Scientific Research and Essays Vol. 7(27), pp. 2350-2362, 19 July, 2012
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.1129
ISSN 1992-2248 ©2012 Academic Journals

Full Length Research Paper

Seamless handoff across heterogeneous networks: A multi-objective optimization approach

E. Arun[1]*, C. P. Maheswaran[2] and R. S. Moni[3]

[1,2]Department of Computer Science and Engineering, Noorul Islam University, Tamil Nadu, India.
[3]Department of Electronics and Communication Engineering, Noorul Islam University, Tamil Nadu, India.

Accepted 7 June, 2012

The growing consumer's demand leads a great access to communication services anywhere and at anytime. It has started to accelerate the development of technologies that would allow for the integration of various Wireless Access Technologies. With regard to vertical handoff performance, there is a critical need for developing algorithms for connection management and optimal resource allocation for seamless mobility. This study proposes a novel Vertical Handoff Decision Making Algorithm (VHDMA) based on analytic multi-objective optimization. The multi-objective cost function involves transmit power of Mobile Terminals (MTs), outage and throughput over Access Points (APs)/Base Stations (BSs). The proposed algorithm lowers the barriers and jointly optimizes all the required objectives. The results showed that the Multi-Objective (MO) optimization has the advantages of optimizing over different and conflicting objectives jointly.

Key words: Seamless mobility, heterogeneous networks, multi-objective (MO) optimization, vertical handover.

INTRODUCTION

The aim of the future wireless networks is to provide universal ubiquitous coverage across different radio technologies, in which a multi-model Mobile Terminal (MT) will be able to connect to several wireless access networks (Niyato and Hossain, 2005) such as Wireless Local Area Networks (WLAN), Universal Mobile Tele-communication Systems (UMTS), Code Division Multiple Access (CDMA) and Wireless Metropolitan Area Network (WMAN) simultaneously. A large variety of applications utilizing these networks will demand features such as real time, high availability across different access technologies in a seamless way. The method of using different networks with the same terminal for inter-network mobile communications is often referred to as inter-technology, heterogeneous, or non-homogeneous networking. The inter-working of such heterogeneous, packet-based Radio Access Networks (RANs), are also technical challenges, among others with the most important being, Mobility Management. One of the most referred to as the next generation or beyond 3G (B3G) mobile data networks. Hui and Yeung (2003) pose many attractive features of Mobility Management is that it would enable service continuity and Internet Protocol (IP) connectivity provision for wireless multi-mode mobile terminals like cellular phones, Personal Digital Assistants (PDAs), and Notebook computers (Yabusaki et al., 2005).

Although, the intersystem mobility has attracted immense research and development effort from research communities and standardization bodies, the support of mobility raises new issues related not only to handoff management such as low disruption time, but also to the Quality of Service (QoS). Each technology provides its own methods to support minimum service disruption when switching from one Access Point (AP) to another, but inter-technology handovers are not yet well supported. The increased dependence on human intelligence in such an environment is behind the motivation for introducing autonomic networking. With regard

*Corresponding author. E-mail: arunsedly@yahoo.com.

to vertical hand off performance, there is a need for developing algorithms for connection management and optimal resource allocation for seamless mobility. The issues related to the integration of diverse wireless access technologies such as Cellular, WLAN and WMAN and also providing QoS to mobile users are the major challenges. In fact, the major concern of Radio Resource Management (RRM) is overseeing the distribution of radio resources to different users, or different classes of users, in order to maximize the number of services delivered (and thus network operator's revenues) while ensuring user satisfaction. The requirements of connection switching are handled by the RRM functions of the network. Handoffs and the handoff algorithm are important element of RRM, together with admission control, load control, power control, and mobility management. The RRM functions are presented in Figure 2. Handoffs are a complex process and it involves several aspects such as methodology, protocol, algorithm, and metrics. The focus of this paper is the handoff decision algorithm, their related metrics and their effects on the performance of a wireless network.

MATERIALS AND METHODS

Study area

Recently, different optimization approaches have been proposed to enhance the performance of handoff in next generation heterogeneous networks. Although, some work have been done to integrate WLANs/cellular networks, most of the previous work concentrated on architectures and mechanisms to support roaming and vertical handoff. Utilization of the overall radio resource optimally, subject to quality of service constraints has not been studied in detail in this coupled environment. Seamless handoff in mobility support has become a great issue in Heterogeneous Wireless Network (HWN). The issues can be categorized into architectural and decision algorithm. The architectural issues are related to handoff control, methodology and the protocols involved in re-routing the connection. Issues related to the decision algorithms are the handoff decision algorithm and the metrics exploited by the algorithm to decide on a handoff.

Rok et al. (2010) proposed a novel Session Initiated Protocol (SIP) based procedure for congestion aware handover in heterogeneous networks. With newly defined SIP messages, the handover decision is based not only on the signal strength, but also on the target network status. According to Di Cola et al. (2000) the handoff process can be divided into three stages: initiation, decision and execution. Handover initiation is responsible for triggering the handover according to specific conditions such as, radio bearer deterioration or network congestion. In the handover decision stage, Access Point (AP)/ Base station (BS) decisions are taken in appropriate time. At this stage, several parameters such as the signal strength of neighboring APs and available radio resources are considered before a final decision is reached. The required signaling exchange for communication re-establishment and data re-routing through the new path is made in the last and final stage.

Akyildiz et al. (1999) and Ghassan et al. (2011) suggested three main alternatives for handover decision depending on the way the network and the MT contribute to it: network-controlled handover, mobile-assisted handover and mobile controlled handover. Qing et al. (2006) and Quoc-Thinh et al. (2008) suggested criteria for triggers and optimization and they are summarized as follows:

1. Received Signal Strength (RSS) or SNR (for example, user uses the network with the best available signal).
2. QoS parameters in the network (for example, some applications require a high level of QoS support).
3. Bandwidth of the target network (for example, user uses the network with the broadest bandwidth).
4. Power consumption (for example, some network interfaces require higher power, which can lead to greater battery consumption).
5. Economic price (for example, user prefers the use of cheapest network).
6. Preferred network operator (for example, user prefers to use particular operator).
7. Combinations of the above triggers.

There are a few trends in decision making in a heterogeneous environment. The popular techniques are: (i) economics-like functions that compute the benefit and cost in order to derive the best solution such as, profit function, degradation utility or customer surplus; (ii) mathematical methods such as game theory, stochastic programming, and objective function; and (iii) Multi-Attribute Decision Making (MADM) such as Fussy Logic Control (FLC), Analytic Hierarchy Process (AHP), or TOPSIS. A new issue raised in a heterogeneous environment is the Joint Resource Management, in which bandwidth allocation to a user can be provided by different networks simultaneously. This idea is important, because the bandwidth that has been allocated to a user can be provided by several networks and thus the problem of load-balancing can be alleviated. However, the actual procedure of setting up this type of an integrated connection in a real environment is still a problem.

