Radio Resource Scheduling Approach For Femtocell Networks

Sultan Alotaibi

College of Computer and Information Systems, Umm Al-Qura University, Makkah, 24381 Saudi Arabia

Summary
The radio resources available in a wireless network system are limited. Therefor, job of managing resources is not easy task. Because the resources are shared among the UEs that are connected, the process of assigning resources must be carefully controlled. The packet scheduler in an LTE network is in charge of allocating resources to the user equipment (UE). Femtocells networks are being considered as a promising solution for poor channel performance for mulitple environments. The implementation of femtocells into a macrocell (traditional base station) would boost the capacities of the cellular network. To increase femtocells network capacity, a reliable Packet Scheduler mechanism should be implemented. The Packet Scheduler technique is introduced in this paper to maximize capacity of the network while maintaining fairness among UEs. The proposed solution operates in a manner consistent with this principle. An analysis of the proposed scheme's performance is conducted using a computer simulation. The results reveal that it outperforms the well-known PF scheduler in terms of cell throughput and average throughput of UEs.
Keywords:
Packet Scheduler, Radio Resource Management, Femtocell, LTE.

1.Introduction

In recent years, there has been a significant growth in the demand for Internet-based applications. One of the issues of LTE networks is meeting these expectations while also taking Quality of Service (QoS) into consideration. Furthermore, the use of an indoor mobile station, such as femtocell base station, makes this problem more difficult. As a result, increasing the capacity of indoor users, also known as User Equipment (UE), in accordance with LTE network architecture becomes a critical concern [1].

However, femtocells have been produced in order to boost the capacity of the cellular network, particularly in indoor environments. Home eNB (HeNB) is another name for a femtocell. Femtocells cover small service area compared to macrocell base stations. The range of a femtocell is typically between 10 and 30 meters in terms of radius. Fig. 1 depicts an overview of the topology of a femtocell network. Furthermore, a femtocell base station is capable of performing the majority of the activities that are normally handled by a traditional cellular base station, which is macrocell. The Femtocell Gateway node is responsible for connecting the femtocell network to the cellular network. Furthermore, since femtocells are deployed by end users, there is no need for further deployment planning. Furthermore, since the distance between the transmitter and the receiver in a femtocell is short, a high degree of quality of service could be attained when femtocells are implemented. The data rate and capacity of UEs improve when the distance between transmitter and receiver is short. The Orthogonal Frequency Division Multiple Access (OFDMA) scheme has been adopted as the downlink transmission technique for the LTE and LTE-Advanced networks. This supports increasing the data rates for UEs. This system splits a given bandwidth into orthogonal subcarriers, allowing for a high data rate to be accomplished.

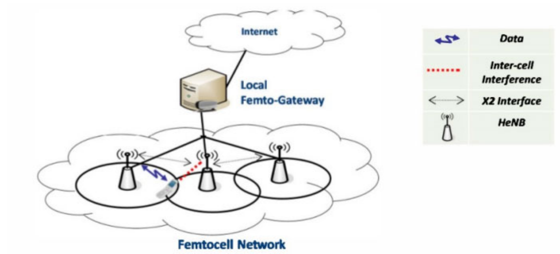

Fig. 1 Overview of Femtocell Network [2].

It is well accepted that radio resource management is one of the most critical aspects that influences network performance. The Packet Scheduler (PS) is a critical function that is carried out by the Radio Resource Management (RRM) entity. Therefore , when an efficient packet scheduling mechanism is considered, the network's capacity could be improved. Additionally,

Manuscript received April 5, 2022
Manuscript revised April 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.4.46

when an inefficient packet scheduling approach is used, the network's performance may be adversely affected.

