Two-Dimensional Markov Chain Model for Performance Analysis of Call Admission Control Algorithm in Heterogeneous Wireless Networks

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Abstract. This paper proposes a novel call admission control (CAC) algorithm and develops a two-dimensional markov chain processes (MCP) analytical model to evaluate its performance for heterogeneous wireless network. Within the context of this paper, a hybrid UMTS-WLAN network is investigated. The designed threshold-based CAC algorithm is launched basing on the user's classification and channel allocation policy. In this approach, channels are assigned dynamically in accordance with user class differentiation. The two-dimensional MCP mathematical analytic method reflects the system performance by appraising the dropping likelihood of handover traffics. The results show that the new CAC algorithm increases the admission probability of handover traffics, while guarantees the system quality of service (QoS) requirement.

Keywords: Call admission control, handover, two-dimension markov chain, heterogeneous networks, dropping probability.

1 Introduction

In the last years, there is an increasing attention towards the transmission of multimedia applications and services over heterogeneous wireless networking technologies [5]. With the increasing demand for mobile multimedia service, the next generation wireless networks are expected to eventually combine multiple radio technologies [1], purvey the high throughput IP-connectivity to users and achieve service roaming across integrated radio access technologies (RATs). However, this hybrid network architecture requires many technical challenges and functions, including seamless mobility, vertical handovers between diverse RATs, security, subscriber administration, quality of service (QoS) and service provisioning [4].

When a mobile subscriber moves across the overlap networks during its lifetime, handover procedures will be delivered. Meanwhile, new connection requests issued by the intrinsic users are coming forth.

The phenomenon is visualized that handover traffics and new connection will scramble for available radio resource of the target network. That may primarily cause

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the handover dropping by virtue of the limitation of wireless resource and the dynamics large number of users' requests. It is apparent that the increasing of customs and subscriber's mobility lead to the predicament of scarcity limited radio resource allocation and QoS degradation. Hence, QoS provision is an increasingly important task in next generation integrated networks.

One of the key elements in providing QoS guarantees is an effective call admission control (CAC) policy, which not only ensures that the network meets the QoS requirements for new coming traffics but also guarantees that the QoS of the existing does not deteriorate [1]. So it is a tendency to develop an evolved CAC policy for the intricate environment and requirements for differentiating services. This paper is going to present a threshold-based CAC, which sorts users into different classes and uses two-dimensional markov chain process (MCP) to analyze system performance.

The reminder of this paper is organized as follows: Section 2 enumerates CAC for homogeneous and heterogeneous networks respectively; in Section 3, a two-dimension analytical model is revealed; Section 4 presents the numerical results to discuss the performance of new CAC algorithm; finally, this paper is concluded in Section 5.

2 Related Literature

Resource allocation schemes dealing with homogeneous networks have been devised and studied [1]; while a serial of revised CAC algorithms for heterogeneous wireless network have been investigated for a long time. In this section, several proposed works related to the CAC strategies will be introduced for both homogeneous and heterogeneous networks.

2.1 Admission Control Algorithms in Homogeneous Networks

In [3], dynamic channel reservation scheme (DCRS) allows assigning the guard channels reserved for handover traffics to new connection services basing on the request probability to increased channel utilization [2]. It keeps the new connection service blocking probability as low as possible but only provides acceptable quality of handoff services [3].

For handover traffics, dual threshold bandwidth reservation (DTBR) accomplishes the maximum efficiency and maintains the other relative call blocking probability [10]. It employs two thresholds to dominate new connection request voice traffics and data service that involves both handover and new connection request data traffics [7].

2.2 Admission Control Algorithms in Heterogeneous Networks

A great of deal of resource allocation mechanisms are previously addressed for the integrated environment. Ramjee et al. proved Guard channel scheme (GCS), which provides the reserving channels for handover traffic to show its priority. It implements low dropping probability for handover services, but increases new connection services blocking likelihood and degrades the resource utilization [11]. In [8], a CAC algorithm is nominated for voice and data traffics in integrated cellular and WLAN networks. [9] gives the highest priority to the sensitive traffics and degrades the lowest priority connection according to per class degradation[7]. And [12] improves GCS by using a two-dimensional stochastic process model.

