國 立 交 通 大 學

電信工程研究所

碩 士 論 文

異質無線網路環境下以議價式賽局為基礎之網路選取機制

The Bargaining Game Based Network Access Selection for Heterogeneous Wireless Networks

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Mandarin Abstract

摘要

因為各種不同無線網路接取技術的發展，創造了異質網路的環境。為了提供行動用戶無縫式(seamless)的網路接取，讓行動用戶能夠連接到多元異質網路的能力在此環境下是不可或缺的。賦予行動用戶多模(multi-mode)的能力，並且能使他們根據通道狀況或自身的服務品質需求(QoS requirement)選擇更適宜的網路的同時，也能夠考慮到系統業者便是異質網路選擇重要的議題。為了支援高傳輸速率的多媒體服務以及高速的行動用戶，一個 CDMA/WMAN/WLAN 的異質網路被提出。

在 CDMA/WMAN/WLAN 的異質網路系統中，為了增加系統吞吐量、減少換手(handoff)的頻率，並且同時保證使用者的服務品質需求，在本篇論文中我們提出了一個以議價式賽局為基礎的網路選取機制。在所定義的議價式賽局中，使用者對網路的喜好程度函式是用來得到行動用戶對服務品質需求的滿足程度，而網路對使用者的喜好程度函式則是用來達到負載平衡(loading balance)及減少換手頻率。藉由行動用戶與網路議價所得到的結果，我們最後會決定一個最合適的接取網路。模擬中顯示我們提出的方法可以減少新使用者被拒絕進入系統中的機率，同時能降低已存在的使用者被強迫中止(forced terminated)的機率。除此之外，換手的頻率也大幅度的下降，並且能符合服務品質需求。

The Bargaining Game Based Network Access Selection for Heterogeneous Wireless Networks

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Abstract

Because of the variety of wireless network technologies, different networks (e.g. CDMA, WLAN, OFDMA-based MAN) create a heterogeneous wireless environments and the network selection problem in such a heterogeneous wireless environments becomes an important issue. In this situation, the mobile terminals with multi-mode have the capability to connect to different types of networks. For the reasons of the fully resource utilization and providing the seamless communications, selecting the most appropriate radio access network will be the main objective. In this thesis, a network selection method that using bargaining game is proposed. We consider the aspect of the user and the network by using predefined utility functions that one can measure the satisfaction of QoS requirements of the call request and the other can measure the suitability that call request is accepted by the network from the perspective of the network. Considering the perspective of the user and the network are different, we use bargaining game to make the decision to maximize system throughput and decreasing the number of handoffs.

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古蕊綺 謹誌

民國九十九年七月

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Different wireless network technologies, (e.g. CDMA, WLAN, OFDMA-based MAN) with different communication characteristics comprise a heterogeneous wireless networks. In order to maximize wireless resource utilization and provide the seamless multimedia services in such heterogeneous wireless networks, the network selection problem becomes an important issue. An advanced mobile terminal with multi-mode support is capable of accessing multiple wireless technologies.

Network selection problem in the heterogeneous wireless networks is influenced by several factors. Improper or insufficient considerations of the decision factors may lead the non-optimal network to be selected and result in the degradation of system performance. Bari and Leung proposed the multiple attribute decision making (MADM) method [1]. They considered seven parameters that affect the final decision and used Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) combined with different attribute weights assignment to get the final decision. Song and Abbas adopted a combination of the analytic hierarchy process (AHP) and the grey relational analysis (GRA) as the network selection scheme [2]. AHP is to calculate the relative level between each element that user will consider, and then GRA is to decide the selection decision by choosing least difference between different series.

Some approaches provide cost function based or utility function based methods to solve the network selection problem. The final decision of the network selection is based on the value of the cost function or utility function of each candidate network. Wang, et al. proposed a policy-enabled handoff system with a simple cost function and the primary object is to avoid the problem of handover instability [3]. Iera, et al. proposed an algorithm which stressed on the design of the cost function with dynamic weighting adapted [4], but the simulation results did not show the advantage of design.

The mobile terminals may experience the horizontal handoff in the heterogeneous wireless networks. Luo and Bodanese proposed a radio access network selection algorithm [5], in which the mobility is considered and combined with data rate adaptation scheme to increase the resource utilization and user satisfaction. In [6], the utility function is defined to reflect not only the QoS requirement such as data rate, delay, and packet error rate, but also the speed of the mobile nodes. And the evaluation functions are designed with load balancing index to achieve the goal of load balancing. In the heterogeneous wireless networks, load balancing is important to increase the overall system utilization. Ning, Zhu, Peng, and Lu proposed a load balancing algorithm that only assigned non-real time services in overloaded networks to handover to under-loaded networks and access the new calls to under-loaded networks [7]. However, it may be inappropriate to select the networks simply according to the network loading. A dynamic load balancing algorithm based on sojourn time which is added the mobility into consideration is proposed in [8]. The algorithm can decrease the dropping probability for handoff calls and increase the total system utilization.

The approach of game theory can be adopted when dealing with the complex strategy of network selection. The complex strategy may contain many different kinds of factors that influence the decision of network selection. Antonious and Pitsillides modeled the network selection as non-cooperative game with simplified utility function [9]. However, the degree of the user satisfaction of QoS will not be linear because user is just aware of QoS in a certain range and the call request must be served in the tolerant duration. Charilas, et al. proposed a scheme that fusing network selection mechanism (AHP and GRC) and game theory [10]. This scheme has the similar issue as [9]. Since the call request needs to be served as soon as possible, it is impractical to wait for several call requests to play the game. In [11], Cesana, et al. proposed a bi-level stage game, network selection and resource allocation game (NSRAG), from both user's and network's point of view. In NSRAG, the payoffs of the resource allocation game played by the access networks depend on the result of a network selection game which is played by the end users at the lower level. Niyato and Hossian proposed a special type of game approach named evolutionary game which refined the solution of traditional game theory. The players can change their strategies slowly in order to achieve the desired solution eventually [12]. But this type of game might cause the number of handoffs increasing. Afterwards, they proposed two types of game for resource management [13]. The non-cooperative game is formulated to solve the bandwidth allocation problem with the purpose of maximizing the utility of selfish network. And the bargaining game is formulated to achieve the fair resource sharing between new call, horizontal handoff, and vertical handoff connections. In [14], the Utility and Game-theory (UGT) based selection scheme is proposed. They use the utility function to evaluate the degree of QoS satisfaction of the user and model the preference of candidate networks as a cooperative game.

In this thesis, a bargaining game based network access selection (BGNAS) is proposed for heterogeneous wireless networks. The scheme of BGNAS intends to maximize system throughput, minimize the number of handoff calls and support QoS as well. First, three constraints are set to select candidate networks to participate in bargaining games. The model in BGNAS consists of several two-person bargaining games, one player in one bargaining game is the user and the other is one of the candidate networks. If there are three candidate networks, there will be three two-person bargaining games. And two preference functions are designed to represent the degree of preference of one player to the other player. Both two preference functions are classified based on the type of call request (real time and non-real time) including several functions. For the user, the preference function of real time services is designed according to the degree of fulfillment of QoS requirements (packet delay, packet dropping rate), and the preference function of non-real time services is designed according to the available resource that the candidate network can allocate. User bargains with one of candidate networks over the resource. For real time services, the user may prefer the candidate network that has lower packet delay evaluation. For non-real time services, the user may prefer the candidate network that can support higher bit rate. But these two preference functions for two players (user and candidate network) in a two-person bargaining game are designed in opposed ways, which means that the best amount of resource allocation for one user might be equal to the amount of resource that can just meet the QoS requirement. Besides, the preference function of one of candidate networks also includes two sub-functions. One is the function of the loading of the candidate cell and the other one is the function of dwell time of a user in the candidate network. By using these two functions, we want to achieve load balancing and decrease the number of handoffs.

We also take the bargaining power into consideration. In the design of BGNAS, a candidate network with lower loading would have more bargaining power. We model each two-person bargaining game as a bargaining problem and by some axioms show that the problem exists a unique solution which is the best contract. We choose the best one over these two-person bargaining games as the selection decision. Through this bargaining model, the selection of the user will be case by case corresponding to different variation of system status.

The rest of the thesis is organized as follows. Chapter 2 describes the system model. Chapter 3 introduces game theory and the bargaining game. Chapter 4 is the proposed bargaining game based network Access Selection (BGNAS). Simulation results and discussion are shown in chapter 5, and the conclusions and future works are given in chapter 6.

Chapter 2
System Model

2.1 Heterogeneous Wireless Access Environment

The heterogeneous wireless access environment which containing a CDMA cellular system, an IEEE 802.16 OFDMA-based WMAN system, and an IEEE 802.11 WLAN system is considered and shown in Fig. 2.1. CDMA services are available at any place, while OFDMA-based WMAN and WLAN services are only available regionally. It is assumed that WLANs are deployed only at some places for high-speed data services in the urban area.

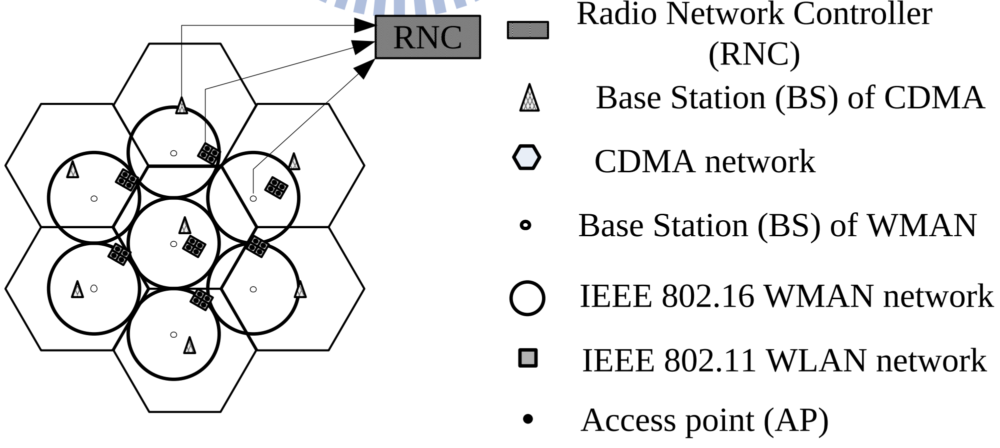

Fig. 2.1 : The network topology of OFDMA-based WMAN, CDMA and WLAN systems

Base stations (BSs) of WMAN and CDMA systems and access points (APs) of the WLAN system can collect the information of a call request, including received signal strength, estimated velocity, position, direction of motion, and traffic class of a call request [15]. An access point (AP) of the WLAN acts as the BS in CDMA network. The proposed scheme is designed in a radio network controller (RNC), which gathers information from BSs for selection. These three different wireless access networks are described as follows.

2.1.1 CDMA Cellular Network

For the interference-limited CDMA networks, the BS needs to control interference in the cell. In this thesis, only the uplink direction is considered, and it is assumed that whenever the uplink channel is assigned, the downlink is established. For example, in WCDMA, the data of the user is sent by dedicated physical data channel (DPDCH) and the control information is sent by dedicated physical control channel (DPCCH).

