Modeling Admission Control in OFDMA System Using Petri Nets

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Abstract—**Admission control plays an important role in OFDMA system. However, admission control becomes rather complex along with the increase of users' demand and the diversification of service types, so building an appropriate stochastic model is especially significant. The Petri net can distinctly describe the stochastic process. In this paper we build and analyze the Petri net model of admission control in OFDMA system. The simulation results demonstrate our theoretical analysis and indicate that the PN model is effectively to analyze the process of admission in OFDMA system.**

Keywords-OFDMA; admission control; Petri net; blocking probability

I. INTRODUCTION

Along with the development of mobile communication technique and continual increase of users' demand, many research institutions, operators and makers begin to gaze at the research of 3G and 4G mobile communication system. At present, OFDMA technique becomes the dominating technique in physical layer, which makes the system can accept multiuser synchronously, thereby meeting QoS demand of multi-users and multi-services [1].

Call admission control strategy decides whether a call request can be admitted or not according to some criterion [2]. A good admission control strategy can not only ensure service quality of new and present users, but also improve performance and utility of resource, make the service distribution more reasonable, resource allocation more scientific. Due to the adaptive technique in OFDMA system, the system's capability is soft (not hard like FDMA or TDMA), then call admission strategy becomes rather complex [3], so research on stochastic models of call admission control in OFDMA system is very important.

At present, most of research on admission control is in WCDMA system. For OFDMA system, Lu Yanhui *et al.* mentioned that it's essential to build a suitable stochastic model in OFDMA system in [3]. Fernando J. Jaimes-Romero built the resource management model using Petri nets (PN) in [5] firstly, but not validated by theory. In this paper, we bring forward the stochastic model of admission control in OFDMA system, and the model has been validated by theory analysis.

II. PETRI NET

In 1962, Petri net was firstly brought forward by Doctor Carl A. Petri in his doctor paper, in order to describe causality among events in computer system. From 1970s, PN becomes a very flourishing domain, especially in Europe. In 1992, Davis and Alla published the first book on using Petri net as discrete event system(DES) modeling tools. In recent 30 years, lots of scholars and engineer technicians applied themselves to the research on PN theory and application, making PN theory more perfect [4]. In 1997, in [5], Fernando J. Jaimes-Romero built the resource management model using Petri nets.

PN is a graphic and mathematic tool for describing and studying systems that are characterized as being concurrent, asynchronous, distributed, parallel, and/or nondeterministic. A Petri net model is made up of places, transitions and functions (input and output), denoted respectively by circles, rectangles (or wide line) and directional arcs in PN's directional graph. What's more, the number of tokens (presented by dot in circle) means place's state, see figure 1. In figure 1, place P0 and P1 meet the condition that transition T0 can fire, so T0 is enabled. After T0 is fired, tokens are moved from input places to output places, the numbers are arc's weights, and default is 1. In addition, arcs with one circle at one end is forbidden arc, namely the transition is forbidden when the number of tokens in input place is larger than or equal to the forbidden arc's weight.

In recent years, time is introduced into Petri net in several ways, and one of them is: setting a random stochastic time lag between transition is enabled and fire. Petri net of this kind is called stochastic Petri net (SPN). Most analysis of SPN's performance are based on that its state space and Markov chain are isomorphic. SPN provided a good way to describe for system's performance model, and stochastic Markov process provided a stable mathematical basic for model's evaluation [6]. In SPN, time lags that transition is fired obey the exponential distribution.

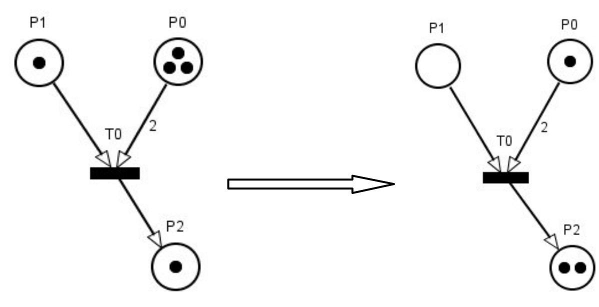

Figure 1. Example of firing transition in PN modeling

Exponential transition is denoted by rectangle in PN's directional graph. See figure 2, transition T0 is enabled in

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current state, but not be fired. After an exponential distributed time lag T0 is fired, system's state changes into the second state.

