Vertical Handoff Decision using Game Theory Approach for Multi-mode Mobile Terminals in Next Generation Wireless Networks

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ABSTRACT
Vertical Handoff Decision Making problem is one of the significant technical issues in the development of Heterogeneous wireless networks. This paper presents a vertical handoff decision algorithm based on game theory approach. In this algorithm, the handoff decision problem is formulated as a non cooperative game between the mobile users and the wireless networks that are available in the vicinity of the mobile user. It considers terminal parameters such as QOS requirements of the mobile application along with the velocity of the mobile terminal. It also considers network parameters such as available bandwidth and cost per bit offered by each network. The algorithm chooses the target network with maximum network utilization that offers services at lower prices.

General Terms
Heterogeneous Wireless Networks, Game Theory

Keywords
Game theory, Vertical handoff, QOS parameters, Cost per bit, traffic class.

1. INTRODUCTION
With the technological advancements in the area of wireless communications, numerous wireless networks such as Bluetooth, Wi-Fi, Wi-Max, GPRS and CDMA have been evolved. These networks were developed individually to meet specific service requirements and have their own advantages and drawbacks. For example, Wi-Fi networks were developed to offer high bandwidths by using unlicensed spectrum at lower cost. But they cover only short ranges and suitable for applications such as internet connectivity from devices such as personal computer, audio player or a game console when they are within the range of a wireless/wired network connected to Internet.

Third generation cellular networks such as UMTS, GSM and CDMA 2000 networks were designed to cover larger distances but the data rates offered by these networks are limited. For world-wide coverage, satellite networks are extensively used in military and commercial applications. But their design, launching and maintenance is expensive. Wi-Max networks which can operate in both licensed and unlicensed frequencies, offer higher bandwidth and greater range as compared to Wi-Fi based wireless systems. But it has the drawbacks of installation and operation costs and lack of quality of service. These wireless networks have their own merits and limitations [1] and there is no single wireless network that can substitute all other technologies.

Next generation (NG) wireless networks also named as Heterogeneous wireless networks [2] are aiming at the integration of various wireless networks to take advantage of the individual strengths of all the networks. With this interoperability, mobile users carrying mobile terminals equipped with multiple interfaces can access a wide range of applications provided by multiple wireless networks in an Always Best Connected mode [3-5]. Heterogeneous wireless networks also enable mobile users to access communication services anytime, anywhere with higher quality of service at a minimum cost.

Seamless mobility support across heterogeneous wireless networks is one of the important research issues [6]. In this context, design of an efficient vertical handoff decision algorithm that enables the multi-mode terminal to choose the best among the available networks is of great importance [7-11]. This paper presents a vertical handoff decision algorithm for multi-mode terminals using Game Theory approach. It considers terminal characteristics such as Quality of Service (QOS) requirements of the application and the speed of the mobile station. Handoff decision problem is formulated as a non cooperative game between mobile user and the available wireless networks. The algorithm enables mobile user to roam across different networks by always connecting to the best network with highest utilization at best prices.

The rest of the paper is organized as follows: Section 2 reviews the concepts of vertical handoff, multi-mode mobile terminals, different traffic classes, Game Theory approach and Media Independent Handover (MIH) Frame work. In Section 3, we present the vertical handoff decision algorithm based on Game Theory approach. Experimental results are shown in Section 4. Finally, conclusions are given in Section 5.

2. RELATED CONCEPTS
This section reviews the concepts of vertical handoff, classification of vertical handoffs, different traffic classes, multi-mode mobile terminals and basics of Game Theory.

2.1 Vertical Handoff
Handoff is the process of transferring an ongoing call or data session from one base station to another base station without loss or disruption of service. If both base stations belong to the same access technology, the handoff is named as horizontal

handoff as shown in Figure 1. On the other hand, if both base stations belong to different access technologies, the handoff is termed as vertical handoff and is shown in Figure 2. The vertical handoff process involves three steps [12]. In the first step, the mobile node identifies which wireless networks are available in its vicinity. This is known as system discovery phase. In the second step, the mobile node decides the most suitable network among the available networks and is termed as handoff decision phase. In the third step, the mobile node executes a handoff procedure required to be associated with the new wireless network and is referred to as handoff execution phase. This paper mainly focuses on the handoff decision phase.

