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Improving the Performance of Channel Allocation in Wireless Communication Network Using Scheduling and Zero Forcing Techniques

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A B S T R A C T

In wireless communication, resource allocation enables device to device (D2D) communication with minimized interference and guarantee quality of service (QoS). This work has presented improving the performance of channel allocation in wireless communication using scheduling and zero forcing techniques. In order to achieve this, a model for multi-cell consisting of one macrocell and two femtocells network was developed. A scheduling algorithm based on round robin technique and a channel equalization scheme with signal interference cancellation capacity called zero forcing-signal interference cancellation (ZF-SIC) technique were implemented. The developed system was implemented in MATLAB environment. Performance evaluation using the round robin algorithm was conducted for four different scenarios for 5 users, 10 users, 15 users, and 20 users per simulation time frame revealed that as the population of the users increasing the average waiting time and turn around time increases. Thus, with 5 users, the resulting average waiting time and turn around time of each user was 2.40 s and 5.00 s respectively. With the number of users increased to 10, the average waiting time and turn around time became 4.30 s and 8.10 s. The average waiting time and the average turn around time were 16.57 s and 21.00 s for 15 users. Furthermore, with number of users equal to 20, the average waiting time was 30.05 s and the average turn around time was 34.80 s. The next approach was to implement ZF-SIC to provide channel equalization and interference cancellation in received signal and as such ensuring that the signal received by each user is coordinated and free from interference. This was measured in terms of bit error rate (BER) performance, which showed that at SNR of 25 dB, value of 0.000454 was achieved better than 0.000827 with conventional ZF. Thus, by reducing the error in received signal, the quality of received signal by users is improved, which is considered in this work as improve in QoS. In order to validate the effectiveness of the implemented round robin and ZF-SIC techniques to improve QoS satisfaction, comparison was done with FCFS scheduling algorithm and conventional ZF scheme. The performance comparison simulations conducted revealed that the proposed system with round robin scheduling algorithm outperformed the system with FCFS in terms of waiting time and turn around time. Similarly, compared to ZF alone, the addition of SIC resulted in improve BER due to cancellation of interference. Therefore, the implementation of ZF-SIC improves the performance of the system as the algorithm compares upcoming symbol or the next signal with previous received signal or symbol to eliminate any interference and thereby reducing the chances of error.

Keywords: Channel allocation, scheduling algorithm, wireless communication, zero-forcing technique

1. Introduction

The reason for wireless communication is to send data between devices via wireless physical medium called channel. Hence, communications are established by sending data as electromagnetic radio waves travelling via the environment (such as air, building, trees, and others) between the devices (Björnson and Jorswieck, 2012). The emitted or transmitted signal is distorted by the wireless channel, which introduces interference from other emitted radio signals in the same frequency band or spectrum including addition to thermal background noise. The frequency spectrum is global resource employed in several areas of radio communication such as mobile networks, radio and television broadcasting, satellite services, and military uses (Björnson and Jorswieck, 2012). This results in it being crowded and its licenses very expensive. Thus, it is expected to design wireless communication systems in such a way that the assigned frequency resources is used efficiently as possible. This is necessary considering the increase in the growth of wireless communication system has resulted in huge consumption of network resources such that it becomes wisely to divide and optimize available resources.

The main core of wireless communications is the cell hence the geographical allocation is very crucial in the provision of suitable network coverage. Users demand for wireless communication comes with different needs from one geographical area to another, for instance, demand of users in rural areas is different from that of those in urban areas. Inside the cell is located an antenna, which is the strength of wireless system and serves as critical infrastructure for propagating frequency through cell.

Resource allocation is necessary to avoid wasting of limited resources such as in the assignment of spectrum resources (Huang et al., 2018). It enables spectrum resources to be assigned in device to device (D2D) communication with reduced interference and guaranteed quality of service (QoS) (Bostov et al., 2015; Huang et al., 2014). Resource allocation is a potential means of addressing challenges in D2D communications essential to 5G standards (Jiang et al., 2016). The spectrum efficiency as well as interference mitigation can achieved using a sophisticated resource allocation technique.