2.Literature review

There have been several resource scheduling systems for femtocells suggested in the literature. The majority of earlier research concentrated on increasing the capacity of UEs while also maintaining an acceptable level of fairness among them. Round Robin technique is one of the most straightforward strategies. Also, it has been shown to give the highest level of fairness among UEs [3]. The First Input First Serve (FIFS) approach was used to schedule UEs without taking into account parameters like channel quality or service type. However, network performance would be compromised and reduced as a result. According to [4], a survey was conducted on resource scheduling approaches in femtocell networks. Round Robin (RR) and Proportional Fairness (PF) techniques were used in the majority of the works. In [5]addition, a cognitive femtocell network was taken into consideration. The resource scheduling mechanism was incubated inside femtocell base stations, with femtocells acting as cognitive nodes. Both fairness and throughput were key factors that have been properly considered once this scheduling algorithm was developed. Its goal was to increase the throughput of the network to its maximum capacity. Furthermore, cognitive femtocells were also deployed in [6]. In that case, a mechanism for distributing resources among the UEs that were connected was developed using the game theory approach. In that cooperative game, a variety of elements were taken into consideration in order to assure a certain amount of fairness while also minimizing the outage probability. In addition, numerous elements such as delay sensitivity were taken into consideration while constructing the resource allocation strategy. Based on delay sensitivity, a scheduling technique was proposed in [7]. The objective was to increase the overall throughput of the femtocell network to its maximum capacity. This study included the implementation of co-channel deployment between femtocell and macrocell. In [8], the authors presented a system that would allow attached UEs to be differentiated according on the femtocell access mode they were using. There were three main access modes available: open access mode, closed access mode, and hybrid access mode. Open access mode was the most widely available. . Furthermore, the access method of hybrid access mode was considered in [9]. To identify between attached UEs, an admission control algorithm was employed to distinguish between them. UEs that were identified as subscribers of a particular femtocell would be given a preference in terms of allocating more resource when they demanded resources for real-time services. In addition, the same principle was taken into consideration in [10]. However, the goal was to increase the entire capacity of the network to its maximum capacity. Authors in [11] also presented a scheduling method that exclusively allocated resources to attached UEs based on the delivery of Quality of Service (QoS).

In this paper, a unique Packet Scheduler method is proposed with the goal of improving network performance. It takes into account optimizing throughput while maintaining fairness across UEs. The remainder of this work is structured in the following manner. The third section contains information on the LTE system model and frame architecture. The fourth section provides an explanation of the resource allocation mechanism as well as the proposed strategy. The findings of the simulation are shown in the fifth section. The conclusion is provided in the last section of the paper.

3. System Model

The structure of LTE frame s demonstrated in Fig.2. The Orthogonal Frequency Multiple Access (OFDMA) transmission scheme has been chosen for LTE and LTE-Advanced in terms of downlink transmission [11]. A single LTE frame is about 10 ms in terms of time domain. Fundamentally, the frame is separated into ten sequence sub-frames. Accordingly, the length of each sub-frame is 1 ms. Furthermore, a divided sub-frame includes two adjacent slots are formed noe sub-frame. A single sub-frame would be 0.5 ms time duration. Also, there are two different types of cyclic prefix that can be used: long cyclic prefix and short cyclic prefix. In long cyclic prefix, each slot includes six symbols. On another hand, short cyclic prefix includes seven symbols. Correspondingly, the frequency based grid of a single slot is demonstrated in Fig.3. Accordingly, Resource Block (RB) is the smallest unit that could be allocated to a specific UE. A RB is symbolized by (0.5 ms × 180 kHz) time-frequency block. Each RB comprises twelve OFDMA subcarriers [11].

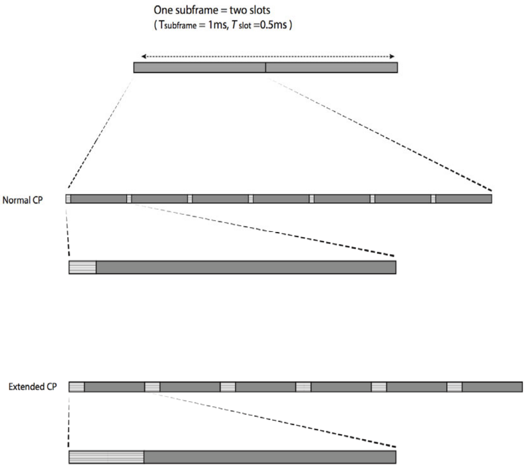

Fig. 2 LTE Frame Structure [16].

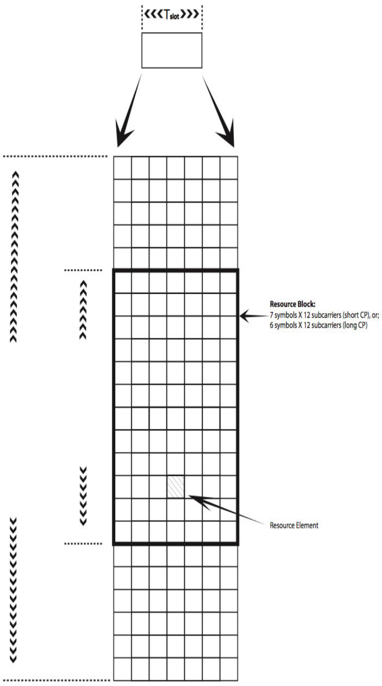

Fig. 1 Time – Frequency Grid of LTE Frame [16].

