Improving Handover Performance in Wireless Mobile Networks

Saied M. Abd El-atty[1] and Konstantinos Lizos[2]
[1]Department of Electronics and Electrical Communications,
Faculty of Electronic Engineering, Menoufia University,
Menouf, 32952, Egypt
[2]Head of IT Department,
Embassy of Greece
Nobels gate 45, 0244, Oslo, Norway

Abstract

In this paper, we propose an enhanced packet scheduling scheme to favour UEs that experienced handover (HO) in wireless mobile networks. The main idea of the proposed scheme is not only prioritized the HO connections at the CAC level but also prioritized the HO connections at the scheduler level. At the CAC level, a guard code scheme favours HO calls over new calls. At the scheduler level, a Packet Scheduler based-HandOver Class (PS-HOC) scheme makes use of the elapsed time of HO connections to classify the HO requests into prioritized HO and non-prioritized HO calls. Further, PS-HOC sorts the connections based on their delay sensitivity and their channel quality. The performance of the proposed scheme is compared with delay driven scheduler (DDS) scheme in terms of average packet delay, average queue size and average packet dropping rate. The simulation results show the effectiveness of our proposed scheme.

Keywords: *Handover, CAC, Packet Scheduling, QoS, WCDMA.*

1. Introduction

In wireless mobile networks (such as GSM, UMTS, HSPA, WiMax and LTE) the interruption of service due to the leak of supporting handover (HO) process is annoying and frustrating to the users [1]. In such networks both soft and hard handovers are possible and the employed handover procedure depends on the type of channel used by each service. For example, in UMTS systems dedicated channels used by conversational services are able to utilize soft handover while for the shared channels, used by streaming interactive and background services, only hard handover is possible. Consequently, both cases lead to poor network performance and should be avoided. As a result, it is important to favor HO requests over new call requests during the bandwidth allocation process.

In wireless mobile networks, a connection admission control (CAC) algorithm in the core of the radio resource management (RRM) is devoted to accept as many new connections as possible, while maintaining the QoS for all the ongoing connections [2]. Therefore, CAC plays an important role at the maximization of the channel utilization. Many works have been proposed CAC schemes for different types of wireless mobile networks. Recently, the authors in [3] have introduced a CAC scheme based speed sensitive in the hierarchical heterogeneous wireless networks in order to measure the performance of traffic loss for multiservices. Further, the authors in [1], discussed and compared handover algorithms intended for WLAN, GSM, and UMTS according to signal strength and distance coverage area. Moreover, optimization of handover process in 3GPP LTE is proposed in [4]. On the other hand, the authors in [5] proposed a CAC based link adaptation in OFDM systems in order to take into account the effect of user mobility and AMC procedure. Most of the above works are focused only on the CAC scheme at the call level. However, at the packet-level QoS metrics (e.g., average packet delay and packet dropping rate) need to be maintained at the desired level. Therefore, the packet scheduler at RRM is necessary in order to decide the desired type of services and the prioritization of users in transmission [6]. We have proposed a RRM scheme [7] which favors the HO call at the CAC level and then we employed a delay driven scheduler (DDS) at the packet level which was aware to the delay requirements to all incoming calls (new and HO).

In this work, we make use of the time delays of HO connections in handover area to establish a new link with base station in order to estimate the elapsed time of connections which are experienced handover. Therefore, we propose an enhanced packet scheduling scheme namely: Packet Scheduler based HandOver Class (PS-HOC) which aims to prioritize HO calls over the new calls at the packet level. Therefore, the main idea of the proposed scheme is not only prioritized the HO connections at the CAC level but also prioritized the HO connections at the scheduler level. As a focus here is on 3G mobile network based-WCDMA system is considered as a case study, the PS-HOC is fairly general to other mobile network scenarios.

The rest of the paper is organized as follows. The WCDMA system model is presented in Section II. In Section III and Section IV, we introduce a snapshot of the prediction criterion and CAC scheme. The heuristic function of the elapsed time is described in Section V. The proposed PS-HOC scheme is introduced in Section VI. Finally, the simulation results are presented in Section VII and Section VIII concludes our work.

