneous wireless networks.**

I. INTRODUCTION

IN heterogeneous wireless networks, both cellular and WLAN access are available to mobile nodes within WLAN hotspots that reside within 3G cells, which we call *double coverage areas*. Because every mobile in a WLAN can also access the 3G cellular network, handovers from the cellular network to a WLAN within it are optional; in a network with limited capacity, the carrier uses these handovers to enhance QoS, reduce cost, or balance traffic load [1][2]. We call a handover from the 3G cellular network to a WLAN a Downward Vertical Handover (DVHO). Similarly, we define an Upward VHO (UVHO) to be a handover from a WLAN to the 3G network.

Most of the mobiles that started their connections over the cellular network, upon entering a double-coverage area, will attempt to handover to the hotspot due to the lower cost of using the WLAN while new calls that originate in the double-coverage area will connect over the hotspot [1][2]. This causes some problems. Highly mobile users, who leave a hotspot soon after entering it, will perform UVHOs soon after completing DVHOs, causing unnecessary VHO processing load. In addition, accepting all DVHOs, especially DVHO calls that will perform a UVHO soon afterward, can cause new connections that intend to use the WLAN to be blocked. Because most WLANs are deployed in indoor environments like cafes, offices and hotels and thus, many calls that originate in the WLAN tend to spend a large fraction of their time in a single location [3], we propose a Call Admission Control (CAC) algorithm to probabilistically reject DVHOs for mobiles with a high probability of UVHO; the WLAN uses the CAC algorithm when the throughput in the hotspot exceeds a threshold. In the proposed CAC scheme, mobiles remain connected even if they are rejected by the WLAN since they maintain their ongoing connections by using the cellular network.

The rest of this paper is organized as follows. In Section II, we derive the probability that a mobile whose connection is initially carried by the 3G network performs a DVHO to the WLAN, and the probability that a mobile that performs a DVHO also performs a UVHO due to leaving the WLAN coverage area. We use both of these probabilities in Section III, where we define the CAC algorithm. In Section IV, we demonstrate the effectiveness of the CAC algorithm by using simulations to compute performance metrics such as the mean DVHO blocking rate, new call blocking rate, number of UHVOs, and WLAN utilization. We present our conclusions in Section V.

II. UVHO PROBABILITIES FOR MOBILES THAT PERFORM DVHOS

In this section, we calculate two probabilities that we use in the CAC algorithm. For the analysis in this section, we use the geometry shown in Fig. 1. We define P_1 to be the probability that a mobile node that started its connection outside the WLAN hotspot ends its connection inside the hotspot. Also, P_2 is the probability that a mobile node that entered WLAN hotspot and performed a DVHO ends its call after leaving the hotspot, which requires that it perform a UVHO. Using these probabilities, we can also get the probability that a mobile performs a DVHO, which is $P_d = P_1 + P_2$, and the probability that a mobile that performs a DVHO also performs a UVHO is $P_u = P_2/P_d$.

A. Probability that a DVHO Mobile Does Not Perform UVHO

In this subsection, we derive P_1, the probability that a mobile node that originates in the 3G cell containing the WLAN hotspot's coverage area enters the hotspot before its call completes and then completes its call before leaving the hotspot. For our investigation of the DVHO probability, we begin by considering a cellular network (UMTS/CDMA)

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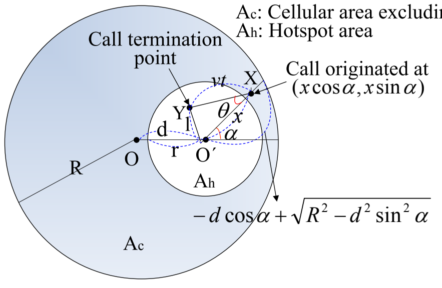

Fig. 1. A cellular coverage area including a single hotspot

containing one hotspot, which is assumed to be covered by one base station without overlapping. In Fig. 1, r and R represent the radius of the hotspot (the small circle) and the cell (the larger circle), respectively. Alternatively, we can regard the small circle as a cluster of WLAN hotspots that form a high density coverage area. $\mathcal{A}_c$ and $\mathcal{A}_h$ are respectively the sets of points that lie within the coverage areas of the cell and the hotspot. Let d be the distance between the centers of the hotspot and the cell. The points X and Y are respectively the call origination point and the call termination point. Then, for our analysis, we make the following assumptions:

- X is uniformly distributed within the area formed by the large circle centered on the point O and excluding the small circle centered on the point O'. The location of X is given in polar coordinates (x, α) relative to the origin O'. $l = \overline{O'Y}$ is the distance from the wireless access point (AP) to the point where the mobile's call ends, Y.
- The call duration, T, is exponentially distributed with density function $f_T(t) = \mu e^{-\mu t}$, $t \geq 0$.
- A mobile user moves at speed v with angle $\theta = \angle YXO'$ that is uniformly distributed between 0 and 2π; neither speed nor direction change as the mobile user moves. This mobility model is known as non-directional mobility [4].

Under the assumption of non-directional mobility, the point where the call originates in the cell, X, is characterized by the joint density of the distance $x = \overline{O'X}$ and phase α of the mobile user $f_{x,\alpha}(x, \alpha) = \frac{1}{\pi(R^2 - r^2)}$ for $(x, \alpha) \in (\mathcal{A}_c - \mathcal{A}_h)$, and the direction of user movement Θ and the call duration T are independent with joint density $f_{\Theta,T}(\theta, t) = \frac{\mu e^{-\mu t}}{2\pi}$ for $0 \leq \theta < 2\pi$ and $t \geq 0$. Since $X \in (\mathcal{A}_c - \mathcal{A}_h)$, under our assumption about the location where the mobile's call begins, X must satisfy the conditions $\overline{OX} \leq R$ and $\overline{O'X} \geq r$, and it follows that $r \leq x \leq -d\cos\alpha + \sqrt{R^2 - d^2 \sin^2 \alpha}$.

$\Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\}$ is the conditional probability that the mobile node call termination point Y is located in the hotspot's coverage area, given a particular call origination point (x, α). $\Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\}$ is independent of α due to α being uniformly distributed over $[0, 2\pi)$. Hence,

$$
\begin{aligned}
P_1 &= \Pr\left\{\overline{O'Y} \leq r\right\} \\
&= \int_0^{2\pi}\int_r^{-d\cos\alpha + \sqrt{R^2 - d^2\sin^2\alpha}} \Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\} f_{X,A}(x, \alpha) x \; dx d\alpha \qquad (1) \\
&= \frac{1}{\pi(R^2 - r^2)} \int_0^{2\pi}\int_r^{-d\cos\alpha + \sqrt{R^2 - d^2\sin^2\alpha}} \Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\} x \; dx d\alpha.
\end{aligned}
$$

From Fig. 1, we see that $\overline{O'Y} \leq r$ if $l^2 = (vt)^2 - 2x(vt)\cos\theta + x^2 \leq r^2$, which has the real solution $\frac{x\cos\theta - \sqrt{r^2 - x^2\sin^2\theta}}{v} \leq t \leq \frac{x\cos\theta + \sqrt{r^2 - x^2\sin^2\theta}}{v}$ when $r^2 - x^2\sin^2\theta \geq 0$. In other words, if $-\theta_0 \leq \theta \leq \theta_0$ where $\theta_0 = \sin^{-1}(r/x)$, the mobile user will stay in the hotspot during the time interval of $t_1 \leq t \leq t_2$ where $t_1 = \frac{x\cos\theta - \sqrt{r^2 - x^2\sin^2\theta}}{v}$ and $t_2 = \frac{x\cos\theta + \sqrt{r^2 - x^2\sin^2\theta}}{v}$. Thus the conditional probability $\Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\}$ has the following alternate form:

$$
\begin{aligned}
&\Pr\left\{\overline{O'Y} \leq r|(x, \alpha)\right\} = \int_{-\theta_0}^{\theta_0}\int_{t_1}^{t_2} \frac{\mu e^{-\mu t}}{2\pi} dt d\theta \\
&= \frac{1}{\pi}\int_0^{\theta_0} e^{-\frac{\mu x \cos\theta}{v}} \left(e^{\frac{\mu\sqrt{r^2 - x^2\sin^2\theta}}{v}} - e^{\frac{-\mu\sqrt{r^2 - x^2\sin^2\theta}}{v}}\right) d\theta. \qquad (2)
\end{aligned}
$$