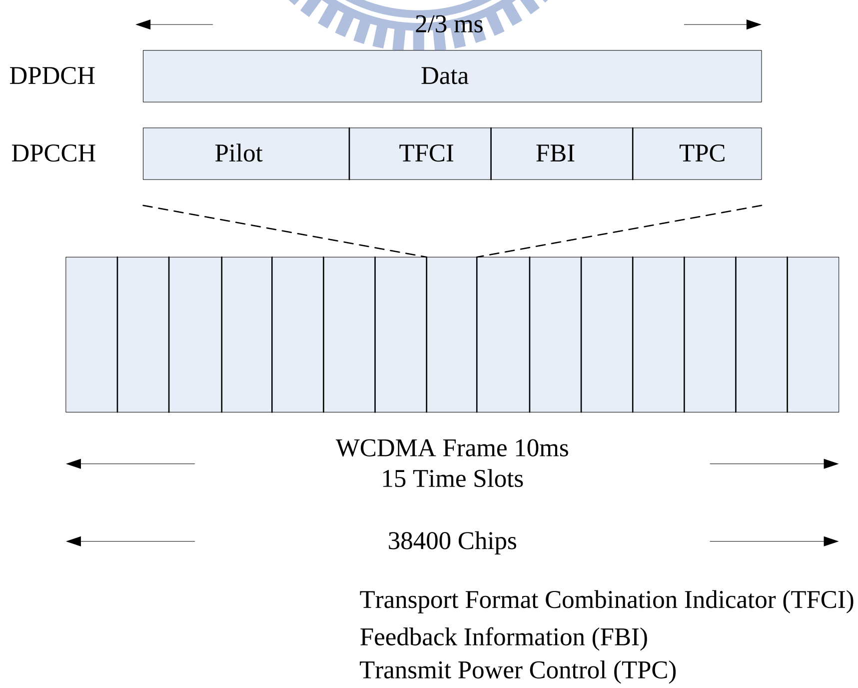

Fig. 2.2: Frame structure for uplink DPDCH/DPCCH

The frame structure of uplink DPDCH/DPCCH is shown by Figure 2.2. In one power-control period, there is 10ms length frame which is split into 15 slots and there are 2560 chips in each slot. That means the chip rate will be 3.84 Mbps. Each user can through a physical random-access channel (PRACH) ask more than one DPDCH to transmit data with different spreading factors (from 256 down to 4) and one DPCCH with spreading factor 256. That means the transmission rate of DPDCH can be adjusted by different DPDCHs and the rate control information is in the Transport Format Combination Indicator (TFCI) in DPCCH.

Besides, it is assumed that the transmitted signal strength for each MS can be adaptively controlled in order to achieve the target received signal strength in the BS. Then the achievable bit rate for MS_j, denoted as AR_j, can be obtained by [16]

$$AR_j = \frac{W}{v_j \cdot (E_b / N_0)_j} \times \frac{P_j}{I_{total} - P_j}, \tag{2.1}$$

where W is the chip rate, v_j is the activity factor of MS_j, $(E_b / N_0)_j$ is the signal energy per bit divided by noise spectral density that is required to meet a predefined QoS of MS_j, P_j is the received signal strength of MS_j from BS, and I_{total} is the total power including thermal noise power received at BS. Note that the requirement of MS_j is determined from the bit error rate requirement, service type, estimated velocity, and so on of the MS_j.

2.1.2 IEEE 802.16 OFDMA-based WMAN

IEEE 802.16 WMAN adopts orthogonal frequency division multiple access (OFDMA) [17]. We consider the OFDMA/TDD frame structure defined in IEEE 802.16, which basic allocation map for downlink and uplink (DL-MAP/UL-MAP) use units of subchannels and symbols. Figure 2.3 shows an example for the frame structure of OFDMA in TDD mode. Suppose there are K sub-channels in the IEEE 802.16 WMAN system, and each sub-channel consists of q spread out sub-carriers. Thus the channel condition of each sub-channel can be regarded as the same, and the frequency selective phenomenon can be compensated. Assume that each frame includes L OFDMA symbols, and the duration for each frame is T. The total number of resource block, defined as one sub-channel and one OFDMA symbol, in a frame will be $K \times L$.

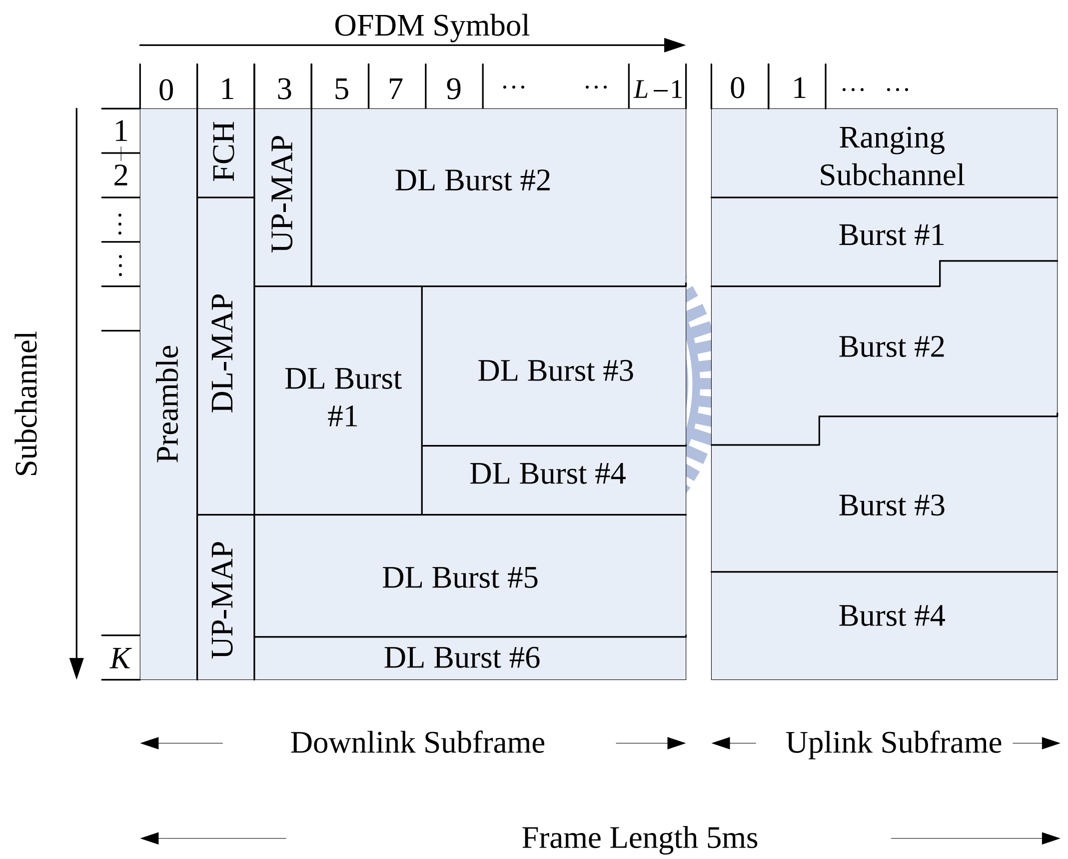

Fig. 2.3: Example for frame structure of OFDMA in TDD mode

Moreover, equal power control, which means the same allocated power to each call request, is adopted. From [18], the number of points in each signal constellation denoted as M, when the required BER is given can be obtained by

$$M = \frac{1.5 \times SINR_{a,k}^{(l)}}{-\ln\left(5 \times BER_a^{*}\right)} + 1, \tag{2.2}$$

where $SINR_{a,k}^{(l)}$ is the received signal to interference and noise ratio (SINR) of call request a on sub-channel k at the ℓth OFDMA symbol and BER_a^{*} is the required bit error rate of call request a. However, there are 4 types of modulation: no transmitted, QPSK, 16-QAM, and 64-QAM. So the usable modulation order of call request a on sub-channel k for the lth OFDMA symbol, denoted by $m_{a,k}^{(l)}$, is given as

$$m_{a,k}^{(l)} = \begin{cases} 0, & \text{if } M < 4, \\ 2, & \text{if } 4 \le M < 16, \\ 4, & \text{if } 16 \le M < 64, \\ 6, & \text{if } 64 \le M. \end{cases} \tag{2.3}$$

Finally, the total allocated B_a bits to call request a in the current frame can be obtained

$$B_a = \sum_{l}^{L} \sum_{k=1}^{K} q \cdot c_{a,k}^{(l)} \cdot m_{a,k}^{(l)}, \tag{2.4}$$

where $c_{a,k}^{(l)}$ is the allocation indicator. The value of $c_{a,k}^{(l)}$ equals to 1, if the scheduler allocates the resource on sub-channel k at the lth OFDMA symbol to the service request a. On the contrary, it will be 0.

2.1.3 IEEE 802.11 WLAN

The WLAN system supports distributed coordination function (DCF) mode and point coordination function (PCF) mode for media access. DCF adopts carrier sense multiple access with collision avoidance (CSMA/CA) protocol with a slotted binary exponential backoff scheme. PCF is a centralized polling protocol controlled by the

AP. In order to support QoS and service differentiation, IEEE 802.11-2007 defines the enhanced distributed coordinator function (EDCF) which provides differentiated channel access to frames of different priorities as labeled by the higher layer. AP can initiate the duration of transmission opportunity in the contention period [19]. The standard also defines four access categories (ACs) and eight priorities to support differentiated QoSs. MSs using EDCF mode to transmit data are assumed in this thesis.

Under the EDCF mode, a MS cannot transmit packets until the channel is sensed idle for a time period equal to the arbitration inter-frame space (AIFS). When a MS senses the channel busy during the AIFS, the backoff time counter is randomly selected from the range [0, CW-1], where CW is the contention window. The value of CW is increased from $CW_{\min}$ to $CW_{\max}$ if consecutive fail transmissions occur, where $CW_{\min}$ is the initial value of CW, $CW_{\max} = 2^m CW_{\min}$ is the maximum value of CW and m is called the maximum backoff stage.

Different ACs have different AIFS[AC], $CW_{\min}$[AC], and $CW_{\max}$[AC]. Traffic classes with smaller values of $CW_{\min}$ and $CW_{\max}$ represent higher priorities. AIFS[AC] for a specific AC can be given by

$$\text{AIFS[AC]} = \text{AIFSN[AC]} \times \text{aSlotTime} + \text{aSIFSTime}, \tag{2.5}$$

where AIFSN[AC] is AIFS number of the AC, aSlotTime is the value of the correspondingly named PHY characteristic, and aSIFSTime is the time duration of a SIFS.

2.2 Channel Model

The wireless fading channel is composed of large-scale fading and small-scale fading. The large-scale fading comes from path loss and shadowing effect, while the small-scale fading is caused by multipath reflection. The path loss is modeled as [22]

$$L_{pathloss} = 128.1 + 37.61 \times \log d_{bm} \left(dB \right), \tag{2.6}$$

where d_{bm} is the distance between the BS and the MS in kilometers. Assume the log-normal shadowing is with zero mean and standard deviation of 8 dB. The Jakes model [23] is used to simulate the small-scale fading channel which assumed the angle of incidence at receiver is uniformly distributed between $[0,\ 2\pi]$, and by choosing the phase shift, it can generate several uncorrelated signals. Furthermore, the channel is assumed to be fixed within a frame and varies independently from frame to frame.

2.3 Mobility Model

For the mobility of MS from 50 km/hr to 80 km/hr, it is assumed that the estimated speed v and direction of motion are unchanged. Because it can be seemed as the MS is on the highway or on the train. In this case, the speed and the direction of the MS can be assumed unchanged. As shown in Fig. 2.4, r is the radius of cell coverage, θ is the angle between BS and the moving direction of MS, where $0 \le \theta \le \pi$, and d_{bm} is the distance between BS and MS, where $0 \le d_{bm} \le r$. Then the total travel distance in the network, denoted by d, can be obtained by

$$d = \sqrt{r^2 - \left(d_{bm} \cdot \sin \theta \right)^2} + d_{bm} \cdot \cos \theta, \ \ 0 \le d \le 2r. \tag{2.7}$$

So we can estimate the dwell time of the MS in this network T_{dwell}, by

$$T_{dwell} = d / v. \tag{2.8}$$

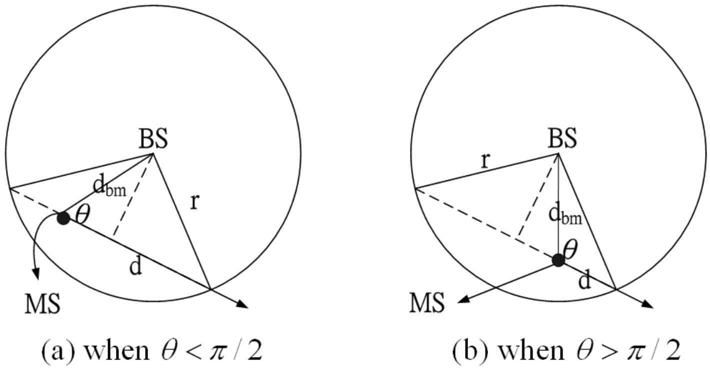

Fig. 2.4: Mobility of MS from 50 km/hr to 80 km/hr

For the mobility of MS from 3 km/hr to 50 km/hr, it is also assumed that the speed is unchanged. But the direction will be changed randomly every certain fixed duration. In this case, we use the random walk mobility model which the MS moves toward the next location by choosing a direction from predefined ranges $[-\varphi, \varphi]$ randomly. We consider that if the MS can make a turn it will have a longer path in comparison with direction unchanged. Therefore, it can be seemed as the direction is still unchanged but the radius of the cell which MS sojourned is larger than original. For this reason, we can obtain an equivalent cell radius $r' = (1 + 0.0038\varphi) \cdot r$ [27]. In this thesis, the value of φ is set 90° which conform to the situation of general street block. And the mobility is lower than 3km/hr it will be seemed as a pedestrian.