A review of vertical handoff decision algorithms were mentioned by Sun (2007) and Feng et al. (2008). A robust algorithm should ensure good QoS irrespective of the physical environment based on Dongyeon et al. (2006). QoS depends on the type of application, that is, conversational, streaming and interactive applications which possess different bandwidth, delay, jitter etc. A right vertical handoff decision algorithm by determining the “best” network at the “best” time among available networks based on dynamic factors such as “Received signal strength (RSS)” of network and “velocity” of mobile station, simultaneously with static factors like usage expenses, link capacity and power consumptions are presented by Goyal and Saxena (2009). The importance of mobile station velocity and movement pattern was considered by Lee et al. (2007). Competitive and cooperative relationships among the major ITS communication technologies, WiMax, WLAN and UMTS, were considered by Ma et al. (2004). An AHP based network selection algorithm for UMTS and WLAN was presented by Dhar et al. (2010) and Song and Jamilipour (2005). Sun et al. (2008) formulates the vertical handover decision problem as a Constrained Markov Decision Process (CMDP). A two step, that is, a pre-handoff decision algorithm followed by a handoff decision algorithm was presented by Hwang et al. (2007). An AHP based comparison of different vertical handoff algorithms was presented by Wang and Abu-Rgheff, (2009). An AHP based Multi-Criteria Decision Making (MCDM) tool was designed for vertical handover among WLAN, UMTS and GPRS and was presented by Isakson and Fiedler (2007). A 3-step network selection strategy for new cell arrival in a road condition was demonstrated by Nitiwong et al. (2009). Handoff triggering and network selection algorithm in CDMA-WLAN integrated networks was proposed and QoS performance against velocity of mobile terminal was discussed by Kim et al. (2008). A load balancing vertical handover algorithm, which will maximize the collective battery lifetime of Mobile Nodes, was proposed by Sukyoung et al. (2009). Therefore, the traditional optimization algorithms might not be able to meet the requirements of next generation wireless networks unless they take into account interference in their decision procedures. To the best of authors, none of the optimization handoff algorithms considers ambient

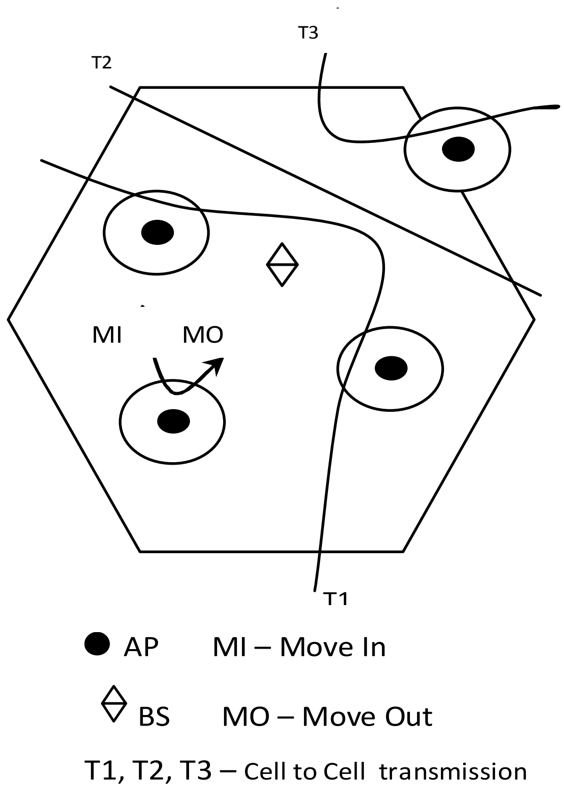

Figure 1. Integrated heterogeneous network.

interference power level as a direct input to their decision mechanism.

Vertical handoff decision making algorithm

This study describes how to formulate the vertical handoff decision making algorithm to optimize and select an appropriate attachment point and implement the VHDMC. The proposed algorithm's unique feature is, that when the Mobile Terminal (MT) uses more transmit power than required, then its own QoS will be degraded.

It is considered a heterogeneous wireless access environment consisting of Base Stations (BSs), Access Points (APs) and Mobile Terminals (MTs) as shown in Figure 1. An MT can exist at any given time in the coverage area of a BS alone but due to mobility, it can move into the region covered by more than one access networks, like cellular BS and 802.11 AP. Multiple 802.11 WLAN coverage areas are usually contained within the cellular coverage area.

A Wi-MAX coverage area can overlap with WLAN and/or cellular coverage areas. In dense urban areas, even the coverage areas of multiple CDMA BSs can overlap. Thus, at any given time, the choice of an appropriate attachment point (BS or AP) for each MT needs to be made. The service continuity and QoS offered to the MT can be significantly enhanced with the capabilities of vertical handoff. A single operator or multiple operators may operate the BSs and APs within a coverage area. Thus, multiple access technologies as well as multiple operators are typically involved in vertical handoff decisions.

The objectives of the proposed framework are, to maximize network utility through efficient resource allocation, achieve prioritization among different types of connections, such as, new connections and vertical and horizontal hand off connections, and ensure that the performance of ongoing connections does not deteriorate due to accepting too many connections in a service area. Figure 2 illustrates how the Vertical Handoff Decision (VHD) is to be implemented. The proposed VHDM algorithm is implemented in multiple Vertical Handoff Decision Making Controllers (VHDMC). These VHDMCs are located in the access networks as shown in Figure 2 and can provide the VHD function for a region covering one or more APs and/or BSs. The decision inputs for the VHDMCs will be obtained via the Media Independent Handover Function (MIHF).

The VHDMC is conceptually a network controlled mobility management entity utilizing the 802.21MIHF. Some experimental implementations of this nature are in progress. Future networks also expected to embrace heterogeneity comprising of different network control technologies in such a manner that it appears homogeneous to potential users of network services. In order to address some of these challenges, the IEEE 802.21 Media Independent Handover (MIH) service work group has introduced a standard for handovers without the constraints of particular wireless technologies.

The MIHF facilitates message exchanges between the various access networks or attachment points to share information about the current link layer conditions such as, traffic load, network capacities, and commands to control the behavior of the lower layers.

Optimization problem formation

The problem of joint call admission control in the integrated optimal algorithm should optimize the average network revenue and

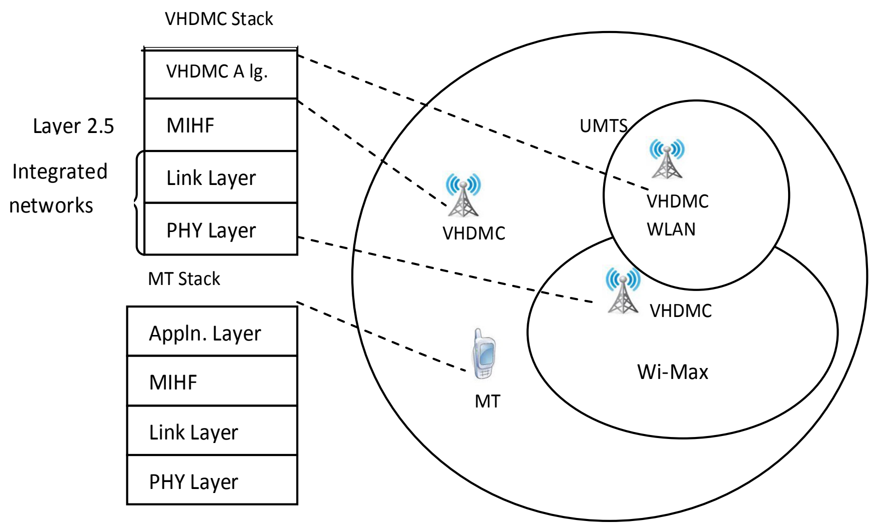

Figure 2. VHDMC implementation based on MIHF.

