# A Utility-based Optimal Joint Call Admission Control Scheme with Vertical Handoff in Heterogeneous Wireless Networks

Yu Zhang
Student, Department of Electrical Engineering, East China Normal University, China
E-mail: zhangyu95900@163.com

Lina Chen and Zhengqi Zheng
Department of Electrical Engineering, East China Normal University, China
E-mail: chenlina@zjnu.edu.cn, zqzheng@ee.ecnu.edu.cn

***Abstract*—This paper comes up with a mechanism of optimal joint call admission control based on different service types. Considering practical wireless transmission environment, it divides the heterogeneous wireless network into several areas and also defines the peak rates that its users could get in each area. The process of call admission control is modeled into a semi-Markov process for the two typical services of streaming media service and elastic traffic which need high band width demand. In accordance with the features of different services, it also defines corresponding admission utility function. The optimal admission strategy with highest admission utility in the whole process of call admission control is obtained on the basis of guaranteeing successful session admission and vertical handoff. Simulation results show that the defined admission utility function could effectively reflect the influence of the change of network status to admission control. The suggested optimal joint call admission control excels the both schemes of non-combined call admission control and non-supporting users' mobility in terms of average admission utility and call blocking rate, and is capable of ensuring lower blocking probability and handoff success ratio.**

***Index Terms*—heterogeneous wireless networks, joint call admission control, semi-Markov process, utility function**

## I. Introduction

The next-generation wireless network with heterogeneity has many different wireless access technologies, such as LTE, WiMAX, UMTS, WLAN, Ad Hoc, etc [1,2]. and each of which is different in terms of coverage area, capacity, safety level, service charge and QoS offered to the users. Each technology has its own advantage and limitation, and none of them is capable of provide ubiquitous coverage and persistent QoS of high level in the multiple wireless transmission environment [3]. So a management mechanism of combined wireless resources is necessary to ensure QoS of different services and increase the utilization rate of wireless resources. Heterogeneous wireless network admission or rejecting a call to access some certain network for the purpose of optimal using of wireless resources is called Joint Call Admission Control (JCAC), which plays a significant role in wireless resources management.

Up to now, there have already been some algorithmic mechanisms for providing system performance, but most of these algorithmic mechanisms are limited within coexistence mechanism research in the level of network element, without considering optimal utilization of the whole network resources in the context of heterogeneous wireless network. References [4] and [5] respectively put forward a network selection method of default scheme: in the combinational network of TD-SCDMA and WLAN, users firstly choose WLAN; when WLAN comes to its maximum, users could choose TD-SCDMA. To achieve the above is very simple, but it doesn't take the features of different wireless network and QoS requirement of different service types into account. The aim of JCAC algorithm based on load balancing is to evenly distribute traffic load of network into different networks in heterogeneous wireless networks, so as to better utilize wireless resource [6-8]. This algorithm takes network as center, which may result in lower user satisfaction. The JCAC based on utility or cost function refers to that utility is calculated by multiple decision making indexes or cost function is to control a call admission corresponding network, which is very effective for call admission control [9,10]. Taking restrictive condition of users' time into consideration, reference [11] proposes an algorithm based on utility, and estimates the transmission time that file accessing each network needs, then selects the most suitable network based on different surplus consumers. But this algorithm is only designed for non-real-time traffic. JCAC algorithm based upon computational intelligence refers to selecting a wireless access network for a call


doi:10.4304/jcp.8.12.3152-3159

through application of computational intelligence in allusion to some network-selecting decision making indexes. Often computational intelligence technology includes fuzzy logic [12-15], fuzzy neural network [16], and fuzzy multiple attribute decision making [17]. This algorithm, boasts high validity, and could raise users' satisfaction in heterogeneous environment. However, it is more complex.

This paper, with the help of the achievement that have been acknowledged, comes up with a mechanism of optimal call admission control based on distinguishing service types. It takes two typical services of streaming media service and elastic traffic (file transfer) which need high traffic demand into account, and models the process of call admission into a Semi-Markov decision process (SMDP). It defines corresponding state space and action space, and deducts transition probability of systems in different spaces. In order to better reflect admission utility, based on users' preference and features of different services, the paper defines corresponding admission utility function, and confirms the admission utility of different services under different network status, finally achieves the optimal admission control strategy when obtaining maximum admission utility. This strategy can ensure the success rate of service access and vertical handoff on the basis of keeping lower blocking rate.

## II. Network and Service Model

### A. Network Architecture and Location Division

Next generation wireless network shall be capable of providing higher bandwidth and better QoS for all service types. This paper takes two types of wireless access network consisting of heterogeneous wireless network that can provide service with high traffic rate into consideration, and one of which is LTE, the other is WLAN (802.11n). LTE network covers a larger radio area while WLAN locates in hotspot area, and LTE network completely covers WLAN. These two kinds of network form a combined network with a tight coupling structure, and are put in unified management by one operator.