2.4 Traffic Class

We consider four services classes considered [24]: conversational class, streaming class, interactive class (HTTP) and background class. The conversational class represents real time multi-media applications such as voice over IP (VoIP). The streaming class includes streaming type of applications, like video on demand (VoD).

The interactive class is composed of applications for Web-browsing, chat room, etc. Finally, the background class is the service using best effort transmission, such as file transfer protocol (FTP). It can be found that the first two classes are delay-sensitive (real time), and the last two classes are delay-tolerant (non-real time).

Each call request has different QoS parameters according to their service types. Intuitively, the real time services request low delay, low jitter, and the number of handoff must keep as low as possible. But they are tolerant of certain level of packet loss. On the other hand, non-real time services may request high bandwidth, and low packet dropping rate, etc. However, variable transmission rate is acceptable to them.

The conversational class services are modeled as the ON-OFF model [25] shown in Fig. 2.5. During ON period, voice packets are generated with rate D_v bps. During OFF period, there is no packet generated. This model has a transition rate with value *y* in the ON state and a transition rate with value *z* in the OFF state.

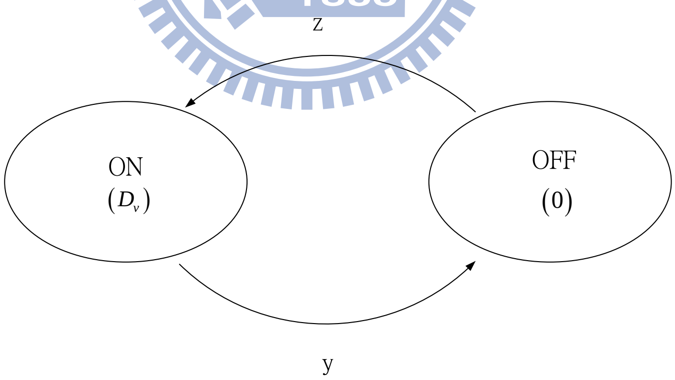

Fig. 2.5 : Voice source model

Fig. 2.6 depicts the packet trace of one video streaming session model, which is composed of a sequence of video frames generated regularly with a constant interval T_f [22]. Each video frame consists of a fixed number of slices N_s, where each slice corresponds to a single packet. The size of packet is denoted by P_s, and the inter-arrival time between each packet is T_p.

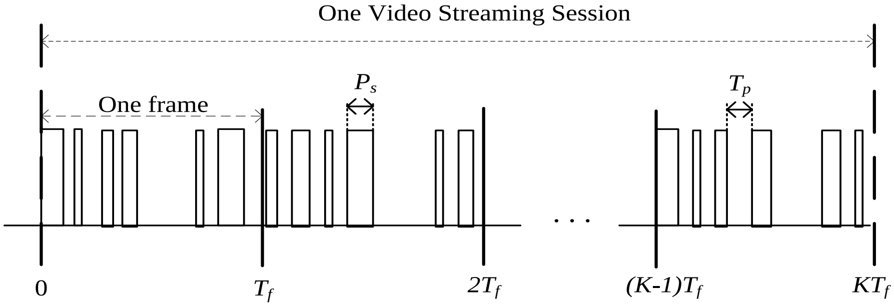

Fig. 2.6 : Video streaming source model

Fig. 2.7 shows the Packet trace of one HTTP session model. The interactive class services can be modeled as a sequence of packet calls (pages), and each packet call consists of a sequence of packet arrivals, which is composed of a main object and several embedded objects [22]. Four parameters, including the inter-arrival time *Treading* (reading time), main object size S_m, embedded object size S_e, the number of embedded objects per packet call N_e, and the packet inter-arrival time T_p are used in this model.

The background class services are modeled as a sequence of file downloads [22] and is shown in Fig. 2.8. Denote the size of each file by S_f, and the inter-arrival time between each file by T_f.

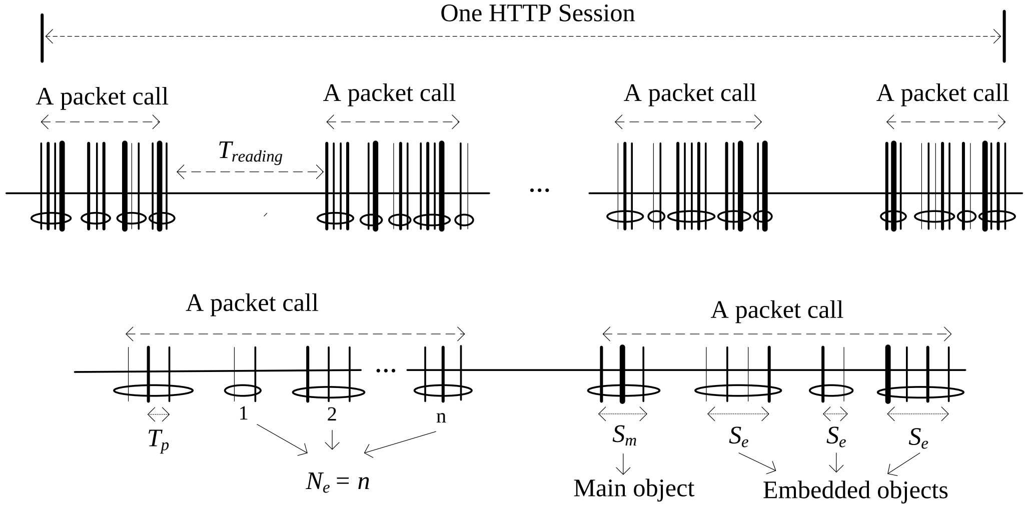

Fig. 2.7 : HTTP source model

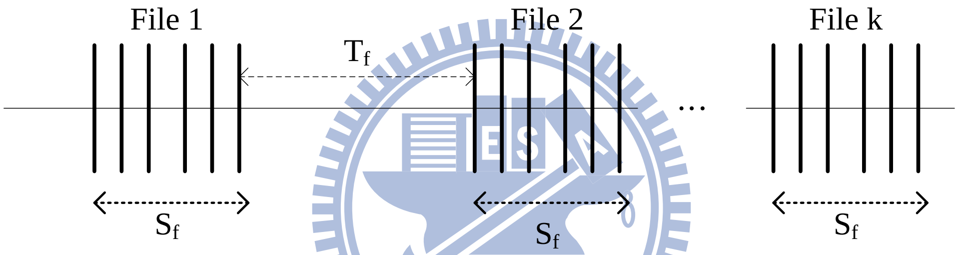

Fig. 2.8 : FTP source model

Chapter 3
Bargaining Game

3.1 Introduction to Game Theory

In the process of people interaction, sometimes the interaction is belonging to cooperative behavior that all the players want to maximize the joint profits. Sometimes the interaction is competitive and only one is the winner. In the competitive game, players focus on maximizing their own benefits by considering mutual influence of actions and behaviors among players. This means the classification of games is according to the relation of cooperation between the participants (cooperative game/non-cooperative game). A classical example in figure 3.1 is the prisoner's dilemma. In a non-cooperative game, both two prisoners will choose betray regardless of what the opponent chooses, because two players are selfish. But if it is a cooperative game, they will choose to stay silent and get the best payoff.

The game can also be classified by participants in accordance with the order of deciding the action. From this perspective, games can be classified into static game (simultaneous game) and dynamic game (sequential game). In a dynamic game, the player can decide the strategy by observing the actions done by other players did previously. An example of static game is "paper, scissors, stone" game, in which all players need to choose one strategy simultaneously. An example of dynamic game is chess, in which players can choose one best strategy to react on opponent's action.

	Prisoner B Quiet	Prisoner B Betrays
Prisoner A Quiet	Each serves 4 months	Prisoner A: 5 years Prisoner B: goes free
Prisoner A Betrays	Prisoner A: goes free Prisoner B: 5 years	Each serves 3 years

Fig. 3.1 Prisoner's Dilemma

The level of mutual information understood by players is another way for classification. If each player in the game knows others information such as players features, payoff function or utility function, then it is a complete information game. Otherwise, it is an incomplete information game. There are few complete information games in practical. Most games belong to incomplete information game. For example, you cannot know others bids or maximum tolerant offers in a seal-bid auction.

Another common way of classification is perfect information game and imperfect information game. A game is said to be a perfect information game if all players know all moves that have taken place by all players. The chess game, tic tac toe, and GO are obvious examples. Fantan is an example of imperfect information game because you do not know which cards are hidden from other players [20], [21].

3.2 Bargaining Game

Although there are different ways of classification of games, the basic of the game is a set of players, game rules, an action set of the players, and their corresponding payoffs. In this thesis, we use bargaining game to model the selection problem. Bargain is a common action in the real world, and followed contracts such as goods exchange, services and divide up the surplus are usually determined through a negotiation process. In this case, people can get more satisfaction through the trade, which will create more value on goods, services, etc. There are many types of bargaining game. For example, a two-person ultimatum bargaining game is the simplest bargaining model, and it is advantageous to the proposer. It is because the player will accept the contract for any offers that is greater than zero against to get nothing. This implies that the proposer will give the offers as smaller as possible.

For a two-person two-period or a two-person infinite-period alternating-offer game, one player will propose an offer to the other player. If the other player is not satisfied with the proposal, he or she can propose a counter offer. An example for infinite-period alternating-offer game is that you want to have some discount when you buy something you want. You will propose a lower price you are willing to pay for it and ask the seller if it is acceptable. If the seller is not satisfied with the offer you proposed, he or she may give another proposal or reject the deal directly. Bargaining periods may continue until both the buyer and the seller come to an agreement or the deal is failed. But sometimes the period latency needs to be incorporated into the game-theoretic models as a discount factor because the procedure of bargaining may take a long time. Therefore, we can say a two-period or an infinite-period alternating-offer game is advantageous to those players who have patience, where the player who has patience means his or her payoff will not decrease over time. In several ways, the bargaining game of alternating offers can be extended to more than two players. If there are n persons in the game, it is called an n-person bargaining game.

The other thing for trade is dividing up the surplus. People usually want to get more benefit over bargaining while using divisible good or price, and the bargaining power can be used to realize the how much benefit the player can get. The definition of bargaining power denotes how players divide the value of their contract. A player with larger bargaining power will get more benefits than the other player(s) or the agreement will more close to his/her expectation than others. It is a concept related to the ability of one player influenced by the other players or by any possible factor. For example, in an infinite-period alternating-offer game, if the payoff of one player decreases over time, the bargaining power would be less than that of the other player whose payoff does not relate to time. Bargaining power can be considered as bargaining weights if the summation of all players' bargaining power is one. Besides, the negotiation or value creation is not necessarily related to actual good exchanges; it can be regarded as establishing partnership.

In this thesis, we use two-person bargaining game to formulate as a bargaining problem. A two-person bargaining problem can be denoted as a (U,d), where U is a set of pairs of numbers (the set of pairs of payoffs to agreements) and d is a pair of numbers (the pair of payoffs to disagreement), $d=(d_1,d_2)$, satisfying the following conditions [21].

- d is a member of U. (Disagreement is a possible outcome of bargaining, and the player may "agree to disagree".)
- For some member (v_1,v_2) of U, $v_1>d_1$ and $v_2>d_2$. (Some agreement is better for both players than disagreement.)
- If both (v_1,v_2) and (w_1,w_2) are in U, then for every α, $0\le\alpha\le1$, the pair of payoffs $(\alpha v_1+(1-\alpha)w_1,\alpha v_2+(1-\alpha)w_2)$ is also in U. (The set U is "convex".)
- U is bounded and closed.

