



Multi-Access Interference Mitigation Using Multi-Level Power Control Algorithm in OFDMA Cellular System

Waleed Saad¹, Mahmoud Nagieb¹ and Mona Shokair¹

¹Faculty of Electronic Engineering, El-Menoufia University, Menouf, 32952, Egypt

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Abstract: Power control is an efficient technique to mitigate the effect of interference, combat the Near-Far problem and conserve the battery life. Thus, an effective implementation of different power control algorithms in cellular radio communication systems can offer a significant improvement in the Quality of Service (QoS) to all the users. In this paper, increasing system capacity and using frequency reuse concept at the same cell will be investigated. That is because of the use of a new Multi-Level Power Control (MLPC) Algorithm to enhance the network performance by the ability of using the available channels in an efficient way and mitigate the interference at the same cell. System simulations are used to compare the performance of the proposed algorithm with the traditional one which done using dense Monte Carlo simulations. In addition, the effects of some system model parameters are discussed.

Keywords: Frequency Reuse, Multi-Level Power Control Algorithm and System capacity.

1. INTRODUCTION

The rapid in demand for mobile communication has led into continuous research and development towards enhancing the cellular network to meet the needs of end users. Spectral reuse and coverage represent one of the most important issues in cellular systems architecture. As the demand increases for wireless services, the required number of assigned channels to a cell to support the required number of users becomes insufficient. In cellular systems, spectral efficiency is achieved by employing spatial frequency re-use techniques on an interference limited basis [1].

The service area is divided into smaller areas called cells, each cell is served by its own base station and a set of frequencies. Frequency reuse is a key concept to mitigate the interference and enhance system performance. There are many frequency reuse schemes and strategies were introduced to enhance system capacity and to mitigate Co-channel interference (CCI) and to reduce its effect at cell borders [2][3]. Fractional Frequency reuse was presented to combat this problem in an OFDMA based systems [4] [5], the basic mechanism of FFR corresponds to partitioning the service area into spatial regions, and each sub-region is assigned with different frequency sub-bands. Therefore, cell-edge-zone devices do not interfere with center-zone devices, and

with an efficient channel allocation method, the cell-edge-zone may not interfere with neighboring cell-edge zone [6]. As a result, the cell-edge zone devices receive an acceptable signal quality, which subsequently reduces the outage probability and increases the network capacity. FFR scheme, when operating on a relatively large timescale, is referred to as a static FFR scheme. In contrast, dynamic FFR (DFFR) schemes can operate on short timescales and can be optimized for system utility with varying network dynamics where the FFR sizes are modified based on cell load. However, they are more complex and less scalable than static schemes.

Power control is an efficient technique to mitigate the effect of interference, combat the near-far problem and conserve the battery life. Thus, an effective implementation of different power control algorithms in cellular radio communication systems can offer a significant improvement in the Quality of Service (QoS) to all the users and it is an important issue of the resource management. To dilate greater number of users, the available spectrum is divided among the users with the aid of some multiple access techniques and the same spectrum can be reused separated in distance. But, if the power levels of a user are not controlled, it will result in co-channel and adjacent channel interference. That is because its task is to maintain the desired link quality with a minimum interference to others [7]. The Power

control strategy is used to increase the bandwidth efficiency and capacity of the cellular systems [8].

In this paper, a new power control algorithm is introduced named as MLPC algorithm which introduced to enhance channel usage and increase system capacity.

The paper is organized as follows, Section 2 introduces the related works, Section 3 introduces a detail description of the proposed Multi-Level Power Control Algorithm, Section 4 illustrates our system model description and the simulation results will be discussed in section 5. Finally, conclusion will be shown in Section 6.

2. RELATED WORK

Previous researches focused on investigating the Quality of Service (QoS) for multimedia traffic of the Medium Access Control (MAC) protocol for Ultra Wide-Band (UWB) networks, enhancing its performance and increase its capacity using Wise Algorithm for Link Admission Control (WALAC) [9], reducing the interference level in downlink and uplink channels and providing the optimum SNR in the cell based on a method of power control policies optimization in radio interface of mobile network with code-division multiplexing [10], Power control has been shown to increase the bandwidth efficiency and the capacity of both channelized cellular systems. Early analytical work focused on maximizing the minimum user Signal-to-Interference Ratio (SIR), this approach was known as SIR balancing [11-14], improve the sum-rate in an underlying LTE-A system that supports Device-to-device D2D communication by proposing a novel mechanism, which combines the resource allocation scheme with the transmit power control scheme to maximize the overall data rate [15].