Suppose a network set $Q$ is combined by $q$ systems, $Q=\{1,2,\ldots,q\}$. When a user who is processing certain service connects a wireless network, the accessible peak rate can be different and it's up to which area the terminal device locates in the cell. The closer the terminal device locates to the access point AP or BS, the higher the peak rate obtains. In order to obtain the real value of throughput of a service in every wireless network, we separate the area covered by BS or AP into different small areas. That is dividing the cell into $n$ concentric circles taking the AP as the circle center, and taking $N$-set as the $n$ types of radio conditions in the cell (AP coverage area),$N=\{1,2,\ldots,n\}$. If a user with radio condition $n$ connects to network $q$, the peak rate he can obtain is defined as $P_n^q$. And for the convenience of calculation of traffic throughput, here we define a vector $K, K=(K_1^1,\ldots,K_n^1,\ldots,K_1^q,\ldots,K_n^q)$, as refer to the number of users for each network in different radio condition.

### B. Network Capacity

Let $C_l$ and $C_w$ be LTE cell and WLAN channel capacity respectively, we assume that there are $G$ class of traffic, $b_{\min}^g$ is the lowest bandwidth requirement of class $g$ call, $g=1,2,\ldots G$. $M_l^g$ and $M_w^g$ are the capacity maximums of the two networks for different service class, then we may respectively have $M_l^g \le \lfloor C_l / b_{\min}^g \rfloor$ and $M_w^g \le \lfloor C_w / b_{\min}^g \rfloor$.

### C. Service Model

Considering most of the literatures in the past had carried out an extensive discussion about voice service and data service as typical ones, we also select the two classic traffics as the representatives of real-time and non-real-time respectively, namely streaming service and elastic traffic ( for example, email, file transfer). One of the users' goals of streaming service is to ensure superior video quality via the throughput supported by coder-decoder. The throughput with lower and upper limitations can be defined as $b^s \in [b_{\min}^s, b_{\max}^s]$ .Note $s$ as streaming service, if $b^s$ is less than $b_{\min}^s$,which means the video quality is very poor or cannot play; if $b^s$ is greater than $b_{\max}^s$ , the traffic will surpass the largest throughput supported by coder-decoder, which doesn't have any improvement for video quality, or rather which couldn't further improve user QoE and waste a lot of broadband resources. However, Elastic traffic is different from streaming media service. The users of elastic traffic could obtain the transmission rate that is variable within the largest network capacity. Theoretically speaking, elastic service doesn't have specific transmission requirement. While in order to get better QoE for users, note the lowest throughput that file transmission needs as $b_{\min}^f$ , mark $f$ as the file transmission in elastic service, the size of file is submitted to exponent distribution with a mean of Z.

The throughput that a service obtains when connecting a network not only depends on the peak rate, but also depends on the number of users that connect network. Assuming fair scheduling is achieved among different users in proportion, the throughput of a user with radio condition class $n$ connected to system $q$ is given by Eq.(1).

$$b_n^q(K) = \min[P_n^q \frac{F(K)}{\sum_{n=1}^{N} K_n^q}, b_{\max}^s] \tag{1}$$

Where $F(K)$ is the opportunistic scheduler gain. If a network is to admit a streaming media service, the lowest throughput that the service needs shall be ensured, namely $b_n^q(K) \ge b_{\min}^s$

Similarly, the throughput that elastic traffic obtains is illustrated in (2):

$$b_n^q(K) = P_n^q \frac{F(K)}{\sum_{n=1}^{N} K_n^q} \quad (2)$$

To admit an elastic traffic for network, the requirement of minimum throughput $b_{\min}^f$ must be met, the largest throughput of transmitting data $b_{\max}^f$ equals to channel capacity $C_q$, namely $b_{\max}^f = C_q$.The range of throughput of elastic traffic is $b_{\min}^f \le b_n^q(K) \le b_{\max}^f$.

Assuming the arrival rate of new streaming service are satisfied Poisson distribution within the space of LTE and WLAN, and respectively are $\lambda_{l,n,s}$ and $\lambda_{w,n,s}$. Similarly, the arrival rate new elastic service are $\lambda_{l,n,f}$ and $\lambda_{w,n,f}$. In line with practical situation, the mobility of users must be taken into account. Suppose streaming media service and elastic traffic within LTE respectively taking the Poisson arrival rate of $\mu_{l,h,s}$ and $\mu_{l,h,f}$ as vertical handoff rate to WLAN, and streaming media service and elastic traffic within WLAN respectively taking the Poisson arrival rate of $\mu_{w,h,s}$ and $\mu_{w,h,f}$ as vertical handoff rate to LTE. The call duration time of streaming media service within LTE and WLAN are exponentially distributed with mean of $1/\mu_{l,t,s}$ and $1/\mu_{w,t,s}$ respectively. The average transmission time of elastic service within LTE and WLAN are $1/\mu_{l,t,f}$ and $1/\mu_{w,t,f}$ respectively.

## III. Admission Control Problem Modeling

### A. State Space

At the decision point of t, the whole network space could be divided into two parts of the service number in LTE network and service number in WLAN network.

The state vector in LTE is illustrated by Eq. (3)

$$x_l(t)=[n_{l,1}(t),n_{l,2}(t),\ldots,n_{l,G}(t)] \quad (3)$$

Where $n_{l,g}(t)$ is the number of class $g$ call in LTE.