Substituting Eq. (2) into Eq. (1) yields

$$
\begin{aligned}
P_1 = &\frac{1}{\pi^2(R^2 - r^2)} \int_0^{2\pi}\int_r^{\delta(\alpha)}\int_0^{\theta_0} x e^{-\frac{\mu x\cos\theta}{v}} \\
&\times \left(e^{\frac{\mu\sqrt{r^2 - x^2\sin^2\theta}}{v}} - e^{\frac{-\mu\sqrt{r^2 - x^2\sin^2\theta}}{v}}\right) d\theta dx d\alpha. \qquad (3)
\end{aligned}
$$

where $\delta(\alpha) = -d\cos\alpha + \sqrt{R^2 - d^2\sin^2\alpha}$.

B. Probability that a DVHO Mobile Performs UVHO

We now derive P_2, the probability that a DVHO call performs a UVHO before its call terminates given that the call is accepted to the hotspot. From Fig. 1, a UVHO happens if $\overline{O'Y} > r$ or if $l^2 = (vt)^2 - 2x(vt)\cos\theta + x^2 > r^2$. Let $t_3 = (D\cos\theta' + \sqrt{R^2 - D^2\sin^2\theta'})/v$ where $D = \sqrt{x^2 + d^2 + 2xd\cos\alpha}$, $\beta = \angle OXO'$, and $\theta' = \theta - \beta$. Then, using the same approach as for obtaining P_1, we have

$$
P_2 = \frac{1}{2\pi^2(R^2 - r^2)} \int_0^{2\pi}\int_r^{\delta(\alpha)}\int_{-\theta_0}^{\theta_0} x\left(e^{-\mu t_2} - e^{-\mu t_3}\right) d\theta dx d\alpha. \qquad (4)
$$

III. Call Admission Control Algorithm for Double-Coverage Area

In this section, we develop the CAC algorithm by using P_d and P_u, which we derived in Section II. We assume that there is a uniform call generation density within the 3G cell; in other words, new users appear at a rate of λ calls/s/m^2. From this, it follows that new mobile users appear in the WLAN hotspot at a rate of $\lambda_h = A_h\lambda$ calls/s, where $A_h = \pi r^2$ m^2 is the coverage area of the hotspot. Likewise, new users appear in the portion of the cell that is not covered by the hotspot at a rate of $\lambda_c = (A_c - A_h)\lambda$ calls/s, where $A_c = \pi R^2$ m^2 is the coverage area of the cell. ¿From the properties of Poisson processes, DVHOs from the cell to the hotspot occur according to a Poisson arrival process with rate $P_d\lambda_c$. We also assume that the call duration is exponential with mean $1/\mu$.

The CAC algorithm that we propose is probabilistic. Suppose that we randomly reject DVHO calls with probability P_R. Then, the effective arrival rate to the hotspot is $\lambda_h + (1 - P_R)P_d\lambda_c$. The resulting average load for the hotspot is

$$
\rho = \left\{\lambda_h + (1 - P_R)P_d\lambda_c\right\}\frac{1}{\mu}. \qquad (5)
$$

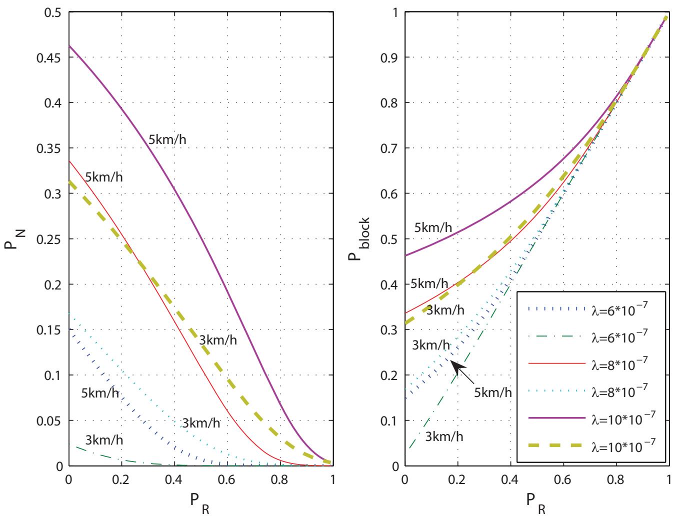

Fig. 2. Impact of P_R on DVHO blocking probability (P_{block}) and hotspot new connection blocking probability (p_N).