As result of the exponential growth in number of connected users' equipment, a rapid increase in data traffic and demand for higher data rate has resulted in wireless networks such as Long Term Evaluation (LTE) to experience enormous challenge in handling of huge data amount, especially in environments that are most crowded and at edges of cell. These challenges are associated with limited available spectrum and capacity bound of network. One approach to address these challenges is by increasing base stations (BSs). However, deploying more BSs increases system complexity and cost. Another possible solution is to use smaller cells, which allows for increasing frequency reuse but performance in terms of efficiency, peak data rate, and cell-edge data rate is limited as a result of inter-cell interference. This performance variation in wireless network and consumption of resources is regarded as it weakness. In this work, a scheduling algorithm and zero-force (ZF) (coordination) schemes is proposed for resource allocation and coordination in wireless communication network.

2 Empirical review of related literature

Huang et al. (2018) examined the problem of resource allocation considering a scenario whereby common resources of multiple cells are utilized by device to device (D2D) communications fundamental to 5G network and the transmission parameter (information) by a player is not known to others. The study developed a novel game theoretic technique to address the problem. Initially, a static game model was presented and then extended to an iterative one. A resource allocation algorithm was developed based on the extended game model in accordance with the communications among base stations (BSs) and devices. The mechanism of the developed resource allocation algorithm was analysed to show its optimality and with sufficient condition derived for its stability. Simulation results revealed that under incomplete information condition, utility, sum rate, and sum rate gain of each player was outperformed that under complete information condition.

Guzmán et al. (2020) investigated the performance of various resource allocation techniques that are appropriate for multi-cell cooperative transmission in optical wireless cellular networks requiring illumination. The first approach used in the study was to derive procedure to keeping the constant spatial distribution of signal to interference plus noise ratio (SINR) in each multi-cell environment sector should there be non-cooperative and cooperative transmission. The next approach was to identify potential resource allocation structures for both non-cooperative and cooperative transmission modes for different illumination (light emitting diode, LED) types and available orthogonal resources. Analysis of the data rate gain of the multi-cell resource allocation was carried out, even as the limitations of illumination were being verified. The results of the study revealed that suitable design of cooperative transmission structures would be vital in the provision of reliable wireless network in the deployment of very dense visible light communication.

Oh et al. (2014) developed a resource allocation technique for device to device communications in multi-cell environment. The resource allocation scheme addressed the problem of inter-cell interference by allocating pre-assigned resource group and shares the information with neighbouring cells. Simulation results showed that the average signal to interference plus noise ratio (SINR) of the wireless mobile uplink and device to device communications link were mostly higher than 10 dB with the application of the developed scheme. Also, with the non-coordinated inter-cell resource allocation technique provided average SINR of the device to device communication link decreased by 0 dB. The study revealed that the developed scheme could enhance the throughput of the cell by almost 8% compared with non-coordinated inter-cell resource allocation scheme.

Debnath et al. (2021) attempted to solve the recurrent problem related to user association and resource allocation together with the optimal use of base station (BS) in multiple radio access technology (Multi-RAT)-aided heterogeneous network (Het-Net). Debnath et al. stated that the task to ensure that each user's minimum require data rate is challenging taking into consideration real time scenarios and optimal allocation of resources in Het-Net. A hybrid memory-based dragonfly algorithm with differential evolution (DADE) was implemented to solve the problem. Simulations were extensively performed to obtain the optimal network utility considering non-uniform distribution of user and adjusting their respective set and pact of associated parameters. The study revealed that the developed scheme improved network utility in terms of utilization of radio resource and energy consumption with user demands satisfied.

Trabelsi et al. (2017) stated that homogeneous cellular networks have been facing limitations when handling traffic as the demand for higher data rates increases exponentially, and that these constraints are associated with available spectrum and capacity of network. The key solution to improve spectral efficiency for each unit area and to address coverage imbalances was said to be HetNets, which consists of Macro cells (MCs) and Small cells (SCs). However, intelligent User Association (UA) is required to carry out load balancing and to support some SCs attraction against MCs in order to solve the large imbalance in transmit power between SCs and MCs. Also, because the same frequency sub-bands are used LTE networks, UEs could face strong inter-cell interference (ICI), especially at edge of cell. In order to solve these problems, the authors proposed generic technique for optimizing UA and resource allocation in LTE networks. The scheme was based on game theory, such that it allowed the computation of Cell Individual Offset (CIO) and a guide of power transmission for each cell over frequency and time domain. Results obtained from simulation depicted significant gains in average throughput including cell edge user throughput of 40% and 55% gains, and with significant energy efficiency improvement.