3 Analytical Framework for Admission Control Scheme

3.1 Integrated UMTS-WLAN Network

The combination between third-generation (3G) cellular and the IEEE 802.11/16 based wireless networks has been considered as a suitable and viable evolution path toward the next generation of wireless networks [6].

This paper focuses attention on a single UMTS cell and two WLANs, which is shown in Figure 1. In this paper, three classes of user are defined according to the user's moving tendency. *User 1* previously connects with *WLAN A* and tends to move towards to *WLAN B* passing through overlap area. *User 2* is served by *UMTS* network and going to enter *WLAN B* coverage are. *User 3* stays in a stable situation and always has connection with *WLAN B*.

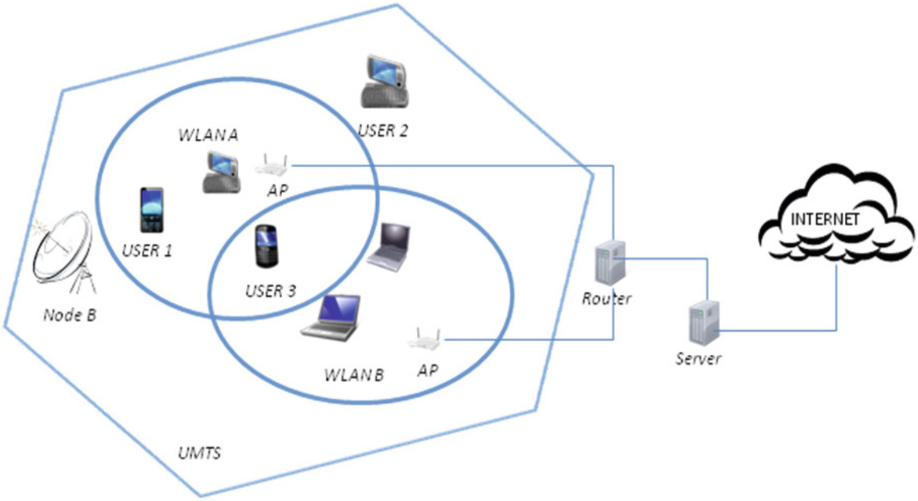

Fig. 1. This figure describes an integrated network consisting of one single UMTS cell and two WLANs. There are three types of user, which are classified according to their mobility.

User 1 and *User 2* send up handover traffics; *User 3* sets up new connection services. Generally speaking, customers prefer to give a higher priority to handover traffics rather than new connection services, especially an ongoing handover traffic. Handover may bring service break off, and it is more annoying to have a call abruptly terminated in the duration of the connection than being blocked occasionally on a new connection attempt [13].

On the other hand, *User 1* ought to bear a higher predominance than *User 2*. The reason is that when *User 1* moves out of *WLAN A* towards to *WLAN B*, *WLAN A* will release the connection with *User 1,* once *User 1* reaches the coverage area of *WLAN B*. If *WLAN B* does not assign the radio resource to *User 1*'s handover traffic, that will cause disruption; while *User 2* has the capability of keeping a continuous serving by *UMTS* network, even if *WLAN B* rejects to permit the channel request from *User 2*. *User 1* is claimed precedence over *User 2* for avoiding service termination. Hence, the channel requests from *User 1* are treated as the highest priority; *User 2* has the intermediate and the resource request from new connection has the lowest priority.

Assuming that the target *WLAN B* has a total channel capacity *C* units and each radio request will occupy one unit. A new connection will be accepted if the occupied channels do not reach *Threshold 1* and a low-priority handover traffic is served when the amount of used resource is not up to *Threshold 2*. A high-priority handover traffic will be accepted as long as there are free channels. Figure 2 shows the channel allocation theory of this new CAC scheme for handover traffics and new connection services.

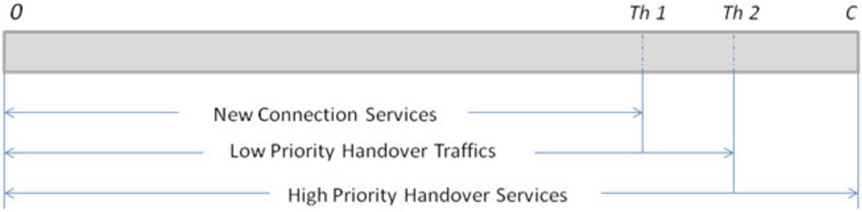

Fig. 2. This diagrammatic sketch illustrates the radio resource allocation policy. It defines two thresholds to measure the priority of different uses.