In terms of system model, the overall throughput is computed as follows [12]:

$$\Gamma = \sum_{u} \sum_{s} \beta_{u,s}\, Capacity_{u,s} \qquad (1)$$

where βu,s indicates that subcarrier s is allocated to UE u. βu,s = 1 when s is allocated. βu,s = 0 if s is not allocated to any UE. Also, $Capacity_{u,s}$ denotes to the estimated throughput of UE u when s is allocated. It can be given as follows [12]:

$$Capacity_{u,s} = \Delta f\, log_2(1 + \alpha\, \delta_{u,s}) \qquad (2)$$

where α is the BER. Δf indicates the subcarrier spacing. $\delta u, s$ is the anticipated (SINR). The SINR of $UE\ uj$, which is allocated to subcarrier s, is given as follows [12]:

$$SINR_{i,s} = \frac{\gamma_{m\ ,s}\ G_{i,m,s}}{\sum_{m'} \gamma_{m',s}\ G_{i,m',s} + \sum_{F} \gamma_{F,s}\ G_{i\,,F,s} + N_0\, \Delta f} \qquad (3)$$

the transmitting power for serving macrocell m on subcarrier s and the transmitting power for adjacent macrocells m′ on subcarrier s are represented by $\gamma_{m\ ,s}$ and $\gamma_{m',s}$, respectively. The channel gain is indicated by $G_{i,m,s}$, where m represents serving macrocell, i represents macrocell's UE, and s represents received subcarrier. The channel gain $G_{i,m',s}$ indicates interfering signal received from adjacent macrocell, where m′ represent adjacent macrocell, i represent UE, and s represents the subcarrier. Also, in case of receiving interference from femtocells, which are adjacent to macrocell's UE i, $\gamma_{F,s}$ indicates femtocell's F transmission power on subcarrier s, and $G_{i\,,F,s}$ indicates gain of received subcarrier s. Spacing of subcarrier is indicated by Δf and white noise power spectral density is indicated by N_0 .

Also, the channel gain of an UE is expressed by [12]:

$$Gain = 10^{-PathLoss/10} \qquad (4)$$

4. LTE RB Allocation Procedure and The Proposed scheme

The Packet Scheduler entity controls the task of allocating available RBs among the associated UEs. The decision of allocating RBs for attached UEs is made every TTI round. TTI is the duration time of a single sub-frame, which is 1 millisecond. The assignment of RBs is based on some predefined metrics. The Packet Scheduler maps RBs to relevant UEs on the basis of this information in order to meet a preset criterion, which is considered when the scheduling algorithm is developed. Accordingly, the scheduler would choose the scheduled UE based on his metric's value. For example, if the following measure is fulfilled, the j th UE would be allocated to the k th RB:

$$metric_{j,k} = max_i[m_{i,k}] \quad (5)$$

Those metrics have been developed in response to specific performance requirements. For the purpose of determining an acceptable metric, the intended performance's aim is employed. In order to decide on the optimum mappings between RBs and UEs, each TTI Packet Scheduler calculates the metric for all of the UEs that have been connected to it. The Packet Scheduler is part of the Radio Resource Management (RRM) entity, which aids in making the optimal choice. The UE would send a report to the base station on the channel state. First, the base station would broadcast a reference signal to all of the UEs that were connected. Each UE receives and decodes the signal. This signal would be utilized to determine the Channel Quality Indicator's value (CQI). After that, each UE provides a report. In this report, the base station receives information about CQI of the UE. The SINR would be estimated based on this information. A appropriate Modulation and Coding Scheme (MCS) is chosen in accordance with the SINR degree. As a consequence, the base station may define the consequent data rate for each UE based on the number of RBs that have been allocated to it.

In this section, a novel resource scheduling approach is presented. The proposed scheme aims to assign available RBs to attached UEs with maximizing network capacity under maintaining fairness between UEs. The most well-known schedulers would be presented first and foremost. Then, proposed scheme described. The Round Robin (RR), Maximum Throughput (MT), and Proportional Fairness (PF) scheduler algorithms are the most often utilized in the literature.