Mathonsi et al. (2020) maintained that several challenges such as inefficient allocation and management of resources in Heterogeneous wireless networks (HWNs) are still present regarding the use of modern cellular wireless communication networks for example, wireless local area network (WLAN), LTE, and 5G. The authors highlighted the cause of the challenges to include the allocation of available resources by many users, random distribution of wireless channels, wireless spectral resources scarcity, and dynamic characteristics of generated traffic. However, with previous resource allocation techniques implemented in HWNs, the authors argued that these schemes did not consider class of traffic rather focused on resource allocation and management, which significantly increase end-to-end delay and packet loss and as such resulted in poor user quality of service (QoS) and network throughput. Thus, they developed an enhanced resource allocation (ERA) technique to address the identified limitation. Simulation was conducted for performance comparison of ERA with joint power bandwidth allocation (JPBA) algorithm and dynamic bandwidth allocation (DBA) algorithm. Result on average showed that ERA provided bandwidth allocation of 98.2%, end-to-end delay of 0.75 s, packet loss of 1.1%, and throughput performance of 98.9% at a time period of 100 s. Whereas JPBA and DBA algorithms yielded 82% and 79% bandwidth allocation, 1.6 s and 2.2 s end-to-end delays, 15% and 19% packet loss, and 85% and 81% throughput performance respectively.

Yang et al. (2020) studied wireless communication network with distributed reconfigurable intelligent surfaces (RISs) based on resource allocation problem. In the network, wireless users were served by several spatially distributed RISs and the maximization of the network energy efficiency was achieved by dynamically controlling the on-off status of each RIS including maximizing the RISs reflection coefficient matrix. This was considered as a joint optimization problem involving transmit power and control of RIS; with the objective to maximize the energy efficiency under reduce users' constraints. An alternating algorithm was proposed to iteratively solve two sub-problems. Successive convex approximation method was used to solve the phase optimization sub-problem while dual method was used to solve the RIS on-off optimization sub-problem. Results of simulations revealed that the scheme provided improved gains in terms of energy efficiency compare to conventional RIS and amplify-and-forward relay scheme respectively.

Nazir et al. (2021) stated that modern wireless methods are essential to aid the various higher-speed data communication facilities of subscribers such as cloud-based video streaming. The use of efficient resource allocation technique for transmitters and receivers was regarded as one of the methods to achieve higher data rate in wireless communication. The authors argued that power and resource allocation are still the main problem in wireless communication as a result of the lack of resources by optimizing the number of users and services. Therefore, Nazir et al. discussed various algorithms and techniques employed to improve resource allocation in wireless communication such as power-efficient resource allocation algorithm, NOMA, SCMA, device-to-device communication, real-time scheduling algorithm, OFDMA, power and resource distribution in 5G, harmony search algorithm, and others.

Nguyen et al. (2014) considered the inevitability of energy efficiency in wireless cellular networks, and therefore attempts to improve the number of bits transmitted to users per unit energy consumption in downlink OFDMA cellular networks with coordinated base stations (BSs). Due to the fact that the channel qualities of users are shared by each BS with others and mutually choose the set of co-channel users together with transmit power allocated to maximize the energy efficiency of the system subject to each BS transmit power ceiling, a nonlinear fractional optimization problem was formulated using nonlinear fractional programming. This allows two iterative algorithms that achieve virtually the same maximum energy efficiency. Numerical results revealed that convergence and advantage of the two algorithms.

Awad et al., (2019) explained that non-orthogonal multiple access (NOMA) as one of the most potential multiple access techniques that is projected to improve spectral efficiency in 5G standards. An integration of joint-transmission coordinated multiple-point transmission (JT-CoMP) with NOMA that is, a JT-CoMP-NOMA network was considered to improve data rates of cell-edge users that tend to suffer severe inter-cell interference. Hence, a centralized resource allocation problem for JT-CoMP-NOMA was proposed to carry out joint subcarrier assignment and power allocation in multi-cell downlink NOMA networks. The study served as a yardstick to sum rate performance evaluation of network for JT-CoMP-NOMA systems resource allocation.