The state vector in LTE is illustrated by Eq. (4)

$$x_w(t)=[n_{w,1}(t),n_{w,2}(t),\ldots,n_{wG}(t)] \quad (4)$$

Where $n_{w,g}(t)$ is the number of class $g$ call in WLAN.

By this we could get state vector of the whole network at $t$, shown as Eq.(5)

$$x(t)=[\, x_l(t), x_w(t)] =[n_{l,1}(t),n_{l,2}(t),\ldots,n_{l,G}(t),n_{w,1}(t),n_{w,2}(t),\ldots,n_{w,G}(t)] \quad (5)$$

Gathering all network state vectors at $t$ together is state space of the whole Markov process, shown as Eq.(6).

$$X=\{x=[x_l,x_w]=[n_{l,1},n_{l,2},\ldots,n_{l,G},n_{w,1},n_{w,2},\ldots n_{w,G}]\} \quad (6)$$

### B. Decision Epochs and Admission Control Actions

Under the network state, at the moment of $t$, when a new or vertical handoff call arrives, admission control algorithm makes decision on whether to admit the call or not in accordance with service types. Here $t$ is called decision epoch. Equally, each time when a call departure occurs, the state space of network also changes, which is called virtual decision epochs. For unification, we choose the decision epochs to be the set of all session arrival and departure instances. Let $t_0$=0. The decision epochs are taken to be the instances $t_k$,$k$=0,1,2,… At each decision epoch $t_k$,, the network makes a decision for each possible call arrival that may occur in the time($t_k$,$t_{k+1}$]. These decisions are collectively referred to as an action. Action $a$ ($t_k$) at decision epoch is defined as

$$a(t_k)=[a_{l,n}(t_k),a_{l,h}(t_k),a_{w,n}(t_k),a_{w,h}(t_k)] \quad (7)$$

where $a_{l,n}(t_k)$,$a_{l,h}(t_k)$,$a_{w,n}(t_k)$ and $a_{w,h}(t_k)$ are defined and interpreted as follows:

(1) Admission actions when new call service and vertical call service arrive in LTE network

$$a_{l,n}(t_k)=[a_{l,n,1}(t_k), a_{l,n,2}(t_k),\ldots,a_{l,n,G}(t_k)]\in \{0,1\}^G$$

$$a_{l,h}(t_k)=[a_{l,h,1}(t_k), a_{l,h,2}(t_k),\ldots,a_{l,h,G}(t_k)]\in \{0,1\}^G$$

Where denote $a_{l,n,g}(t_k)$ and $a_{l,h,g}(t_k)$ the actions for class g new call and vertical handoff call arrivals in the LTE area at decision epoch $t_k$ respectivly. If $a_{l,n,g}(t_k)$=1 and $a_{l,h,g}(t_k)$=1, arriving services in the interval ($t_k$,$t_{k+1}$] are admitted to LTE network; if $a_{l,n,g}(t_k)$=0 and $a_{l,h,g}(t_k)$=0, they are rejected.

(2) Admission actions when new call service and vertical handoff call service arrive in WLAN network

$$a_{w,n}(t_k)=[\, a_{w,n,1}(t_k), a_{w,n,2}(t_k),\ldots a_{w,n,G}(t_k)]\in \{-1,0,1\}^G$$

$$a_{w,h}(t_k)=[\, a_{w,h,1}(t_k), a_{w,h,2}(t_k),\ldots a_{w,h,G}(t_k)]\in \{0,1\}^G$$

Where denote $a_{w,n}(t_k)$,$a_{w,h}(t_k)$ the actions for class g new call and vertical handoff call arrivals in the WLAN area at decision epoch $t_k$. If $a_{w,n}(t_k)$=1and $a_{w,h}(t_k)$ =1, arriving services in the interval ($t_k$,$t_{k+1}$] are admitted to WLAN network; if $a_{w,n}(t_k)$=0and $a_{w,h}(t_k)$ =0, they are rejected; if $a_{w,n}(t_k)$=-1and $a_{w,h}(t_k)$ =-1, the call service will be admitted to LTE network.

The total action space could be defined as:

$$A=\{a=[a_{l,n},a_{l,h},a_{w,n},a_{w,h}]: a_{l,n}\in \{0,1\}^G, a_{l,h}\in \{0,1\}^G, a_{w,n}\in \{-1,0,1\}^G, a_{w,h}\in \{0,1\}^G, g=1,2,\ldots G\} \quad (8)$$

If given a state $x\in X$, the action space of admission control can be defined as:

$$A_x=\{a\in A: a_{l,n,g}=0 \text{ and } a_{l,h,g}=0 \text{ if } [x_l+e_g^u, x_w]\notin X, \; a_{w,n,g}\neq 1 \text{ and } a_{w,h,g}=0 \text{ if } [x_l, x_w+e_g^u]\notin X, \; g=1,2,\ldots,G, \text{ and } a\neq(0,0,\ldots,0) \text{ if } x=(0,0,\ldots 0)\} \quad (9)$$

where denotes $e_g^u \in \{0,1\}^G$ a row vector contains only zeros except for the $g$th component, which is $x_w+e_g^u$ corresponds to an increase of the number of class $g$ call by 1 in the WLAN network.