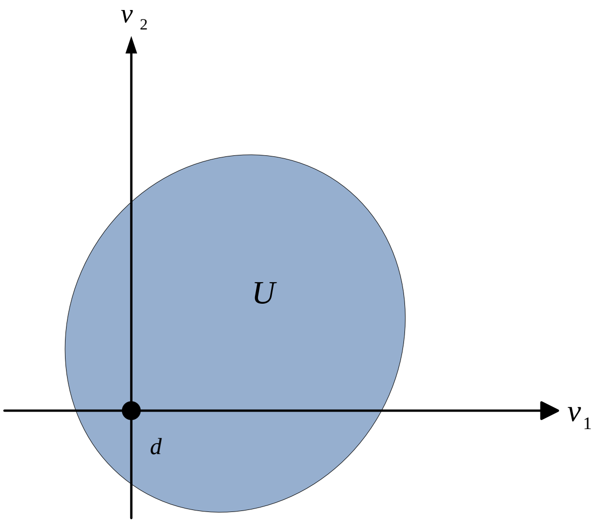

Fig. 3.2 An illustration of a bargaining problem (U,d)

Figure 3.2 is an example of a bargaining problem. Nash's axiomatic model formulate this two-person bargaining problem as

$$\max_{(v_1,v_2)}(v_1-d_1)(v_2-d_2) \text{ subject to } (v_1,v_2)\in U \text{ and } (v_1,v_2)\geq(d_1,d_2). \qquad (3.1)$$

There exists a unique bargaining solution that solves the problem if it satisfies four axioms:

Axiom 1. Pareto efficiency (PAR):

Let (U,d) be a bargaining problem, and let (v_1,v_2) and (v_1',v_2') be the members of U. If $v_1>v_1'$ and $v_2>v_2'$, then the bargaining solutions does not assign (v_1',v_2') to (U,d).

Axiom 2. Invariance to equivalent payoff representations (INV):

Let (U,d) be a bargaining problem, let α_i and β_i be two numbers with $\alpha_i>0$ for $i=1,2$, let U' be the set of all pairs (v_1',v_2'), where $v_i'=\alpha_i v_i+\beta_i$ for

$i = 1, 2$ and (v_1, v_2) is a member of U, and let $d' = (\alpha_1 d_1 + \beta_1, \alpha_2 d_2 + \beta_2)$. If the bargaining solution assigns (v_1, v_2) to (U, d), then it assigns (v_1', v_2') to (U', d').

Axiom 3. Independence of irrelevant alternatives (IIA):

Let (U, d) and (U', d') be bargaining problems for which U' is a subset of U and $d = d'$. If the agreement the bargaining solution assigns to (U, d) is in U', then the bargaining solution assigns the same agreement to (U', d').

Axiom 4. Symmetry (SYM):

Let (U, d) be a bargaining problem for which (v_1, v_2) is in U if and only if (v_2, v_1) is in U, and $d_1 = d_2$. Then the pair (v_1^*, v_2^*) of payoffs the bargaining solution assigns to (U, d) satisfies $v_1^* = v_2^*$.

In [28], Kalai generalized Nash's bargaining game by removing the axiom of symmetry by using the concept of bargaining power p_i and showed that any solution to the resulting game is the unique point that maximizes $\prod_{i \in B} (v_i - d_i)^{p_i}$, over all $v_i \in U$, for some choice of positive numbers p_i, for $i \in B$, where B is the set of players, such that $\sum_{i \in B} p_i = 1$.

Chapter 4

Bargaining Game Based Network Access Selection

A mobile user with a new call request or a handoff call request has to perform scanning of nearby BSs first by detecting pilot or synchronization signals. The list of detected BSs are provided to the anchor BS to determine the candidate network set, denoted by N, for network selection. The anchor BS is one of the detectable BS for the mobile user with a new call request or the serving BS for the mobile user with handoff request. To decide the most suitable network in N for a specific call request, the selection problem is formulated as a bargaining game based on the perspective of mobile user and networks. We here propose a bargaining game based network access selection (BGNAS). It designs a preference function from the aspect of user corresponding to the network i, $i \in N$, denoted as UP_i, which is defined to estimate the degree of suitability. Similarly, the ability function from the aspect of network, denoted by NP_i, is defined to represent the degree of suitability of the call request in network i. The concept of bargaining power is used to differentiate the degree of user preference and network ability. For instance, if the ability of one network is larger than others, the bargaining power will be larger than others.

The main goals of BGNAS are to maximize the system throughput by load balancing and reduce the number of handoffs while satisfying QoS requirements.

4.1 The Decision of Candidate Network Set

Three constrains are proposed to determine the candidate network set. They are the signal strength constraint, network loading constraint, and the mobility constraint. A network in the candidate network set needs to satisfy all these three constraints.

4.1.1 Signal Strength Constraint

The received pilot signal strength from a network i at the MS is defined as PW_i, and network i is in the candidate network set, that is $i \in N$ if the following condition is satisfied:

$$PW_i \geq PW_{th} \quad , \tag{4.1}$$

where the PW_{th} is the predefined signal strength threshold. If the received signal power does not exceed the threshold, this network will not participate in the after procedure. Note that the threshold of the predefined signal strength will be different in the different kinds of networks.

4.1.2 Network Loading Constraint

It is assumed that the user must inform the characteristic parameters of the requested service when it asks. The purpose of this constraint is to ensure when a network accept the request will not influence the quality of existing communication. And considered the buffer size is infinite, the mean bit rate can be seemed as equivalent capacity C for estimating network loading increment.

Defined the current network i loading intensity before accommodating the new request is $\rho_{E,i}$, where $0 \leq \rho_{E,i} \leq 1$, and the loading intensity increment of network i

for new request is $\Delta\rho_i$, $i \in \{\text{WMAN, CDMA, WLAN}\}$. Therefore, the network in the candidate network set can accept the new request if the criterion

$$\rho_{E,i} + \Delta\rho_i \le \rho_{th,i} \tag{4.2}$$

holds, where $\rho_{th,i}$ is predefined loading threshold for network i. Otherwise, this network will not be considered as the available network.

In the CDMA network, the loading intensity increment for a new request can be estimated as [17]

$$\Delta\rho_i = (1+f)\frac{1}{1+W/(C\cdot(E_b/N_0))}, \tag{4.3}$$

where f denotes the ratio of interference from other cells (inter-cell interference) to own cell interference (intra-cell interference), W is the chip rate of the system, (E_b/N_0) is the required bit energy to noise density. And the loading of existing connections $\rho_{E,i}$ is estimated as $\rho_{E,i} = \sum_{e\in E}\rho_e$, where E is the set of existing connections in the CDMA network, and $i \in \{\text{CDMA}\}$.

In IEEE 802.16 OFDMA-based WMAN system, the mean capacity of WMAN can be estimated as $4\times K\times L\times q/T$ (bps). Therefore, the loading intensity increment for a new request can be calculated as

$$\Delta\rho_i = C\ /(4\times K\times L\times q/T), \tag{4.4}$$

and the existing loading is estimated as the same way, $\rho_{E,i} = \sum_{e\in E}\rho_e$, here E is the set of existing connections in the WMAN network and $i \in \{\text{WMAN}\}$.

For WLAN network, the measurement-based network loading intensity will be used. Assume that T_s is the total busy occupation transmission time, which consisting of the successful transmission time and collision time in the latest observation duration T_d . Therefore, the loading intensity will be defined as $\rho_{E,i} = T_s / T_d$. And the network is in the candidate network set when the following criterion is satisfied.

$$\rho_{E,i} \le \rho_{th,i} , \tag{4.5}$$

note that the threshold of the loading intensity will be dissimilar in the different kinds of network.

4.1.3 Dwell Time Constraint

When a mobile user is in the coverage of a small cell but with high mobility, this means it is possible to pass through this cell quickly. If the user is admitted in this small cell it will suffer from frequent handover. For this reason, we assume that $T_{dwell,i}$ is the sojourn time for the call request in the cell i which can be estimated from the radius of network coverage, local position, velocity, and the direction of motion of MS. And the $T_{holding}$ is the mean holding time for the new call request which obtained from the statistical results of serving and served calls which have the same service type as the call request. Thus, we can defined mobility factor of the call request in the cell i $x_i = T_{dwell,i} / T_{holding}$, this means the x_i is larger the probability that transmission can complete is higher in network i . If the x_i is smaller than predefined threshold for the call request in the cell i $x_{th,i}$, $x_i < x_{th,i}$, the cell i cannot be considered in the candidate network set. And the threshold will be set different by distinct networks.

By this way, the frequency of handover can be reduced, and the value of the threshold will be set different in the different networks.

4.2 Bargaining Game Based Network Access Selection (BGNAS)

4.2.1 Preference Functions

We consider two preference functions in the selection of networks. One is from user's side and the other is from network's side. For the user, the degree of the satisfaction of QoS can represent for the preference of the user. The preference function for the user corresponding to the candidate network i is denoted by UP_i, which consists of several functions of QoS-related factors.

UP_i is defined as

$$UP_i = \begin{cases} f_D(d_i) \cdot f_P(p_i), & \text{for the voice or the video call request,} \\ f_B(b_i), & \text{for the HTTP or the best effort call request,} \end{cases} \quad (4.6)$$

Where $f_D(d_i)$, $f_P(p_i)$, $f_B(b_i)$ are the function of packet delay, packet dropping rate and data rate measured in the access network i. For real time service, user bargains with one of candidate networks over the acceptation of the delay of packets. For non-real time service, user will bargain with one of candidate networks over the bit rate that candidate network can afford to allocate.

The design of $f_B(b_i)$ is

$$f_B(b_i) = \begin{cases} 0, & \text{if } b_i < B^*, \\ 1 + \dfrac{1}{1 + \alpha \cdot e^{-\beta\left(\left(b_i - B^*\right)/B^*_{\max}\right)}}, & \text{if } B^* \le b_i \le B^*_{\max}, \end{cases} \quad (4.7)$$

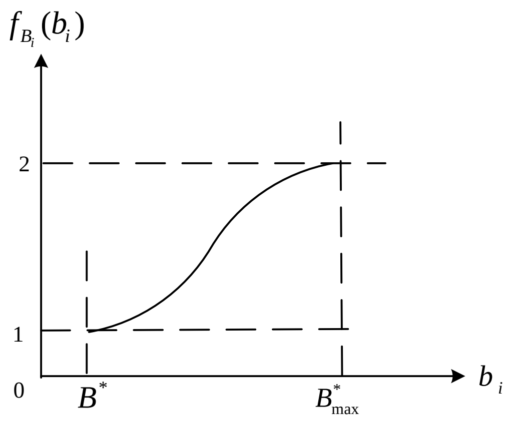

Fig. 4.1 : The function of $f_B(b_i)$

where B^*_{max} is the maximum allowable data rate from all candidate networks, B^* is the minimum transmission rate for this non-real service. For FTP services, the reason of the setting of this value is keeping the session continued. $b_i \in [B^*, B^*_{max}]$ is the possible data rate that the user can obtain from candidate network i. Figure 4.1 shows the concept of design. When b_i is close to B^*_{max}, the value of $f_B(b_i)$ will be close to the maximum preference value 2, which means that user has the greatest preference for network i. When b_i is close to B^*, the value of $f_B(b_i)$ will be close to 1 and in the middle of B^* and B^*_{max} is corresponding to the half of the maximum preference value 1.5. Besides, this function is defined as the sigmoid curve (S shape) so that when b_i is very large or very small, the increase of b_i will not make user feel much better or worse. Hence, the values of α and β in (4.7) are constants and set to 10 and 10, respectively.

$f_D(d_i)$ is defined as

$$f_D(d_i) = \begin{cases} 0, & \text{if } D^* < d_i, \\ 2 - \dfrac{1}{1+\alpha \cdot e^{-\beta\left(\left(d_i - D_{\min}\right)/D^*\right)}}, & \text{if } D_{\min} \le d_i \le D^*, \end{cases} \tag{4.8}$$

where D_{min}, d_i are the measured minimum packet delay from all candidate networks within an observed duration and the expected packet delay when user is accepted by network i, respectively, and D^* is the maximum tolerant packet delay for this service request. If d_i is close to $D_{\min}$, it means that the call request can obtain more resource and the value of $f_D(d_i)$ will be higher, meaning that the value of $f_D(d_i)$ will be close to 2. In this case, user will prefer this network. On the contrary, the value of $f_D(d_i)$ will be close to 1. In the middle of D^* and $D_{\min}$ is corresponding to the half of maximum preference value. The range of d_i for user is $[D_{\min}, D^*]$. This function is considered only for the real time services. The design principles of this function are the same as equation (4.7), and the values of α and β in (4.8) are set to 100 and 8, respectively.