Akhter et al. (2019) discussed the deployment of femtocell in LTE network. Femtocells were described as the basic cell of a macrocellthat requires no intervention of frequency planning to eliminate traffic. Hence, the blocking probability expression for both macrocell and femtocell in terms of network traffic parameters was derived using Markov chain. Considering low dense femtocellular network for LTE, a combination of mobility and probability tree was used to develop an analytical model to derive the expression of forced termination (FT). The study designed two different trees characterised as a newly originating call that starts its session in a femtocell and another that originate from in a macro cell. A real-life network probability of FT was determined by integrating the developed traffic model with the link parameters of small scale fading wireless network with MIMO capacity. The study also presented a new state transition chain including its technique for LTE traffic of variable bandwidth (BW).

Kuboye (2018) carried out performance analysis of scheduling algorithms for 4G Long Term Evolution (LTE). It analyzed the effect of resource scheduling techniques on LTE (4G) and WCDMA (3G) networks' performance. Full illustration of LTE system was provided including the different scheduling schemes. Simulation was conducted in using Simulink simulator in MATLAB to evaluate the performance of 3G WCDMA and 4G LTE networks. It considered average system throughput, packet delay, latency and allocation of fairness as the performance metrics. The scheduling algorithms employed were Round Robin, Best Channel Quality Indicator (CQI) and Proportional fair Packet. The simulation results indicated that 4G LTE outperformed 3G WCDMA in all the scheduling algorithms applied.

Cheikh et al. (2013) investigated handover procedure for the two-tier macro/femto LTE networks. An optimized handover algorithm with an efficient call admission control was proposed and described. The proposed scheme was largely designed to minimize the number of unnecessary handovers and to maintain the communication quality during the handover. The choice of the femtocell target takes into account the direction of the mobile user, its velocity and the quality of the signal. Performance evaluation results showed that the algorithm minimized both the number of hand-in and the handover drop rate. Besides, the signal quality in terms of signal to interference noise ratio (SINR) after the hand-in is maintained higher than a fixed threshold, which maximizes the sojourn time of the mobile user within the selected femtocell.

Rastogi and Kumar (2013) considered the problem of resource allocation for proportional fairness (PF) of long term received rates of data users and quality of service for real time sessions in OFDMA-Femtocells based system. Available sub-channels and subcarriers were allocated by the network to individual users based on long term average received rates; quality of service (QoS) based rate constraints and channel conditions. Three Quality of Service (QoS) parameters namely packet loss rate (PLR), fairness and sum throughput were used as performance metrics in the study. The PF scheme generalizes the basic idea of proportional fair scheduling (PFS) algorithm and considers not only the network traffic, but also the user throughput and packet delay before making the final decision. Compared with the traditional Modified Largest Weighted Delay First (MLWDF) and Greedy scheduling, the proposed PF scheduler algorithm can obtain larger system throughput for Constant bit data and lower average packet delay with approximately the same user fairness and MLWDF and Greedy will show better results for the variable bit rate (VBR). Simulation results verify that the PF, MLWDF and Greedy schemes are able to make a better tradeoff between system throughput and user fairness and would minimize the PLR in comparison to each other.

Karthik and Kumaran (2013) stated that resource allocation is an important issue in Orthogonal Frequency Division Multiple Access (OFDMA) systems. For multicell systems, the interference across different cells makes the optimization of resource allocation difficult. While Inter-Cell Interference (ICI) for the downlink of multi-cell systems in general and orthogonal frequency division multiple access networks, the uplink has received less attention. Inter-Cell Interference Coordination (ICIC) schemes can be viewed as a scheduling strategy used to limit the inter-cell interference such that cell-edge users in different cells preferably are scheduled on complementary parts of the spectrum when needed. The common theme of ICIC avoidance schemes is to apply restrictions to the usage of downlink resources such time/frequency and/or transmit power resources. Such coordination of restrictions will provide an opportunity to limit the interference generation in the area of the cellular network. Accordingly, Signal to Interference and Noise Ratio (SINR) can be improved at the receivers in the coverage area which will provide capability for increased (cell-edge) data-rates over the coverage area or increased coverage for given data-rates.

3. Methodology

This section begins with the description of the proposed macro-femtocell network. The situation in LTE with integrating macro-femto is different from that of micro-macro cellular system under a macrocell, which continuously forms coverage. This is because continuous coverage is not formed by femtocells under a microcell (Akhter et al., 2019). This work therefore proposed multi-cell coordinated wireless network, which has one macrocell and two fentocellswith 10 users (maximum) per femtocell. The block diagram of the existing system with single femtocell is shown in Fig. 1, while the block diagram for the proposed system is shown in Fig. 2. The proposed system model or architecture is shown in Fig. 3.