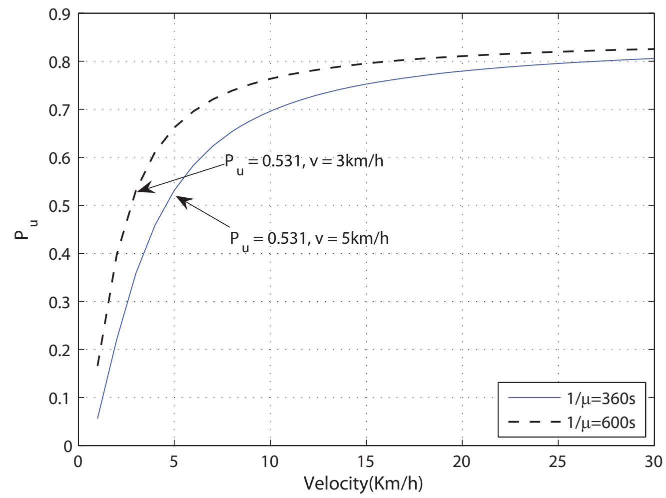

Fig. 3. Impact of v and μ on P_u.

Let N be the maximum number of users that the hotspot can accommodate. To compute N, we use the normalized saturation throughput of the Distributed Coordination Function (DCF) mode of IEEE 802.11 protocol, S which is estimated in [5][1]. Since the parameters of S include the number of users, n, we obtain N as the value of n that maximizes S.

We define the state of the hotspot to be the number of users that are actively consuming the access point's resources. We can model the system using a $M/M/N/N$ queue where the probability that the system is in state n (i.e. supporting n users) is p_n. The probability that this system is not capable of accepting any more users is $p_N = \frac{\rho^N/N!}{\sum_{n=0}^{N} \rho^n/n!}$.

A mobile user's DVHO attempt can fail because the hotspot's bandwidth is fully allocated (i.e., the hotspot is in state N) or because the probabilistic CAC algorithm rejects DVHO calls even though bandwidth is available. The DVHO blocking probability is therefore

$$P_{\text{block}} = \sum_{n=0}^{N-1} P_R p_n + p_N = p_N + P_R(1 - p_N). \qquad (6)$$

If $n \neq N$, the DVHO call's connection attempt will fail with the probability P_R if the CAC algorithm is active. If no CAC is used, then $P_R = 0$ resulting in $P_{\text{block}} = p_N$.

As an example, we consider the network topology shown in Fig. 1, where the cell has a radius of $R = 2$ km while the hotspot's radius is $r = 200$ m. The distance from the cell tower to the hotspot's AP, d, is also 200 m. New connections are generated at a rate λ taking different values of $\{6, 8, 10\} \times 10^{-7}$ calls/s/m^2. For example, when $\lambda = 6 \times 10^{-7}$, the new call arrival rate in the hotspot is about $\lambda_h = 0.08$ arrivals/s. If we suppose that the average connection duration, $1/\mu$, is 360 s, there will be on average around 27 active calls in the hotspot. Likewise, the average DVHO the rate is the overall arrival rate of new calls in the 3G cell multiplied by the probability that the mobiles that make the calls move into the hotspot: $\lambda_{\text{DVHO}} = P_d \lambda_c$. Using these parameters, we can express p_N and P_{block} as a function of P_R, both of which are shown in Fig. 2 for each value of the call arrival rate λ, where we assume that mobile users move at pedestrian speeds of $v = 3$ and 5 km/h.

In Fig. 2, we consider values of P_R between 0 and 0.99. We observe that as P_R increases, p_N decreases while P_{block} increases for each of the three arrival rates. We also observe that increasing the arrival rate λ results in a corresponding increase in p_N and P_{block}. However, from Eq. (6), P_{block} increases as P_R increases, resulting in an "over-rejection problem" that causes the CAC algorithm to block calls even when the system is not overloaded (i.e., $p_N \approx 0$). This situation grows worse as the value of P_R increases. Note that achieving higher system throughput is also essential to developing an effective CAC algorithm. *Therefore, to avoid the over-rejection problem, we reject DVHO calls only when the number of active calls in the AP exceeds $\hat{N}$ which is the minimum value of n that satisfies* $S \geq S'$, where the value of S' is given by the network operator as a design parameter.