(i) *RR* scheme*:* Round Robin scheme achieves fair distribution of the RBs between UEs. The RR scheme metric is expressed as follows [14]:

$$m_{i,k} = t_c - t_i \quad (6)$$

where t_c , t_i are the present time and previous time UE i was served, respectively. This scheme provides highest achievable fairness among attached UEs. However, it does not provide fairness among UEs in terms of throughput. Therefore, network performance is degraded [14].

(ii) Maximum Throughput (MT) scheme*:* The goal of MT scheme is to maximize throughput of the network. It uses channel aware strategy procedure to sense the channel. In this scheme, the available RBs would be allocated to UEs, which have the best channel quality condition. Therefore, it enhances the overall throughput of the system as well as maximizes the spectrum utilization. Its metric is given based on the following expession [14]:

$$m_{i,k} = R_k{}^i(t) \quad (7)$$

where $R_k{}^i\,(t)$ denotes the expected thrughput of UE i on RB k at time t. The UEs with a channel that could achieve highest data rate would be nominated for scheduling.

MT scheme obviously maximizes the overall network throughput. However, the rest of UEs with poor channel conditions would not be scheduled for RBs allocation. This violates the fairness among UEs. Also, some UEs might suffer from starvation. Thus, a radio resource scheduler mechanism should trade-off between achieving accepted fairness level among attached UEs and maximizing the network capacity. Proportional Fairness (PF) approach is introduced in [14] to meet this condition.

(iii) Proportional Fairness (PF) scheme: PF scheme is introduced to support cell throughput with achieving an acceptable level of fairness among UEs. PF's metric is expressed as follows [14]:

$$m(i,j) = \frac{D_j^i(t)}{R^i(t-1)} \quad (8)$$

where $D_j^i(t)$ is the estimated throughput for UE i at time t on RB j. $R^i(t-1)$ is the past average throughput of UE i.

The proposed scheme's goal is to optimize cell throughput while maintaining a fairness restriction. When it comes to optimizing throughput, the system tends to make trade-offs with the achievement of a high fairness degree. It is essential issue to boost the total throughput of the cell. Some UEs, particularly those with poor channel conditions, may suffer starvation as a result of this. Because of this, the proposed approach takes both cell throughput maximization and fairness among UEs into consideration simultaneously. First and , the previous throughput obtained can be utilized to determine the sanctification of the system as well as the usage of the spectrum. The result of dividing previous achieved throughput by maximum achievable throughput reveals if the system meets satisfied throughput or whether throughput should be enhanced. This is presented in the following expression:

$$\lambda = \frac{T\,(T\,-\,1)}{T_{Max}} \qquad (9)$$

where $T(t-1)$ and T_{Max} are the cell past attained throughput and a predetermined maximum cell throughput, respectively. This is used to increase the cell throughput when it is diminished.

Moreover, the ratio of estimated throughput will be used to denote the channel quality of the UE i . It is expressed as follows:

$$\alpha_i = \frac{T_E}{T_{i,\ Max}} \qquad (10)$$

where T_E and $T_{i,\ Max}$ are the estimated attained throughput and maximum throughput of UE i, respectively.

In addition, the value of UE's throughput is used to manage the fairness among UEs. The estimation of fairness satisfaction level can be expressed as follows:

$$\beta i = (1 - \theta i) \qquad (11)$$

Where θi is expressed as follows:

$$\theta i = \frac{T\,(AVG)_i}{T_{i,\ Max}} \qquad (12)$$

where $T\,(AVG)i$ is the average of past gained throughput of UE_i. $T_{i,\ Max}$ is the maximum throughput of UE_i.

Eventually, the proposed metric can be calculated according to the following expression:

$$\Gamma_{i,k} = [(\beta_i * \lambda) + (\sigma * \alpha_i)] \qquad (13)$$

Where σ is calculated according to the following expression:

$$\sigma = (1 - \lambda) \qquad (14)$$

5. Simulation Results

Through the use of a MATLAB tool, the suggested scheduling strategy is tested and assessed. For the purpose of spreading femtocells across apartments, a dual strip block concept is used [15]. Table 1 lists the simulation parameters that were taken into consideration for this study.