3. THE SYSTEM MODEL

A. Preliminaries

Among different Radio Resource Management (RRM) techniques, power control which also known as TPC (Transmit Power Control), is one of the important interference mitigation techniques. The system capacity and performance are affected badly by the interference. So, power control plays an important role in an interference-limited system, which increases the efficiency by mitigating the adjacent and co-channel interference in the system. Resource allocation or channel assignment for users in the traditional approach depends only on the number of the available channels that affects on system capacity and increasing blocking probability rate. The proposed Multi-level Power Control Algorithm gives the ability to reuse the same channel at the same cell which increases system channel utilization and decreases blocking probability therefore the total system capacity will be increased. The new algorithm depends on varying

the power level value from P_{\min} to P_{\max} with resolution value ΔP as shown in Fig.1, it can be calculated as,

$$\Delta P = \frac{P_{\max} - P_{\min}}{\text{Number of steps}} \quad (1)$$

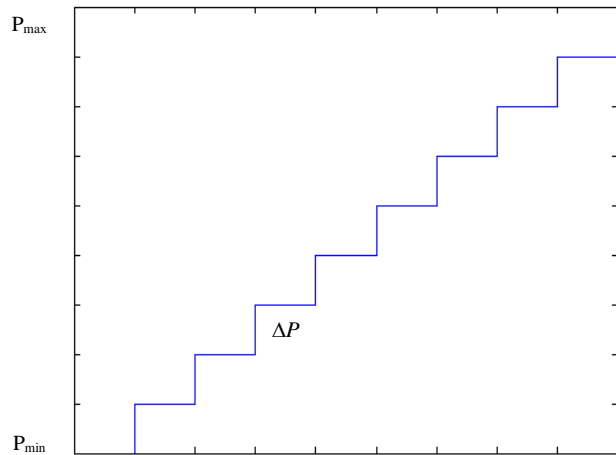


Figure 1. Multi-Power Levels with resolution ΔP .

Reusing the same channel must be subjected to the Signal to Interference plus Noise Ratio for any (y) $SINR_y$ must be larger than or equal the threshold value (γ) and can be calculated as [16].

$$SINR_y = \frac{P_i G_{xy}}{\sigma^2 + \sum_{z \in Z} P_z G_{zy}} \geq \gamma \quad (2)$$

Where P_i is the user y transmitted power $P_{\min} < \Delta P < P_{\max}$, G_{xy} is the channel gain between Base Station (BS) x and the user y as $G_{xy} = \|x - y\|^{-\alpha}$, α is the desired path-loss exponent and equal to 4, σ^2 is the noise power and the set Z represents the entire interfering users i.e. users that are using the same sub-band as user y .

From SINR equation, the Interference Margin (IM) [9] equation can be obtained as follows,

$$IM \leq \frac{P_i G_{xy}}{\gamma} - \sigma^2 \quad (3)$$

The IM represents the total interference from other users that using the same channel.

B. System Description

The system model consists of only one cell with radius 50m as shown in Fig.2 with uniformly users distribution, channel allocation will depend on SINR value and changing power resolution value ΔP .

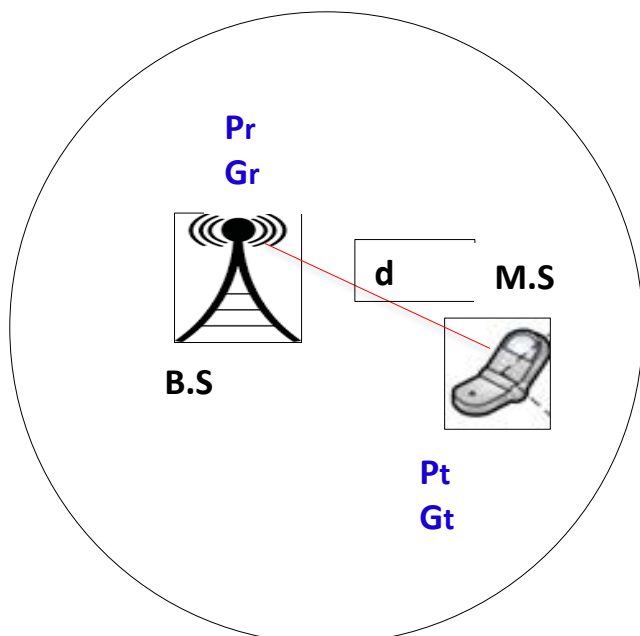


Figure2. System Model.

