Network Selection in Wireless Heterogeneous Networks

P.Prabhavathi and L.Nithyanandan

Abstract—**Next generation wireless networks are expected to be Heterogeneous consisting of several wireless technologies such as 3G, WLAN, WiMAX, LTE etc. Users of future mobile networks will be able to choose from different radio access technologies. These networks vary widely in service capabilities such as coverage area, bandwidth and error characteristics. Network selection is a challenging task in heterogeneous network and will influence the performance metrics of importance, for both service provider and subscriber. Network selection is performed by using game theory based selection algorithms such as Bush – Mosteller based COmbined fully DIstributed PAyoff and Strategy Reinforcement Learning (CODIPAS-RL) and Boltzmann-Gibbs based CODIPAS-RL. In this paper network selection is performed in WLAN-WiMAX integrated networks using Boltzmann-Gibbs based CODIPAS-RL, the performance of which is proved to be better in routing. The parameters such as BER, throughput, Network Selection Probability and payoff for selecting a network are obtained. From the simulation results it is inferred that the performance of Boltzmann-Gibbs based CODIPAS-RL is better than the Bush –Mosteller based CODIPAS-RL.**

Index Terms—**CODIPAS-RL, Heterogeneous networks, WiMAX, WLAN.**

I. Introduction

During the past decade both communication and internet technologies have been in a phase of rapid development. The number of mobile phones and wireless internet users has increased significantly in recent years. Heterogeneous networks refer to the integration of different Radio Access Technologies (RAT) such as WLAN, WiMAX, UMTS and LTE etc. Each of these wireless networks differs in data rate, coverage area, bandwidth and mobility etc. Wireless and mobile technologies are evolving towards integration of heterogeneous access networks in order to provide ubiquitous availability of multimedia services and applications. Hence it is essential for the users to make the best possible use of combined resources of the available heterogeneous networks (WLAN, WiMAX, 3G, etc.) for seamless connectivity. The main benefit of heterogeneous networks is the effective utilization of available bandwidth to meet demands for high performance applications such as multimedia, video, video-conferencing, global mobility and service portability.

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Users with multi mode mobile terminal can select the specific network from the different Radio Access Networks (RAN). Based on the variation in radio environment and user mobility, the characteristics and availability of a network will change in time and depends on the location. Hence, the dynamic reselection of radio access network is the major task of mobility management process. When users need to migrate between heterogeneous networks for effective utilization of service and better performance, network selection is necessary.

One of the important challenges in heterogeneous network is the selection of better network. Some of the approaches used for network selection process are Multi Attribute Decision Making (MADM) algorithm, fuzzy logic based approach, mathematical approaches such as Analytical Hierarchy Process (ARH) and Grey Relational Analysis (GRA). These approaches are not suitable in dynamic environment. Hence game theory based approach is used in dynamic environment for the purpose of network selection.

Basically there are two constraints for network selection process. They are selection of network in an uncertain environment and network centric approach for network selection [1]. In a dynamic or uncertain environment there will be variability of user demands, random activity of users and uncertainty of system parameters and hence the network selection process is tedious. In a network centric approach a centralized controller in the Base Station (BS) selects the network, based on the information obtained from the user. This approach does not satisfy the user's needs and does not provide optimum results. If the network selection is made user centric better performance can be realized. In user centric approach [2] users themself can select the network according to their level of satisfaction. The end user is provided with game theory based network selection algorithm for the user centric approach.

The structure of the paper is as follows. Section II describes the network selection process. Section III deals with existing and proposed network selection algorithms. Section IV presents the simulation results and finally section V concludes the paper.

II. NETWORK SELECTION PROCESS

Selecting a specific network from the converged network is called network selection. The user device faces the problem of selecting a network from a number of RANs [7] that differ in technology, coverage, bandwidth, pricing scheme, etc., belonging to the same or different service providers. Network selection mechanisms are enabled in heterogeneous networks in order to keep the mobile users "Always Best Connected (ABC) anywhere and anytime". A network selection decision is made (i) At the initiation of service connectivity (ii) As a part of handover execution when the current RAN characteristics are worse (iii) When a better RAN is available (iv) When user changes their preference or requirements [3].