2. System Model based OVSF Channelization Codes

The forward and reverse links for third generation (3G) and beyond wireless networks will be a bottleneck since the new services and applications introduced in these networks typically download and upload, respectively. Furthermore, in wideband code division multiple access (WCDMA) systems the multi rate transmission is supported through the use of Orthogonal Variable Spreading Factor (OVSF) codes. In this paper our discussion will be focused on the forward (downlink) link as shown in Fig.1. In WCDMA system, the code is allocated to the connections by employing OVSF code tree [8], [9]. The OVSF codes can be represented by a binary tree with K layers, where each code tree corresponds to a particular spreading factor (SF). The code rate of channelization code at different level results in variable rate. Hence, the root channelization code has maximum bandwidth; meanwhile, the leaf channelization codes have minimum bandwidth as illustrated in Fig.1. The bandwidth of a specified level k{1, 2, 3,..., K} is double the bandwidth of the adjacent lower level k+1. If the bandwidth of the bottom level is 1R, the bandwidth of next high level will be 2R, and so on. Finally, the bandwidth of the root code will be 2^{K-1}R, which is the same as the total capacity of the OVSF code tree.

3. Prediction Criterion based SIR Measurement

The use of a common set of orthogonal codes at the downlink of a WCDMA system should theoretically eliminate intra-cell interference. However, due to multipath propagation, the downlink signals are not perfectly orthogonal. Consequently, the Signal-to-Interference-Ratio (SIR) perceived by user i, from a set of M_u active users, can be expressed as [10]:

$$SIR_i = \frac{SF_i \times P_{r,i}}{\alpha \cdot I_{intra,i} + I_{inter,i} + P_N} \qquad (1)$$

where α is the orthogonality factor, SF_i is the spreading factor of the assigned OVSF code, $P_{r,i}$, is the received power of user i, $I_{intra,i}$ is the interference generated by the received signals of the other n-1 users which are connected to the same cell, $I_{inter,i}$ is the interference received from other neighboring cells and P_N is the thermal noise power. During connection setup, each connection i negotiates with the network management module its SIR threshold ($SIR_{T,i}$) and delay threshold $D_{th,i}$. The UE is able to measure and report the respective SIR to the Node B at each frame. Based on a finite state Markov chain (FSMC) model the next state of the wireless channel can be predicted

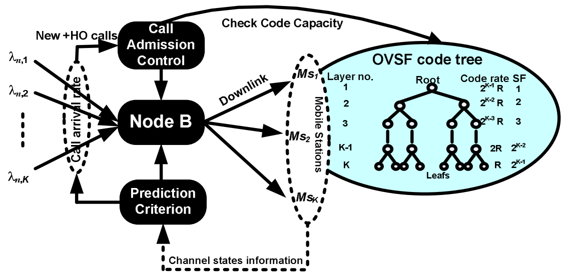

Fig.1Node B based-OVSF code tree.

according to the measured value of SIR, γ_i at the previous frame. Therefore, for each connection i, the predicted bit error probability, $P_{e,i}$ is [7]:

$$P_{e,i} = \frac{1}{\pi_n} \int_{\Gamma_n}^{\Gamma_{n+1}} p(\gamma_i) p_m(\gamma_i) d\gamma \qquad (2)$$

At Eq.(2) π_n is the steady state probability that corresponds to the state n of the Markov chain, $[\Gamma_n,\Gamma_{n+1})$ is the SIR range and $p(\gamma_i)$ is the *pdf* function of the measured SIR. For WCDMA systems with QPSK modulation, under additive Gaussian noise, $p_m(\gamma_i)$ is given by Eq. (3):

$$p_m(\gamma_i) = \frac{erfc(\sqrt{\gamma_i})}{2} \qquad (3)$$

4. CAC based Reservation Scheme

In WCDMA systems, the QoS of different UEs is maintained based on the available capacity at the Node B. Ongoing connections probably consumed the most volume of that capacity and HO connections are suffered from the deterioration of service. The CAC mechanism helps to manage the available capacity and to mitigate traffic overloading at the 3G systems. We have proposed a call admission control (CAC) mechanism based on the reservation code threshold C_T, which allows HO calls to use the total capacity of the OVSF code tree, but restricts the new calls to use only a part of the tree capacity. Thus, the incoming HO calls gain higher priorities compared to the ongoing calls and the handover procedure becomes more transparent to the user. Assuming that the arrival rate $\lambda_{h,k}$ for each class k of handover calls requesting an average rate of r_k is known by measurements collected at the Node B, the handover reservation threshold C_T can be expressed as follows [7]:

$$C_T = \Phi \times \sum_{k=1}^{K} \left(\lambda_{h,k} \times r_k \times \frac{1}{\mu_{S,k}} \right), \quad \Phi \in (0,1] \qquad (4)$$

where Φ and $1/\mu_{s,k}$ are the reservation factor and the average service time respectively of class k call. In sequel requesting an average rate of r_k is expressed in terms of {1R, 2R, 4R, 8R, 16R} thus $C_T \in$ R.