Table 1: Simulation Parameters

Parameter	***Value***
System Bandwidth	1.4 MHz
Subcarriers	6
Subcarriers Bandwidth	180 KHz
Noise Power Spectral Density	-174 dBm/Hz
Subcarrier Spacing	15 KHz
Channel Model	PedB
Carrier Frequency	2000 MHz
Number of femtocells	10
Number of UEs Per Femtocell	1 -10
Transmit Mode	Spatial Multiplexing
Femtocell Transmit Power	21 dBm
Cyclic Prefix Type	Normal

Figure 4 depicts the average throughput of UEs in a femtocell network. The number of femtocells in this configuration was set to 10. The number of UEs linked to femtocells has been increased from 10 up to 100. Consequently, as the number of associated UEs increases, the average throughput of UEs decreases. For instance, number 20 implies that each femtocell has at least two UEs. Thus , there would be a total of 20 UEs in the system as a whole. It is self-evident that the maximum throughput can be attained with the MT scheme in all cases. The RR method achieves the lowest throughput possible. This is due to the fact that when RBs are given to UEs, RR does not take into account the channel quality condition. On the other side, MT obtained the greatest average throughput because it only distributes RBs to UEs that have the best channel quality condition. Furthermore, the average throughput of the PF system is between MT and RR since it takes into account both channel quality condition and fairness. However, the proposed scheme outperforms PF in terms of average throughput. This demonstrates that it is feasible to get higher average throughput while maintaining as much fairness as possible. With an increase in the number of UEs, all four schemes saw a decrease in average throughput. In order to maximize the benefits of installing a femtocell network, the number of femtocell's UE should be in the range of 1 - 10.

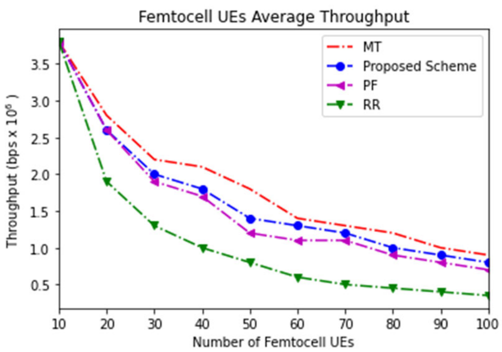

Fig. 4 Average UE Throughput.

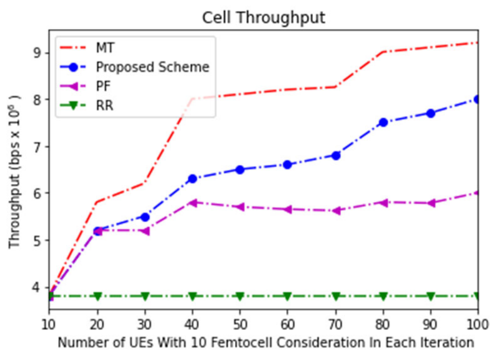

Fig. 5 Cell Throughput.

The network accumulated throughput is demonstrated in Figure 5. As seen in the illustration, when the MT technique is used, cell throughput increases considerably. MT is clearly the most efficient method for aggregating cell throughput. This is due to the fact that MT only distributes RBs to UEs that have the best channel quality condition. RR, on the other hand, provides the lowest cell throughput when compared to the other schemes. Additionally, when the number of UEs grows, MT is able to determine the optimal channel quality condition. Because of this, the likelihood of improving cell throughput is also higher than it would otherwise be. Furthermore, both PF and the proposed approaches are capable of delivering the same throughput. When the number of UEs is increased, the proposed scheme outperforms the PF scheme. Increases in the number of UEs in the system may result in increased throughput when using the proposed scheme. After adding four UEs to each femtocell, the performance of the PF system is almost same. It implies that PF is not an appropriate scheme when additional UEs are included in the system.

6. Conclusion

The resource scheduling in a femtocell network is the subject of this research. Downlink transmission schemes such as OFDMA were investigated for the LTE network's downlink transmission. The RB unit is the lowest resource unit in OFDMA LTE and LTE-Advanced. Different UEs with varying channel conditions compete with one another for the right to be scheduled for a given resource. The Packet Scheduler entity is responsible for mapping available RBs to relevant UEs based on predefined criteria. Additionally, the Packet Scheduler must meet the performance requirements as well as the design goals. The scheduler schemes RR, PF, and MT are the most often used in the literature. The MT system can achieve the largest throughput, while the RR scheme can reach the best level of fairness. The RR strategy, on the other hand, has a poor throughput, while the MT strategy unfairly allocates resources among the UEs. The proposed trade-off between MT and RR is referred to as PF. In this paper, a novel scheme is proposed that performs well while taking both fairness and throughput into account. Its goal is to improve throughput while adhering to the fairness requirement. In the simulation, the proposed scheme surpasses PF in terms of aggregated throughput for cells as well as average throughput for UEs.