2.2 Classification of Vertical Handoffs

2.2.1. Upward and Downward Handoffs

Vertical handoffs can be classified based on the coverage of source and target networks as upward and downward vertical handoffs. If the mobile switches from the network with a small coverage to a network of larger coverage, it is termed as upward handoff. On the other hand, a downward handoff occurs in the reverse direction, i.e. from a network of larger coverage to a network of smaller coverage.

2.2.2. Hard and Soft handoffs

The Vertical handoff process where a mobile node associates with the new base station after getting disconnected from the previous base station is termed as hard handoff or break before make. On the other hand, in soft handover a mobile node maintains the connection with the previous base station till its association with the new base station is completed. This process is also termed as make before break and the mobile node maintains simultaneous connections with both the base stations during the interim period. Soft handoffs are preferable compared to hard handoffs as they eliminate the problem of disruption of service.

2.2.3. Imperative and Alternative handoffs

An imperative handoff [13] occurs due to weakening of signal strength from a base station or access point. On the other hand, an alternative vertical handoff is initiated to provide the user with better performance.

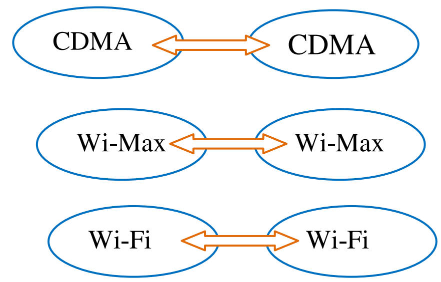

Figure 1. Horizontal Handoff

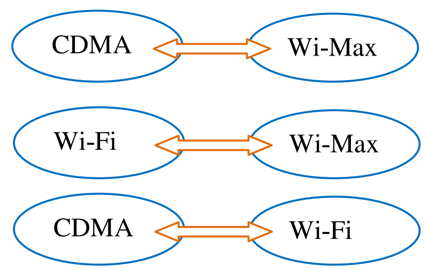

Figure 2. Vertical Handoff

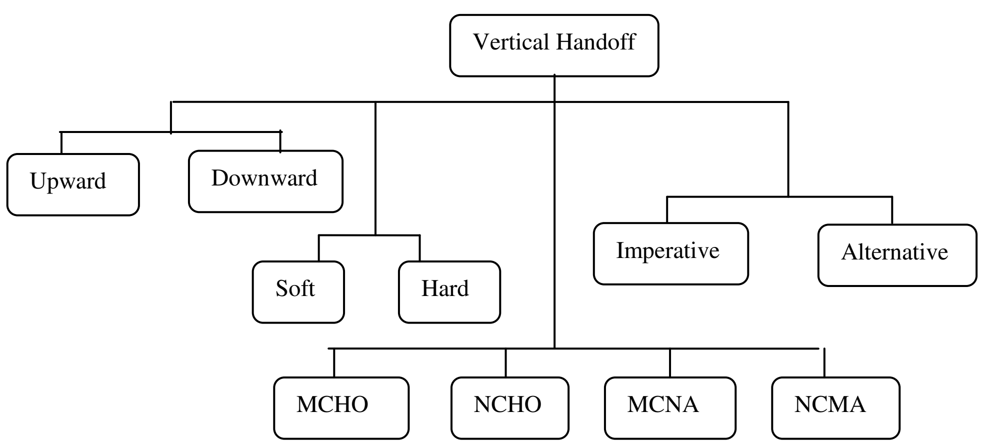

Figure 3. Classification of Vertical Handoffs

For imperative handoffs, it is sufficient to consider signal strength received from a base station, where as for alternative handoffs several other network parameters such as available bandwidth, supported velocity and cost of the network are to be considered in addition to the device parameters such as quality of service demanded by the application and user preference.

2.2.4. Mobile Controlled and Network Controlled handoffs

Vertical handoffs can further be classified based on who controls the handoff decision. If mobile node controls the handoff decision, it is termed as Mobile controlled handoff (MCHO). In Network controlled Handoff (NCHO) networks control the handoff decision. The handoff decision control is shared between the network and mobile in case of Mobile controlled Network Assisted (MCNA) and Network Controlled Mobile Assisted handoffs (NCMA). MCNA handoffs are more suitable because only mobile nodes have the knowledge about the network interfaces they are equipped with and user preferences can be taken into consideration. A summary of classifications is shown in Figure 3.