C. Performance Measurement Parameters

The performance measurement is done using two metrics which are the blocking probability (P_b) and the channel utilization (U_{ch}).

- Blocking Probability (P_b): is defined as the probability that a new call request be denied for lack resources and if the both two conditions mentioned at equations (2) and (3) not achieved.

$$P_b = \frac{\text{Numberofblockedcalls}}{\text{Totalnumberofcalls}} \quad (4)$$

- Channel utilization (U_{ch}): is defined as the average number of admitted users per simulation time U_{ch} is an indicator of channel usage efficiency.

$$U_{ch} = \text{avg}\left(\frac{\text{Numberofadmittedusers}}{\text{Simulationtime}}\right) \quad (5)$$

4. THE PROPOSED MULTI-LEVEL POWER CONTROL (MLPC) ALGORITHM

The proposed MLPC algorithm is shown in Fig. 3 which can be stated as follows,

1. In case if a new user needs to originate a new call, BS will check if there is available free channel or not,
 - a) If there is available channel, user will take it and transmit with the minimum power $P = P_{min}$ and make a call.

- b) If not, in the traditional algorithm the call will be blocked but in our proposed algorithm we will check the total interference for each channel.
2. Check total interference for each channel, choose the minimum interference value, new user will transmit with the minimum power $P = P_{min}$ then we will calculate the Signal to interference and Noise Ratio (SINR).
 3. SINR value will be calculated and compared to the threshold value $SINR_{th}(\gamma)$,
 - a) If $SINR > \gamma$, we will check if there is IM violation for the primary users who already use the channel,
 - a.1) if yes, call will be rejected.
 - a.2) if no, IM value will be updated for all primary users and call will be admitted.
 - b) If $SINR < \gamma$, Power will be increased by resolution value ΔP and check Power value,
 - b.1) if $P > P_{max}$, call will be rejected.
 - b.2) if $P < P_{max}$, we will return to step 2 again but with the new power value.

All users who already use the channel called primary users and any new user (secondary user) can use the channel only when meets the two conditions which mentioned above. With the proposed Multi-Level Power Control Algorithm, system capacity will be increased with an efficient usage for the available channels.

5. SIMULATION RESULTS

A. Simulation Setup

The impact of number of users, number of channels, average call rate and number of power levels will be studied using Carlo MATLAB simulation, the simulation parameters are illustrated in Table 1.

TABLE I. SYSTEM PARAMETERS

Parameter	Value
Outer Cell Radius	50m
Number of Cells	1
P_{max}	50 mw
P_{min}	10mw
Background Noise (PN)	-102 dBm
γ	20
Average Call Duration	120 sec
Simulation Time	2×10^4 sec

Simulation Step Time	0.01
Number of Users	15
Number of Channels	10
Average Call Rate λ	6 call/hour

B. Impact of changing number of users

The effect of changing number of users on P_b and U_{ch} with fixing the other parameters values will be illustrated as the number of the available channels = 10, $\lambda = 6$ call/hour and number of power levels (n) = 4.

From Fig. 4 it is shown that with increasing number of users, P_b increases for both traditional and proposed algorithm but the proposed algorithm gives a superior performance and big enhancement as it decreases the P_b values than the traditional one, by comparing the two systems at number of users equal to 40 as an example we can find that the proposed gives an enhancement sixteen times than the traditional one.

From Fig.5, U_{ch} increases with increasing number of users but the proposed algorithm enhanced channel usage efficiency than the traditional one, by taking the same number of users equal to 40, we can find that the proposed enhanced the channel usage six times than traditional one.

By increasing the number of users at the system it will lead to a big congestion at the system which leads also in increasing the probability that the call will be blocked incase that all available channels are taken so in this case the proposed algorithm gives high performance and less P_b as it provides more available channels to be used and to be shared at the same time with interference mitigation unlike the traditional system which makes limitation in using the available channels.