### C. Expected Sojourn Time

(1) Definition of total accumulated event rate

The sum of the total business arrival rate and the total service leaving rate is the total accumulated event rate. If LTE network and WLAN network accept class g call new arrival service and vertical handoff service, the total service arrival rate is expressed as follows:

$$\sum_{g=1}^{G}(\lambda_{l,n,g}+\mu_{w,h,g}n_{w,g}+\lambda_{w,n,g}+\mu_{l,h,g}n_{l,g}) \quad (10)$$

The total service leaving rate:

$$\sum_{g=1}^{G}(\mu_{l,t,g}n_{l,g}+\mu_{w,h,g}n_{w,g}) \quad (11)$$

(2) Expected sojourn time

Referring to the expected time from the time when state x adopts admission control behavior to the time when the next network state transfers. Due to the dynamic nature of the network state, the network stay time in each state varies. The time is the reciprocal of the total accumulated event rate, expressed as follows [18]:

$$\tau(x,a_x)=[\sum_{g=1}^{G}(\lambda_{l,n,g}a_{l,n,g}+\mu_{w,h,g}n_{w,g}+\lambda_{w,n,g}\left|a_{w,n,g}\right| \\ +\mu_{l,h,g}n_{l,g}a_{w,h,g}+\sum_{g=1}^{G}(\mu_{l,t,g}n_{l,g}+\mu_{w,t,g}n_{w,g})]^{-1} \quad (12)$$

### D. State Transfer Probability

In Semi-Markov decision process, the dynamic changes of the network state can be expressed by the state transfer probability of the embedded Markov chain and expected sojourn time of each state [19,20].

$$p_{xy}(a)\triangleq P(x(t_{k+1})=y\mid x(t_k)=x,a(t_k)=a) \quad (13)$$

$$\tau(x,a_x)\triangleq E\{t_{k+1}-t_k\mid x(t_k)=x,a(t_k)=a) \quad (14)$$

The transfer probability from state $x$ to state $y$ in LTE/WLAN heterogeneous network system is expressed as follows:

$$p(y\mid x,a_x)= \begin{cases} [\lambda_{l,n,g}a_{l,n,g}+\lambda_{w,n,g}\delta(-a_{w,n,g})]\tau(x,a_x), & if\ y=[x_l+e_g^u,x_w] \\ \lambda_{w,n,g}\delta(a_{w,n,g})\tau(x,a_x), & if\ y=[x_l,x_w+e_g^u] \\ \mu_{w,h,g}n_{w,g}a_{l,h,g}\tau(x,a_x), & if\ y=[x_l+e_g^u,x_w-e_g^u] \\ \mu_{l,h,g}n_{c,g}a_{w,h,g}\tau(x,a_x), & if\ y=[x_l-e_g^u,x_w+e_g^u] \\ \mu_{c,t,g}n_{c,g}\tau(x,a_x), & if\ y=[x_l-e_g^u,x_w+e_g^u] \\ [\mu_{w,t,g}+\mu_{w,h,g}(1-a_{l,h,g})]n_{w,g}\tau(x,a_x), & if\ y=[x_l+e_g^u,x_w-e_g^u] \\ 0 & \text{else} \end{cases} \quad (15)$$

Where, $\delta(x)$ is the sign function,

$$\delta(x)=\begin{cases}0, & x\le 0\\ 1, & x>1\end{cases} \quad (16)$$

### E. Utility Function

When the network state is $x$ and the selected admission behavior of the arrival service is $a_x$, the system will obtain the corresponding utility. If the utilities obtained by the admission new call and vertical handover call in the LTE network are respectively $r_{l,n}$, $r_{l,h}$, the utilities obtained by the admission new call and vertical handover call in the WLAN network are respectively $r_{w,n}$, $r_{w,h}$, the system admission utility function can be expressed as follows:

$$r(x,a_x)=\sum_{g=1}^{G}[r_{l,n,g}a_{l,n,g}+r_{l,h,g}a_{l,h,g}+r_{w,n,g}\delta(a_{w,n,g}) \\ +r_{l,n,g}\delta(-a_{w,n,g})+r_{w,h,g}a_{w,h,g}+r_{l,n,g}(1-a_{w,n,g})] \quad (17)$$

The method to obtain utility values $r_{l,n}$, $r_{l,h}$, $r_{w,n}$ and $r_{w,h}$ in the admission of different call will de described in detail in the next part. Eq. (17) shows the type of service and the state of the current network system determine admission behavior and admission utility of the system.

Given the system state is $x\in X$, select admission behavior $a_x\in A_x$ according to strategy $u_x\in U$, where $U$ is a set of admissible policies, as shown below:

$$U=\{u:X\rightarrow A\mid u_x\in A_x,\forall x\in X\} \quad (18)$$

The average utility standard is selected as performance standards of Markov decision process, as for given initial state $x_0$ and strategy $u\in U$, the average utility can be expressed as:

$$R_u(x_0)=\lim_{T\to 0}\frac{1}{T}E\left\{\int_0^T r(x(t),a(t))dt\right\} \quad (19)$$

Where $T$ represents the elapsed time of the Markov process as a whole, and $r(x(t),a(t))$ represents the expected utility generated before the transfer of the next state in the decision-making moment. The purpose is for an arbitrary initial state $x_0$, finding an optimal strategy $u^*$ so as to maximize the average utility $R_u(x_0)$