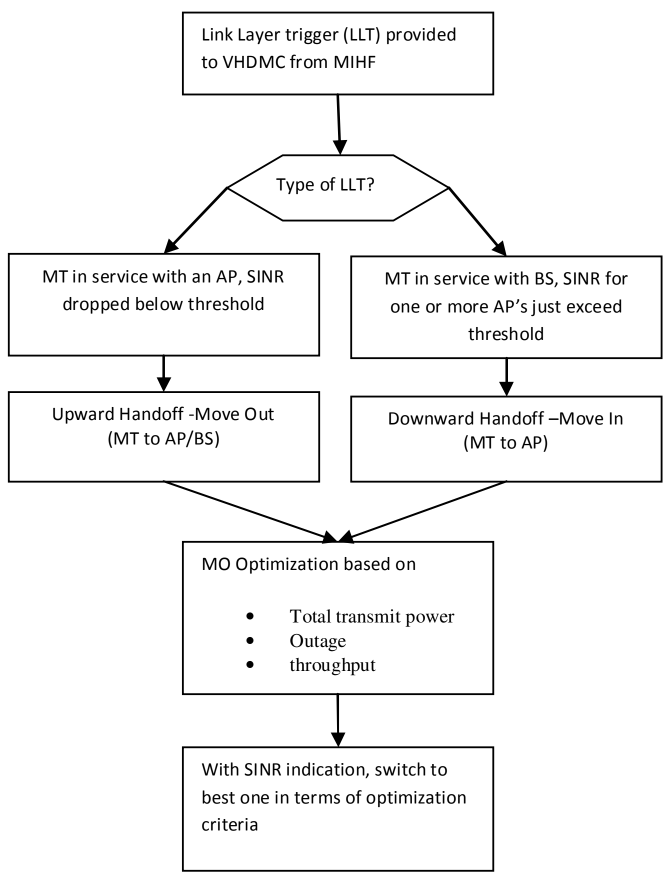

Figure 3. High level procedure used by the VHDMC.

guarantee QoS constraints in both APs and BSs coverage AP/BS, a new or vertical handoff call arrival should be allocated. An optimal algorithm should optimize the average network revenue and guarantee QoS constraints in both APs and BSs coverage networks. Formulating vertical handoff decision making algorithm with MO optimization is also presented in detail. The high level procedure used by the VHDMC is shown in Figure 3. The considered optimization objectives are to:

a. Minimize the total transmit power.
b. Minimize the outage.
c. Maximize the transmission rate (throughput).

It is known that objective (a) generally conflicts with objective (c) because reducing the transmit power of a MT without constraints leads to decreasing the data rate and/or the Signal to Noise Ratio (SINR). Objective (c) is incompatible with objective (b) since MTs with high throughput occupy most of the available radio resources which leads to a high system outage.

Based on the literature survey carried out, the Radio Resource Scheduling (RRS) problem was formulated as a single objective optimization problem (minimizing cost function or maximizing certain utility function) and the rest, treated as constraints. Two formulations are very widely used in different literature. The first was based on finding the optimal power and rate vectors that maximize the total throughput (c) and using the target SINR and transmit power as constraints according to Song and Mandayam (2001) and Oh et al. (2003). The second formation was based on minimizing the total transmit power (a) and using the target SINR and data rates as constraints, which has been developed by Sampath et al. (2003).

This work proposes the third formulation by optimizing jointly the objectives (a to c) of the radio resource using multi-objective optimization approach. This formulation leads to a more general solution than conventional methods. The basic concept of the MO optimization technique was introduced by Elmussratti et al. (2008), Norozi et al. (2011). The vertical handoff problem can be formulated using an MO optimization problem as follows:

Find the rate vector $R=[R_1,\dots R_u]$ and the power vector $P=[P_1,\dots P_u]$ that minimize the following vector objectives:

$$\min_{P,R}\{f1, f2, -f3\} \quad P \in S_p \text{ and } R \in S_R \tag{1}$$

Where each cost function f_1 to f_3 corresponds to (a) to (c) respectively. S_p is a non empty region of feasible power solution, that is, the possible transmission values, S_R is a non empty region of feasible rate solutions that is, the possible transmission data rate values, and U is the number of active mobile terminals. Note that the minus sign is used to maximize the objective. The selection of proper cost function depends on many factors such as the type of scenario, simplicity to solve, etc. Different objective functions can be used for estimating Equation 1; however, the choice is quite open and offers an exhaustive area for research.

Formation of vertical handoff decision making algorithm (VHDMA)

In this section, details of the Multi-Objective Optimization techniques used in the proposed vertical handoff decision making algorithm and how it is implemented in the Vertical Handoff Decision Making Controller (VHDMC) are explained. The WLAN hotspots are typically configured as small cells within the cellular coverage area of GPRS/UMTS or CDMA which is relatively larger compared with WLAN hotspots as shown in Figure 1.

Let $A = \{a_1,\dots,a_N\}$ and $C = \{c_1,\dots,c_M\}$ be the sets of APs in a cellular coverage area and BSs covering the cellular coverage area respectively. Usually $M=1$ except in the case of highly dense urban area. The VHDMC maintains the sets A and C covering the cellular coverage area as a list of candidate attachment points. It adds all available WLAN access points (APs) in to the set A, and collects the information about transmission rate (that is, throughput) on every AP in the set A and every BS in the set C.

In the cellular coverage area, $U = \{u_1,\dots u_k\}$ is defined as the set of all MTs. Each MT has either requested a handoff or not, that is, currently serviced by an AP ($\in A$) or BS ($\in C$) with no need for mobility at the time of the optimization decision. Hence, the set U can be divided in to the following two sub-sets at certain time t: $U_t = \{u_{n1}, u_{n2,\dots} u_{nm(t)}\}$ where $m(t)$ is the number of MTs requesting handoff at time t, and $n1,\dots nm(t)$ are the corresponding indexes of those MTs. Let $V_t = U\text{-}U_t$ which represents the set of MTs that do not required a handoff (good connection) to an AP or a BS.

It is assumed that each AP a_i and BS c_i have maximum data rate R_i and R^c_i, *respectively*. In an interference limited wireless network, the average SINR of user u_i at time t can be represented as

$$\delta_i^{(t)} = \frac{R_s}{R_i^{(t)}}\gamma_i \tag{2}$$

Where

$R_i^{(t)}$ is the achieved data rate,
R_s is the requested data rate during time slot t,
γ_i is the required SINR value of user i during time slot t which is given by:

$$\gamma_i = \frac{P_{t_i}(x)h_{ii}}{R_i(\eta_i + T_f\sigma^2 \sum_{j=1\, j\neq i}^{u} P_{t_j}(x)h_{ji})} \tag{3}$$

$i=1,\dots.u$,

Where

$P_{t_i}(x)$ denotes the average transmission power of MT,
η_i is the background noise,
σ^2 is a parameter depending on the shape of the pulse (Cuomo et al., 2002) and
T_f is the pulse repetition time.

The channel gain from link i's transmitter to link j's receiver can be represented as:

$$h_{ij} = k\, d_{ij}^{-\theta}$$

Where k and θ are constants, and d_{ij} is the distance from link i's transmitter to link j's receiver, and u is the number of mobile nodes.

To formulate the optimal VHDM algorithm, Let $X=\{x_{ij}\}(N+M)\times K$ be an association matrix for a cellular coverage area such that:

$$\sum_{1\le i\le N+M} x_{ij} = 1 \quad \text{for } (1 \le j \le k)$$

$x_{ij} \in \{0,1\}$ and $x_{ij} = 0$ if target SINR of MT, u_i $\delta_i^{(t)} <$

$$\begin{cases} \theta_a \; for \; 1 \le i \le N \\ \theta_c \; for \; N+1 \le i \le N+M \end{cases}$$

Where θ_a is the SINR threshold to connect to AP and θ_c is the SINR threshold to connect to BS. Where x_{ij} $(1 \le N, 1 \le j \le k)$ and $x_{(N+i)}$ $(1 \le i \le M, 1 \le j \le k)$ are binary indicators, each of which has a value of 1 if and only if, the former MT u_j hands off to AP a_i while the latter, MT u_j hands off to BS c_i.