Generally the network selection problem is considered as a part of handoff process and it is modeled using centralized or decentralized approach. Centralized approach is called as network-centric which consists of a centralized controller for selecting a network. The network-centric approaches are based on the cooperation of subscribed user devices in obeying the decision made by the centralized controller. In the decentralized approach, network selection decision is made at user side either by the user or automatically by the mobile terminal. Mostly decentralized user-centric approaches are considered in the case of multiple networks in which the users can choose the suitable RAN.

The network selection decision making process involves relevant input information for selecting best network [8]. The decision criteria used for network selection are

(1) Network metrics which includes the technical characteristics of networks such as coverage, technology, RSS and security
(2) Device related information such as supported interfaces and mobility support
(3) Application requirements such as BER, throughput, delay and packet loss
(4) User preference such as budget and service quality expectation

Game theory based selection algorithms are used for network selection in a dynamic environment. The network selection algorithms used in this paper are Bush Mosteller based CODIPAS-RL and Boltzmann Gibbs based CODIPAS-RL. Network selection using Bush Mosteller based CODIPAS-RL was discussed in [1]. Boltzmann Gibbs based CODIPAS-RL was implemented for routing in dynamic environment [5] and its performance was found to be better than Bush Mosteller based COPIPAS-RL. In literature network selection was done using Bush Mosteller based CODIPAS-RL but Boltzmann Gibbs based CODIPAS-RL was not used for network selection process. Hence in this paper we propose Boltzmann Gibbs based CODIPAS-RL for network selection process.

III. NETWORK SELECTION ALGORITHMS

A. Bush Mosteller based CODIPAS-RL

Reinforcement learners' use their experience to choose or avoid certain actions based on their consequences [4]. Actions that led to satisfactory outcomes will be repeated in the future, whereas actions that led to unsatisfactory experiences will be avoided. In Bush and Mosteller based reinforcement learning, players will decide the actions i.e., the strategy of each player is defined by the probability of undertaking each of the two actions available to them. Based on the action, each player determines the corresponding payoff (utility) and updates the action.

The probability of selecting an action a_j is given in eqn.(1). where λ_j is the player *j*'s learning rate ($0 < \lambda < 1$), $s_{j,t}$ is the stimulus for the action $a_{j,t}$ given in eqn. (2) and its value lies in the range [-1, 1]. The increase in values of stimulus or learning rate will increase the changes in network selection probability.

$$x_{j,t+1}(a_j) = x_{j,t}(a_j) + \lambda j S_{j,t}(1 - x_{j,t}(a_j)) \quad (1)$$

$$S_{j,t} = \frac{u_{j,t} - M_j}{sup_a|U_j(a) - M_j|} \quad (2)$$

where $u_{j,t}$ denotes the perceived utility at time *t* of player *j* , M_j is aspiration level of player *j*. Based on the action, payoff of user is determined using eqn. (3)

$$\hat{u}_{j,t+1}(a_j) = \hat{u}_{j,t}(a_j) + v(t) * (u_{j,t} - \hat{u}_{j,t}(a_j)) \quad (3)$$

The time required for network selection using Bush-Mosteller based CODIPAS-RL is high.