As mentioned in Section I, the goal of our CAC algorithm is to reduce unnecessary VHO processing. To achieve this goal, we do not randomly reject all DVHO mobiles but only DVHO mobiles whose speed is higher than a certain threshold, $\hat{v}$, with probability P_R because faster mobiles have a higher UVHO probability, P_u, as we can see in Fig. 3. In the figure, we chose 0.531 to be the highest UVHO probability that we are willing to accept. We can observe that P_u is greater than 0.531 for $1/\mu = 360$ s and $v > 3$ km/h and also for $1/\mu = 600$ s and $v > 5$ km/h, so we would choose 3 km/h and 5 km/h as our values for $\hat{v}$ for the two mean call holding times that we considered. Note that different values of $\hat{v}$ can be used depending on the network design. Thus, to reject faster mobiles with a higher UVHO probability while avoiding the over-rejection problem, we define P_R to be

$$P_R = \beta P_u(v) \frac{n - \hat{N}}{N - \hat{N}} \qquad (7)$$

for $n \geq \hat{N}$, where β is a design parameter; for instance, if

[1] $S = E[\text{packet payload size}]/(T_s - T_c + \frac{\sigma(1-p_t)/p_t + T_c}{p_s})$ where T_s is the average successful transmission time, T_c is the average collision time, p_t is the probability that there is at least one transmission, p_s is the successful transmission probability, and σ is the duration of an empty slot time.

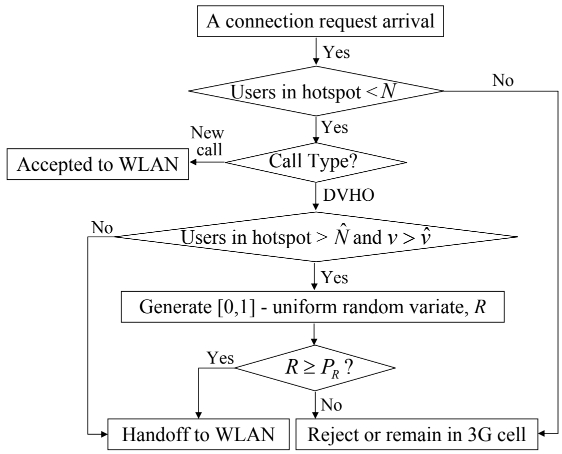

Fig. 4. CAC procedure for DVHO calls in the double-coverage area.

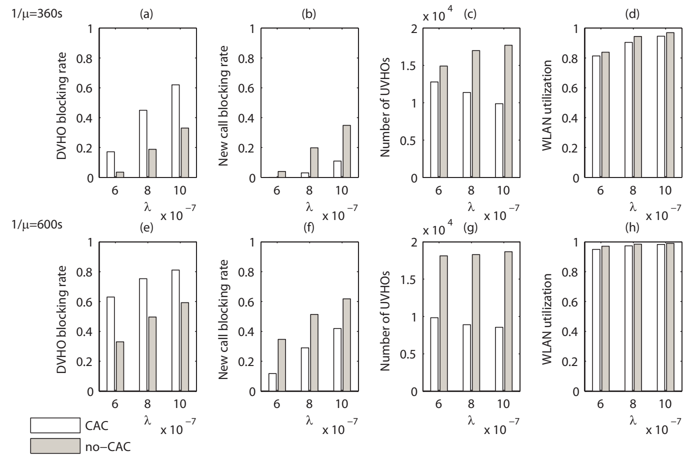

Fig. 5. DVHO blocking rate, new call blocking rate, number of UVHOs and WLAN utilization for $1/\mu = 360$ and 600 s.