Let i denote $i - N$; $(N+1 \le i \le N+M)$. Let $w(i)$, $(1 \le i \le N+M)$ denote the pre-defined costs of weights for the data rate of AP a_i $(1 \le i \le N)$ and BS c_i $(N+1 \le i \le N+M)$. Each $a_i \in A$ has a limited transmission range and serves only MTs that reside in its range. V_t is divided in to subsets $V_t^{(a)}$ and $V_t^{(c)}$ depending on whether $u_k \in V$ has a connection in a WLAN area or a cellular network area respectively. $m(t)$ is the number of MTs requesting handoff at time t that are candidates for vertical handoff that can belong to a WLAN or a cellular network, subsequent to the handoff decision.

Each AP $(a_i \in A)$ or BSs $(c_i \in C)$ can maintain the effective data rate e_{ij} and $e_{ij}^{(c)}$ for MT u_k when it belongs to $V_t^{(a)}$ or $V_t^{(c)}$ respectively. However, for each MT $u_k \in U$, the AP to which the MT will hand off, cannot evaluate its effective data rate due to the absence of active signaling between the AP and the MT before the handoff. Thus, the requested data rate R_s is defined for each MT $u_k \in U$. Otherwise, it is assumed that each MT is equipped with client software that periodically collects the bit rate information for every AP/BS in its neighborhood by using beacon messages. It is possible to evaluate the effective bit rate e_{ij} and $e_{ij}^{(c)}$ from each AP $a_i \in A$ and BS $c_i \in C$ respectively to each user $u_k \in U$. The collected information about the effective bit rate is available to the VHDMC via the IEEE802.21 MIHF.

The maximum allowed Bit Error Rate (BER) can be determined by specifying the target SINR value. The allowed BER depends on the applications example; f, generally a higher BER can be allowed for the voice applications rather than for data applications. From Equation 2, it is clear that by fixing the SINR for user i (MT), will increase the achieved data rate $R_i^{(t)}$ as follows:

$$R_i^{(t)} = \frac{R_s}{\delta_i^T}\gamma_i \tag{4}$$

Where δ_i^T is the target SNIR for user i. Achieving only objective (*c*), that is, maximizing total throughput, implies that all users must send at the highest possible transmit power which leads to a very high outage. To reduce the outage probability, it is defined that the minimum required SINR value of user i at the minimum allowed data rate as,

$$\gamma_i^{\min} = \frac{R_i^{\min}}{R_s}\delta_i^T \tag{5}$$

The maximum required SINR value of user i at the minimum allowed data rate as:

$$\gamma_i^{\max} = \frac{R_i^{\max}}{R_s}\delta_i^T \tag{6}$$

For an MT to be in service with the AP/BS, the minimum required SINR should be achieved. This corresponds to the minimum allowed data rate. This study explains the MO method to handle the network selection problems. It is assumed that a competitive environment in which each MT try to get the highest possible resources at the same time considering the other terminals.

Multi objective optimization scheduler

It is assumed without loss of generality that all users with target SINR vector $\delta_i^T = [\delta_1^T, \ldots \delta_u^T]$ and data vector $R^{min} = [R_1^{min}, R_2^{min}, \ldots R_u^{min}]$ have the same maximum possible data rate R^{max}. The objective here is, to find the optimum power vector $P = [P_1, P_2, \ldots P_u]$ and the optimum data vector $R = [R_1, R_2, \ldots R_u]$ that minimizes the following cost function:

$$G = \sum_{i=1}^{J}\sum_{t=1}^{N}\alpha^{N-t}e_i^2(t) \quad \forall \; P \in Sp \text{ and } R \in SR \tag{7}$$

Where,

N is the optimization time window.

α is a real-valued constant adaptation factor.

$e_i^{(t)}$ is the error function which is defined according to the weighted metrics method with p=1 by Elmussratti et al. (2008).

$$e_i^{(t)} = \lambda_{i,1}\left|P_i^{(t)} - P^{\min}\right| + \lambda_{i,2}\left|\gamma_i^{(t)} - \gamma^{\min}\right| + \lambda_{i,3}\left|\gamma_i^{(t)} - \gamma^{\max}\right| \tag{8}$$

Where $0 \le \lambda_{i,k} \le 1$ $(\forall_k = 1, 2, 3)$, are real valued tradeoff factors, and $\sum_{k=1}^{3}\lambda_{i,k} = 1$.

Using Equation 7 a general solution can be obtained to minimize all users in a given time window N.

Error function Equation 8 is a mathematical interpretation of the objectives (a to b). Its first term is set to minimize the transmit power $P_i(t)$ and should be as close as possible to P^{min}. It is interpreted that there is a penalty for using extra power. This term represents the objective (a).

Objective (b) is achieved with the second term of the error function. In this term, the transmit power is selected so that the total SINR value is as close as possible to the minimum required SINR. Achieving the minimum required resource for each and every MT, minimizes the total system outage.

The third term represents objective (c), where the MT tries to be as close as possible to the maximum possible SINR, so that they can transmit at the highest data rate. The tradeoff between these contradicting objectives is achieved by the factors $\lambda_{i,1}, \lambda_{i,2}$, and $\lambda_{i,3}$. By solving Equations 7 and 8 in a one dimensional case for N=1, the VHDMC algorithm is obtained.

$$P_i(t+1) = \frac{\lambda_{i,1}P^{\min} + \lambda_{i,2}\gamma_i^{\min} + \lambda_{i,3}\gamma_i^{\max}}{\lambda_{i,1}P_i(t) + (\lambda_{i,2} + \lambda_{i,3})\gamma_i}P_i(t) \tag{9}$$

$$R_i(t+1) = \frac{R_s}{\delta_i^T}\gamma_i \quad (10)$$

$P^{\min} \leq P_i(t) \leq P^{\max}$ and $R_i^{\min} \leq R_i(t) \leq R^{\max}$

Correlated channel is assumed since there is a delay of at least one time slot between the Carrier Interference Ratio (CIR) measurement and the power and rate update. In other words, it is assumed that the time slot duration is less than the coherence time of the channel. The VHDMC algorithm given by Equations 9 and 10 has some interesting characteristics. By changing the values of the tradeoff factors $\lambda_{i,1}$,$\lambda_{i,2}$, and $\lambda_{i,3}$ different optimum solutions in different senses are obtained. Let's consider first the extreme cases. For example, to achieve only the objective (*a*) (set $\lambda_{i,1}$=1, $\lambda_{i,2}$=0, and $\lambda_{i,3}$=0), it is clear that VHDMC algorithm results in fixed level of transmit power, and user *i* will send always at the minimum power.

For $\lambda_{i,1}$ = 0, $\lambda_{i,2}$= 1, and $\lambda_{i,3}$ = 0, each MT tries to achieve its minimum required data rate, so that the outage is minimized. At $\lambda_{i,1}$= 0, $\lambda_{i,2}$= 0, and $\lambda_{i,3}$ = 1, each MT will attempt to transmit at the maximum allowed data rate and the interference will be rather high. If proper dropping algorithm is used, then most of the users will be dropped out and only the very few users with high data rate services will be supported, that is, the outage will be high. From previous extreme conditions, one can make a tradeoff between these objectives to obtain the best possible performance according to the required specifications. The selection of the tradeoff values should be based on the communication link condition as well as the network and the user requirements. A wide range of different solutions can be obtained by changing values of the tradeoff factors. The selection of the right solution is the job of the decision maker. The tradeoff factors can be time-varying, that is, updated with time to achieve certain objectives.