B. Boltzmann Gibbs based CODIPAS-RL

The Boltzmann-Gibbs based learning scheme [6] (also called softmax) achieves equilibrium in small number of iterations itself i.e., time taken for network selection is less when compared to Bush Mosteller based CODIPAS-RL also computational capabilities and memory requirements are less. This is because Boltzmann Gibbs based CODIPS-RL produces the expected utility and makes decisions without the knowledge of their opponents. The Boltzmann-Gibbs distribution is given by

$$B_{j,\epsilon}(\hat{u}_{j,t})(a_j) = \frac{e^{\frac{1}{\epsilon_j}\hat{u}_{j,t}(a_j)}}{\sum_{a`_j \in A_j} e^{\frac{1}{\epsilon_j}\hat{u}_{j,t}(a`_j)}}, a_j \in A_j, j \in K \quad (4)$$

eqn.(4) attains equilibrium when $\frac{1}{\epsilon_j}$ is large which denotes the rationality level of player *j*. The probability of selecting an action a_j is given in eqn. (5)

$$x_{j,t+1}(a_j) = x_{j,t}(a_j) + \lambda j \left(\frac{e^{\frac{1}{\epsilon_j}\hat{u}_{j,t}(a_j)}}{\sum_{a`_j \in A_j} e^{\frac{1}{\epsilon_j}\hat{u}_{j,t}(a`_j)}} - x_{j,t}(a_j) \right) \quad (5)$$

Based on the action in (5), each player determines their payoff given in eqn.(6) and updates the action,

$$\hat{u}_{j,t+1}(a_j) = \hat{u}_{j,t}(a_j) + v(t) * \left(u_{j,t} - \hat{u}_{j,t}(a_j)\right) \quad (6)$$

assuming that each player does not know their payoff, but only knows the estimation of average payoff of other actions. Hence the user takes a decision based on the average payoff to update the action. Each player considers only the payoff of the selected action at time t, and updates the action.

IV. SIMULATION RESULTS

The software used for simulation is MATLAB and the simulations are carried out in Rayleigh fading channel with modulations 16 PSK, 64 PSK for WiMAX and WLAN respectively. Fig.1 shows the error performance of the system (WLAN and WiMAX) in isolated mode and integrated mode. It shows that the performance of the system in integrated mode is better than the performance in isolated mode. Before integration, the user is connected to only one network hence the performance of the system is moderate. After integration users will be connected to more than one network. Based on their requirements, users can shift to different networks, for example initially users registered in WLAN can migrate to WiMAX when they need multimedia or video calls, better QoS, willing to pay more for a particular service, higher security, better RSS and increased coverage. Therefore the performance of the system and throughput after integration will be better than before integration.

Figs.2 and 3 show the throughput of the system before and after integration. The throughput of the system after integration was found to be higher than the throughput before integration. This is due to the fact that the resource of both the network is utilized by all the users and hence due to higher available resource, throughput increases.