$f_P(p_i)$ is defined as

$$f_P(p_i)=\begin{cases}0, & \text{if } P^* < p_i,\\ 2-\dfrac{1}{1+\alpha\cdot e^{-\beta\left(\left(p_i-P^*\right)/P^*\right)}}, & \text{if } p_i \le P^*,\end{cases} \tag{4.9}$$

where p_i is the measured average packet dropping rate of network i and P^* is the maximum acceptable packet dropping rate for specific service request. This function is considered only for the real time services because of QoS requirement. In order to guarantee the QoS requirement, if measured average packet dropping rate is larger than the requirement this function will be zero, because this network should not be chosen. When p_i is much smaller than P^*, this function will be close to two. When p_i is half of P^*, the preference value will decrease to about 1.5. When p_i is equal to P^*, the value of this function will decrease to one which means the probability of this network cannot guarantee the QoS requirement will be very high. Based on these design principles, the values of α and β in (4.9) are set to 1/9 and 8, respectively.

For candidate network i, the preference function is denoted by NP_i. The concept of NP_i is the degree of the suitability of the candidate network i for the call request, which is defined as

$$NP_i = \begin{cases} g_D(d_i) \cdot g_\rho(\Delta\rho_i) \cdot g_m(x_i), & \text{for the voice or the video call request,} \\ g_B(b_i) \cdot g_\rho(\Delta\rho_i) \cdot g_m(x_i), & \text{for the HTTP or the best effort call request,} \end{cases} \tag{4.10}$$

where $g_B(b_i)$, $g_D(d_i)$, $g_\rho(\Delta\rho_i)$ and $g_m(x_i)$ are the function of data rate, packet delay, loading intensity increment, and the mobility factor measured at network i for this call request, respectively.

We define $g_B(b_i)$ as

$$g_B(b_i) = \begin{cases} 0, & \text{if } b_i < B^*, \\ 2 - \dfrac{1}{1 + \alpha \cdot e^{-\beta\left(\left(b_i - B^*\right)/B^*_{\max,i}\right)}}, & \text{if } B^* \le b_i \le B^*_{\max,i}, \end{cases} \tag{4.11}$$

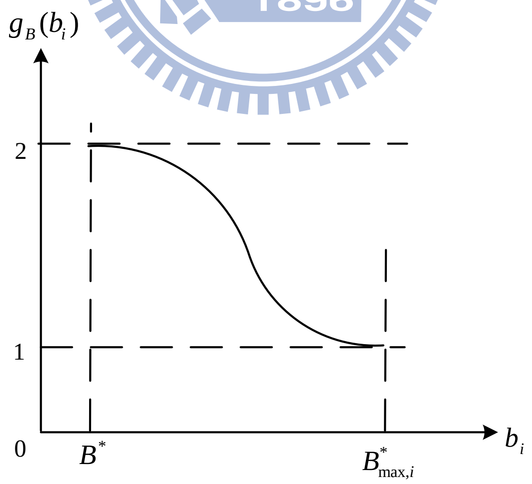

Fig. 4.2 : The function of $g_B(b_i)$

where $B^*_{\max,i}$ is the maximum allowable data rate for candidate network i, B^* is the minimum transmission rate for this non-real time service and b_i is the possible data rate the user can obtain from candidate network i, where $b_i \in [B^*, B^*_{\max,i}]$.

Figure 4.2 shows the concept of design, which is adverse to that in Fig. 4.1. Fig. 4.2, candidate network i prefers to allocate the data rate which is close to the minimum transmission rate to the call request to accommodate as many users as possible. When b_i is close to B^*, the value of $g_B(b_i)$ is close to 2, which is the maximum preference value of network i. When b_i is close to $B^*_{\max,i}$, the value of $g_B(b_i)$ is close to 1. The values of α and β in (4.11) are set to 100 and 13, respectively. This function is considered for non-real time services only.

$g_D(d_i)$ is designed as

$$g_D(d_i) = \begin{cases} 0, & \text{if } D^* < d_i, \\ 1 + \dfrac{1}{1+\alpha \cdot e^{-\beta\left(\frac{(d_i - D_{\min,i})}{(D_{\max,i})}\right)}}, & \text{if } d_i \le D^*, D_{\max,i} \le D^*, D_{\min,i} \le d_i \le D_{\max,i}, \\ 1 + \dfrac{1}{1+\alpha \cdot e^{-\beta\left(\frac{(d_i - D_{\min,i})}{(D^*)}\right)}}, & \text{if } d_i \le D^*, D^* < D_{\max,i}, D_{\min,i} \le d_i \le D^*, \end{cases} \quad (4.12)$$

where d_i, $D_{\max,i}$, $D_{\min,i}$ are the expected packet delay when call request is accepted by network i, the measured maximum packet delay, and the measured minimum packet delay of an observed duration for candidate network i. D^* is the maximum tolerant packet delay for this service request. The range of d_i for network i is $[D_{\min,i}, \min(D_{\max,i}, D^*)]$. When d_i is close to $D_{\min,i}$, network i needs to allocate more resource to guarantee the packet delay, which means the value of $g_D(d_i)$ will be lower. This function is also considered only for the real time services because of the QoS requirement. The design concept of this function is the same as equation (4.11), and the values of α and β in (4.12) are also set to 5 and 8, respectively.

$g_{\rho}(\Delta\rho_i)$ is designed as

$$g_{\rho}(\Delta\rho_i)=2-\frac{1}{1+\alpha\cdot e^{-\beta\left(\left((\rho_{E,i}+\Delta\rho_i)-\rho_{th,i}\right)/\rho_{th,i}\right)}}, \tag{4.13}$$

where $\Delta\rho_i$ is loading intensity increment of network i, $\rho_{E,i}$ is the current loading intensity of network i before accommodating the new call request, and $\rho_{th,i}$ is a predefined loading threshold for network i. When the loading of the network i is very light, which means $\rho_{E,i}+\Delta\rho_i$ is much smaller than $\rho_{th,i}$, the value of this function will close to two. When the value of $\rho_{E,i}+\Delta\rho_i$ rises to about half of the threshold for network i, the value of the preference will decrease 1.5 approximately. If the loading intensity reaches predefined loading threshold, which means the loading of network i is very heavy, the value of this function will decrease to one. For these principles of design, the values of α and β in (4.13) are set to 1/9 and 7, respectively. By these design concepts, the call request can be accepted in the network with light loading and the system can achieve load balancing.

$g_m(x_i)$ is defined as

$$g_m(x_i)=\begin{cases}0, & \text{if } x_i < x_{th,i}, \\ 1+\dfrac{1}{1+\alpha\cdot e^{-\beta\left(x_i/x_{th,i}\right)}}, & \text{if } x_{th,i}\le x_i,\end{cases} \tag{4.14}$$

where x_i is the mobility factor of the call request for the network i. When the dwell time of the call request in network i is long, x_i will be large. $x_{th,i}$ is the predefined threshold of the specific service for the network i. If the dwell time of the call request is very long in network i, then x_i can be much larger than $x_{th,i}$, and the value of the preference will close to two. The value of this function will decrease to 1.5 if x_i is 1.5 times of $x_{th,i}$. If x_i is equal to $x_{th,i}$, the preference value will decrease to one. For these principles of design, the values of α and β in (4.14) are set to 150 and 2, respectively. By the design of this function, candidate networks can avoid accepting the call request with too short dwell to decrease the number of handoffs.

4.2.2 Bargaining Power

In many cases, bargaining power will be expressed as a discount factor which represents the patience for the time. But in this thesis, the bargaining power is not regarded as a discount factor because the bargaining procedure is not modeled by many bargaining sessions which vary over time. That means all the bargaining procedures can be finished very soon. And the disagreement points for the user and network i are equal to zero because if the user does not connect to any one of the network, which means user do not prefer any one of the network or all networks cannot accommodate this user. In the design of BGNAS, the bargaining power is based on the balance of system loading, since maximizing throughput can be achieved by loading balance as mentioned previously. The bargaining power of the network i, denoted by θ_i, is defined as

$$\theta_i = \frac{1}{1+\alpha \cdot e^{-\beta(\rho_{E,i}-\rho_{avg})}}, \tag{4.15}$$

where $\rho_{E,i}$ is the current load intensity measured at candidate network i, ρ_{avg} is the average load intensity of candidate network set before the call request is accepted. If the acceptance of the call request in network i leads less impact in balance system loading, the network i will have higher bargaining power to accept the call request according to our design concept. If network i accepts the call request the loading of which is higher than average, it will cause the loading of network i is further away from the average loading, so the bargaining power of network i should be smaller than those of other networks. When compared the bargaining power of network i with that of the user, the bargaining power of network i and the user will be the same if $\rho_{E,i}$ is equal to ρ_{avg}, because there is no reason to emphasize the factor of loading from the system loading point of view. Besides, the bargaining power of the user is $1-\theta_i$ [28], and the values of α and β in (4.15) are set to 150 and 2, respectively.

We take bargaining power into consideration because sometimes the opinion of the user is more important than that of network i, sometimes the contrary, and sometimes they are equally important. Therefore, we want to reinforce the balance of system loading based on our concept of design. Two scenarios are considered. First one is the value of $g_{\rho}(\Delta\rho_i)$, which is a little higher than the value of $g_m(x_i)$. Second one is the value of $g_m(x_i)$, which is a little higher than the value of $g_{\rho}(\Delta\rho_i)$. The values of NP_i for these two scenarios are the same. If we reinforce the balance of system load, the value of NP_i in the first scenario will higher than the second one.

4.2.3 The Selection Decision

Notice that, the default outcomes or named threat points in some books for the user and network i are zero because the user do not prefer any one of the network or all networks cannot accept this user if the user and network i does not achieve the contract. Since there are n candidate networks, it can be regarded as n two-person bargaining games. For one of two-person bargaining games, the values of UP_i and NP_i in $[1,2]$ which means the set of pairs of payoffs to agreements are bounded and closed when all the parameters are equal to or larger than the requirement or the threshold. We can find a unique solution of the bargaining problem which is defined as

$$\max((UP_i)^{1-\theta_i} \cdot (NP_i)^{\theta_i}) . \tag{4.16}$$

After finding out the maximum value with the product of the preference for the user and for the network i in each two-person bargaining game we can compare these maximum values in these n two-person bargaining games and find the maximum one, as shown in (4.17).

$$i^* = \arg_i \max_{i \in N} \max((UP_i)^{1-\theta_i} \cdot (NP_i)^{\theta_i}) . \tag{4.17}$$

Chapter 5
Simulation Results

5.1 Simulation Environment

The simulation environment is shown in Fig. 2.1 which includes 7 CDMA cells, 7 WMAN networks and 28 WLAN networks. Table 5.1 shows the system parameters of this heterogeneous environment. The channel model and the characteristic of MSs have been introduced in chapter 2.

Table 5.1: System parameters for CDMA, WMAN, and WLAN

Parameters	CDMA	WMAN	WLAN
Cell radius	1.6 Km	2 Km	0.1 Km
Frame duration(time slot duration)	10 ms	5 ms	9 us
Carrier frequency	2 GHz	2.5 GHz	2.4 GHz
Load intensity threshold ρ_{th}	0.75	1	0.75
Dwell time threshold x_{th}	0.5	0.5	0.4
Number of cells	7	7	28
Chip rate (W)	3.84 Mbps		
Ratio of inter-cell interference to the total	0.55		
Number of subchannels (K)		4	
Number of data subcarriers per subchannel		48	
Number of slots per frame (L)		16	
Capacity			11 M bps

5.2 Source Model and QoS Requirements

As described at chapter 2, there are four traffic classes considered. The source model parameters for conversational, streaming, interactive, and background traffic classes are shown in Table 5.2, 5.3, 5.4, and 5.5, respectively.