RESULTS AND DISCUSSION

The goal of this study was to validate and evaluate the effectiveness of the proposed handoff optimization scheme by investigating different user movement scenarios. It was shown that the proposed scheme can achieve significant performance improvement over other AP/BS integration schemes. In the first scheme, admission control was done independently in individual networks and there was no vertical handoff between the AP and BS network coverage area. Due to the overlay of the two networks, it was assumed that half of the new call arrivals in the AP area will request admissions to the BS area and the rest will request admissions to the AP coverage area network. When a mobile user with a WLAN call moves from the AP area, it will be dropped because there is no vertical handoff mechanism between these two networks. In the second scheme, vertical handoff between the two networks can be supported. It was assumed that new call arrivals in the AP area will request admission to the WLAN. When a mobile user with WLAN call moves from the AP area, it will handoff to the BS coverage network if the SINR drops below the threshold value. This corresponds to the minimum allowed data rate. On the other hand, when an MT with a BS area network, calls moves in the WLAN area, it will handoff to the AP coverage network if SINR exceeds the threshold. The decision inputs for the VHDMC can be obtained through the Media Independent Handover Function (MIHF). The MIHF facilitates standard based message exchanges between various access networks to share information about the current link layer conditions.

Therefore, the MT can only connect to an IEEE 802.11 Access Point (AP), namely AP1 or AP2. In the second case, the MT has a second available interface of type IEEE 802.16, which allows it to connect to the 802.16 Base Station (BS). When the SINR decreases below a pre-configured threshold, there is a need for a link change. In all cases, the MT is first connected to AP1 and moves away at constant speed. In addition, the lower layer periodically generates Link_Going_Down events with parameter reports. The simulation scenario is shown in Figure 4. The list of parameter values used for the numerical results is shown in Table 1.

Performance improvement

The average network reward for the proposed scheme was compared to that from two other AP/BS integration schemes with no multi-objective optimization but with vertical handoff and with no vertical handoff. Figure 5 shows the average reward earned in various schemes. The reward earned in the proposed scheme was always more than what was received in the other two schemes, and the reward was the least in the scheme that has no vertical handoff. The percentage of reward gain is shown in Figure 6.

It is observed that the higher the new call arrival rate, the less the percentage of reward gains. This is because the system becomes saturated when the arrival rate is high, and the proposed scheme has no room to select calls to admit based on the reward rate. Nevertheless, the reward earned in the proposed scheme was about 32% higher than that in the scheme without vertical handoff support even when the system's load was high.

Effect of the percentage of call arrivals in the AP area

The percentage of call arrivals in the AP area may not be of constant value. Figure 7 shows the reward gain with the different percentages of traffic in the AP area (from 0 to 100%). λ_n = 0.01 and other parameters remain the same in this example. It was observed that the proposed scheme was effective with different traffic load in the AP area. It can be seen that the higher the percentage of traffic in the AP area, the higher will be the reward in the proposed scheme. This is because the proposed scheme can optimally admit some traffic in the AP area to the BS

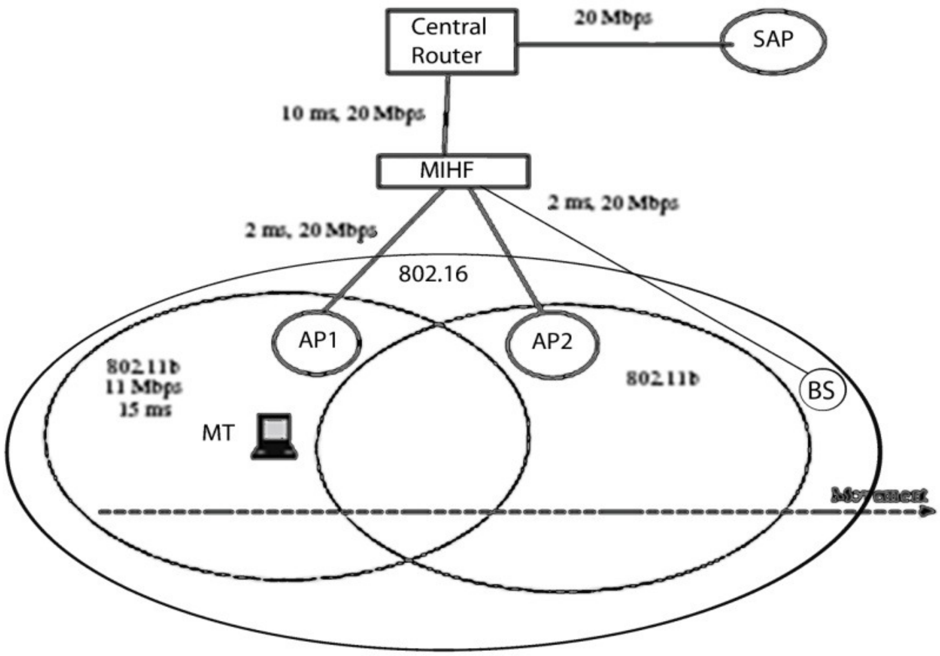

Figure 4. Simulation topology.

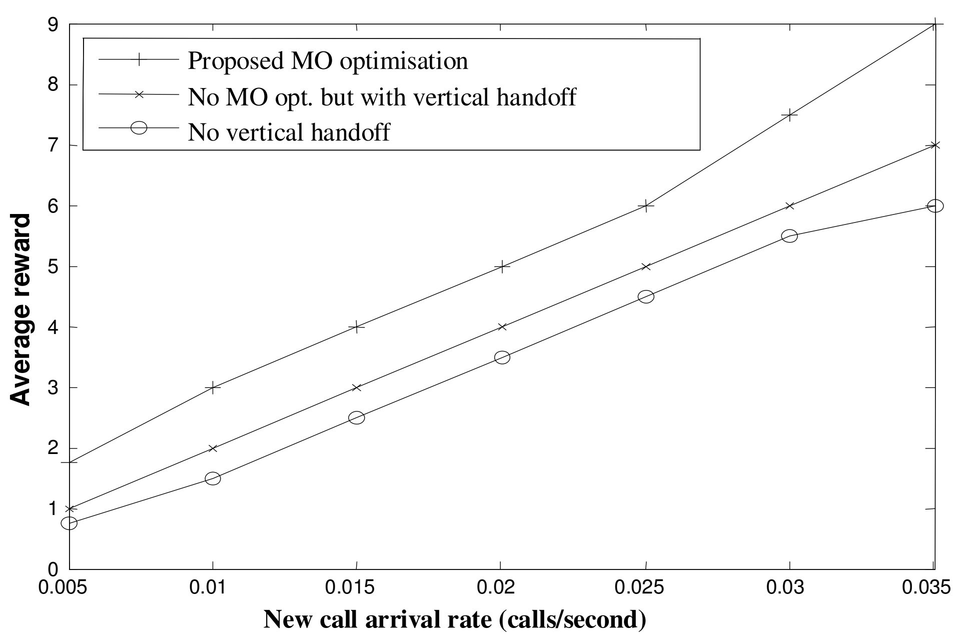

Figure 5. Average reward in different schemes.

coverage network area when the traffic load in the AP area is high.