2.3 Multi-Mode Mobile Terminals

Mobile nodes equipped with multiple interfaces in order to access services from different wireless networks are referred to as Multi-mode mobile terminals. Advanced mobile phone system on code division multiple access dual function cell phone, dual function satellite cell phone and global system for mobile telecommunications are examples of Multimode mobile terminals

The protocol stack of a multi-mode mobile terminal consists of radio access technology (RAT) specific protocols for physical and data link layers and a common set of protocols for network, transport, and application layers.

2.4 Traffic Models

There are four classes of traffic Models that include conversational, streaming, interactive, and background traffic. The conversational class represents real-time multi-media applications such as voice telephony. The streaming class includes the real-time video stream applications. The interactive class is composed of non-real time applications such as web browsing. The background class is the service using best effort transmissions such as file transfer protocol (FTP). The QOS requirements of each traffic class are listed in Table 1.

2.5 Game Theory Approach

Game Theory is a set of mathematical models and techniques developed in economics to analyze interactive decision process, predict outcomes of interactions and identify optimal strategies [14, 15]. Earlier Game theory has been widely used in biological and social science research. In recent years, it has started to be applied in wireless networks. Game theory techniques were adopted to solve many protocol design issues like resource allocation, power control in wireless networks. This paper proposes a vertical handoff decision algorithm based on Bayesian Evolutionary game model.

When a mobile host is under the coverage of more than one wireless network, it performs network selection iteratively to achieve best quality of service with minimum cost. The decisions evolve to the equilibrium point at which the quality of network access service is maximized and the cost of the service is minimized. This solution is termed as Bayesian Nash equilibrium and is found by solving pair-wise matrix. If there is no Nash equilibrium solution for the game, the algorithm finds the sub-optimal solution. The results ensure the convergence to either equilibrium or sub-optimal solutions to the mobile users under incomplete information environment.

2.6 IEEE 802.21 Framework

In this algorithm, it is assumed that the mobile node acquires network parameters by using IEEE 802.21 framework [16-18]. IEEE 802.21, also known as Media Independent Handover is designed to support seamless handover among both homogeneous and heterogeneous wireless networks. It provides 3 types of services namely

a. Media Independent Event Service (MIES)
   It enables the lower layers to generate triggers to the upper layers when dynamic changes in the link characteristics are observed.
b. Media Independent Command Service (MICS)
   The upper layers can pass handover commands to the physical and data link layers along with control information. This control information is useful for selecting an appropriate network.
c. Media Independent Information Service (MIIS)
   The MIHF entity in the mobile can obtain the information about the available networks in its vicinity by using MIIS service.

Table 1. Traffic classes and their QOS requirements

Traffic	BER	Delay	Jitter	Bandwidth
Conversational	Need not be Low	Should be Low	Should be Low	Need not be High
Streaming	Need not be Low	Should be Low or medium	Should be Low	Should be High
Interactive	Should be Low	Should be Low or medium	Need not be Low	Need not be High
Background	Should be Low	Need not be Low	Need not be Low	Should be medium at least

3. PROPOSED ALGORITHM

Input:

Offered values of network parameters

B_i −Bandwidth or Data Rate
D_i−Packet Delay
V_i −Supported velocity
J_i −Jitter
E_i −Bit Error Rate

1. QOS parameters requested by the user's application that include
   B_{req} - Requested Bandwidth
   D_{req} -Tolerable Packet Delay
   V_{req} -Velocity of the mobile
   J_{req} -Tolerable Jitter
   E_{req} -Tolerable Bit Error Rate

2. Threshold Values of the QOS parameters which represent highest level of satisfaction that include B_{Th}, D_{Th}, V_{Th}, J_{Th} and E_{Th}.

3. Prices offered per bit of each Network, C_i

Output:

1. Pair-wise-matrix which has the elements (U_i, UP_j), *Where*
   QNS_i −Normalized value of Quality of Network Access Service of the i[th] network.
   UP_j − Pay of j[th] user
2. Network Selection based on (i*, j*) if equilibrium exists, Otherwise find $(\bar{\imath}, \bar{\jmath})$.