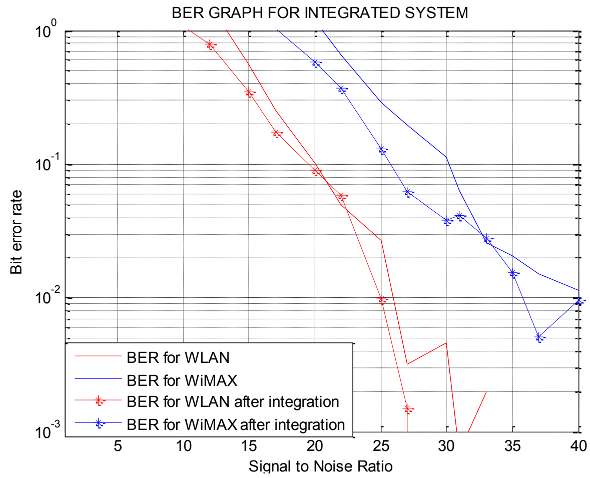

Fig.1 Error performance in isolated and integrated modes

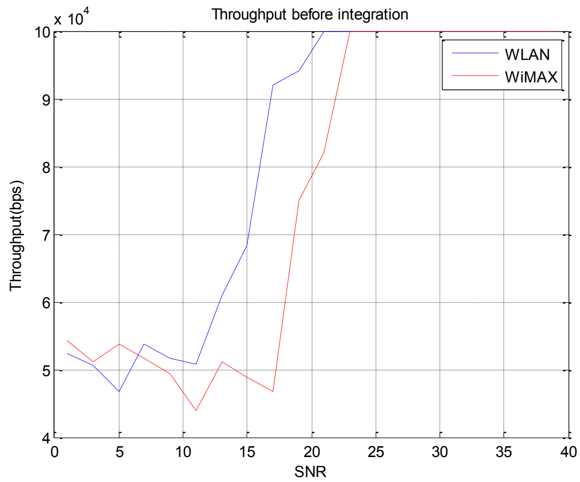

Fig.2 Throughput in isolated mode

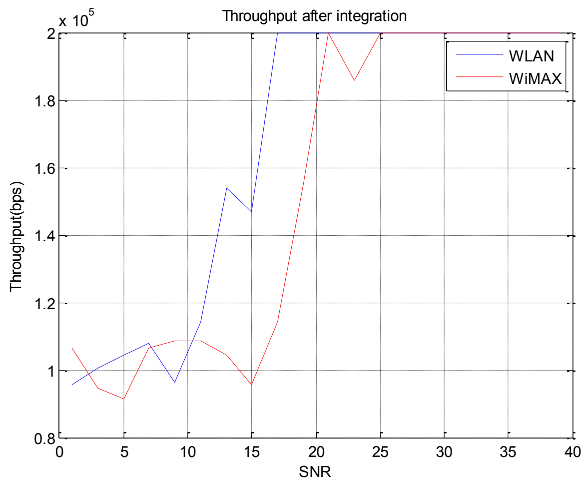

Fig.3 Throughput in integrated mode

The implementation of Bush-Mosteller based CODIPAS-RL for two users and same action set is shown in Fig.4. It is inferred that the trajectory goes to equilibrium with equal probabilities (1/2, 1/2) for the two users. The same actions set shows that both users can share the benefits equally.

The trajectory reaches the equilibrium with two different probabilities for the different action sets chosen by the user as shown in Fig.5. The different action set shows that a single user can benefit individually by opting a particular action. The convergence time to attain equilibrium is found to be around 200 iterations.

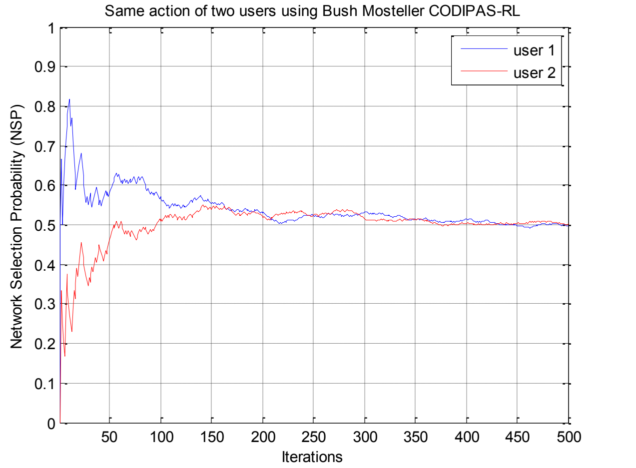

Fig. 4 NSP using Bush-Mosteller based CODIPAS-RL (same action set)

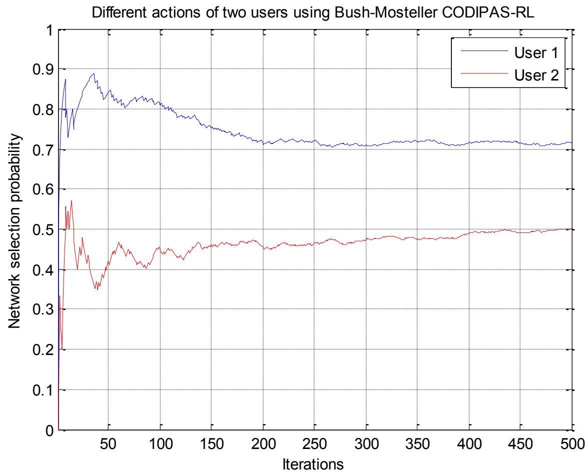

Fig.5 NSP using Bush-Mosteller based CODIPAS-RL (different action sets)

Payoff is a numerical value which indicates the gain or profits obtained by the users. Figs.6 and 7 show the behaviour of the user 1 and user 2 and their estimated payoffs. This is somewhat similar to the different action set of the user, where each user will be having different probabilities.