## IV. Admission Utility Function And Optimal Strategy Based On The Utility Function

Taking into account QoS factors of different services, for the effective use of network resources, and the improvement of the satisfaction of the users for the network service, the service utility functions are defined as follows:

### A. Utility Function of Service

Occupied bandwidth ($B$), delay ($D$) and bit error rate ($E$) of current network are selected as the performance indexed, the admission reward is assessed with service utility function. First, the QoS level of the network $q$ for different services was defined:

$$L_q=\prod_{j=1}^{3}(1-h_j)^{\theta_g^j} \quad (20)$$

Where $h_1=B_q/B_{q,M}$ $h_2=D_q/D_M$,$h_3=E_q/E_M$, $B_q$,$D_q$,$E_q$ represent network $q$ current occupied bandwidth, delay and bit error rate respectively, while $B_{q,M}$ ,$D_M$,$E_M$ represent network $q$ maximum bandwidth, all services QoS limited maximum delay and maximum bit error rate. $\theta_g^j$ represent corresponding class $g$ call weight corresponding to $j$th performance index factor (1-$h_j$)and $\sum_{j=1}^{3}\theta_g^j=1$. In order to derive a business utility function, it is necessary to further analyze data transfer of the specific service, taking into account the user QoE. For elastic service, such as file transfer, it was necessary to set minimum rate requirements, especially for large files. For streaming service, it was proper to meet the minimum rate requirements and improve the video quality through increasing the transmission rate, even if there is the upper limit to the maximum allowable transmission rate of a coder. In essence, the transmission rate of streaming service can be adjusted in a certain range, and this is similar to the elastic service, except that the transmission rate of the elastic service has a much greater range. In terms of service features described herein, and the above analysis, the utility functions of streaming service and elastic service are all concave function between the lowest transmission rate and the maximum transmission rate. Therefore, these two service utility function were defined as follows:

$$z_q(g)=\begin{cases}\dfrac{1-e^{-\alpha_g b_g}}{1-e^{-\alpha_g(b_{\max}^g-b_{\min}^g)}}L_q, & if\ b_g\ge b_{\min}^g\\ 0, & if\ b_g<b_{\min}^g\end{cases} \quad (21)$$

Where $z_q(g)$ represents the utility obtained by network $q$ through acceptance of class g call. $b_g$ represents bandwidth allocated by the current network to class g call. $b_{\min}^g$ and $b_{\max}^g$ respectively represents the minimum required and the maximum achievable bandwidth value by class g call. The selection of $\alpha_g$ determined the shape of the curve of the function. It should be emphasize that the streaming service and elastic service witnessed the concave function, but the range of both additional value is different, so the Eq. (1) could still highlight the characteristics of the two businesses. Definition of service utility function made by Eq. (21) achieved $r_{l,n,s}=r_{l,h,s}=z_l(s)$ , $r_{l,h,f}=r_{l,h,f}=z_l(f)$ , $r_{w,n,s}=r_{w,h,s}=z_w(s)$, $r_{w,n,f}=r_{w,h,f}=z_w(f)$

### *B. The Optimal Strategy*

Considering all the network states $x\in X$ and all probable corresponding admission control behavior $a\in A$, the maximum network acceptance utility can be expressed as follows [21]:

$$\max\sum_{x\in X}\sum_{a\in A_x} r(x,a_x)\tau(x,a_x)\pi(x,a_x) \quad (22)$$

Subject to

$$\sum_{a_y\in A_y}\pi(y,a_y)-\sum_{x\in X}\sum_{a_x\in A_x}p(y\,|\,x,a_x)\pi(x,a_x)=0,\ y\in X \quad (23)$$

$$\sum_{x\in X}\sum_{a_x\in A_x}\tau(x,a_x)\pi(x,a_x)=1 \quad (24)$$

$$\pi(x,a_x)\ge 0,\quad x\in X,\quad a_x\in A_x \quad (25)$$

Variable $\pi(x,a_x)$ meeting conditions (23)-(25) indicates steady-state probability that the system is in state $x$ and acceptance behavior $a_x$ is selected. Linear programming approach is adopted to achieve the optimal admission control policies $u^*$ with meeting certain restrictions, so as to maximize the network admission utility.

### *C. Session Blocking Probability*

To LTE network, new session and vertical handoff session blocking probability are defined respectively as Eq.(26) –(27).

$$b_{l,n,g}=\sum_{x\in X}\sum_{a_x\in A_x}(1-a_{l,n,g}(x))\pi(x,a_x) \quad (26)$$

$$b_{l,h,g}=\sum_{x\in X}\sum_{a_x\in A_x}(1-a_{l,h,g}(x))\pi(x,a_x) \quad (27)$$

To WLAN network, new session and vertical handoff session blocking probability are defined respectively as Eq.(28) –(29).

$$b_{w,n,g}=\sum_{x\in X}\sum_{a_x\in A_x}(1-\left|a_{w,n,g}(x)\right|)\pi(x,a_x) \quad (28)$$

$$b_{w,h,g}=\sum_{x\in X}\sum_{a_x\in A_x}(1-a_{w,h,g}(x))\pi(x,a_x) \quad (29)$$