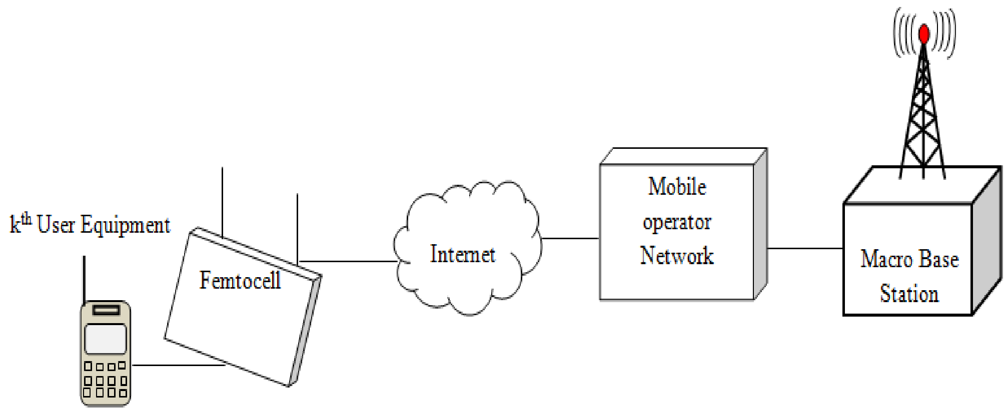


Fig. 1 – Block diagram of single femtocell under a macro cell

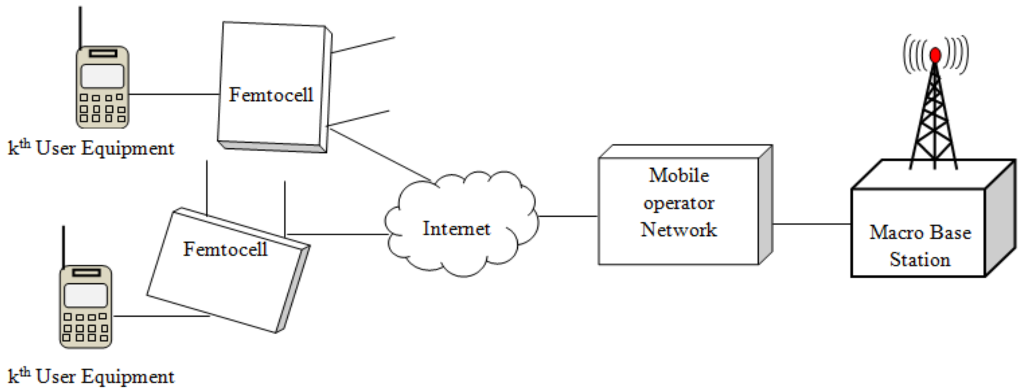


Fig. 2 – Block diagram of two femtocells under a macro cell

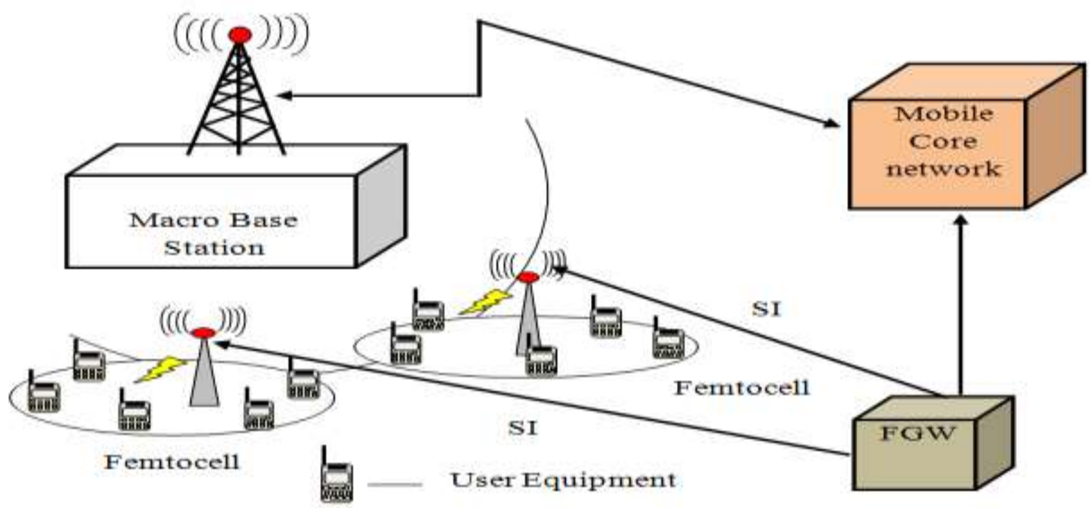


Fig. 3 – Proposed System architecture

The system architecture shown in Fig. 1 is taken in this work as femtocellular network deployed in a low dense manner for LTE to cover an indoor area. Channels between femto user equipments (FUEs) and their femto access points (FAPs) usually experience good propagation conditions in such environment, but highly attenuated signals are received from outdoor macrocells (Abdelnasser et al., 2014). The following generalize assumptions have been adoptedfor the proposed system as with similar study on femtocell network by Abdelnasser et al. (2014):

i. All UEs that is FUEs and macro UEs (MUEs) exist indoor, but the MUEs are served by outdoor macro base station (MBS).

ii. The same channel states of the sub-carriers hold within a sub-channel of bandwidth.

iii. Since a very small distance exists between an FUE and its serving FAP, the channel gain between a femtocell and an FUE that is served by another femtocell can be approximated the channel gain between the two femtocells (Ning et al., 2012).

iv. Downlink communication is assumed for the system.

Cell-specific reference signals and unique cell-identities (cell-ids) are used by femtocell networks. Hence, the capability to receive cell-specific reference signals and identify interference source is possessed by every FUE (Abdelnasser et al., 2014). Also, as shown in Figure 3.1, the connection of femtocells to the mobile core network is achieved using digital subcarrier line or cable television (that is user's broadband connection) via the Femto Gateway (FGW) or Home eNB Gateway (Third Generation Partnership Project, 2013). The SI interface is the interface between femtocell and an FGW.

3.1 Mathematical modeling

The objective to formulating a mathematical model is to enable analysis and at the same time is accurate enough to give valuable insights.Two scenarios are considered for the downlink communication. The first is that of a single-cell where *N* base station antennas communicate with K_r user equipments. Mathematically, for kth user mobile station MS_k with a single effective antenna, the received signal is given by Björnson&Jorswieck 92012):