Steps:

1. Formulate network selection game as
   G=< X, Y, S_x, S_y, QNS_x , UP_y >
   Where X and Y are players and
   X- set of available networks {1,2,…,m}
   Y- set of users {1,2,…,n}
   S_x −Set of strategies for network set
   S_y −Set of strategies for user set.
   QNS_x − Normalized value of Quality of network Access Service
   UP_y − User Pay
2. Find Network Utility of the i[th] network (NU_i)

$$NU_i = \frac{U_i}{\sum_{k=1}^{m} U_k} \quad (1)$$

Where $U_i = f_{B,i} * f_{D,i} * f_{V,i} * f_{P,i} * f_{E,i}$
and

$$f_{B,i} = \begin{cases} 1.5, & if\ B_i \geq B_{Th} \\ 1 + \frac{0.5(B_i - B_{req})}{(B_{Th} - B_{req})}, & if\ B_{req} \leq B_i < B_{Th} \end{cases} \quad (2)$$

$$f_{D,i} = \begin{cases} 1.5, & if\ D_i \leq D_{Th} \\ 1 + \frac{0.5(D_{req} - D_i)}{(D_{req} - D_{Th})}, & if\ D_{Th} < D_i \leq D_{req} \end{cases} \quad (3)$$

$$f_{V,i} = \begin{cases} 1.5, & if\ V_i \geq V_{Th} \\ 1 + \frac{0.5(V_i - V_{req})}{(V_{Th} - V_{req})}, & if\ V_{req} \leq V_i < V_{Th} \end{cases} \quad (4)$$

$$f_{J,i} = \begin{cases} 1.5, & if\ J_i \leq J_{Th} \\ 1 + \frac{0.5(J_{req} - J_i)}{(J_{req} - J_{Th})}, & if J_{Th} < J_i \leq J_{req} \end{cases} \quad (5)$$

$$f_{E,i} = \begin{cases} 1.5, & if\ E_i \leq E_{Th} \\ 1 + \frac{0.5(E_{req} - E_i)}{(E_{req} - E_{Th})}, & if\ E_{Th} < E_i \leq E_{req} \end{cases} \quad (6)$$

3. Find User's Pay

$$UP_j = C_i * Q_j \quad (7)$$

C_i − Cost per bit of the i[th] network and
Q_j − QOS requirement of the j[th] user.

Where

$$Q_j = \begin{cases} 1, if\ B_i > B_{req}, D_i < D_{req}, V_i > V_{req}, J_i < J_{req}, E_i < E_{req} \\ \infty, Otherwise \end{cases} \quad (8)$$

4. Find
   If the Equilibrium (i*, j*) exists, such that
   QNS_{i*} −max{QNS_i / i=1,2,…m } and
   UP_{j*} −min{UP_j /j=1,2,…n}

   else
   Find the suboptimal solution (i^, j^) such that
   arg max$\{\frac{QNS_i}{UP_j}, |i = 1,2, \dots, m; j = 1,2, \dots, n\}$

4. EXPERIMENTAL RESULTS

We consider a particular service area of heterogeneous wireless network environment, where a mobile node is under the coverage of three different wireless networks Wi-Fi, Wi-Max and CDMA. We implemented the algorithm using Java and the QOS parameters of the three networks are as shown in Table 2.

The quality of service parameters for conversational, Streaming, Interactive and Background Traffic classes are set according to their requirements as shown in Table 3.

Table 2. Offered QOS parameters of Wi-Fi, Wi-Max and CDMA

Network	Band width (Mbps)	Packet Delay (msec)	Supported Velocity (Kmph)	Jitter (msec)	Bit Error Rate (per 10^8)
Wi-Fi	1	160	10	200	200
Wi-Max	0.5	120	20	120	150
CDMA	0.2	80	60	30	100

Table 3. QOS parameters of various traffic classes

Parameter	Band width (Mbps)	Packet Delay (msec)	Mobile Velocity (Kmph)	Jitter (msec)	Bit Error Rate (per 10^8)
Conversational	0.002	200	5	60	400
Streaming	0.05	300	5	60	400
Interactive	0.004	300	5	200	250
Background	0.02	400	5	300	250

The threshold values of the parameters above which the QOS is highly satisfied are set as shown in Table 4. Prices per bit offered by Wi-Fi, Wi-Max and CDMA are as shown in Table 5.

The algorithm is simulated for the four different traffic classes and the resulting pair-wise matrix is shown in Table 6. Each element of this matrix represents the normalized value of quality of service of the network and cost per bit paid by the user.

It is observed that Bayesian Nash equilibrium occurs for conversational and streaming classes at CDMA network. For Interactive traffic and Background traffic classes, Bayesian Nash equilibrium occurs at Wi-Max and Wi-Fi networks respectively.