Effects of the reward rate ratio between the BS and AP coverage network

The reward rate ratio between BS coverage networks and AP coverage networks differs among network operators. If the ratio is less than 1, operators earn less reward when a call is admitted to the BS coverage network instead of an AP. Otherwise, operators earn equal reward (ratio is 1) or more reward (ratio greater than 1). Figures 8 and 9 show the reward gain with λ_n =0.001 and λ_n = 0.003, respectively. It is interesting to

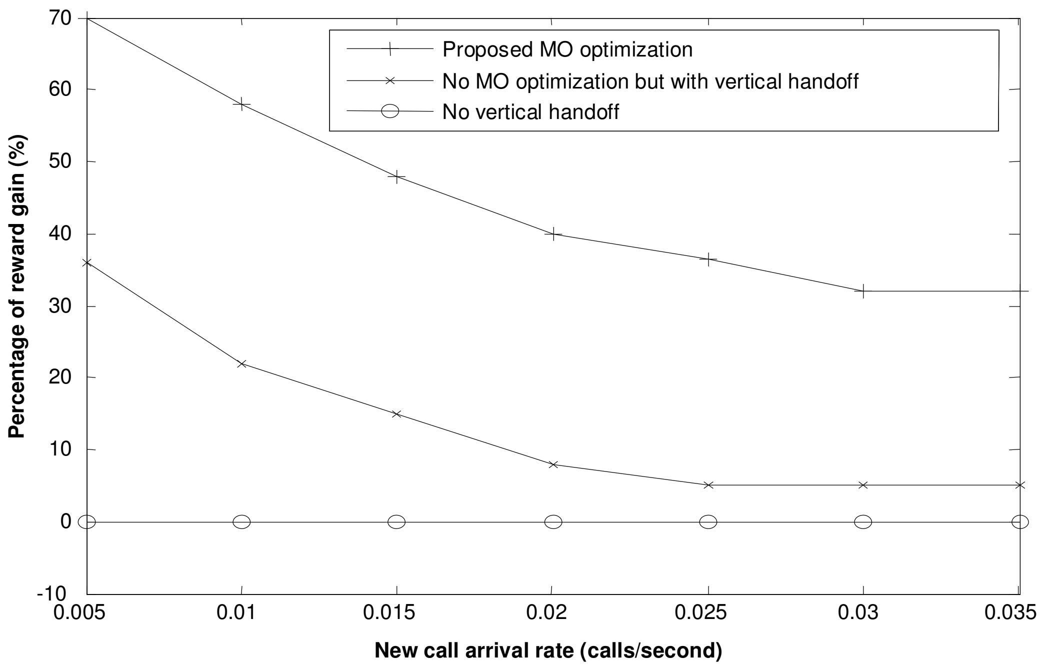

Figure 6. Percentage of reward gain versus new call arrival rate.

Table 1. Parameters used for performance analysis.

Parameter	Value used
Minimum SINR	6 db
Wireless link failure probability	0.5
Movement detection delay	100 ms
WLAN cell coverage	Disk with radius=50 m
WiMAX cell coverage	Disk with radius=500 m
L2 hand off delay	50 ms
Data rate	11 mbps
Packet loss	0-35%
Modulation	64 QAM ¾
Default propagation model	Two ray ground
Average packet arrival per session	20
802.11 wireless link bandwidth	1 mbps
802.16 wireless link bandwidth	15 mbps
Velocity	1 m/s
Default no. of stream	1
Wired link bandwidth	10 mbps

observe that the reward in the scheme with vertical handoff but no multi-objective optimization will be less than that in the scheme without vertical handoff support when the ratio is larger than center values (4 in Figure 8 and 3.1 in Figure 9). However, the proposed scheme can always have a reward gain with a large range of ratio values.

The performance of the VHDM algorithm at extreme tradeoff factor values $(\lambda_{i,1}, \lambda_{i,2}, \lambda_{i,3}) \in$ {(1,0,0), (0,1,0), (0,0,1)} is depicted. It considers five users uniformly distributed in one cell under a snapshot assumption. White Gaussian noise was added with zero mean and -63dBm average power at the input of the receiver.

The maximum transmitter power is 1 W. The minimum allowed SINR is 6dB. An MT is considered in outage, if at least one of the QoS requirements, such as the minimum

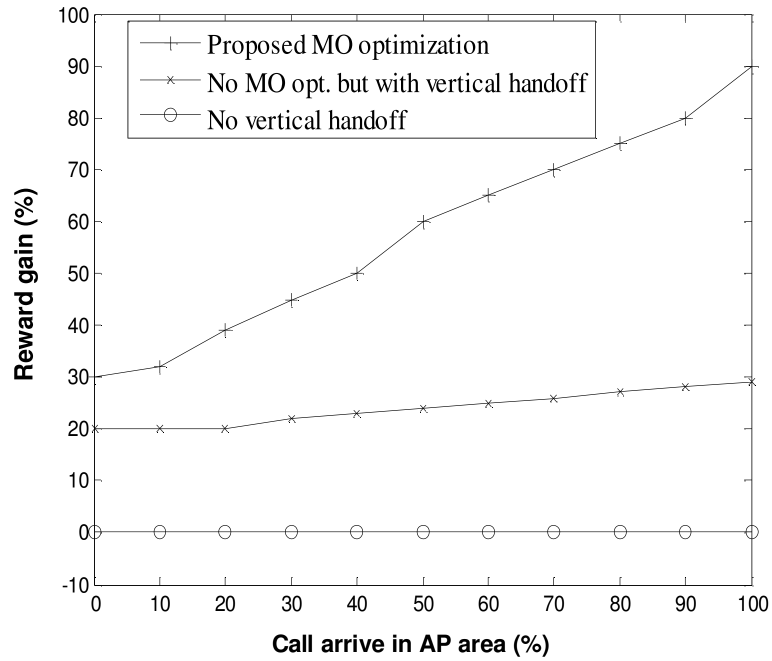

Figure 7. Percentage of reward gain versus % of call arrivals in AP area.

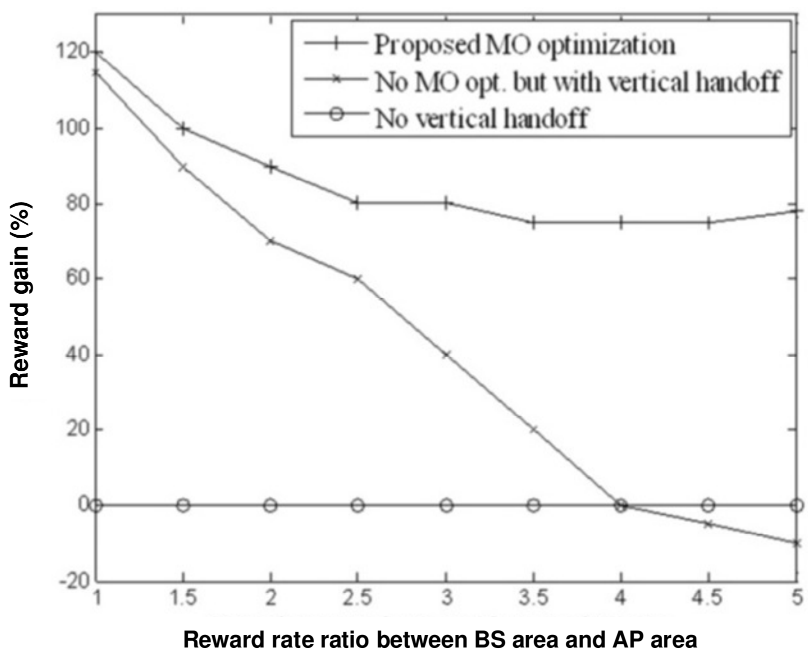

Figure 8. Reward rate ratio between BS area and AP area (λ_H=0.001).