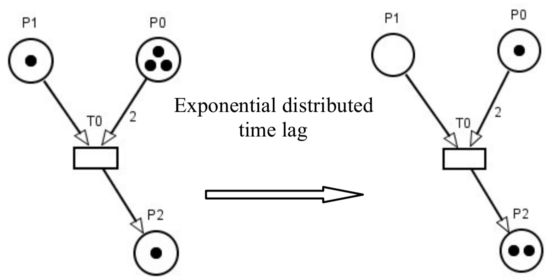

Figure 2. Example of SPN modeling

III. PN's MODEL OF OFDMA SYSTEM

In this part, PN's models of admission control in OFDMA system are given.

A. Admission Control's Model with New Calls and Handoff Calls

Figure 3 is the model of single cell's admission control, with fixed subcarriers allocation. There are two places in the model:

- Cap: idle subcarriers in the cell. Its originally state is the total subcarriers number N.
- Using: occupied subcarriers in the cell. Its originally state is 0.

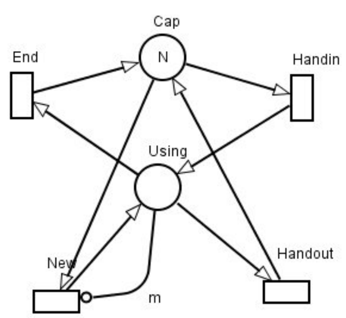

Figure 3. Admission control's model with new calls and handoff calls

Transitions in the model are:

- New: arrival of new calls. Supposed system load is L, average call duration is T, arrival rate is λ, then $L=T*\lambda$, so transition New's time lag is exponential distributed, its mean is T/L. When New is fired, one subcarrier is occupied, namely one token is moved from Cap to Using.
- End: end of calls. Its time lag is exponential distributed, its mean is T. When End is fired, system release a subcarrier, namely one token is moved from Using to Cap.
- Handin: arrival of handoff calls. Supposed handoff calls is one third of the total calls, i.e. one second of new calls, then arrival rate is one second of new calls' arrival rate, so its time lag is twice over New's time lag, namely 2T/L.
- Handout: leave of handoff calls. Supposed the cell is in balance, and then calls that handoff in is equal to calls that handoff out, so its time lag is same with Handin.

What's more, drop in handoff process may bring more dissatisfaction than new call is blocked, so we set a higher priority for handoff calls. When there are both new call request and handoff call request in the system, system admit the handoff call firstly. The priority is incarnated by a forbidden arc between place Using and place transition New, and its weight is m. That means if the number of occupied subcarriers is larger than or equal to m, then new call's admission is forbidden, and only handoff calls can be admitted.

B. Admission Control's Model with Voice Service and FTP Service

1) Setting priority for voice service

Compared with FTP service, voice service is real-time service, so the blocking of an FTP call is less annoying than a voice call being blocked. Based on this idea, we set a higher priority for voice service. What's more, the data rate that FTP service need is 64kbps. According to standard IEEE802.16e, bandwidth 5 MHz is divided into 512 subcarriers, and the peak data rate is 15Mbps, per subcarrier's average data rate is 30 kbps, so we assign 3 subcarriers for FTP service, and one subcarrier for voice service since data rate of voice service is 8kbps.