Therefore for the specified parameter settings, CDMA, Wi-Max Wi-Fi and CDMA are selected as the target networks for Conversational, Interactive, Background and Streaming traffic classes.

Table 4. Threshold values of QOS parameters

B_{Th}	D_{Th}	V_{Th}	J_{Th}	E_{Th}
0.1	100	60	50	150

Table 5. Cost per bit offered by each network

Wi-Fi	Wi-Max	CDMA
0.2	0.4	0.6

Table 6. Pair- wise matrix

Traffic Class	Wi-Fi	Wi-Max	CDMA
Conversational	0.1283, ∞	0.3641, ∞	0.5076,0.6
Streaming	0.1368, ∞	0.3661, ∞	0.4972,0.6
Interactive	0.357, ∞	0.4022,0.4	0.2408,0.6
Background	0.3835,0.2	0.3942,0.4	0.2223,0.6

The impact of varying bandwidth and mobile velocity on the Network Utilization to Cost Ratio (NUCR) for the four traffic classes are shown in Figure 4. to Figure 11.

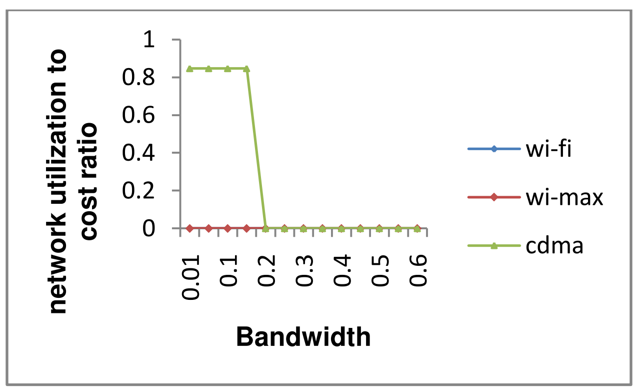

Figure 4. Network Utilization to cost ratio of conversational traffic for varying bandwidth with mobile velocity =5Kmph

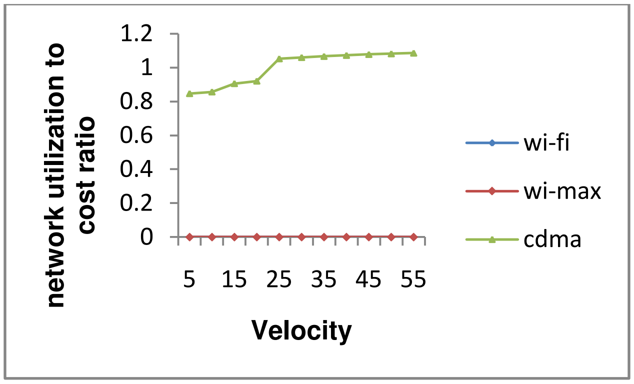

Figure 5. Network Utilization to cost ratio of conversational traffic for varying velocity with requested bandwidth=0.002

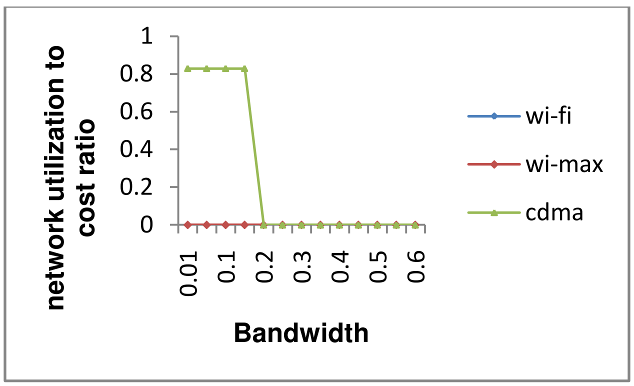

Figure 6. Network Utilization to cost ratio of streaming traffic for varying bandwidth with mobile velocity=5Kmph