5. Handover Class based Elapsed Time

Call drops annoy UEs with direct consequence in user service. This is particularly critical for 3G systems, where high data rate users will be major candidates for being dropped [8]. On the other hand, unnecessary handover entails QoS deterioration and leads to OVSF capacity waste. The UEs that have experienced HO sailed in the HO area before they are able to get in touch with new Node B. The measured period of HO connections in that area till they are able to establish a connection with new Node B is defined as the elapsed time. Notably, the amount of time over which a UE connection is maintained within a particular Node B is defined as the dwell time. According to the mean dwell time $1/\mu_{d,k}$ and threshold value of the elapsed time T_E or $(1/\mu_E)$, the Node B employs a heuristic indication function ($I_{h,k}$) to categorize the HO connections into prioritized and non-prioritized HO calls as follows:

$$I_{h,k} = \min\left\{1, \frac{1/\mu_E}{1/\mu_{d,k}}\right\} \quad (5)$$

Therefore at scheduler level, based on the indication function, $I_{h,k}$, the call arrival rate of HO calls can be expressed as follows:

$$\lambda^{sch}_{h,k} = I_{h,k} \cdot \lambda_{h,k} \quad (6)$$

As an extreme case at the scheduler level, we consider HO calls that have gained higher priorities compared to the ongoing calls, therefore if $T_E = 1/\mu_E = 0$ then $I_{h,k} = 0$, hence $\lambda^{sch}_{h,k} = 0$. This indicates that HO calls will not be prioritized at the scheduler level and the HO call will be treated as new calls and the code allocation for those calls will be assigned from the available capacity that equals to total capacity, excluded the handover reservation threshold (i.e., C-C_T). While $1/\mu_E \geq 1/\mu_{d,k}$ then $I_{h,k} = 1$, and thus $\lambda^{sch}_{h,k} = \lambda_{h,k}$,therefore the HO calls will be prioritized and the code allocation will be assigned out of the total capacity C.

6. Packet Scheduling based HO Class (PS-HOC) Scheme

6.1 Sorting Priority

The proposed scheduler introduces different properties aiming at supporting the QoS of the handover connections since it assigns different service level for the prioritizing HO calls. The priority criterion depends on the elapsed time of the HO calls, since Node B adjusts the value of elapsed time threshold (T_E) which is less than the mean service duration ($1/\mu_{s,k}$). The HO calls whose elapsed time is less than T_E are considered to be prioritized. The scheduler sorts these connections according to the delay requirements and the priority criterion. The utilized criterion which is used to select the first connection in the list at the start of each frame n is:

$$P_i = \frac{d_i(nT_S)}{D_{th,i}} \quad (7)$$

While the rest of HO calls whose elapsed time is greater than T_E are considered to be non-prioritized HO calls and are treated as the new calls at the scheduling procedure. The scheduler will sort these connections not only according to the delay sensitivity but also according to the successful transmission probability. The criterion priority that is used to select the first connection in the list is presented as follows:

$$P_i = \frac{d_i(nT_S)\times(1-P_{e,i})}{D_{th,i}} \quad (8)$$

where $d_i(nT_s)$ is the head-of-line packet delay for queue i, T_S is the scheduling period of the scheduling scheme, D_{th} is the delay threshold and P_e is the transmission error probability at the next frame. P_e is given by Eq.(2) and is recalculated at the start of each frame just like PS-HOC scheme that uses P_e as a criterion to determine if the service of a connection should take priority over another. Consequently, two connections with the same head-of-line packet delay and delay threshold will have different priorities if they have different probabilities for successful transmission.

6.2 PS-HO Algorithm

The algorithm of the proposed scheme can be concluded as follows:

CAC Level

Measure the HO load traffic
Set C_T threshold value
Wait for call request arrival
When New call request arrives
    If($C_{Occupied} + r_k$)< (C-C_T)
        Admit New call with rate r_k
    Else
        Reject New call request
When HO call request arrives
    If($C_{Occupied} + r_k$) ≤ C
        Admit HO call with rate r_k
    Else
        Dropped HO request

Scheduler Level

When New and HO call requests are accepted
Set T_E threshold value
For : HO calls
    If (Elapsed_Time)<T_E
        HO call will be prioritized HO call
        Sort the connections according to
        $P_i = \frac{d_i(nT_S)}{D_{th,i}}$
        Assign a code rate from the total capacity, C
    Else
        HO call will be Non-prioritized HO calls