Figure 4 is admission control's model with voice service and FTP service, which is very familiar with figure 3. The difference is that the arrival and leaving of FTP service respectively occupy and release 3 subcarriers. Accessorial places V and F represent the numbers of voice users and FTP users. Transitions NewV, EndV, NewF and EndF respectively represent arrival and leaving of voice service and FTP service. Supposed the load of voice service and FTP service are respectively equal to half of total system load(L), then the time lag of NewV and NewF is 2*Tv/L, 2*Tf/L, Tv and Tf is the average duration of two services. The time lag of EndV and EndF is respectively Tv, Tf.

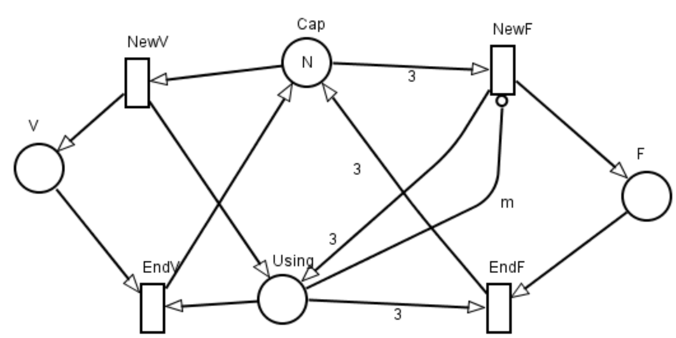

Figure 4. Admission control's model with voice service and FTP service

2) Queuing management to voice calls

Figure 5 is admission control's model with voice service and FTP service plus queuing management to voice calls. Place Universe represents the total users in the cell. When transition NewV is fired, there are tokens in place P1, so transition free, nofree, exit are enabled, but only one of these could be fired. If there are tokens in place Cap, i.e. there are idle subcarriers in system, then transition free is fired, and admit the request. Or else there is no token in Cap, put the voice user into the queue. The capacity of the queue is qCap. If any subcarriers are released when waiting, users in the queue will be admitted firstly, i.e. transition Nowfree is fired. Otherwise exit, request is blocked. Places P0 and P2 represent the numbers of voice users and FTP users.

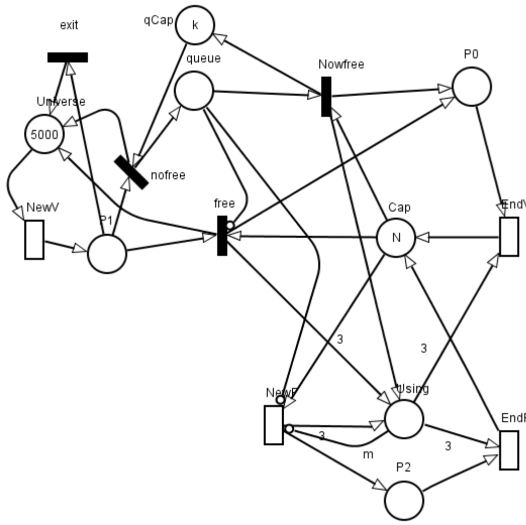

Figure 5. Admission control's model with voice service and FTP service plus queuing management to voice calls

The descending order of the priority of the four immediate transitions is: Nowfree, free, nofree, exit. The three forbidden arcs incarnate the priority of users in the queue, new voice users and new FTP users.

IV. THEORETICAL ANALYSIS AND RESULTS

In order to analyze the models above, we build the Markov model of figure 3 and get its state space [7]. Figure 6 is the Markov model, λ_1, λ_2, μ_1, μ_2 are arrival rate and leaving rate of new calls and handoff calls. From figure 6, we can get:

$$(\lambda_1+\lambda_2)P_{k-1}=(k\mu_1+\mu_2)P_k,\ 1\le k\le 17 \tag{1}$$

$$\lambda_1 P_{k-1}=(k\mu_1+\mu_2)P_k,\quad 18\le k\le 20 \tag{2}$$

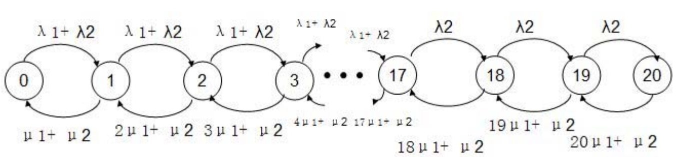

Figure 6. Markov model of figure 3

So
$$P_k=\begin{cases}\dfrac{(\lambda 1+\lambda 2)^k}{\prod\limits_{m=1}^{k}(m\mu 1+\mu 2)}P_0, & 0\le k\le 17\\[2ex] \dfrac{\lambda 2^{(k-17)}*(\lambda 1+\lambda 2)^{17}}{\prod\limits_{m=1}^{k}(m\mu 1+\mu 2)}P_0, & 18\le k\le 20\end{cases} \tag{3}$$

Because $\sum\limits_{k=0}^{20} P_k=1$, so we can get that:

$$P_k=\left(1+\sum_{k=1}^{17}\frac{(\lambda 1+\lambda 2)^k}{\prod\limits_{m=1}^{k}(m\mu 1+\mu 2)}+\sum_{k=18}^{20}\frac{\lambda 2^{(k-17)}*(\lambda 1+\lambda 2)^{17}}{\prod\limits_{m=1}^{k}(m\mu 1+\mu 2)}\right)^{-1} \tag{4}$$

Blocking probability of new calls is P=sum(P(k)), k≥17, and blocking probability of handoff calls is P(20). Figure 7 is our theoretical results of blocking probability. From the result, we can see that blocking probability of handoff calls is much lower than new calls due to the priority. Next section, we will validate it with simulation results.

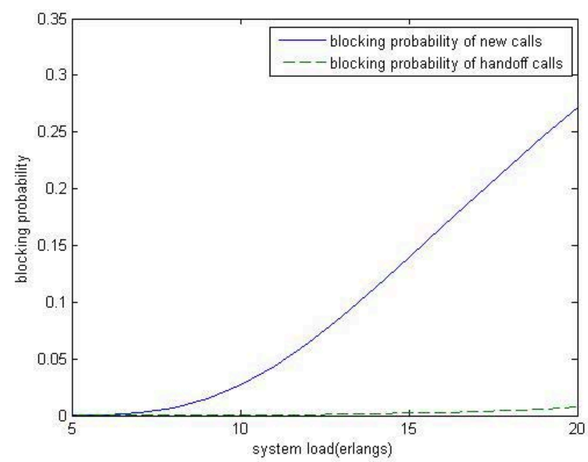

Figure 7. Theoretical results of the model showed by figure 3

V. SIMULATION RESULTS AND VALIDATION

All the simulations in this paper are carried in software TimeNet, and type of PN is EDSPN. In the simulation, we supposed there are 20 subcarriers in the system, namely N=20, and m=17. Tv=100s, Tf=250s.

In the model showed in figure 3, blocking probability of handoff calls is P{Cap=0}, blocking probability of new calls is P{Using>=m}, Comparisons of simulation results and theory results is showed by figure 8 and figure 9. From these two figures we can see that the two results are completely accordant. And now the theory that SPN's state space and Markov chain are isomorphic has been validated.

In the model showed in figure 4, blocking probability of voice users is P{Cap=0}, blocking probability of FTP users is P{Using>=m}. In the model showed in figure 5, blocking probability of voice users is P{Cap=0ANDqueue=k}, supposed k=3, which means that the capacity of queue is 3. Blocking probability of FTP users is P{Using>=m}. Figure 10 and figure 11 are comparison of two models, from which we can see that, the blocking probability of voice users decreases largely at the cost of slight increase of FTP's blocking probability. It answers for our demand.