The user 1 who is connected to WiMAX experiences more benefit when compared to WLAN and hence the payoff for the user 1 in WiMAX will be higher. Similarly user 2 is connected to WLAN experiences more benefit than WiMAX because user 1 already gets maximum benefit from WiMAX. Hence it is found that the maximum payoff for user 1 is obtained by selecting WiMAX and the payoff is maximum for user 2 by selecting WLAN.

The evolution of strategies i.e., the probability of both the users selecting WLAN based on the estimated payoff is shown in Fig.8. The action of the users will be determined based on the payoff achieved by the users. Since the payoff for the user 2 in selecting WLAN is high, the network selection probability for the user 2 is also high.

The implementation of Boltzmann-Gibbs based CODIPAS-RL for two users and same action set was shown in Fig.9. It is inferred that the trajectory goes to equilibrium with equal Network Selection Probability (NSP) (1/2, 1/2) for the two users. The same action set of two user shows that both users can share the benefits equally. The trajectory reaches the equilibrium with two different probabilities for the different action sets chosen by the user as shown in Fig.10. The different action set shows that a single user can benefit individually by opting a particular action. The convergence time to attain equilibrium is found to be around 100 iterations.

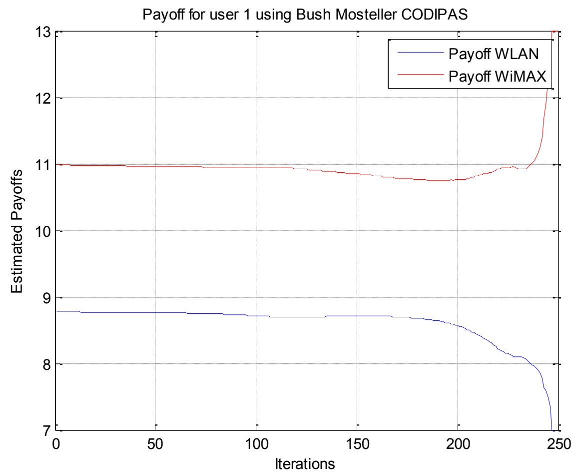

Fig.6 Payoff using Bush Mosteller based CODIPAS-RL (user 1)

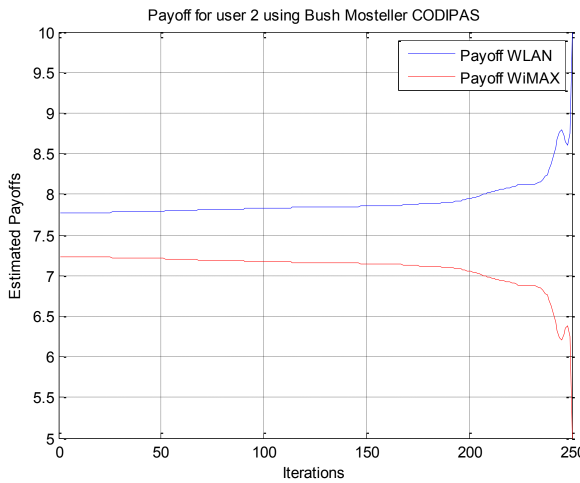

Fig. 7 Payoff using Bush Mosteller based CODIPAS-RL (user 2)