Table 5.2: Source model parameters for conversational class traffic

Component	Distribution	Parameters
ON time	Exponential	Mean=1 sec
OFF time	Exponential	Mean=1.35 sec
Packets per second	Deterministic	50
Packet size	Deterministic	28 bytes
Call holding time	Normal	Mean=90 sec,
Data rate during active period		11.2 Kbps
Active rate		0.426
Mean data rate		4.77 Kbps

Table 5.3: Source model parameters for streaming class traffic

Component	Distribution	Parameters
Inter-arrival time between each video frame (T_f)	Deterministic	100 ms
Number of packets in each video frame (N_s)	Deterministic	8
Packet size (P_s)	Truncated Pareto	Min.=40 bytes, Max.=250 bytes Mean=100 bytes, α=1.2
Inter-arrival time between packets in a frame (T_p)	Truncated Pareto	Min.=2.5 ms, Max.=12.5ms Mean=6 ms, α=1.2
Call holding time	Normal	Mean =120 sec, variance =30 sec
Data rate during active period		133.33 Kbps
Active rate		0.48
Mean data rate		64 Kbps

Table 5.4: Source model parameters for interactive class traffic

Component	Distribution	Parameters
Main object size (S_m)	Truncated Lognormal	Min.=100 bytes, Max.=2 Mbytes Mean=10710 bytes, std. dev.=25032bytes
Embedded object size (S_e)	Truncated Lognormal	Min.=50 bytes, Max.=2 Mbytes Mean=7758 bytes, std. dev.=126168 bytes
Number of embedded objects per page (N_e)	Truncated Pareto	Mean=5.64, Max.=53
Inter-arrival time between each page ($T_{reading}$)	Exponential	Mean=30 sec
Packet size	Deterministic	Chop from objects with size 1500 bytes
Packet inter-arrival time (T_p)	Exponential	Mean=0.13 sec
Call holding time	Normal	Mean =120 sec, variance=30 sec
Data rate during active period		92.3 Kbps
Active rate		0.136
Mean data rate		12.55 Kbps

Table 5.5: Source model parameters for background class traffic

Component	Distribution	Parameters
file size (S_f)	Truncated Lognormal	Min.=50 bytes, Max.=5 Mbytes Mean=2 Mbytes, std. dev.=722 Kbytes
Inter-arrival time between each file (T_f)	Exponential	Mean = 180 sec
Packet size	Deterministic	3000 bytes
Call holding time	Normal	Mean =180 sec, variance =40 sec
Data rate during active period		88.9 Kbps
Active rate		1
Mean data rate		88.9 Kbps

As mentioned, the calls with different traffic classes have different QoS requirements. The QoS requirements of each traffic class are listed in Table 5.6, [24].

Table 5.6: The QoS Requirements of each traffic class

Traffic class	Requirement	Value
Conversational (voice)	Required BER	10^{-3}
	Required E_b/N_0	4 dB
	Max. delay tolerance	40 ms
	Max. allowable packet dropping rate	1%
Streaming (video)	Required BER	10^{-4}
	Required E_b/N_0	3 dB
	Max. delay tolerance	100 ms
	Max. allowable packet dropping rate	1%
Interactive (HTTP)	Required BER	10^{-6}
	Required E_b/N_0	2 dB
	Min. transmission rate	100 kbps
Background (FTP)	Required BER	10^{-6}
	Required E_b/N_0	1.5 dB

5.3 UGT Based Network Selection Scheme

In the simulation, the proposed BGNAS is compared with the UGT based network selection scheme [14]. When a new call request or a handoff call request arrives, UGT will find the candidate networks which are suitable for the call request first but only with the signal constraint and network loading constraint. After obtaining the candidate networks, UGT will compute the utility value from the satisfaction of QoS requirements of the call request and the network preference from predefined cooperative game for each candidate network. The payoff function of UGT is defined as $PO_{total}(NP_1, NP_2, ..., NP_n) = \sum_{i=1}^{n} A_i \times (NP_i - w_i \times NP_i^2)$, where NP_i is the preference of network i, A_i is the remaining resource available before allocating resource to network, and w_i is the penalty weight of network i which consists of the relative position in the network i when the speed of MS is low and the dwell time in network i when the speed of MS is from 3 km/hr to 80 km/hr. When the speed of MS is from 3 km/hr to 80 km/hr, the dwell time estimation of UGT is using (2.7) and (2.8), which means UGT without consider the effect that the estimation will be different if the direction will change when MS is moving.

The final step of UGT is choosing the maximum linear combination of utility values and network preference from all candidate networks. Then UGT can have the decision, $i^* = \text{Arg } \underset{i}{Max} \ [\alpha NU_i + (1-\alpha) NP_i]$, where α is a constant whose value is between 0 and 1, NU_i is the normalized utility value of candidate network i.

5.4 Simulation Results and Discussions

Suppose that one call request can only connect to one access network at a time here. For each cell, assume the new call arrival rate of conversational, streaming, interactive, and background traffic class calls in the heterogeneous network are $AR \times 1/40$, $AR \times 1/120$, $AR \times 1/120$, and $AR \times 1/240$ (users/second), respectively, where *AR* is the equivalent arrival rate. In the simulation, *AR* is chosen from 1, 3, 5, 7, and 9. Besides, there are three algorithms, BGNAS (proposed), BGNAS$^-$, and UGT in the simulation. BGNAS is the proposed method which uses bargaining game and the mobility model that is mentioned in chapter 2 has an improvement. BGNAS$^-$ also uses bargaining game but the mobility model is the same as UGT.

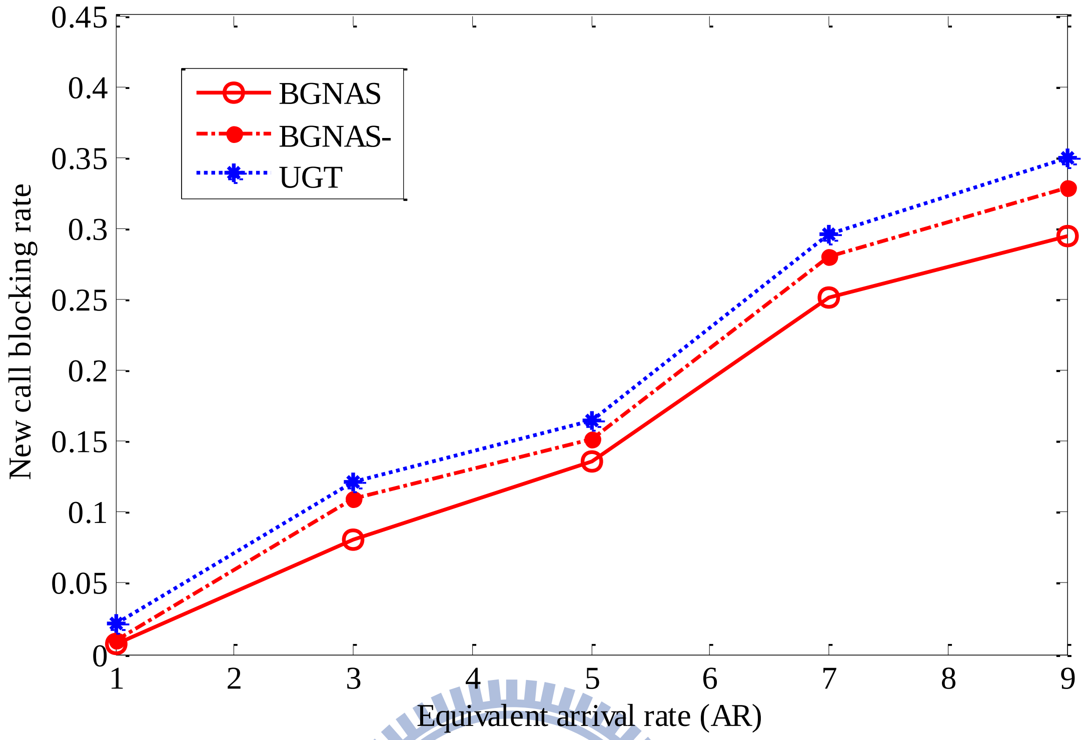

Fig. 5.1 : New call blocking rate

Fig. 5.1 shows the new call blocking rate. It can be found that BGNAS and BGNAS^{-} have a little lower new call blocking rate than UGT generally. The difference between BGNAS and BGNAS^{-} is the improvement of the mobility model. If the values of $x_{th,i}$ are the same in BGNAS and BGNAS^{-}, new call blocking rate will be higher in BGNAS^{-} than in BGNAS because of more precise estimation. Besides, in BGNAS and BGNAS^{-}, the design of bargaining power can reinforce the balance of networks loading, which means it can accommodate more call requests for the whole system. By bargaining problem formulation, it can be found an optimal solution according to different bargaining game, and then choose the best network when compare these solutions. Because choosing the maximum value among these optimal solutions means choosing the network which can lead to the maximum benefit for the user and the network.

We can observe Fig. 5.2, which plots the number of calls. We can found that BGNAS and BGNAS⁻ have more calls than UGT when traffic loading is getting higher especially. In UGT, it also considers the effect of loading balance, but the influence is not obvious. Besides, UGT did not show that whether the selection decision is an optimization problem or not. Because in UGT, the values of NP_i are obtained from the cooperative game which only considered from the aspects of networks. If UGT wants to add the perspective of the user, a linear combination might not be an optimize way, which means the user might choose an inappropriate network for different case.

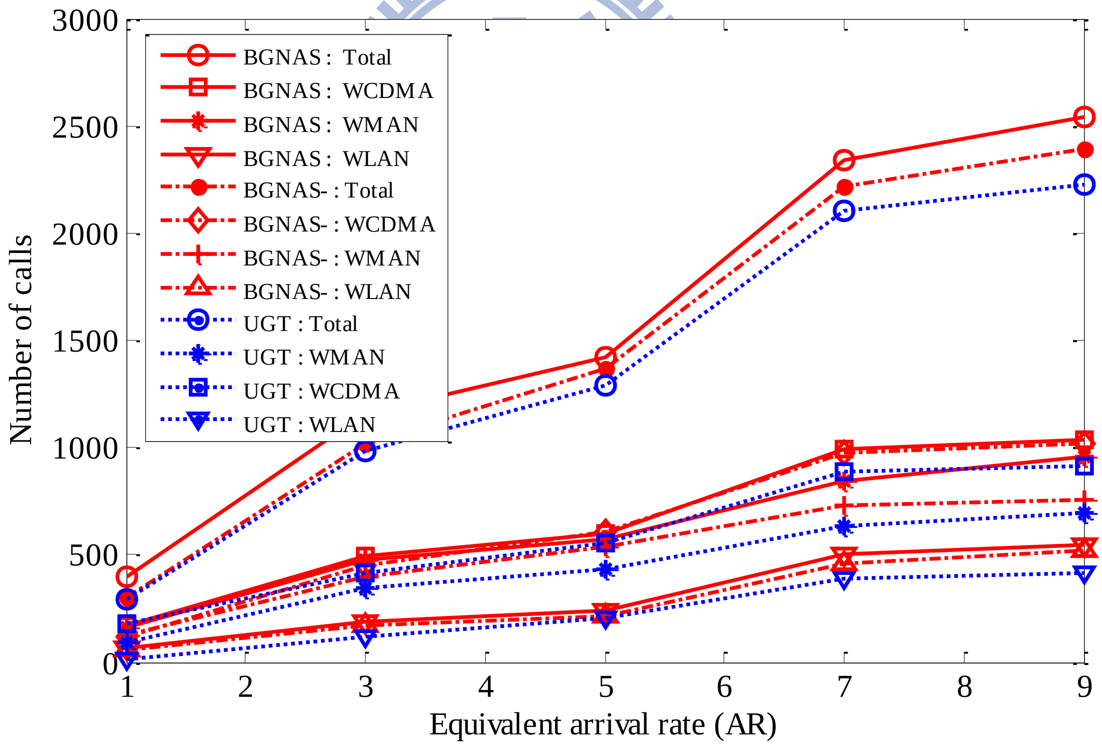

Fig. 5.2 : Number of calls

Fig. 5.3 can also be explained by this phenomenon. It can be found that BGNAS and BGNAS^{-} have higher throughput than UGT especially when equivalent arrival rate is getting higher. This is because BGNAS and BGNAS^{-} not only consider the loading of each network but also emphasize it with the design of bargaining power. And by bargaining problem formulation, the optimal solution can be found for each bargaining game. By bargaining, BGNAS and BGNAS^{-} give non-real time services more resources to achieve minimum transmission rate as far as possible. But UGT will accept a non-real time services without transmission. By this way, BGNAS and BGNAS^{-} can achieve higher average throughput than UGT.