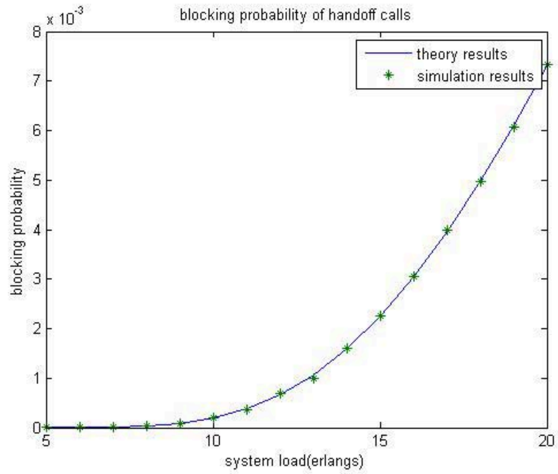

Figure 8. Comparison (1) of simulation result and theory results of model showed by figure 3

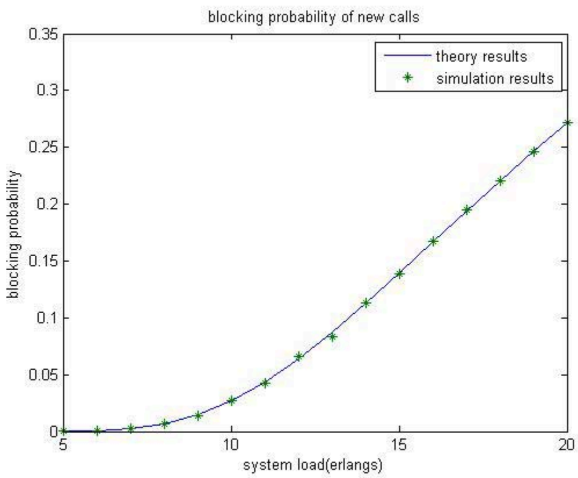

Figure 9. Comparison (2) of simulation result and theory results of model showed by figure 3

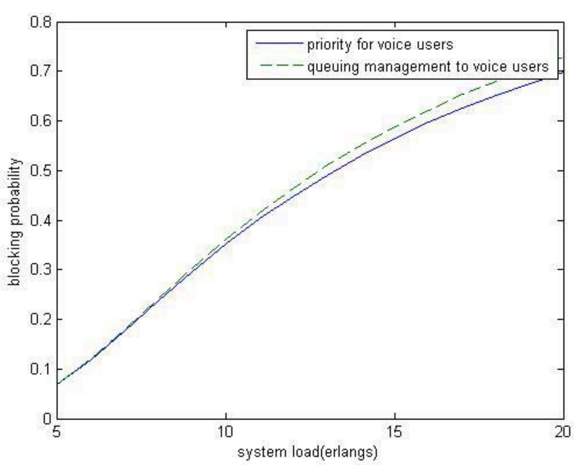

Figure 10. Blocking probability of FTP users in the two models

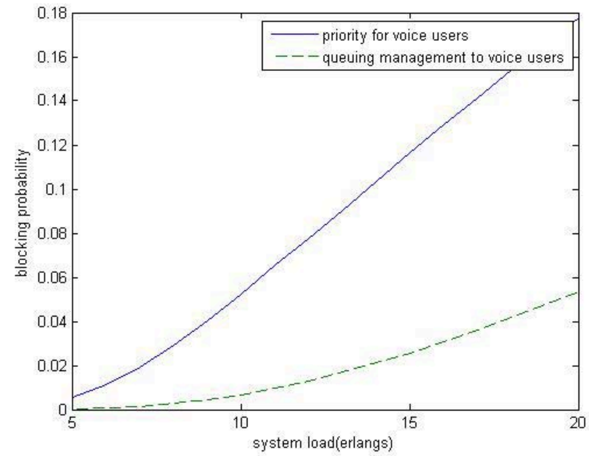

Figure 11. Blocking probability of voice users in the two models

VI. CONCLUSION AND EXPECTATION

We present the PN models of admission control and their simulation results above, from which we can see that introducing Petri net in wireless resource management of mobile communication system is completely feasible. What's more, Petri net is more flexible compared with Markov chain, especially in the situation of multi-services. Next, we will take up with the throughput of the system, and manage to get the interrupted probability result, finally devise a scientific admission control strategy.

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