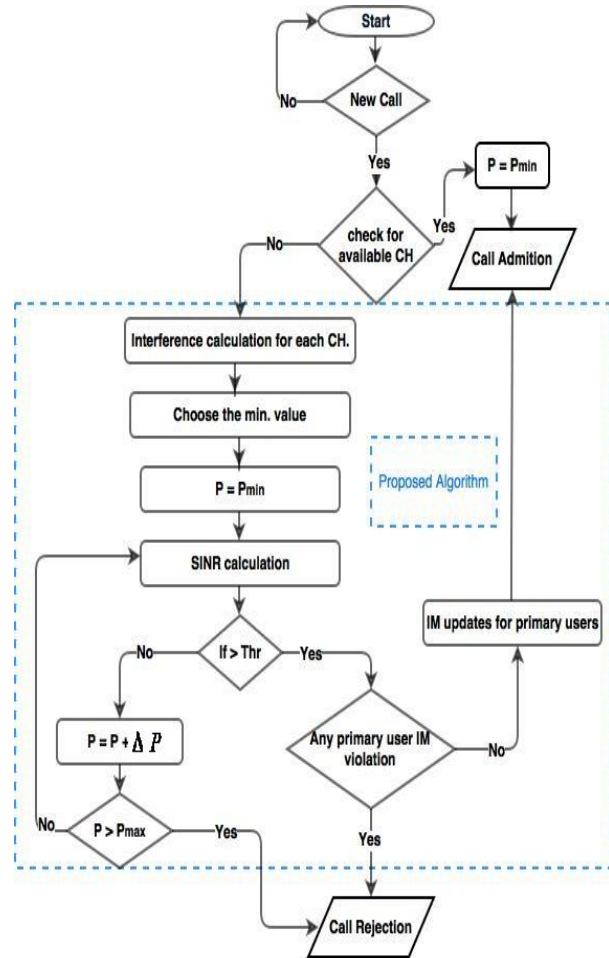


Figure 3. Flow chart of MLPC Algorithm

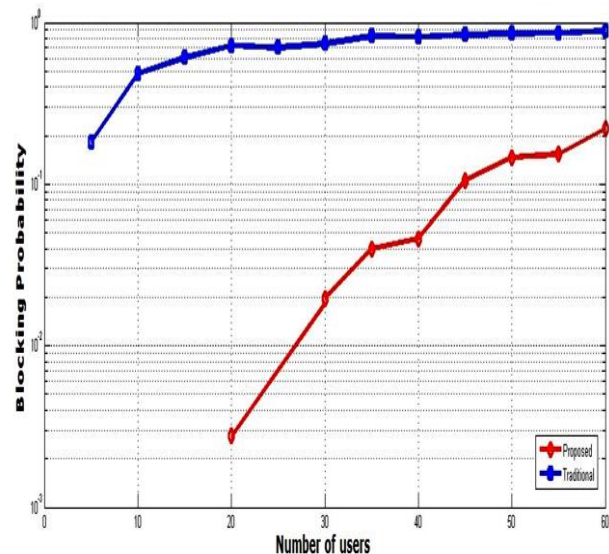


Figure 4. Relation between P_b and number of users

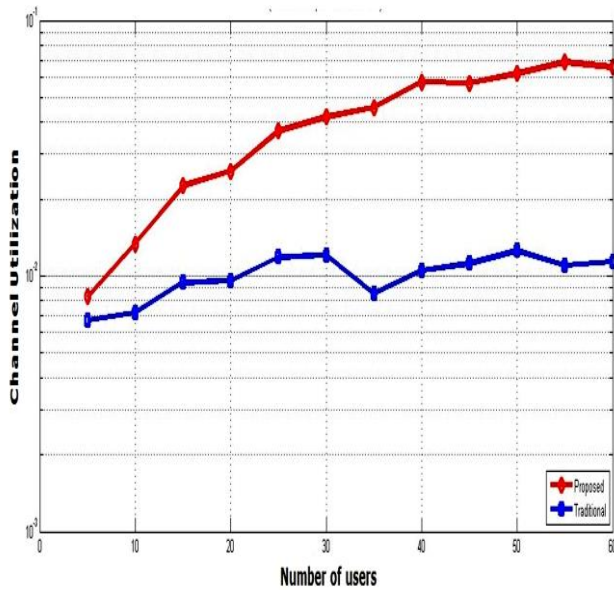


Figure 5. Relation between U_{ch} and number of users

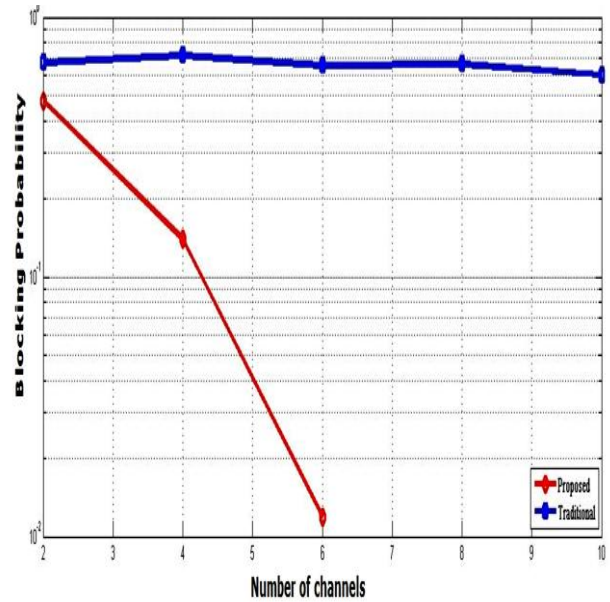


Figure 6. Relation between P_b and number of channels

C. Impact of changing number of channels

The effect of changing number of channels on P_b and U_{ch} with fixing the other parameters will be studied as the number of the available users = 15, $\lambda = 6$ call/hour and number of power levels (n) = 4.

From Fig.6, it is shown that with increasing number of channels, P_b decreases but the proposed algorithm gives an obvious enhancement as it decreases the P_b values than the traditional one, by comparing the two systems at number of available channels equal to 6 as an example we can find that the proposed gives an enhancement seventeen times than the traditional one.