## V. Simulation Results And Analysis

Heterogeneous wireless network model shown as in Fig.1 indicates the LTE network has a WLAN AP, LTE network has a coverage radius of 1000m, WLAN has a coverage radius of 400 meters. In order to simplify the analysis of the problem, it is assumed each network was divided into two types of radio conditions, good radio conditions close to the base station or the AP center, corresponding to Area A (0-500 m) and Area C (0-200m).The peak rate is respectively represented by $P_1^l$ and $P_1^w$, far from the base station. The AP center in the edge with poor radio conditions corresponds to Area B (500-1000 meters) and Area D (200-400m).The peak rate is respectively $P_2^l$ and $P_2^w$. Thus, the user in different areas has different radio conditions and thereby can reach different peak rates.

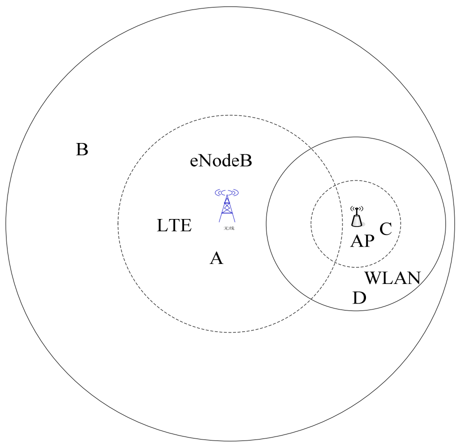


Figure 1. Heterogeneous wireless network simulation scene

### *A. Simulation Parameters Setting*

This paper considers the two typical service streaming and file transfer with high rate requirement. The WLAN is characterized by sufficient distribution areas, with its service operations accounting for 30% of the total volume of services in the non-overlapping coverage areas. The service of the overlapping coverage area accounts for 70% of the total services. The proportion of the amount of the two operations is 1:1.The total arrival rate of the streaming service is $\lambda_{n,s}=\lambda_{l,n,s}+\lambda_{w,n,s}$, and elastic service arrival rate is $\lambda_{n,f}=\lambda_{l,n,f}+\lambda_{w,n,f}$. Vertical handover rate $\mu_{l,h,s}$ and $\mu_{l,h,f}$ of the streaming media and elastic service in LTE is 0.006. Vertical handover rate $\mu_{l,h,s}$ and $\mu_{l,h,f}$ of the streaming media and flexible service in WLAN is 0.0004. The streaming service average session duration time is $1/\mu_{l,t,s}=1/\mu_{w,t,s}=120$s. The weights of the streaming service and elastic service on occupied bandwidth $B$, delay $D$ and bit error rate $E$, the three performance indexes factors, are $Ws$=(0.2,0.4,0.4)and $W_f$=(0.5,0.1,0.4) respectively. Other parameter values are shown as in Table I.

TABLE I.
SIMULATION PARAMETERS VALUES

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| $C_l$ | 50Mbsp | $P_1^l$ | 50Mbsp |
| $C_w$ | 100Mbsp | $P_2^l$ | 30Mbps |
| $b_{min}^s$ | 1Mbsp | $P_1^w$ | 100Mbps |
| $b_{max}^s$ | 2Mbsp | $P_1^w$ | 60Mbps |
| $b_{min}^f$ | 0.5Mbsp | $D_M$ | 400ms |
| Z | 1MB | $E_M$ | $10^{-3}$ |

## *B. Simulation Results and Performance Analysis*

In order to compare the performance of different admission control mechanisms, this paper compared the developed optimal joint call admission control mechanism (Optimal JCAC) to two other admission control mechanisms, with one of them as vertical handover non-Joint Call Admission Control mechanisms (Non-JCAC). Each network admission control independently controls the new call service or vertical handover call service. Another joint call admission control does not support vertical handover admission control, that is, does not support the handover calls generated by the user when the network is moving.

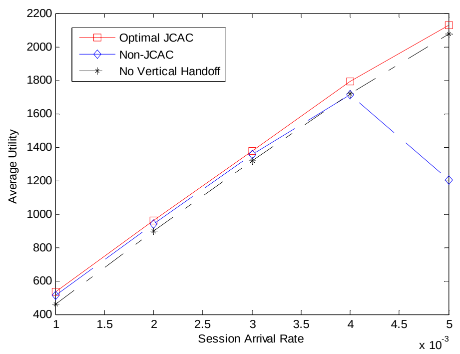


Figure 2. System average utility

As shown in Fig.2, with the arrival rate of the service of streaming and file transfer operation increases from 0.001 to 0.005, the average utility obtained by the optimal admission control mechanism proposed by this paper is always greater than that of the other two mechanisms. When the session arrival rate is relatively low, the performance difference is not obvious. When the session arrival rate is relatively high, the network traffic becomes saturated. The Optimal JCAC average utility value is much higher than that of the Non-JCAC because the joint mechanism can balance network load through selecting the network increasing bandwidth utilization of the two networks, and it is possible to accept more service and increase the average utility of the system. The Non-JCAC cannot achieve the two network load balancing control, leading to early access to network saturation, resulting in average utility value rapid decrease after saturation. The average admission utility not supporting vertical handover control mechanism is slightly lower than that of the optimal acceptance mechanism. The main reason is that the vertical handoff call produces dropping, reducing the admission utility value.