$$y_k = h_k^H x + n_k \quad (1)$$

where h_k^H is the channel for each user, x is the transmitted signal, and n_k is the additive noise and interference from surrounding systems for each user.

Now, for a multi-cell downlink scenario, the channel from base stations (BSs) to MS_k is given by:

$$h_k = \left[h_{1k}^T \quad h_{2k}^T \quad \cdots \quad h_{jk}^T\right]^T, \; j = 1, 2, 3 \cdots K_t \quad (2)$$

where h_{jk} is the channel from *jth* BS. Since only certain channel elements of h_k that will carry data and/or non-negligible interference based on dynamic cooperation clusters (DCC), these can selected by diagonal matrices D_k and C_k (Björnson&Jorswieck, 2012). Thus, extending Eq. (1) to multi-cell scenario, received signal at mobile station or user equipment MS_k is given by Björnson&Jorswieck (2012):

$$y_k = h_k^H C_k \sum_{i=1}^{K_r} D_i x_i + n_k \quad (3)$$

where C_k and D_k are the diagonal matrices that carry non-negligible interference (or coordination from BS_k) and data (or data from BS_k) respectively. $h_k^H C_k$ is the channel that carry non-negligible interference, x_i is the ith transmitted signal (for i = 1, 2, 3 ….. k_r).

3.1.1 Multi-Cell Performance Measure

The performance of a multi-cell system can be measured in terms of each user experiences and system utility, which is determined from the aggregate achievable user performances. In this work, the performance measure considered is based on user experiences. The performance of a user can be expressed in terms of signal to interference noise ratio (SINR). Thus, for kth user mobile station (or equipment), MS_k the corresponding signal to SINR is given by Björnson & Jorswieck (2012):

$$\mathrm{SINR}_k(S_1,\cdots,S_{K_r}) = \frac{h_k^H C_k D_k S_k D_k^H C_k^H h_k}{\sigma_k^2 + h_k^H C_k \left(\sum_{i\neq k} D_i S_i D_i^H\right) C_k^H h_k}$$

$$= \frac{h_k^H D_k S_k D_k^H h_k}{\sigma_k^2 + h_k^H C_k \left(\sum_{i\in I_k} D_i S_i D_i^H\right) C_k^H h_k} \quad (4)$$

where the second expression follows from $C_k D_k = D_k$ and $C_k D_i \neq 0$ for users i in Björnson&Jorswieck (2012):

$$I_k = \bigcup_{\{j\in J: k\in C_j\}} D \setminus \{k\} \quad (5)$$

Equation (5) is a set of co-users that are being served by the same BSs that coordinate interference toward MS_k. where S_k is the signal correlation matrix for user k, (where $k = 1, 2, ..., k_r$).