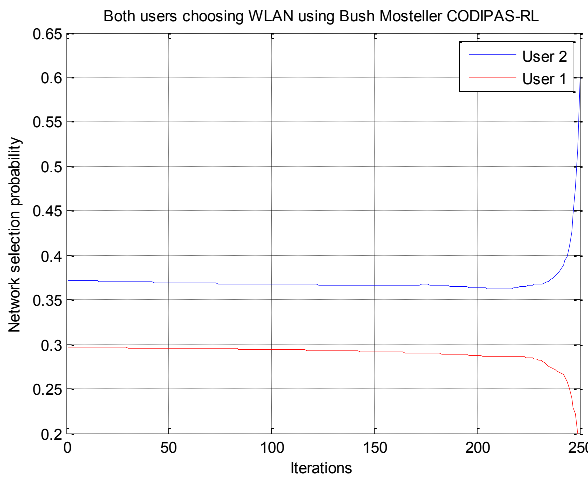

Fig.8 NSP using Bush Mosteller based CODIPAS-RL (both users selecting WLAN)

Figs.11 and 12 show the behaviour of the user 1 and user 2 and their estimated payoffs using the proposed Boltzmann-Gibbs based CODIPAS-RL. The user 1 who is connected to WiMAX experiences more benefit when compared to WLAN and hence the payoff for the user 1 in WiMAX will be higher.

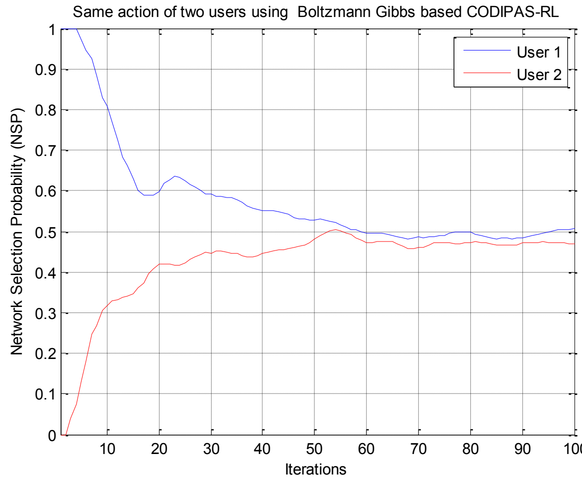

Fig.9 NSP using Boltzmann-Gibbs based CODIPAS-RL (same action set)

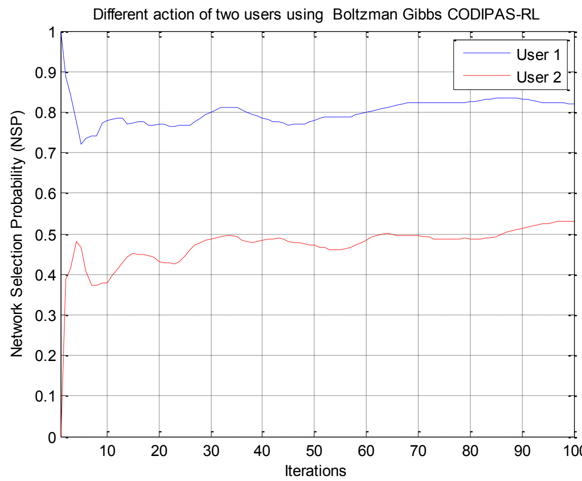

Fig.10 NSP using Boltzmann-Gibbs based CODIPAS-RL (different action sets)

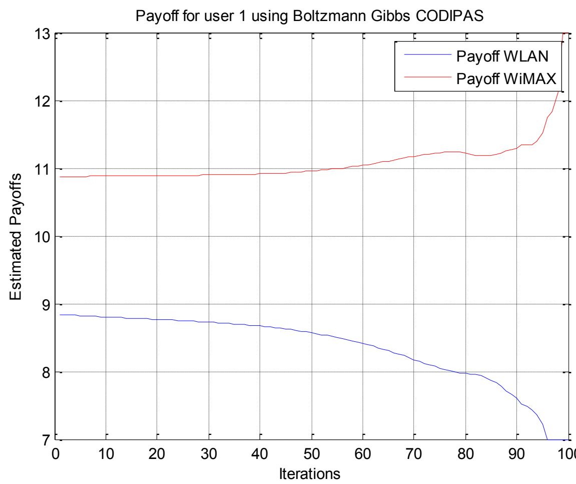

Fig.11 Payoff using Boltzmann-Gibbs based CODIPAS-RL (user 1)