This threshold-based CAC reflects the priority of each kind of user. A new resource request comes, if there are Th_1 channels are used, the resource request from *User 3* will be denied; once the used channels are up to the amount of Th_2, in that case, not only *User 3*'s but also *User 2*'s channel requests are rejected; with the growth of served traffics, the available radio resource go critical and come of *C*, by then, any channel request will be dropped, even sent from *User 1*.

3.2 Two-Dimensional Traffic Model

Basing on the expatiation above, a two-dimensional MCP system is used to model the prioritized- based CAC algorithm and analyze the performance. The corresponding markov state diagram is portrayed in Figure 3.

Let v_1, v_2 and v_3 are channel request rates of high priority handover traffic, low priority handover traffic and new connection service; the mean serving times for them are $1/\xi_{HH}$, $1/\xi_{LH}$ and $1/\xi_N$, which are following a negative exponential distribution.

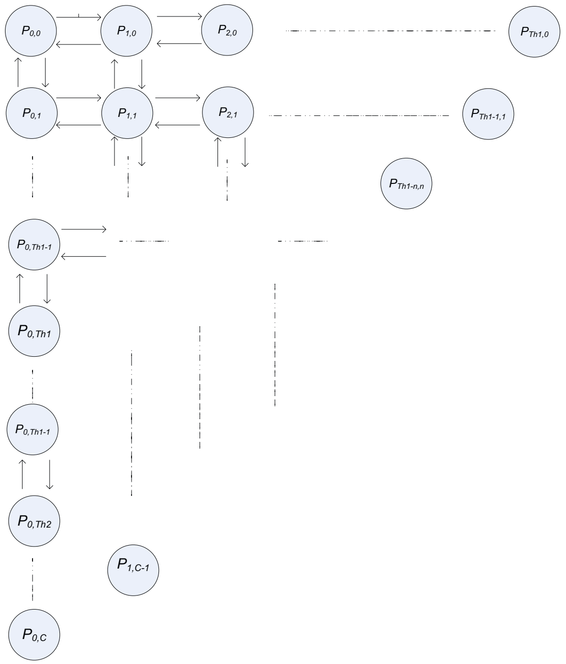

Fig. 3. This is two-dimensional Markov Chain Model. $P_{x,y}$ stands for the steady state probability. Defining Th_1 and Th_2 are thresholds for this scenario.

The intensity of channel request is expressed:

$$I = \frac{v_H}{\xi_H} + \frac{v_3}{\xi_N} \tag{1}$$

Where v_H and $1/\xi_H$ are average channel request rate and service time of handover traffics (both high and low priority).

In this proposed scheme, the performance evaluated parameters are handover traffic dropping probability and new connection blocking probability. The possible state spaces are depicted:

$$S = \{(x,y) \mid x+y \leq C\}. \tag{2}$$

Two-dimensional model settles one server for this system. Each state (x, y) demonstrates the amount of occupied channels: the value of x represents channel number occupied by new connection service and y specifies the quantity of used channel by (high/low priority) handover traffics. Let $S(x,y;x',y')$ stands for the transition rate from state (x,y) to state (x',y') [2]. $P_{x,y}$ clarifies the steady state probability. The channel request rates of new connection and handover traffics are assumed to follow a Poisson arrival process.