From Fig.7, U_{ch} increases with increasing number of available channels but the proposed algorithm enhanced channel usage efficiency than the traditional one, by taking the same number of available channels equal to 6, we can find that the proposed doubled the channel usage than the traditional.

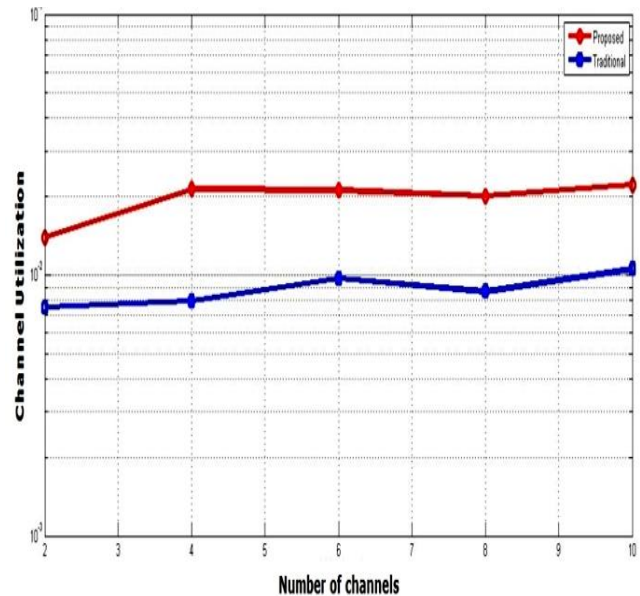


Figure 7. Relation between U_{ch} and number of channels

D. Impact of changing average call rate

The effect of average call rate (λ) on P_b and U_{ch} with fixing the other parameters will be studied as the number of users = 15, number of available channels = 10 and number of power levels (n) = 4.

From Fig.8, its shown that with increasing λ , P_b increases but with the proposed algorithm P_b values enhanced than the traditional one, by comparing the two systems at $\lambda = 14$, we can find that the proposed gives an enhancement sixteen times than the traditional one.

From Fig.9, U_{ch} increases with increasing number of available channels but the proposed algorithm enhanced channel usage efficiency than the traditional one, by taking $\lambda = 14$, we can find that the proposed gives an enhancement four times than the traditional one.