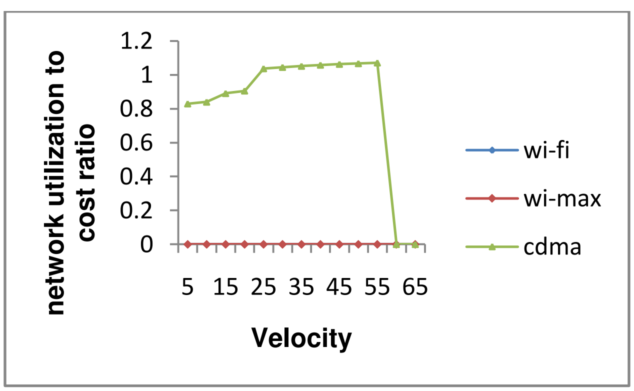

Figure 7. Network Utilization to cost ratio of streaming traffic for varying velocity with requested bandwidth=0.05

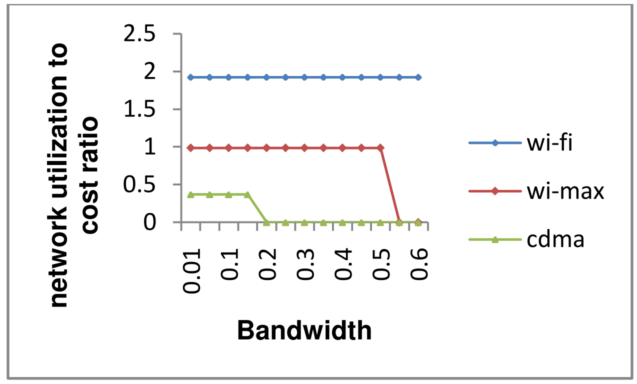

Figure 8. Network Utilization to cost ratio of Interactive traffic for varying bandwidth with mobile velocity=5Kmph

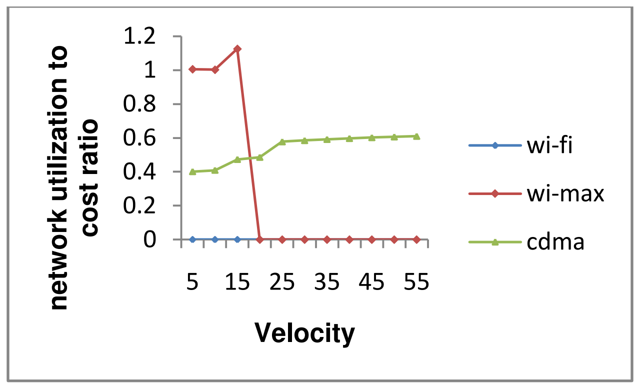

Figure 9. Network Utilization to cost ratio of Interactive traffic for varying velocity with requested bandwidth=0.04

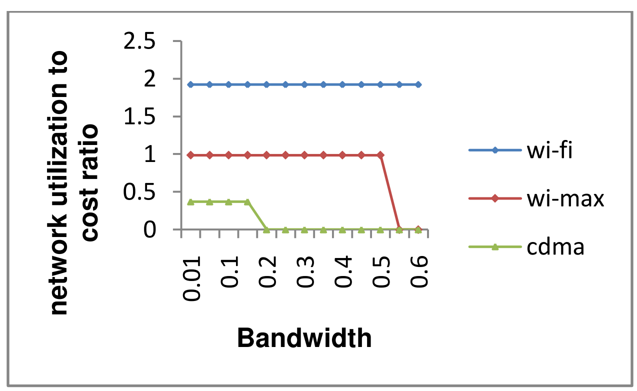

Figure 10. Network Utilization to cost ratio of background traffic for varying bandwidth with velocity=5Kmph

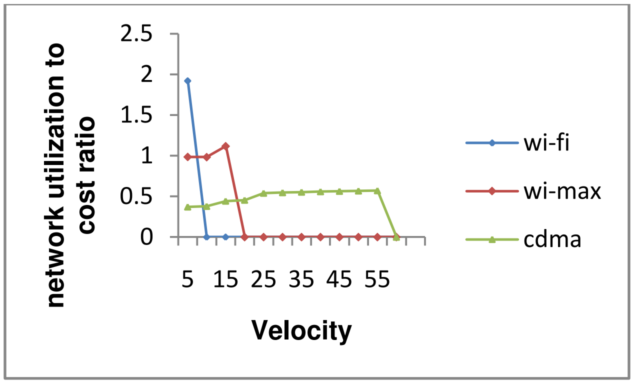

Figure 11. Network Utilization to cost ratio of background traffic for varying velocity with requested bandwidth=0.02

5. CONCLUSIONS

In this paper, we formulate game-theoretic approach for network selection in heterogeneous wireless access networks and a novel network selection algorithm based on Bayesian evolutionary game is proposed. The algorithm enables mobile users to choose optimal network based on Bayesian Nash-equilibrium point that maximizes the offered quality of service with minimum cost. The algorithm finds sub-optimal solution for the games that do not achieve Nash equilibrium. Numerical results are presented to demonstrate that mobile users can avail highest quality of service with minimum cost. As the algorithm is considering MIH framework for network parameter acquisition, it greatly reduces the handoff delay in scanning the available networks.