data rate or the minimum allowed SINR is not achieved. Figures 10, 11 and 12 showed the average power, sum of the data rates and the outage probability, respectively. The time slot in the x-axis is defined as the time where the transmit power as well as the data rate is updated. Figure 10 shows the average power for the three extreme cases. In the first case ($\lambda_{i,1}$, $\lambda_{i,2}$, $\lambda_{i,3}$) = (1,0,0) $\forall$ i =1,…5, the objective is to minimize the total power. Thus, the power is very small compared to other two situations;

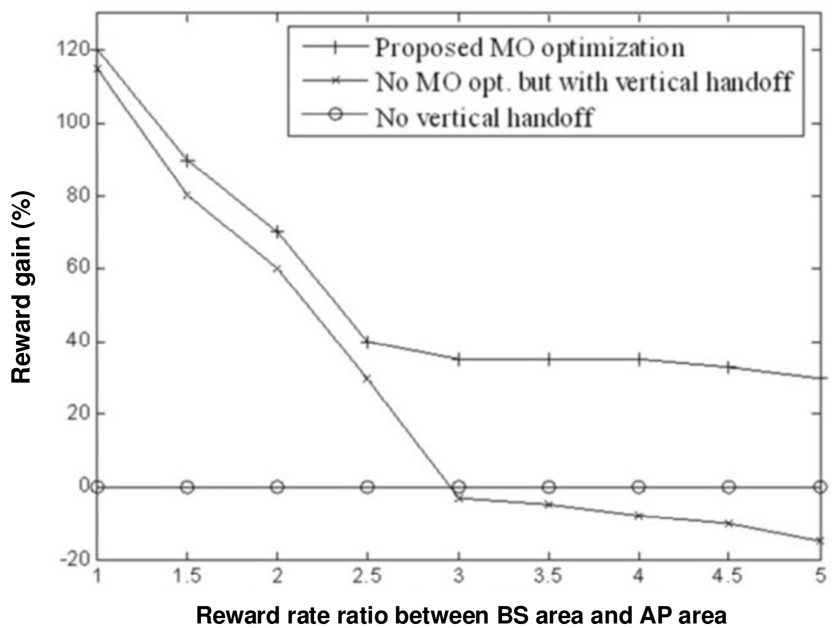

Figure 9. Reward ra te ratio between BS area and AP area (λ_{n}=0.003).

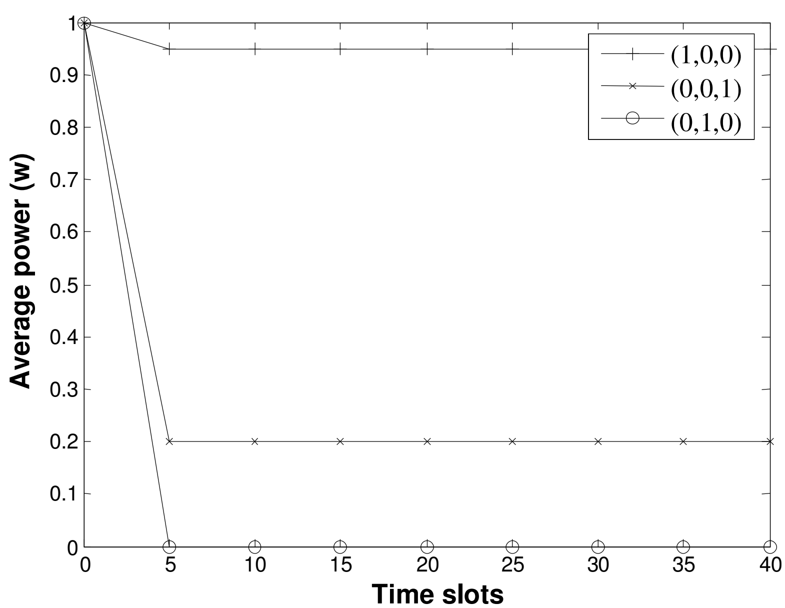

Figure 10. Average power comparison of VHDMA at extreme trade-off factors.

but the sum of data rate is zero and the outage is very high that is, 100% as shown in Figure 10. In the second case, ($\lambda_{i,1}$, $\lambda_{i,2}$, $\lambda_{i,3}$) = (0,1,0) $\forall$ i = 1,…5, the objective is to maximize the outage. The average power and the sum of data rates are fair, and the outage converges to zero as shown in Figure 11.

In the third case ($\lambda_{i,1}$, $\lambda_{i,2}$, $\lambda_{i,3}$) = (0,0,1) $\forall$ i = 1,…5, the objective is to maximize the total data rates. The average power and the total data rate are the highest. The outage is considerably high as shown in Figure 12. It was observed that the performance of the VHDMA algorithm has a wide range of behavior depending on the

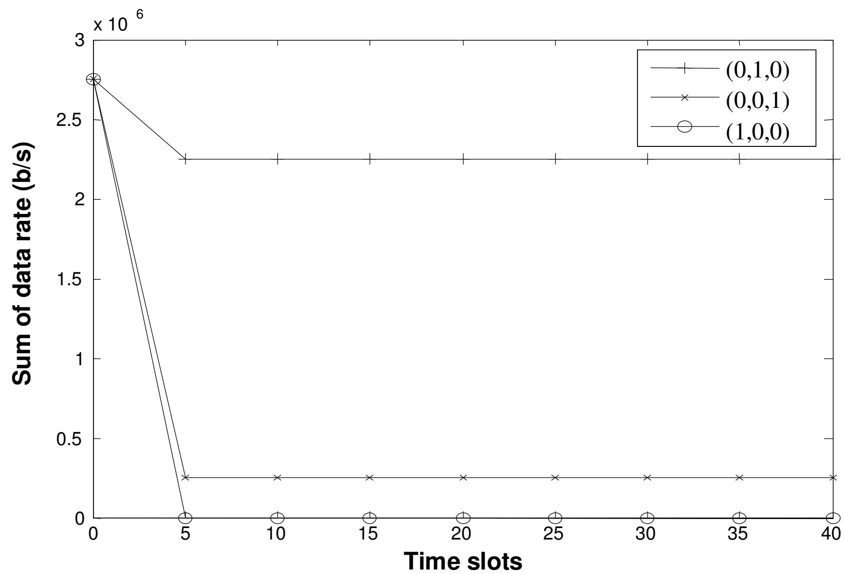

Figure 11. Data rate comparison of VHDMA at extreme trade-off factors.

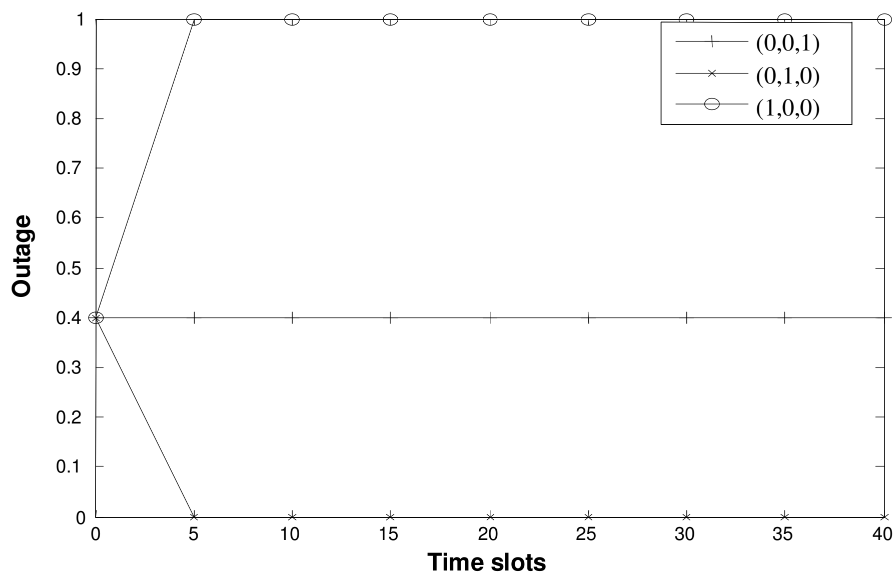

Figure 12. Outage comparison of VHDMA at extreme trade-off factors.

selected values of the tradeoff factors.