The evolution of strategies i.e., the probability of both the users selecting WLAN based on the estimated payoff is shown in Fig.13. Since the payoff for the user 2 in selecting WLAN is high, the network selection probability for the user 2 is also high. The simulations results show that the convergence time required for the Boltzmann-Gibbs based CODIPAS-RL is less when compared to the Bush Mosteller based CODIPAS-RL.

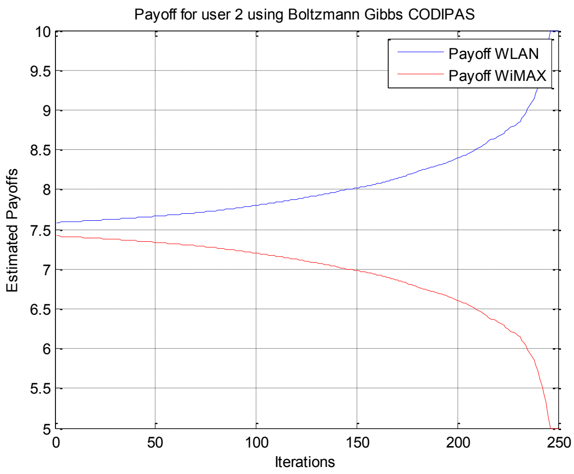

Fig.12 Payoff using Boltzmann-Gibbs based CODIPAS-RL(user 2)

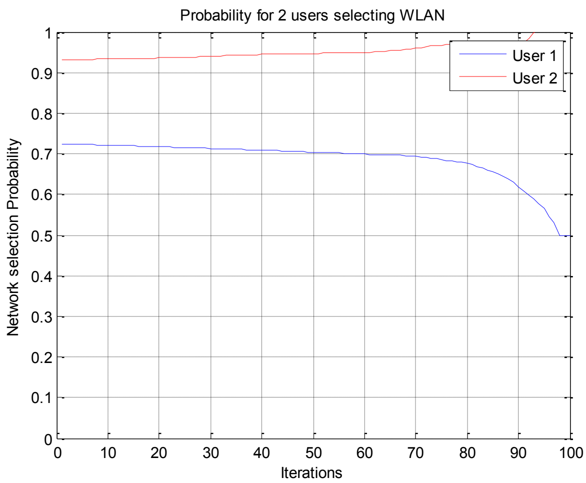

Fig.13 NSP using Boltzmann-Gibbs based CODIPAS-RL (both users selecting WLAN)

V. CONCLUSION

In this paper we have presented network selection in the integrated WLAN-WiMAX networks. The simulation results show that the network in integrated mode outperforms the network in isolated mode for the QoS parameters Bit Error Rate (BER) and throughput. For BER of 10^{-3}, the system in integrated mode requires 4 dB lesser SNR than isolated mode. The throughput for integrated mode is 50% higher than the isolated mode. This is because the users can share the combined resources of both the networks.

The network selection probability and the payoff based on the NSP are determined using network selection algorithms. The existing Bush Mosteller based CODIPAS-RL performs the network selection in 107.5ms whereas the proposed Boltzmann Gibbs based CODIPAS-RL performs the network selection in 47.8ms. In terms of the number of iterations, the Bush Mosteller based CODIPAS-RL takes nearly 200 iterations and Boltzmann Gibbs based CODIPAS-RL takes 60 iterations. Hence the Boltzmann Gibbs based CODIPAS-RL is found to be better than the existing network selection algorithm.

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