we set β (and by extension, P_R) to a small enough value, DVHO calls will have the same priority as new calls. We propose the following two mechanisms to obtain a velocity estimate. In the above Eq. (7), the mobile is assumed to be equipped with Global Positioning System (GPS) devices to detect its velocity v. Then, it sends a connection request with the information about its velocity v to the AP, as proposed in [7] where the call sends a request with the channel utilization parameters to the AP. For example, the velocity v can be contained in Probe Request message as an optional element (Element ID, Length, Velocity)[2]. Alternatively, without receiving the velocity information from the mobile, the WLAN can estimate the mobile's velocity using the maximum Doppler frequency of the signal received from the mobile using one of the four classes of estimators discussed by Abdi et al. [8]. Of these four classes (crossing-based techniques, covariance-based techniques, power spectrum techniques, and maximum likelihood techniques), the first two are more widely used because they are less complex and simple to implement.

We show a flowchart for the CAC algorithm in Fig. 4. The WLAN AP computes P_u and N offline for the hotspot using current traffic statistics. If a DVHO mobile with speed higher than $\hat{v}$ requests a connection to the hotspot and the number of users in the WLAN is greater than $\hat{N}$ such that $S \geq S'$, the AP generates a random variate R that is uniformly distributed over the interval $[0, 1]$ and compares it to P_R. If R is less than P_R, the connection request is rejected and the user must instead keep using the cellular network. Otherwise, the DVHO connection request is accepted.

IV. Simulation Results

We present simulation results that show the effectiveness of the proposed CAC algorithm. For the simulation, we developed a discrete event-driven simulator in the C++ language. The simulation model is consistent with the network topology and parameters used for obtaining the numerical results in Section III, except that in the simulation, 5 hotspots are implemented in the cell. Each WLAN provides a data rate of 6 Mbps while each mobile's data rate is 64 Kbps. $N = 62$ which maximizes S in [5]. We set $S' = 0.8$ which yields $\hat{N} = 49$. In the simulation, we have used $\beta = 1$ in determining the value of P_R in Eq. 7. In addition, to verify that our CAC algorithm is valid for realistic wireless networking environment, our simulation is conducted based on the enhanced random mobility model presented in [6].

Fig. 5 shows the average DVHO blocking rate, the new call blocking rate, the average number of UVHOs, and the average resource utilization for a WLAN for the three arrival rates that we considered. The average WLAN utilization is computed as the ratio of the average number of connections in the WLAN to N. It can be observed from Figs. 5-(c) and (g) that the total number of UVHOs in our CAC is reduced by 31.4% and 50.4% on average for $1/\mu = 360$ s and 600 s, respectively, versus the no-CAC case. This is because DVHO calls with higher P_u are blocked with probability P_R by our algorithm as we see in Figs. 5-(a) and (e). The reduced number of UVHOs indicates that the proposed algorithm can reduce the overall VHO processing load in the integrated WLAN and cellular networks. Interestingly, the number of UVHOs decreases as λ increases. This is because more new calls request resources in the WLAN increasing the load in the hotspot and hence, the AP blocks more DVHO calls associated with mobiles passing through the hotspot. We also observe from Figs. 5-(a) and (e) that more DVHO calls are accepted for $1/\mu = 360$ s than for $1/\mu = 600$ s because for $1/\mu = 360$ s, $\hat{v}$ is set to 5 km/h which is higher than 3 km/h for $1/\mu = 600$ s as shown in Fig. 3. Further, it can be seen from Figs. 5-(d) and (h) that when $1/\mu = 600$ s, although the algorithm rejects more DVHO calls since it rejects DVHO mobiles with the velocity ranging from 3 to 5 km/h for $1/\mu = 600$ s while accepting such DVHO mobiles for $1/\mu = 360$ s, it can achieve a smaller number of UVHOs, compared to the case of $1/\mu = 360$ s.

The proposed CAC algorithm delivers almost the same WLAN utilization as the case of no-CAC, which is confirmed in Figs. 5-(d) and (h). This can be attributed to the fact that our CAC accepts more new calls and DVHO calls with lower P_u (i.e., lower speed) rather than DVHO calls with higher UVHO probability. The fact is corroborated by the average new call

[2]The example is given based on "Extended Supported Rates" element which can be included in Probe Request message optionally for IEEE 802.11g.