Conclusion

In this paper, the metrics best suited for the vertical handoff decision are proposed. In addition, an algorithm for vertical handoff decision that optimizes a multi-objective cost function involving transmit power of MTs, outage and throughput over APs/BSs was developed. Simulation results showed that improved performance was obtained by adapting multi-objective optimization between different resources which significantly enhances the handover performance in heterogeneous wireless networks. It has been shown that the higher the percentage and traffic in the WLAN area, the higher is the reward in the proposed scheme. It is worth noting here that the computational complexity of the proposed VHDMC optimization algorithm is very manageable. The topic is very rich and the present work opens the doors for many future research issues. Some of them are: optimization of the Radio Resource Scheduling (RRS) using different analytical MO optimization methods, cross-layer optimization using analytical MO optimization. Also, the optimization framework can be extended to consider cost optimization with QoS improvement using scalable video.

ACKNOWLEDGEMENT

This research was supported by AICTE, India under RPS (F.No: 8023/BOR/RID/RPS-66/2010).

REFERENCES

Akyildiz IF, McNair J, Ho JSM, Uzunalioglu H, Wang W (1999). Mobility Management in Next Generation Wireless Systems. IEEE Proceed. J. 87:1347-1385.

Dhar S, Ray A, Bera R, Sur SN, Ghosh D (2010). A Complete Simulation Of Intra Vehicle Link Through Best Possible Wireless Network. Int. J. Comput. Elect. Eng. 2:673-668.

Di Cola F, Chan PML, Sheriff RE,Hu YF (2000). Handover and QoS Support in Multi-Segment Broadband Networks, Proceedings of the 4th European Workshop on Mobile and Personal Satellite Communications, London, UK.

Dongyeon L, Han Y, Hwang J (2006). QoS Based Vertical Handoff Decision Algorithm in Heterogeneous Systems, IEEE 17th International Sympos. Personal, Indoor Mobile Radio Commun., pp. 1-5.

Elmussratti M, El-sallabi H, Kovio H (2008). Applications of Multi-objective optimization techniques in radio resource scheduling of cellular systems, IEEE Trans. Wireless Commun. 7:343-353.

Feng Z, Le V, Zhang P (2008).A Seamless Vertical HandoverScheme for End-to-End Reconfigurability Systems.In Proc. IEEE Vehicul. Technol. Conf., pp. 11-14.

Ghassan A, Abed M, Ismail KJ (2011). Characterization and observation of (transmission control protocol) TCP-Vegas performance with different parameters over (Long term evolution) LTE networks, Sci. Res. Essays 6:2003-2010.

Goyal P, Saxena SK (2009). A Dynamic Decision Model for Vertical Handoff across Heterogeneous Wireless Networks. Int. J. Comp. Sys. Sci. Eng. 1:70-75.

Hui S, Yeung K (2003).Challenges in the migration to 4G mobile systems. IEEE Commun. Mag. 41:54-59.

Hwang JY, Oh J, Han Y (2007). A Two Step Vertical Handoff Algorithm in Heterogeneous Traffic and Systems. IEEE 66th Vehicular Technology Conference pp. 1543-1547.

Isakson L,Fiedler M (2007).Seamless connectivity in WLAN and cellular networks with multi-criteria decision making. In Proc. IEEE NGI, pp. 21-23.

Kim J, Serpedin E, Shin DR, Qaraqe K (2008). Handoff Triggering and Network selection algorithms for Load-Balancing Handoff in CDMA-WLAN Integrated Networks. Journal on Wireless Communications and Networking. pp. 99-107.

Lee W, Kim E, Kim J, Lee I, Lee C (2007). Movement Aware Vertical Handoff of WLAN and Mobile WiMax for seamless Ubiquitous Access. IEEE Transactions on Consumer Electronics. pp. 12-21.

Ma L, Yu F, Leung, VCM, Randhawa T (2004). A new method to support UMTS/WLAN vertical handover using SCTP. IEEE Wireless Commun. 11:44-51.

Nitiwong K, Komolkiti P, Aswakul C (2009). Performance Evaluation Model of Heterogeneous Wireless Network Selection Strategy with Macroscopic User Mobility Model, In proc: NTC, pp. 5-6.

Niyato D, Hossain E (2005). Call Admission Control for QoS Provisioning in 4G Wireless Networks: Issues and Approaches, IEEE Networks 19:5-11.

Norozi A, Ariffin MKA, Ismail N, Mustapha F (2011). An optimization technique using hybrid GA-SA algorithm for multi-objective scheduling problem, Sci. Res. Essays 6:1720-1731.

Oh S, Zhang D, Wasserman K (2003).Optimal resource allocation in multiservice CDMA networks, IEEE Trans. Wireless Commun. 2:811-821.

Qing W, Karoly F, Christian P, Paulo M, Bernhard P (2006). Context-aware handover using active network technology, Comput. Networks, 50:2855-2872.

Quoc-Thinh N, Nazim A, Yacine G (2008). A user-centric and context-aware solution to interface management and access network selection in heterogeneous wireless environments, Comput. Networks 52:3358-3372.

Rok L, Ales S, Gorazd K (2010). A novel SIP based procedure for congestion aware handover in heterogeneous networks, Comput. Commun. 33:2176-2184.

Sampath A, Kumar P, Holtzman J (2003). Power control and resource management for a multimedia CDMA wireless system. In Proc. IEEE PIMRC, pp. 21-25.

Song Q, Jamilipour A (2005). Network Selection in an Integrated Wireless LAN and UMTS Environment Using Mathematical Modeling and Computing Techniques, IEEE Wireless Communications. pp. 22-27.

Song L, Mandayam N (2001). Hierarchical SIR and rate control on the forward link for CDMA data users under delay and error constraints," IEEE J. Select. Areas Commun. 19:1871-1882.

SuKyoung L, Sriram K, Kyungsoo K, Kim YH, Golmie N (2009).Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless N/ws, IEEE Transactions On Vehicular Technology. pp. 57-63.

Sun J (2007). A review of Vertical Handoff Algorithms for Cross Domain Mobility, In Proc. ICWCNMC, pp. 21-25.

Sun C, Navaro ES, Wong VWS (2008). A Constrained MDP Based Vertical Handoff Decision Algorithm for 4G Wireless Networks, IEEE International Conference Communication pp. 2169-2174.

Wang Q, Abu-Rgheff MA (2009). Towards a complete solution to Mobility Management for Next-Generation Wireless System, IEEE Personal Commun. 10:480-497.

Yabusaki M, Okagawa T,Imai K (2005). Mobility management in All-IP mobile network: end-to-end intelligence or network intelligence, IEEE Commun. Mag. 43:16-24.