Treat Non-prioritized HO as New calls
Sort the connections according to

$$P_i = \frac{d_i(nT_S)\times(1-P_{e,i})}{D_{th,i}}$$

Assign a code rate from the rest capacity, C -C_T

6.3 Bandwidth Allocation

The flows of prioritized and (new and non-prioritized HO) connections are sorted in decreasing order, according to their priorities. The scheduler assigns to the highest priority connection, the maximum transport frame and resource combination (TFRC) for the current subframe according to the predicted SIR and the available OVSF capacity. The rate allocation procedure continues with the next connection in the sorted list until either (a) all the connections of the list are examined and all their respective queued packets are scheduled for transmission during the next subframe, or (b) all the available capacity has been allocated. The flow chart of the bandwidth allocation procedure in PS-HOC is illustrated in Fig.2.

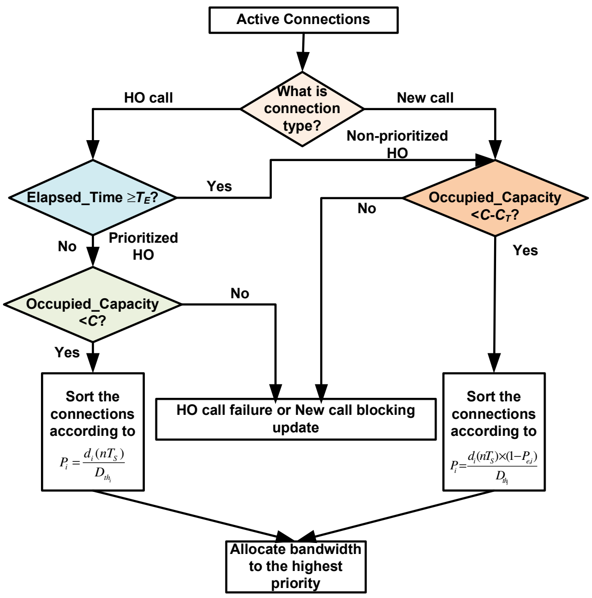

Fig.2 Bandwidth allocation in PS-HOC scheme.

7. Simulation Results

The performance of the proposed scheme is evaluated via event-driven simulation. We compared the performance of the proposed (PS-HOC) scheme with DDS scheme. The reservation factor (Φ) is 10% and the elapsed time threshold T_E sets to 90s. The traffic load increases by increasing the number of UEs in cell. We assume a single cell scenario where the Node B is located at the centre of a hexagonal cell with a radius of R_{cell} =1km. We also assume a 7-layer OVSF code tree and therefore a total capacity of 64R. We consider the maximum power for each traffic channel is set to 30 dBm and the maximum Node B power is set to 43 dBm [10]. We also assume an isolated cell, thus inter-cell interference, I_{inter} = 0, however for calculation intra-cell interference in downlink, we consider the total power transmitted by the Node B, the orthogonality factor and the path loss between Node B and UE. Therefore, intra-cell interference I_{intra} at Eq. (1) can be expressed as follows:

$$I_{intra,i} = (P_t - P_{NodeB\rightarrow UE_i})\times L_P(d_i) \qquad (9)$$

where P_t, is the total power transmitted by the Node B, $P_{\text{Node B}\rightarrow\text{UEi}}$ is the power transmitted by the Node B to the UE in which interference is being calculated, and $L_P(d_i)$ is the propagation path loss between Node B and UE. In sequel the macro cell propagation model proposed in [6] is adopted for calculating the path loss at distance d_i (Km) from the Node B. Consequently, the attenuation L_p of the transmitted signal for a Node B antenna height of 15 meter and a 2 GHz carrier frequency is defined by the following Equation:

$$L_p(d_i) = 128.1 + 37.6\ \log(d_i)\quad [dB] \qquad (10)$$

The call arrival process is modelled by a Poisson distribution, while the call duration is exponentially distributed with equal mean. The traffic load increases by increasing the number of users in the cell. During connection set-up, the mobile user negotiates with the network management module for a delay threshold D_T. The UE's are uniformly distributed in the cell and each class k connection has an average velocity of v_k. Thus, the boundary crossing rate $\lambda_{h,k}$, for the class k connections is [11]:

$$\lambda_{h,k} = \frac{D_k v_k L_{cell}}{\pi} \qquad (11)$$

where L_{cell} is the length of the perimeter of the cell and D_k is the density of the UE's in the cell. The initial value of D_k is 50 connections per square kilometer. For each connection the traffic is assumed to arrive according to an "ON-OFF" model [12]. As long as the connection is in the "OFF" state, it has no arrivals. While in the "ON" state a batch of N packets arrives per timeslot. N is uniformly distributed between N_L and N_H, where $N_L, N_H \in R$ and $N_L, N_H > 0$. A packet is defined as the amount of bits that can be received during one timeslot at the lowest available rate R. The probability P_{on} of being in the ON state, the N_L, N_H, and the delay threshold D_T are predefined for each connection. We employ two service classes which have the characteristics presented at Table 1. The FSMC model, used for the partitioning of the wireless channel, has four states while the equal probability method (EPM) is used to determine the steady state probabilities, as well as the transition probabilities [3].

Table1: Traffic, Power and QoS parameters

Traffic Parameters	***Class1***	***Class2***
N_H, N_L	6, 4	12, 4
P_{on}	0.4	0.5
Average service time	180sec	180sec
Average data rate	2R	4R
Transmission power parameters		
P_N (thermal noise power)	-99dBm	
P_t	43dBm	
Maximum channel power	30dBm	
Orthogonality factor (α)	0.4	
QoS Requirements	***Class1***	***Class2***
Delay threshold (D_{th})	0.5sec	1sec
Target BER	10^{-4}	10^{-4}

7.1 Performance of the traffic scheduler

Figures 3 and 4 show the average packet delay for HO and new calls of classes 1 and 2, respectively. Looking at the overall performance of HO calls under the two schedulers, we can observe that PS-HOC outperforms DDS at all traffic loads. However, the performance of the new calls under PS-HOC scheme suffered higher delays in comparison with HO calls. This is due to non-prioritized HO call after the elapsed time estimation is treated as new call. Therefore, the loads of new calls are increased; this leads to an increase in the average packet delay of the new calls dramatically compared to the performance of new calls under DDS scheme. In addition, the DDS scheme prioritizes the connections regardless the class of call new or HO at the packet level and then the average packet delay of new calls might close to the average packet delay of HO calls. On the other hand, the average packet delay of HO calls decreases significantly compared to the average packet delay of new calls under the PS-HOC scheme at all traffic loads.

7.2 Queue size and packet dropping rate

The average queue size of all the ongoing connections is depicted at Fig. 5 under DDS and PS-HOC schemes. As the traffic load increases the average queue size of all ongoing connections is also increased. As we can see the queue size at PS-HOC is very close to the queue size at DDS from low to medium traffic load. However at high loads, under PS-HOC scheme, the connections experience high packet delays. This is due to the non-prioritized HO load, which is added to new calls load. As a result, the queue size of PS-HOC is larger than DDS scheme at high traffic loads. However, the beneficial of PS-HOC is capable of prioritizing HO calls over new calls at the packet level at all traffic load. Therefore, by employing PS-HOC scheme, the average packet dropping rate of HO calls is smaller compared to DDS scheme as depicted at Fig. 6. Though, the cost of the packet dropping rate of new calls might be increased significantly when the traffic load increases from medium to high load.

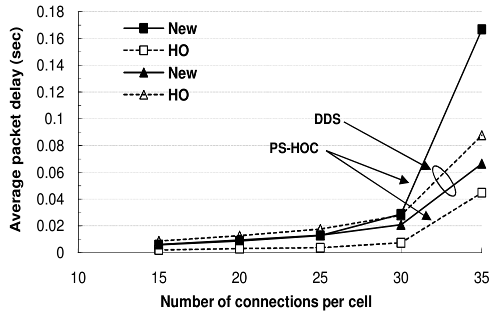

Fig.3. The average packet delay of Class1 HO and New calls under DDS and PS-HOC schemes.

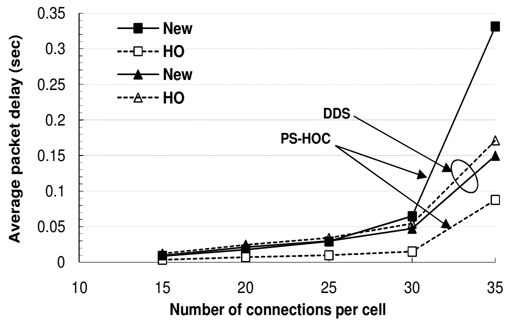

Fig.4. The average packet delay of Class2 HO and New calls under DDS and PS-HOC schemes.