Fig.3 shows the system throughput with the increasing of the session arrival rate. It can be seen from the figure that the difference in throughput between the various admission controls is not obvious since the system is not saturated then. But with the increase in service volume, Optimal JCAC mechanism outweighs the Non-JCAC mechanism, providing greater throughput to the service because it has the function of balancing the loads between networks, allocating available bandwidth resources in a full and balanced manner and achieving higher bandwidth utilization. Non-joint admission control mechanism cannot adjust bandwidth allocation according to the state of each network between the two networks, or rationally use radio resources, making either network reserve certain available bandwidth resources. Therefore, when the system is close to saturation, the throughput is lower than that of the other two algorithms. The mechanism not supporting vertical handover adopts the admission selection strategy the same as optimal admission control, thus basically maintain the same throughput as the optimal acceptance mechanism, slightly lower when it is close to saturation. The higher throughout means better video quality and faster file download rate.

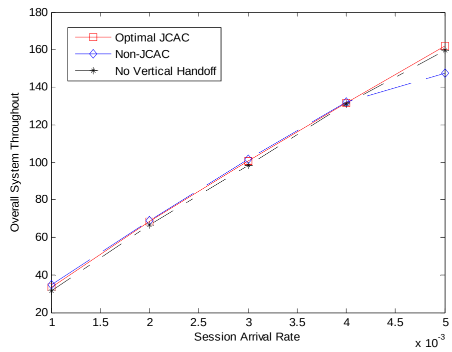


Figure 3. System throughout

Fig.4 shows the blocking probability of the vertical handoff call increasing with the session arrival rate. The Optimal JCAC balances the load between networks since it allocates available bandwidth resources in a full and balanced manner. Blocking appears only when the network is saturated. Due to the relatively small amount of handover operations, the blockage rate is relatively low. Non-JCAC mechanism adopts the same strategy in dealing with vertical handoff call as the optimal admission. However, because of the system earlier saturation, blockage appears earlier. The reason why its blockage rate is higher than that of the Optimal JCAC is its bandwidth utilization rate is lower. The admission control mechanism not supporting vertical handover has its blocking rate constantly as 1.

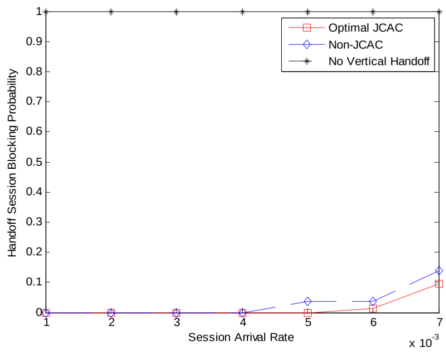


Figure 4. Handoff session blocking probability

Fig.5 shows the change of the new call blocking probability with the increasing of session arrival rate. Optimal JCAC produces blocking case until the network become to congestion. Compare to the Non-JCAC mechanism, Optimal JCAC can allocate reasonably service between networks that reduces load balancing, and improve resource utilization. However, Non-JCAC cannot allocate jointly service into the two networks. As a result, the surplus bandwidth of the two networks is not be used which reduce higher blocking case easily. To no vertical handoff JCAC, it can keep the similar performance compare with the optimal JCAC because of the jointly resource allocation. Moreover, its new service blocking is lower than that of optimal JCAC, it can save more bandwidth through dropping of handoff service to admission more new call and reduce the service blocking. Of cause, the cost is higher handoff blocking probability.

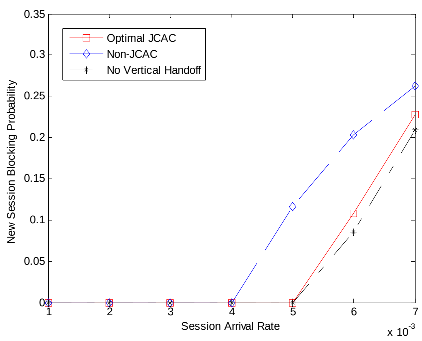


Figure 5. New session blocking probability

## VI. Conclusion

This paper proposes a differentiated service joint call admission control scheme in heterogeneous wireless networks. The peak rate of different area of networks is considered. A theoretical model of admission control with different service types is proposed on basis of Markov decision process theory. Furthermore, a admission utility evaluation mechanism is presented based on the analysis of relationship of service QoS requirements and network state, then the optimal admission control policy that maximizes system utility with corresponding constraints is formulated. The simulation results show that the proposed admission utility function can reflect the network dynamics and satisfy different services QoS requirement. The average utility obtained in the optimal joint call admission control policy is larger than two other scheme in which joint call admission control and mobility are not considered. In addition, the proposed scheme has higher throughput while keep lower session blocking probability compare with other schemes and improves overall resource utilization.

## References

[1] C.F. Wang, C.H. Lan, S.F. Niu. "An ID-Based Certified E-mail protocol with STTP Suitable for wireless mobile environments," *Journal of Computers,* vol. 8, pp. 3-9, 2013.