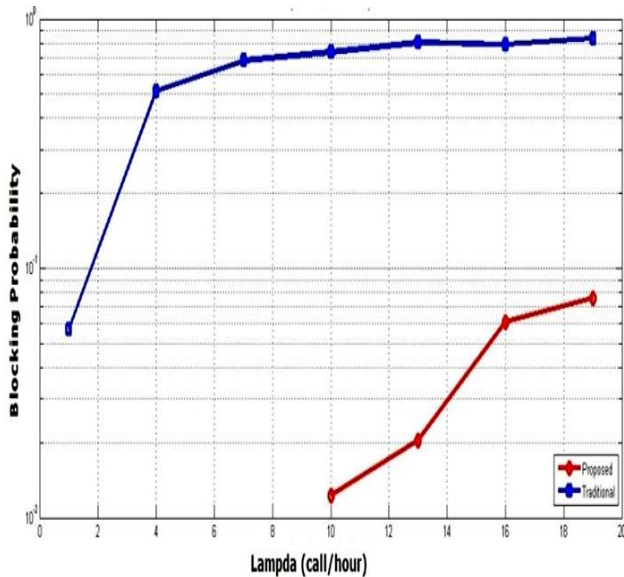


Figure 8. Relation between P_b and λ

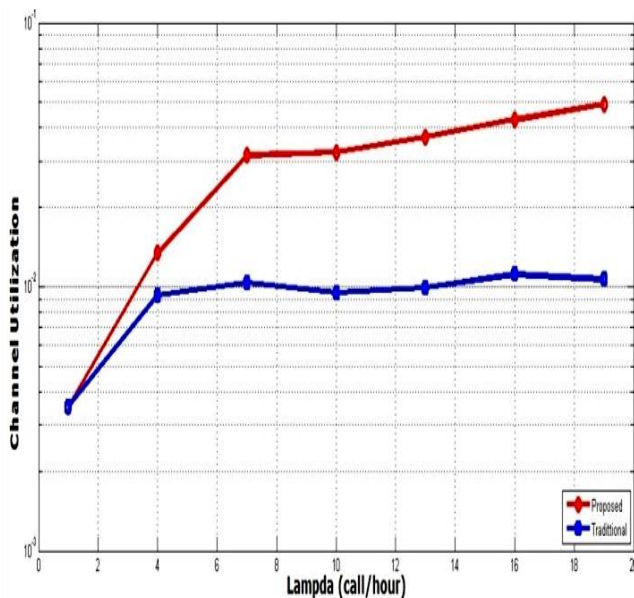


Figure 9. Relation between U_{ch} and λ

6. CONCLUSIONS

In this paper, the Proposed MLPC Algorithm has been introduced to increase system capacity and to make full use of the available channels. The MPLC is based on the different power level values which can be assigned to the new channel requesting users and not simply one or

small levels as before. Simulation results have shown that our proposed algorithm has outperformed the traditional one. That is because it decreases the blocking probability and increases the channel utilization that enhances the total system capacity and channel utilization efficiency. Furthermore, the optimum number of the power levels of the proposed MLPC algorithm has been discussed; using MLPC algorithm in OFDMA cellular system based on cognitive radio and will be studied as a future work.