Hence, the equation of *S(x,y;x',y')* is denoted:

$$\begin{cases} S(x,y;x,y+1) = v_H, & (0 < x \le Th_1, x+y < Th_1) \\ S(x,y;x,y-1) = y\xi_H, & (0 < x \le Th_1, x+y < Th_1) \\ S(x,y;x+1,y) = v_3, & (0 < x \le Th_1, x+y < Th_1) \\ S(x,y;x-1,y) = x\xi_N, & (0 < x \le Th_1, x+y < Th_1) \\ S(x,y;x,y+1) = v_H, & (0 < x \le Th_1, Th_1 \le x+y < Th_2) \\ S(x,y;x,y-1) = y\xi_H, & (0 < x \le Th_1, Th_1 \le x+y < Th_2) \\ S(x,y;x,y+1) = v_1, & (0 < x \le Th_1, Th_2 \le x+y < C) \\ S(x,y;x,y-1) = y\xi_{HH}, & (0 < x \le Th_1, Th_2 \le x+y < C) \end{cases} \tag{3}$$

The equation of state probability $P_{x,y}$ is exhibited as follows:

$$P_{x,y} = \begin{cases} \dfrac{P_{0,0}}{x!y!} \bullet \left(\dfrac{v_3}{\xi_N}\right)^x \bullet \left(\dfrac{v_H}{\xi_H}\right)^y, & where\ 0 \le x \le Th_1, x+y \le Th_1 \\ \dfrac{P_{0,0}}{x!y!} \bullet \left(\dfrac{v_3}{\xi_N}\right)^x \bullet \left(\dfrac{v_H}{\xi_H}\right)^{Th_1-x} \bullet \left(\dfrac{v_H}{\xi_H}\right)^{x+y-Th_1}, & where\ 0 \le x \le Th_1, Th_1 \le x+y \le Th_2 \\ \dfrac{P_{0,0}}{x!y!} \bullet \left(\dfrac{v_3}{\xi_N}\right)^x \bullet \left(\dfrac{v_H}{\xi_H}\right)^{Th_1-x} \bullet \left(\dfrac{v_H}{\xi_H}\right)^{Th_2-Th_1} \bullet \left(\dfrac{v_1}{\xi_{HH}}\right)^{x+y-Th_2}, & where\ 0 \le x \le Th_1, Th_2 \le x+y \le C \end{cases} \tag{4}$$

P$P_{0,0}$ is the steady state probability of the system being idle[2]. According to the normalization equation $\Sigma_{x,y}P_{x,y}=1$, $P_{0,0}$ is obtained:

$$\begin{aligned} P_{0,0} = [\ & \sum_{x=0}^{Th_1} \frac{1}{x!}\left(\frac{v_3}{\xi_N}\right)^x \bullet \sum_{y=0}^{Th_1-x} \frac{1}{y!}\left(\frac{v_H}{\xi_H}\right)^y \\ & + \sum_{x=0}^{Th_1} \frac{1}{x!}\left(\frac{v_3}{\xi_N}\right)^x \left(\frac{v_H}{\xi_H}\right)^{Th_1-x} \bullet \sum_{y=Th_1-x+1}^{Th_2-x} \frac{1}{y!}\left(\frac{v_H}{\xi_H}\right)^{x+y-Th_1} \\ & + \sum_{x=0}^{Th_1} \frac{1}{x!}\left(\frac{v_3}{\xi_N}\right)^x \left(\frac{v_H}{\xi_H}\right)^{Th_1-x} \left(\frac{v_H}{\xi_H}\right)^{Th_2-Th_1} \bullet \sum_{y=Th_2-x+1}^{C-x} \frac{1}{y!}\left(\frac{v_1}{\xi_{HH}}\right)^{x+y-Th_2}\ ]^{-1} \end{aligned} \tag{5}$$

Recall that once there are no free channels, high priority handover traffics are dropped, thus dropping probability P_{HH} is achieved:

$$P_{HH} = \sum_{x=0}^{Th_1} \frac{P_{0,0}}{x!(C-x)!} \bullet \left(\frac{v_3}{\xi_N}\right)^x \bullet \left(\frac{v_H}{\xi_H}\right)^{Th_1-x} \bullet \left(\frac{v_H}{\xi_H}\right)^{Th_2-Th_1} \bullet \left(\frac{v_1}{\xi_{HH}}\right)^{C-Th_2} \tag{6}$$