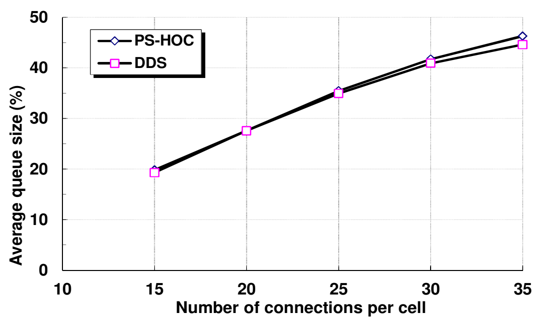

Fig.5. The average queue size under DDS and PS-HOC schemes.

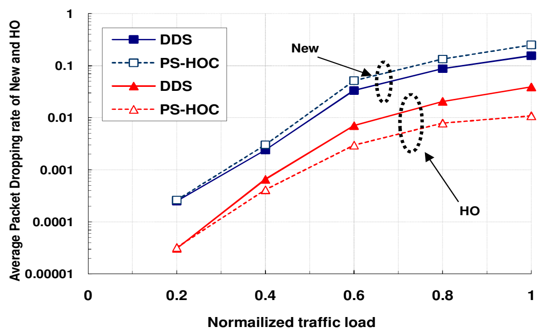

Fig.6. The average packet dropping rate of new and HO under DDS and PS-HOC schemes.

7.3 The effect of Elapsed Time Threshold

Figure 7 illustrates the average packet delay of new and HO calls for the proposed scheme (PS-HOC) under different values of the elapsed time threshold (T_E). As we can see, the average packet delay of HO call is small at high values of T_E. When the elapsed time threshold increases, the more probable for the HO calls to be considered prioritized and as a consequence, PS-HOC assigns the requested bandwidth with precedence over new and non-prioritized HO calls.

This leads to a decrease in the average time delays of the prioritized HO calls at all traffic load. On the other hand, the average packet delays of the new calls is increased by increasing the T_E values that is because of the non-prioritized HO calls treated as new calls and then the overall new calls load is increased dramatically and PS-HOC scheme takes long time to assign the required bandwidth, therefore the average time delay increased.

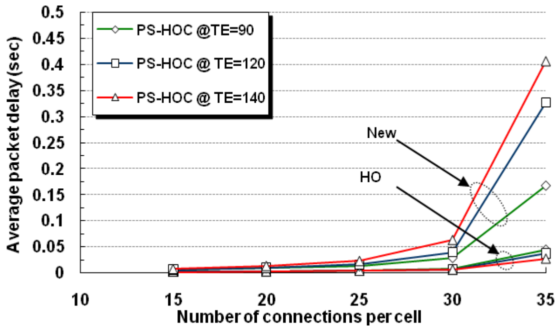

Fig.7. The average packet delay of new and HO calls at different T_E values.

8. Conclusion

In this paper, we proposed a packet scheduling discipline namely Packet Scheduler based-HandOver Class (PS-HOC) in order to enhance the HO performance in wireless mobile networks. At the call level, a guard code scheme based on code reservation favors HO calls over new calls. At the packet level, a PS-HOC scheme makes use of the elapsed time of HO connections to classify the HO requests into prioritized HO and non-prioritized HO calls. The benefit of the proposed scheme is to prioritize the HO calls not only at the CAC level but also at the scheduler level in order to achieve the QoS requirements of HO calls. As the simulation results here are demonstrated the efficiency of the PS-HOC in 3G mobile network based-WCDMA system, PS-HOC is fairly applied to other mobile network scenarios.

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Saied M. Abd El-atty received the B.S. and M.S. degrees from Menoufia University, Faculty of Electronic Engineering, in 1995 and 2001, all in Electronics & Communications Engineering respectively and PhD degree in Wireless Communication Networks from University of Aegean (UOA) at the Information and Communication Systems Engineering Department, Greece, Samos in 2008. He is currently a lecturer in the department of Electronics and Electrical Communication at Faculty of Electronic Engineering, Menouf, Egypt. Dr. Saied's current research interests include design, analysis, and optimization of wireless mobile communication networks and vehicular networks as well as cognitive radio systems.

Konstantinos Lizos received his Engineering degree in 2003 and his M.S.c Degree in 2005, both with honours from the information & Communication Systems Engineering Department in the University of Aegean (UOA). Since 2006, upon completing his military obligations, has joined the Hellenic Ministry of Foreign Affairs. He is currently stationed in Oslo, Norway. He is an active researcher in the fields of wireless networking.