REFERENCES

- [1] N.Rani and S.Kumar, "Comparative Analysis of Traditional Frequency Reuse Techniques in LTE Network," in IJARCC, pp. 139-142, August 2016.
- [2] H.Frank, "Interference Mitigation for Femto Deployment in Next Generation Mobile Networks," Proceedings of the International MultiConference of Engineers and Computer Scientists, IMECS, March 2016.
- [3] Mustafa, S. Abdulkareem. "Interference Estimation and Mitigation in Wireless Networks." Int. J. Com. Dig. Sys 4.4, 2015.
- [4] Begh, Gh Rasool, and Ajaz Hussain Mir. "OFDM for Cognitive Radios: An overview Present Solutions and Future Directions." Int. J. Com. Dig. Sys 4.4, 2015.
- [5] D.Gonzalez, M.Garcia, S.Ruiz, M.Lima and D.Lee, "Multiobjective Optimization of Fractional Frequency Reuse for irregular OFDMA Macrocellular Deployments," in Telecommunications Systems, Volume 61 Issue 4, pp. 659-673, April 2016.
- [6] Y.Li1, C.Niu1, F.Ye1 and R.Qingyang, "A universal frequency reuse scheme in LTE-A heterogeneous networks", WIRELESS COMMUNICATIONS AND MOBILE COMPUTING, Wirel. Commun. Mob. Comput. 2016.
- [7] Tondare S. M., Veeresh G. K. and Kejkar A. S., "Review of Power Control Mechanisms in Cellular System," Global Journal of Researches in Engineering Electrical and Electronics Engineering, Volume 15 Issue 1, 2015.
- [8] A. Tsakmalis, S. Chatzinotas, and B. Ottersten, "PowerControl inCognitive Radio Networks Using Cooperative Modulation andCodingClassification," in Proc. 10th Int. Conf. on Cognitive Radio OrientedWireless Netw. (CROWNCOM), Apr. 2015.
- [9] N. El-Fishawy, M. Shokair, and W. Saad, "Quality of Service Provisioning for Multimedia Transmission over UWB Networks," UBIQUITOUS Computing and Communication (UBICC) Journal, pp. 60-67, 2008.
- [10] Y.Xu and X.Zhao, "Distributed Power Control for Multiuser Cognitive Radio Networks with Quality of Service and Interference Temperature Constraints", Wireless Communications and Mobile Computing, Volume 15 Issue 14 pp. 1773-1783, 2015.
- [11] T. Sub Kim, K.Hyung Lee, S.Ryu and C.Ho Cho, "Resource Allocation and Power Control Scheme for Interference Avoidance in an LTE-Advanced Cellular Networks with Device-to-Device Communication", International Journal of Control and Automation, Volume. 6, No. 1, February 2013.
- [12] M.Hossein Faridi, A.Jafari and E.Dehghani, "An Efficient Distributed Power Control in Cognitive Radio Networks", International Journal of Information Technology and Computer Science(IJITCS), Volume. 8, No. 1, January 2016.

- [13] N.Lee, X.Lin and J.Andrews, "Power Control for D2D Underlaid Cellular Networks: Modeling, Algorithms and Analysis," IEEE Journal on Selected Areas in Communications, Volume: 33, Issue: 1, January 2015 .
- [14] J Gu, S Bae, SF Hasan, MY Chung," A combined power control and resource allocation scheme for D2D communication underlying an LTE-advanced system". IEICE Trans. Commun. E96-B(10), 2683-2692 ,2013.
- [15] H. Shajaiah, A. Khawar, A. Abdel-Hadi, and T. C. Clancy,"Using Re-resource Allocation with Carrier Aggregation for Spectrum Sharing Between Radar and 4G-LTE Cellular System," inIEEE DySPAN, 2014.
- [16] T.Novlan, J.G.Andrews, I.Sohn and R.K.Ganti,"Comparison of Fractional Frequency Reuse Approaches in the OFDMA Cellular Downlink", Global Telecommunications Conference (GLOBECOM) IEEE, pp. 1-5, December 2010.



Waleed Saad has received his B.Sc. (Hons), M.Sc. and Ph.D. degrees from the Faculty of Electronic Engineering, Menoufia University, Menouf, Egypt, in 2004, 2008 and 2013, respectively. He joined the teaching staff of the Department of Electronics and Electrical Communications of the same faculty since 2014. In 2005 and 2008, he worked as a demonstrator and assistant lecturer in the same faculty,

respectively. He is a co-author of many papers in national and international conference proceedings and journals. His research areas of interest include mobile communication systems, computer networks, cognitive radio networks, D2D communication, OFDM systems, interference cancellation, resource allocations, PAPR reduction, physical and MAC layers design, and implementation of digital communication systems using FPGA.



Mahmoud Nagieb has received his B.Sc. and M.Sc. degrees in electronics and communication engineering from the Faculty of Electronic Engineering, Menoufia University, Menouf, Egypt, in 2010 and 2016, respectively. He is working as a project coordinator at SYSTEL telecom. His research areas of interest include mobile communication systems, OFDM systems, power control and resource allocations.



Mona Shokair has received the B.Sc., and M.Sc. degrees in electronics engineering from Menoufia University, Menoufia, Egypt, in 1993, and 1997, respectively. She received the Ph.D. degree from Kyushu University, Japan, in 2005. She received VTS chapter IEEE award from Japan, in2003. She published about 40 papers until 2011. She received the Associated Professor degree in2011. Presently, she is an Associated Professor at Menoufia

University. Her research interests include adaptive array antennas, CDMA system, WIMAX system, OFDM system, and next generation networks