When the amount of occupied channels are same as Th_2, the handover traffics from low priority class of user will not gain the services and be dropped, hence, the dropping probability of low priority handover traffics is depicted as formula:

$$P_{LH} = \sum_{x=0}^{Th_1} \frac{P_{0,0}}{x!(Th_2 - x)!} \bullet \left(\frac{v_3}{\xi_N}\right)^{x} \bullet \left(\frac{v_H}{\xi_H}\right)^{Th_1 - x} \bullet \left(\frac{v_H}{\xi_H}\right)^{Th_2 - Th_1} + \\ \sum_{x=0}^{Th_1} \frac{P_{0,0}}{x!} \left(\frac{v_3}{\xi_N}\right)^{x} \left(\frac{v_H}{\xi_H}\right)^{Th_1 - x} \left(\frac{v_H}{\xi_H}\right)^{Th_2 - Th_1} \bullet \sum_{y=Th_2-x+1}^{C-x} \frac{1}{y!} \left(\frac{v_1}{\xi_{HH}}\right)^{x+y-Th_2} \tag{7}$$

Therefore, the total dropping probability of handover traffic is the sum of P_{HH} and P_{LH}.

The expression of the system utilization is profiled as the ratio of the used channels to the whole channel capacity [7]:

$$U = \frac{\sum_{x,y} x y P_{x,y}}{C} \tag{8}$$

4 Mathematical Results

The handover dropping probability is a key measurement of evaluating the system QoS. Thus, in this section, numerical results will be shown in Figure 4 and Figure 5.

In order to analyze the performance of class-based CAC approach, CAC without threshold and with one threshold schemes are introduced: no threshold scheme assigns all available channels to handover and new connection traffics coequally; one threshold method considers low priority handover traffics have the same level of new connection requests.

Assuming that the total capacity of available channel $C=50$, $1/\xi_{HH}=1/\xi_{LH}=1/\xi_N=150s$, $v_1=0.2\sim0.9$ *channel/s*, $v_2=0.25\sim1$ *channel/s* and $v_3=0.25\sim0.8$*channel/s*.

Figure 4 shows that the dropping probability of handover traffics in CAC without and with one threshold strategies. The horizontal axis stands for the handover intensity and the vertical axis represents the dropping probability of high priority handover traffics. With the increasing of traffics intensity, the dropping probability is also elevating. It is obvious that the CAC without threshold has a higher dropping probability then that of one threshold scheme.

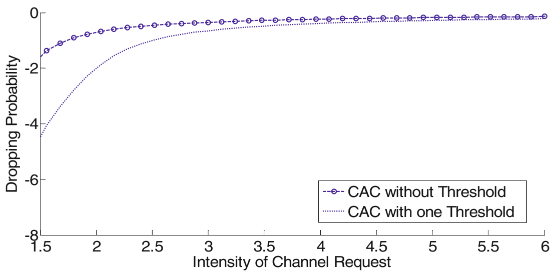

Fig. 4. It plots the dropping likelihood curves for high priority handover traffics of no threshold CAC and one-threshold CAC strategies

Figure 5 explores the dropping probability of high priority handover traffic in one- and two-threshold schemes. Two-threshold based CAC provides a dual-guard for high priority handover traffics; more channels are provided to the highest priority traffics. Therefore, two-threshold method permits more handover traffics to obtain radio channels than other two types of services.

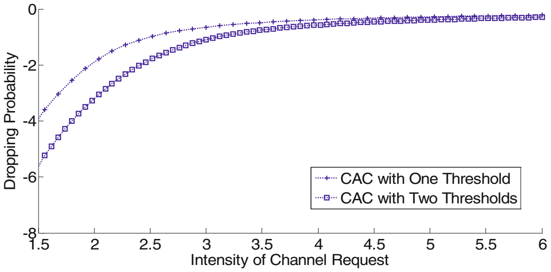

Fig. 5. It appears that two-threshold approach have an advantage in protecting the QoS of high priority handover traffics

The numerical results explicit that two-threshold strategy produces a better performance than no-threshold CAC and one-threshold CAC method in the matter of cutting down the handover services dropping probability and improve the quality of handover services [7].

5 Conclusions

To sum up, this paper utilizes two-dimensional MCP model to resolve class-based CAC algorithm for the next generation wireless networks. This novel method classifies users into distinct levels and assesses the system performance by comparing dropping probability of high priority handover traffics. This approach decreases the dropping probability of handover service, minimizes the dropping likelihood of the user with the highest priority and guarantees the quality of transferred traffic during its lifetime [7].

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