TABLE I
PROBABILITY OF UVHO FOR CALLS THAT PERFORMED DVHO IN SIMULATION ENVIRONMENT USING THE RANDOM MOBILITY MODEL

v (Km/h)			1	3	5	7	10
Probability of UVHO	$1/\mu$ (s)	360	0.30	0.43	0.57	0.68	0.72
		600	0.37	0.52	0.69	0.78	0.81

blocking rate shown in Fig 5-(b) and (f), which indicate that the proposed CAC blocks fewer new calls than the no-CAC scheme. This is desirable because most WLANs are deployed in indoor environments and hence, new users who intend to use the WLAN tend to stay in one place [3]. We also observe that the new call blocking rate for $1/\mu = 600$ s is smaller than that for $1/\mu = 360$ s. That is, the CAC algorithm accepts more new calls by blocking more DVHO calls for $1/\mu = 600$ s than for $1/\mu = 360$ s since P_u for $1/\mu = 600$ s is higher than that for $1/\mu = 360$ s as we know from Fig. 3.

Table I shows the average UVHO probability of calls that performed DVHO in simulation environment with the random mobility model. We see from Table I that in the random mobility environment, the DVHO calls capture the almost same behavior as we have seen in Fig. 3. Hence, it is verified via the results from the table that our analytical model of the UVHO probability can be also useful when applying our CAC algorithm to the random mobility environment. We observe that the agreement between UVHO probabilities obtained using the analysis in Section II and the simulation results is closest for larger values of $1/\mu$ and v. In practice, a network operator can rely on simulations or user mobility statistics to obtain $P_u(v)$ in Eq. (7) and then use table lookup to get P_R.

To see the effect of the velocity estimation error on the performance of our CAC, the CAC is simulated with 5% and 10% velocity estimation error that is the difference between the estimated velocity and the velocity with which the mobiles are generated in the simulation. The analysis in [8] indicates that Doppler frequency errors on the order of 10% or less are achievable if one uses any speed estimation technique except for those techniques based on estimating the covariance of the received signal from the mobile, for noise-free isotropic scattering. The random mobility model is applied to the mobiles as well. We first simulate with the velocity estimation error of 5%. When $1/\mu = 360$ s, the relative error in the DVHO blocking rate is about 0.7%, 1%, and 0.2%, respectively for $1/\lambda$=$\{6, 8, 10\}\times10^{-7}$ s. On the other hand, when $1/\mu = 600$ s, the error in DVHO blocking rate is about 1.4%, 1.2%, and 0.7%, respectively for $1/\lambda$=$\{6, 8, 10\}\times10^{-7}$ s. All the errors are less than 1.5%. Next, the CAC is simulated with the velocity estimation error of 10%. When $1/\mu = 360$ s, the error in the DVHO blocking rate is about 0.1%, 2.5%, and 2.1%, respectively for $1/\lambda$=$\{6, 8, 10\}\times10^{-7}$ s, while when $1/\mu = 600$ s, about 2.7%, 2.4%, and 3.4%, respectively for $1/\lambda$=$\{6, 8, 10\}\times10^{-7}$ s. That is, the error in DVHO blocking rate is less than 3.5% when the velocity estimation error is 10%. From these results, we see that the proposed CAC still performs well when there are 5% and 10% velocity estimation errors since the CAC operates when the WLAN is overloaded and further, does not always but randomly reject the calls that exceed $\hat{v}$.

V. SUMMARY

We have shown that the proposed CAC algorithm for WLANs in heterogeneous wireless networks could reduce unnecessary VHO processing while maintaining high resource utilization in the double-coverage area by rejecting DVHO calls that have high UVHO probability only when the traffic load becomes heavy. We derived expressions for DVHO and UVHO probabilities that we used to construct the basic algorithm. We added heuristic elements that prevent the WLAN AP from rejecting handovers when the WLAN utilization is low or when the user speed is low enough that a UVHO is unlikely. The simulation results showed that the proposed CAC for heterogeneous wireless networks reduces the blocking rate of new calls and unnecessary VHO processing in the hotspot compared to the no-CAC case maintaining the resource utilization in the WLAN at a reasonable level. We have also shown via the simulation results that the DVHO blocking rate error from the proposed CAC is less than 1.5% and 3.5% respectively when the velocity estimation error is 5% and 10%.

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