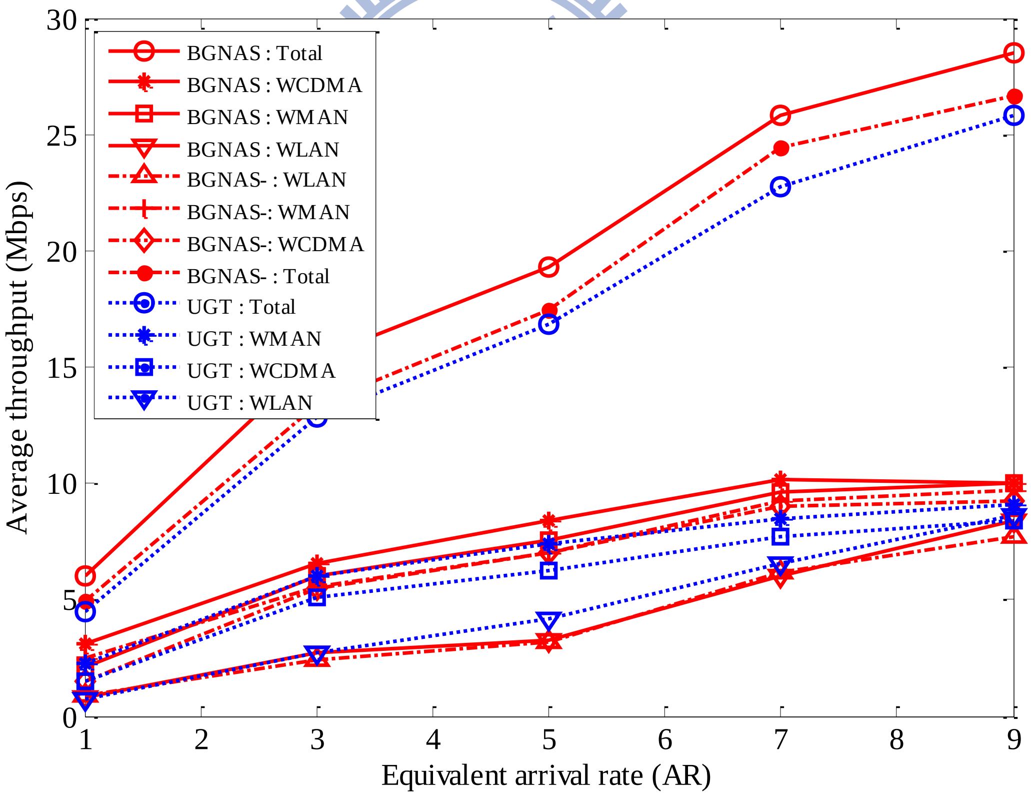

Fig. 5.3 : Total throughput of the system and throughput of each network

Fig. 5.4 and Fig. 5.5, which depict the number of total handoff calls and the number of failed handoff calls, respectively. We can see BGNAS has much fewer total handoff calls and number of failed handoff calls than BGNAS^{-} and UGT. This is because BGNAS^{-} and UGT do not consider the effect if the direction of the MS will change during its holding time. Besides, the number of total handoff calls in BGNAS^{-} is a little lower than UGT. This is because BGNAS^{-} considers the dwell time constraint when decide the candidate network set. By this way, BGNAS^{-} can avoid to choose any network in the candidate network set which those estimated dwell time of candidate networks are all too short.

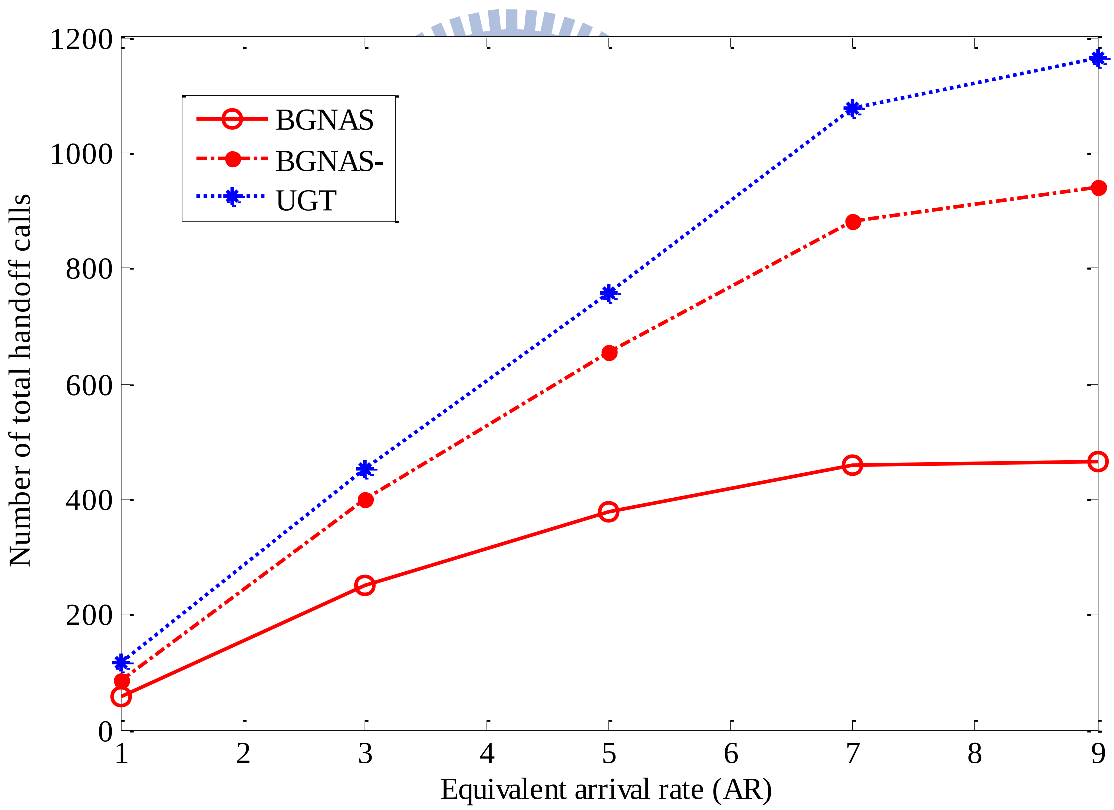

Fig. 5.4 : Number of total handoff calls

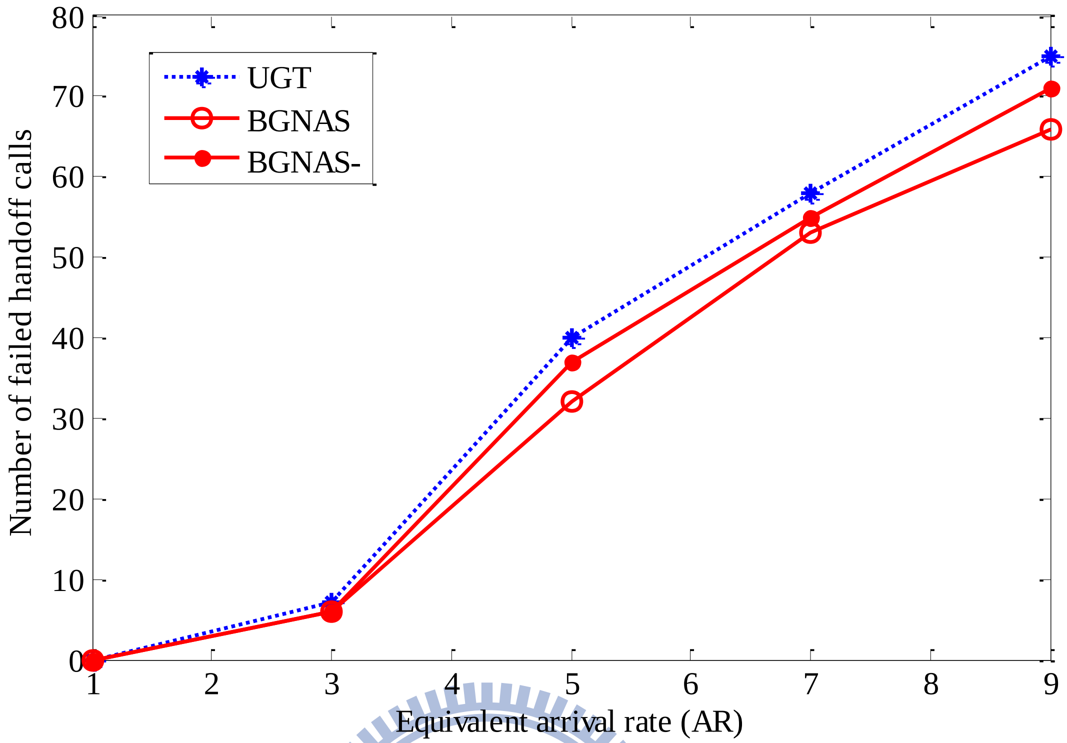

Fig. 5.5 : Number of failed handoff calls

The average delay for voice and video call in the heterogeneous network are shown in Fig 5.6 (a) and 5.6 (b), respectively. It can be found that the average delay for voice call and video call of BGNAS and BGNAS^{-} are a little higher than UGT in CDMA and WMAN. That is because BGNAS and BGNAS^{-} will guarantee transmission rate for non-real time services. This will cause the delay of real time services to be higher. But BGNAS and BGNAS^{-} are a little lower than UGT in WLAN. This is because the number of calls in WLAN with BGNAS and BGNAS^{-} are fewer than UGT and the probability of each call to get the right to access will increase. Besides, the average delay for voice and video calls are much lower than the QoS requirements.