6. REFERENCES

[1] Djamal-Eddine Meddour et al.," Completing The Convergence Puzzle: A Survey And A Roadmap", IEEE Wireless Communications, June 2009.

[2] Dusit Niyato and Ekram Hossain,"A Non-Cooperative Game-Theoritic Framework for Radio Resource Management in 4G Heterogeneous Wireless Access Networks", IEEE Transactions on Mobile Computing, Vol. 7, No. 3, March 2008.

[3] Jonathan Rodriguez et al.," A Middleware Architecture Supporting Seamless Secure Multimedia Services Across an Inter Technology Radio Access Network", IEEE Wireless Communications, pp24-31, October 2009.

[4] E. Dahlman et al., "3G Evolution: HSPA and LTE for Mobile Broadband", Elsevier, 2007.

[5] I. Akyldiz, J.Xie and S. Mohant, "A survey of Mobility Management in Next-Generation All-IP-Based Cellular Systems", IEEE Wireless Communications, August 2004.

[6] Sang-Jo Yoo · David Cypher · Nada Golmie," Timely Effective Handover Mechanism in Heterogeneous Wireless Networks", Wireless Personal Communications, 2010

[7] Q.B. Chen et al., " Game Theoretic Approach for Pricing Strategy and Network Selection in Heterogeneous Wireless Networks", Vol. 5, Issue 5 , pp. 676-682, IET Communications, 2011.

[8] Nay, P., Zhou, C.: 'Vertical handoff decision algorithm for integrated UMTS and LEO satellite networks'. Proc. WRI Int. Conf. CMC, Yunnan, China, January 2009, pp. 180–184

[9] Zhang, Y.Q., Zhuang, W.H., Saleh, A.: 'Vertical handoff between 802.11 and 802.16 wireless access networks'. Proc. IEEE GLOBECOM'08, New Orleans, LA, USA, December 2008, pp. 1–6.

[10] Liu, M., Li, C.Z., Guo, X.B., Dutkiewicz, E.: 'Performance analysis and optimization of handoff algorithms in heterogeneous wireless networks', IEEE Trans. Mobile Comput., 2008, 7, (7), pp. 846–857.

[11] Yang, K., Gondal, I., Qiu, B.: 'Multi-dimensional adaptive SINR based vertical handoff for heterogeneous wireless networks', IEEE Communication Letters., 2008, 12, (6), pp. 438–440

[12] Nasser, N., Hasswa, A., & Hassanein, H., "Handoffs in fourth generation heterogeneous networks. *IEEE Communications Magazine, 44*(10), pp.96–103, 2006.

[13] Enrique Stevens-Navarro, Ulises Pineda-Rico and Jesus Ecosta-Elias, "Vertical Handover in Beyond Third Generation Wireless Networks", International Journal of Future Generation Communication and Networking", pp. 51-58.

[14] Peng Xu, Xuming Fang, Xing wei Liu, "A Non-cooperative Pairwise Matrices Game Model for Heterogeneous Network Selection", Proceedings of International Conference on Communications and Mobile Computing (ICCMC), 2010.

[15] Eric Rasmusen, "Games and Information, Fourth Edition: An Introduction to Game Theory", 24 March 2005.

[16] Kenichi Taniuchi et.al. "IEEE 802.21: Media Independent Handover: Features, Applicability and Realization", *IEEE Communications Magazine,* January 2009.

[17] A. De La Oliva, A. Banchs, I. Soto, T. Melia and A. Vidal, "An Overview of IEEE 802.21: Media Independent Handover services", *IEEE Wireless Communications*, vol. 15, pp.96-103, 2008.

[18] Lampropoulos G., Salkintzis A., Passas N., "Media Independent Handover for Seamless Service Provision in Heterogeneous Networks", *IEEE Communication Magazine*, Vol. 46, No. 1, Jan. 2008.