References

[1] Saquib, N., Hossain, E., Le, L. B., & Kim, D. I. (2012). Interference management in OFDMA femtocell networks: Issues and approaches. *IEEE Wireless Communications*, *19*(3), 86-95.

[2] Pateromichelakis, E., Shariat, M., Quddus, A. U., & Tafazolli, R. (2012, April). Dynamic graph-based multi-cell scheduling for femtocell networks. In *2012 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)* (pp. 98-102). IEEE.

[3] Iosif, O., & Banica, I. (2011, November). LTE uplink analysis using two packet scheduling models. In *2011 19thTelecommunications Forum (TELFOR) Proceedings of Papers* (pp. 394-397). IEEE.

[4] Lee, Y. L., Chuah, T. C., Loo, J., & Vinel, A. (2014). Recent advances in radio resource management for heterogeneous

LTE/LTE-A networks. *IEEE Communications Surveys & Tutorials*, *16*(4), 2142-2180.

[5] Zhang, H., Jiang, C., Mao, X., & Chen, H. H. (2015). Interference-limited resource optimization in cognitive femtocells with fairness and imperfect spectrum sensing. *IEEE Transactions on Vehicular Technology*, *65*(3), 1761-1771.

[6] Zhang, H., Jiang, C., Beaulieu, N. C., Chu, X., Wang, X., & Quek, T. Q. (2015). Resource allocation for cognitive small cell networks: A cooperative bargaining game theoretic approach. *IEEE Transactions on Wireless Communications*, *14*(6), 3481-3493.

[7] Zhang, H., Jiang, C., Beaulieu, N. C., Chu, X., Wen, X., & Tao, M. (2014). Resource allocation in spectrum-sharing OFDMA femtocells with heterogeneous services. *IEEE Transactions on Communications*, *62*(7), 2366-2377.

[8] Hatoum, A., Langar, R., Aitsaadi, N., Boutaba, R., & Pujolle, G. (2013). Cluster-based resource management in OFDMA femtocell networks with QoS guarantees. *IEEE Transactions on Vehicular Technology*, *63*(5), 2378-2391.

[9] Balakrishnan, R., & Canberk, B. (2013). Traffic-aware QoS provisioning and admission control in OFDMA hybrid small cells. *IEEE Transactions on Vehicular Technology*, *63*(2), 802-810.

[10] Estrada, R., Jarray, A., Otrok, H., Dziong, Z., & Barada, H. (2013). Energy-efficient resource-allocation model for OFDMA macrocell/femtocell networks. *IEEE Transactions on Vehicular Technology*, *62*(7), 3429-3437.

[11] Dahlman, E., Parkvall, S., & Sköld, J. (2011). 4G LTE/LTE-Advanced for Mobile Broadband, The Boulevard, Langford Lane, Kidlington.

[12] Lee, P., Lee, T., Jeong, J., & Shin, J. (2010, February). Interference management in LTE femtocell systems using fractional frequency reuse. In *2010 The 12th international conference on advanced communication technology (ICACT)* (Vol. 2, pp. 1047-1051). IEEE.

[13] Access, E. U. T. R. (2010). Further advancements for E-UTRA physical layer aspects. *3GPP Technical Specification TR*, *36*, V2.

[14] Sevindik, V., Bayat, O., & Weitzen, J. (2011, May). Radio resource management and packet scheduling in femtocell networks. In *2011 International Symposium of Modeling and optimization of Mobile, Ad Hoc, and Wireless Networks* (pp. 428-433). IEEE.

[15] Ibrahim, A. S., Darwish, A. M., Makled, E. A., & Elgebaly, H. (2012, April). Adaptive interference mitigation techniques for femtocells. In *2012 IEEE Wireless Communications and Networking Conference (WCNC)* (pp. 1218-1223). IEEE.

[16] Alotaibi, S. (2018, August). Radio Resource Control Approaches for LTE-Advanced Femtocell Networks, dissertation; Denton, Texas., University of North Texas Libraries, UNT Digital Library.

Sultan Alotaibi received the B.Sc. degree in Computer Science from Umm Al-Qura University, the M.Sc. and Ph.D. degrees from University of North Texas, USA. He is currently an Assistant Professor with the Department of Information Systems, College of Computers and Information Systems, Umm Al-Qura University, Saudi Arabia. His research interest includes wireless communication networks, LTE, LTE-A, radio resource scheduling, 5G and data quality in wireless networks.