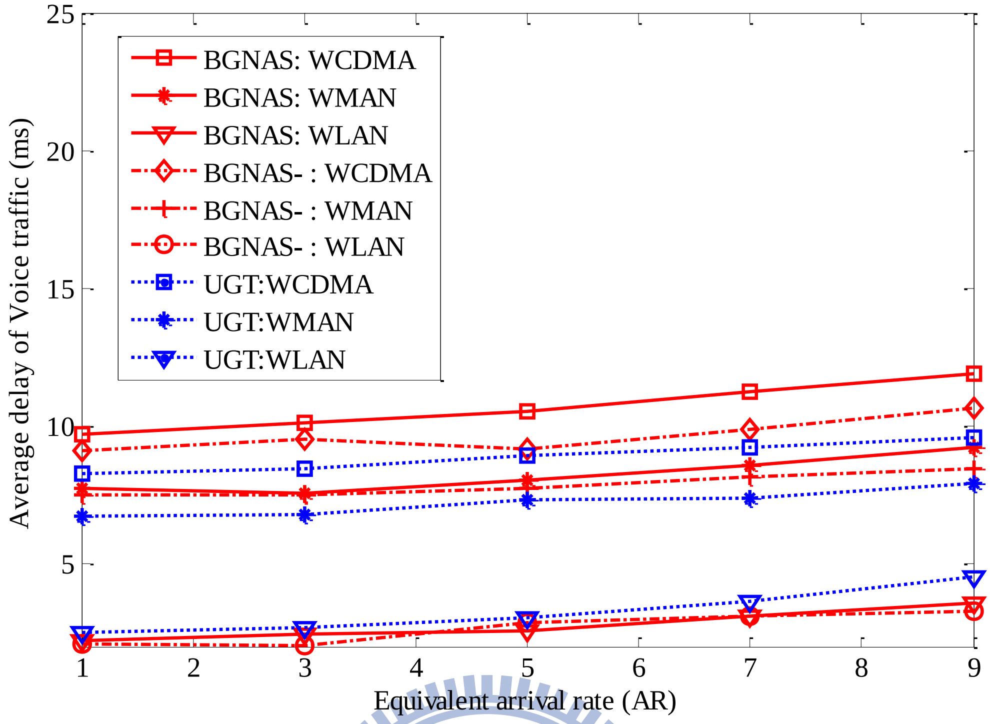

Fig. 5.6 (a) : Average delay of voice traffic

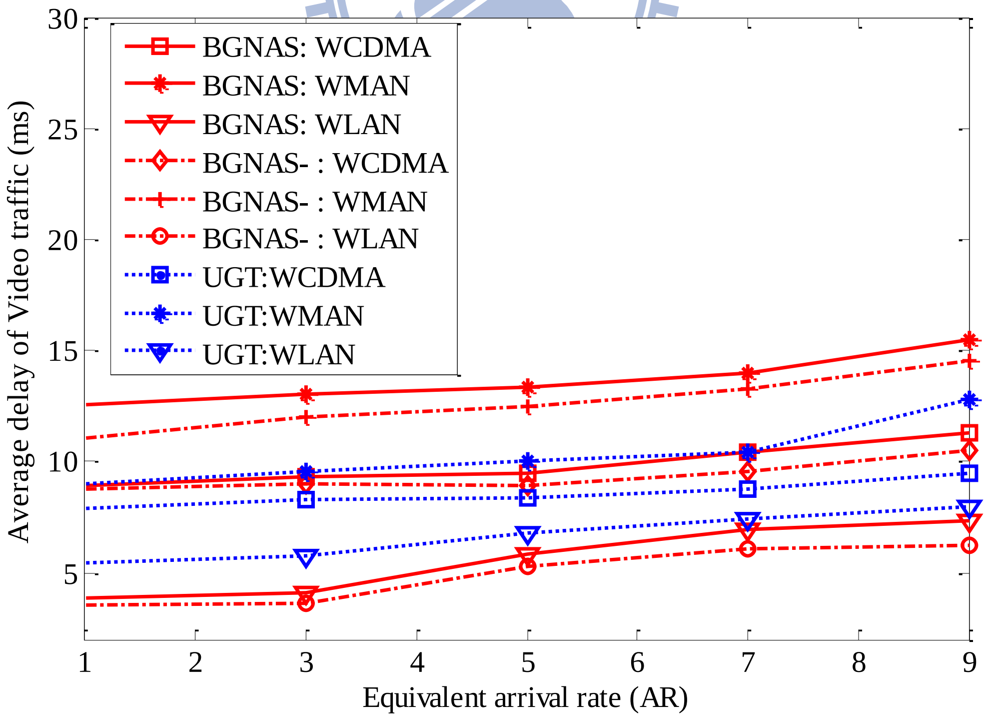

Fig. 5.6 (b) : Average delay of video traffic

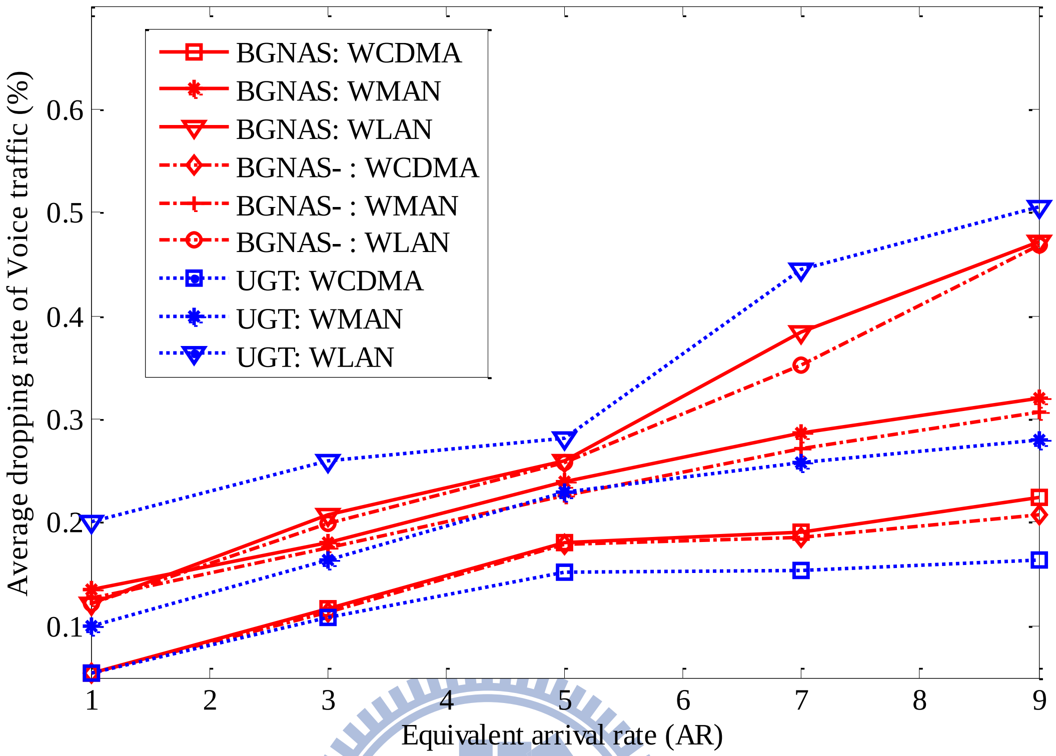

Fig. 5.7 (a): Average dropping rate of voice traffic

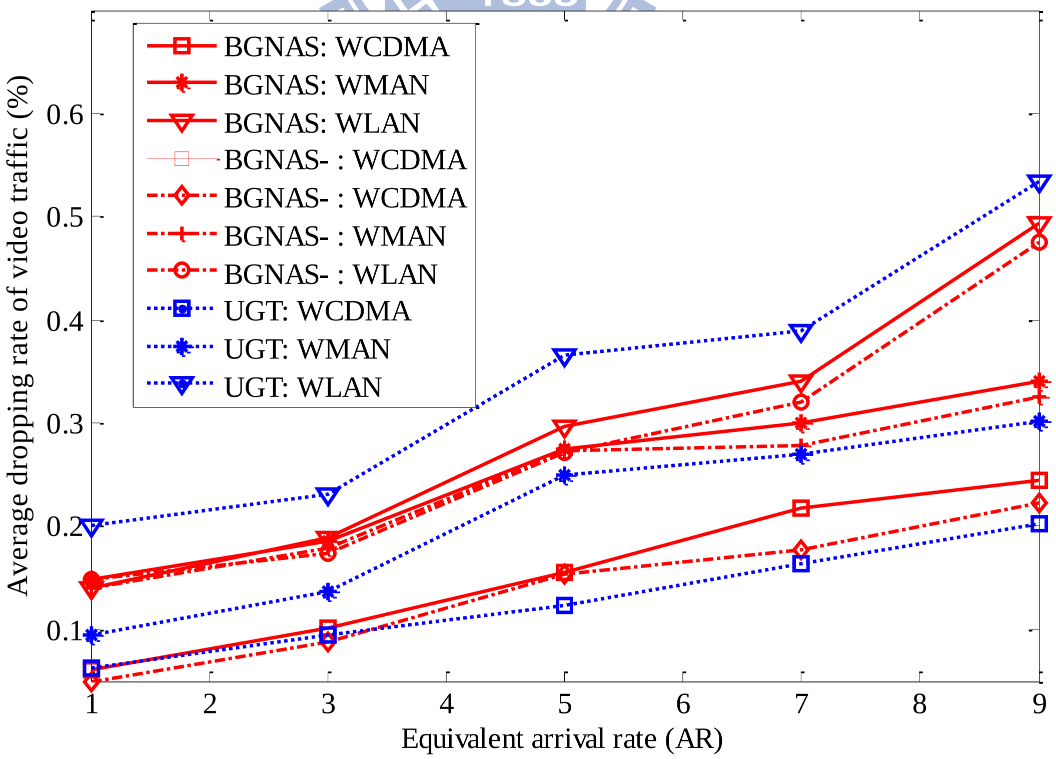

Fig. 5.7 (b) : Average dropping rate of video traffic

The average dropping rate for voice and video call are shown in Fig. 5.7 (a) and Fig. 5.7 (b), respectively. We can see the dropping rates are higher in BGNAS and BGNAS^{-} than that in UGT in CDMA and WMAN. The reason is the same as that for delay. But in WLAN, if the number of calls is higher, the probability that real time services to get the right to transmit the packet will be decrease. This will cause larger delay variance and dropping rate. Besides, the average dropping rate for voice and video call for both of two schemes are much lower than the QoS requirements.

1896

Chapter 6
Conclusions

In this thesis, a bargaining game based network access selection (BGNAS) is proposed for heterogeneous wireless environment, which considers conversational, streaming, interactive, and background services. A candidate network set will be found first by checking three constraints which include signal strength constraint, network loading constraint, and dwell time constraint. These candidate networks will form several two-person bargaining games. One player in one bargaining game is the user and the other player is one of the candidate networks. Two preference functions are designed which consider QoS requirements, mobility, and loading balance to represent the degree of preference of one player to the other player. The bargaining power is considered to reinforce the balance of system loading. By the bargaining problem formulation, there exists a unique solution in one bargaining game. Comparing the solutions of all bargaining games, one network will be selected with maximum value of all bargaining problems.

Simulation results show that BGNAS has higher total throughput than UGT at high arrival rate especially while satisfying the QoS requirements of each traffic class. This result comes from BGNAS gives more resource for non-real time services as far as possible. By sacrificing a little packet delay and packet dropping rate, BGNAS can achieve more system throughput. Besides, BGNAS reduces the number of handoffs calls more than 50% than UGT and without increasing the number of failed handoff calls. Because if a MS will change the direction when they move, the dwell time estimation will not be the same as the direction would not change. In this case, the overhead during the processing of handoff calls can be avoided significantly. When it comes to the packet delay and packet dropping rate, BGNAS is higher than UGT. But these two schemes are all under the maximum acceptable packet delay and packet dropping rate.

Appendix

Followings are proofs of the three axioms mentioned in Chapter 3 for the proposed bargaining problem and the two-person bargaining games.

Axiom 1. Pareto efficiency (PAR):

Let (U,d) be a bargaining problem, and let (v_1,v_2) and (v_1',v_2') be the members of U. If $v_1 > v_1'$ and $v_2 > v_2'$, then the bargaining solutions does not assign (v_1',v_2') to (U,d).

Proof:

Let U be the set of pairs of payoffs to agreements, and (UP, NP), (UP', NP') be the members of U. If $UP > UP'$ and $NP > NP'$, then we can obtain that $UP^{1-\theta} \cdot NP^{\theta} > (UP')^{1-\theta} \cdot (NP')^{\theta}$ since θ is the same in the bargaining game.

Axiom 2. Invariance to equivalent payoff representations (INV):

Let (U,d) be a bargaining problem, let α_i and β_i be two numbers with $\alpha_i > 0$ for $i = 1,2$, let U' be the set of all pairs (v_1',v_2'), where $v_i' = \alpha_i v_i + \beta_i$ for $i = 1,2$ and (v_1,v_2) is a member of U, and let $d' = (\alpha_1 d_1 + \beta_1, \alpha_2 d_2 + \beta_2)$. If the bargaining solution assigns (v_1,v_2) to (U,d), then it assigns (v_1',v_2') to (U',d').

Proof:

Let (U,d) be the proposed bargaining problem, $d = 0$ is the pair of payoffs to disagreement. Let α_u, α_n and β_u, β_n be four numbers with

$\alpha_u, \alpha_n > 0$, and U' be the set of all pairs (UP', NP') , where $UP' = \alpha_u UP + \beta_u$ and $NP' = \alpha_n NP + \beta_n$. (UP, NP) is a member of U .

Let $d' = (\alpha_u d_u + \beta_u, \alpha_n d_n + \beta_n)$, then

$$(UP' - d_u')^{1-\theta} \cdot (NP' - d_n')^{\theta} = (\alpha_u UP + \beta_u - \alpha_u d_u - \beta_u)^{1-\theta} \cdot (\alpha_n NP + \beta_n - \alpha_n d_n - \beta_n)^{\theta},$$

$$= \alpha_u \alpha_n (UP - d_u)^{1-\theta} \cdot (NP - d_n)^{\theta}$$

so the solution of (U', d') is the same as (U, d) .

Axiom 3. Independence of irrelevant alternatives (IIA):

Let (U, d) and (U', d') be bargaining problems for which U' is a subset of U and $d = d'$. If the bargaining solution assigned to (U, d) is in U', then the bargaining solution assigns the same agreement to (U', d') .

Proof:

Let (U, d) and (U', d') be bargaining problems for which U' is a subset of U and $d = d'$. Since any two of outcomes in U are mutually independent, any reduction of the number of outcomes will not affect the result.

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Vita

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