[2] Y.Q. Ding, G.T. Han, X.M Mu. "A Distributed Localization Algorithm for Wireless Sensor Network Based on the Two-Hop Connection Relationship," *Journal of Software*, vol. 7, pp. 1657-1663, 2012.

[3] K. Murray, R. Mathur, D. Pesch. "Network Access and Handover Control in Heterogeneous Wireless Networks for Smart Space Environments," *First International Workshop on Management of Ubiquitous Communications and Services*, MUCS, Waterford, Ireland, December 11, 2003.

[4] E.S.Navarro, V.Wong, Y. Lin. "A vertical handoff decision algorithm for heterogeneous wireless networks," *Proeeedings of the IEEE Wireless Communications and Networking Conference*,pp. 3199-3204,Mar 2007.

[5] L.T.Liang, H.Wang, and P.Zhang."Net utility-based network selection seheme in CDMA cellular/WLAN integrated networks," *Proceedings of the IEEE Wireless Communications and Networking Conferene*,pp.3313-3317,Mar 2007.

[6] A. Tölli, P. Hakalin. "Adaptive Load Balancing Between Multiple Cell Layers," *Proceeding of IEEE 56th Vehicular Technology Conference*,vol.3, pp.1691-1695, 2002

[7] K.H. Suleiman, H.A. Chan, M.E. Dlodlo. "Load balancing in the call admission control of heterogeneous Wireless Networks," *International Conference On Communications And Mobile Computing*, pp. 245-250, 2006.

[8] R. Lian,T. Hui, et al. "QoS-Aware load balancing algorithm for joint group call admission control in heterogeneous networks," *Vehicular Technology Conference (VTC Spring)*, pp. 1-5, 2012.

[9] H. Chen, C.C Cheng, et al."A reduced dimension MDP-based call admission control scheme for next generation telecommunications," *Wireless Communications and Mobile Computing Conference*, pp. 984-989, 2012.

[10] A. Sharna, R. Amin, M. Murshed."Call admission control policy for multiclass traffic in heterogeneous wireless networks," *International Symposium on Communications and Information Technologies Conference,* pp. 433-438, 2011.

[11] O. Ormond, J. Murphy, G. Muntean. "Utility-based

intelligent network selection in Beyond 3G Systems" . *IEEE International Conference on Communications*, Istanbul, Turkey, June 2006.
[12] 0P.M.L. Chan, R.E. Sheriff, Y.F. Hu, P. Conforto, C. Tocci "Mobility Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment,". *IEEE Communications Magazine*, vol. 12, pp.42–51, 2001.
[13] Y.H. Chen, C.J. Chang, C.Y. Huang."Fuzzy Q-Learning admission control for WCDMA/WLAN heterogeneous networks with multimedia traffic," *IEEE Tran. Mobile Computing*, vol. 8, pp. 1469-1479, November 2009.
[14] S. Jie, Y. Zheng, et al, "A novel load balancing algorithm based on utility functions and fuzzy logic in heterogoneous wireless networks,", *International Conference on Fuzzy Systems and Knowledge Discovery*, pp. 414-418, 2012.
[15] S. Sha, R. Halliewell, "Performance modeling and analysis of dynamic class-based call admission control algorithm using fuzzy logic for heterogeneous wireless networks," *International Joint Conference of IEEE TrustCom-11*, pp. 1795-1799, 2011.
[16] R. Agusti, O. Sallent, J. Pérez-Romero, L. Giupponi. "A fuzzy-neural based approach for joint radio resource management in a Beyond 3G Framework. *1st International Conference on Quality of Service in Heterogeneous Wired/Wireless Networks*, Dallas, USA, October, 2004.
[17] W. Zhang. "Handover Decision Using Fuzzy MADM in Heterogeneous Networks," *Proceedings of IEEE WCNC'04*, Atlanta, GA, March, 2004.
[18] M.L.Puterman, Ed, *Markov Decision Processes: Discrete Stochastic Dynamic Programming*. John Wiley&sons, 2000.
[19] Y.Fang, I. Chlamtac, Y-B. Lin."Channel occupancy times and handoff rate for moblie computing and PCS networks," *IEEE Trans. Computing*, pp.679-692, 1998.
[20] Kluwer.C.G. Cassandras and S. Laortune . *Introduction to Discrete Event Systems*. 1999.
[21] H.Tijms, *Stochastic Modeling and Analysis: A computational approach*. Wiley, 1986.

**Yu Zhang** received M.S. degree in computer engineering from Harbin university of Science and Technology, China, in 2006. He is a Ph.D. candidate in the Communication Engineering department at East China Normal University. His interests are in resource management and optimization of wireless communication networks.

**Lina Chen** received the M.S. degree in software engineering from East China Normal University, China, in 2006. She is an Associate Professor at Zhejiang Normal University. Currently, she has been pursuing Ph.D.at East China Normal University since 2011. Her interests are in indoor positioning and trusted computing.

**Zhengqi Zheng** received the M.S. degree in electrical engineering from the East China Normal University, China, in 1990. He received the Ph.D. degree in electrical engineering from the East China Normal University in 1998. He is a professor at East China Normal University since 2002. His research interests include wireless networks and radio resource management in network.