3.1.1 Resource allocation

The resource allocation in this work adopts the multi-objective optimization problems (MOPs). When it is required to simultaneously maximize multi-users performance, the channel gain regions show the innate variance and tradeoffs that become visible (Björnson&Jorswieck, 2012). Thus without loss of generality, the resource allocation problem is defined according to MOP given by Ghorbanzadedeh and Abdelhadi (2017):

$$\underset{S_1 \succeq 0_N,.....,S_{K_r} \succeq 0_N}{\text{maximize}} \left\{ g1(\mathrm{SINR}_1),......gK_r(\mathrm{SINR}_{K_r}) \right\}$$
$$\text{subject to} \sum_{k=1}^{K_r} \mathrm{tr}(Q_{lk} S_k) \leq ql \quad \forall l \quad (6)$$

where gk performance function of user k, ql is total limit of the lth power constraint, S_k is the signal correlation matrix for user k, $\forall l$ means that the statement holds for all l, tr is trace of a square matrix.

The interpretation of MOP can be said to mean searching for a transmit strategy $S_1,......S_{K_r}$ that meets the power constraints and maximizes all users' performance $gk(\mathrm{SINR}_k)$ (Branke et al., 2008).

3.2 Round Robin scheduler

The Round Robin (RR) scheduler is a scheduling algorithm that allocates resource blocks (RBs) to users regardless of the conditions of the channel (Ghosh and Ratasuk, 2011). The RR scheduling algorithm starts with the first user and allocates resource the first RB to it. Then moves to the second user and allocates RB to it. This process is continued until no RBs are left or until no user is left. In any case whereby RBs are more than the number of users, the process starts over and allocates $(K+1)$ th RB to user 1and so on. On the other hand, when the number of users is more than the number of RBs, in the next time slot, allocation start with a user that has not yet been scheduled (example user = RB + 1). The flowchart of RR scheduling algorithm is shown in Fig. 4. The RR scheduler will be implemented using the MATLAB code.

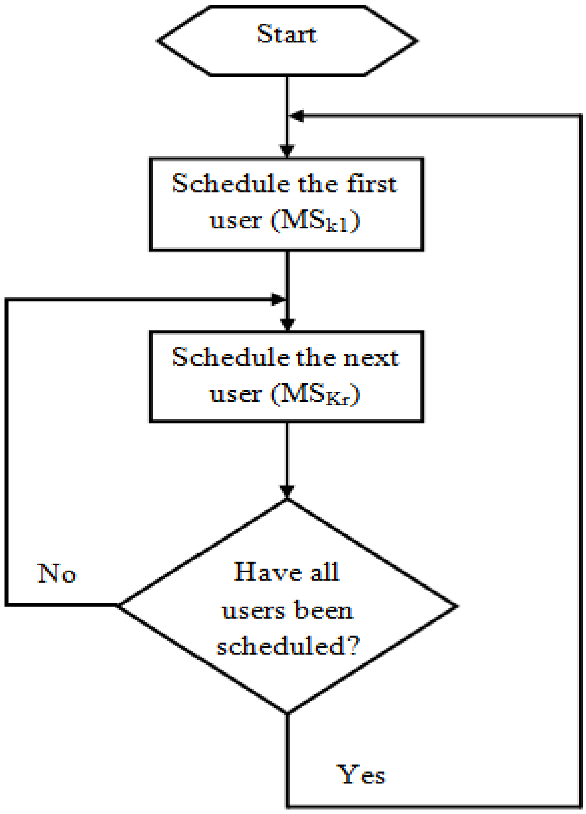


Fig. 4 – Round Robin scheduling algorithm

3.3 Coordination technique

The coordination for the proposed multi-cell system will be achieved using the zero forcing equalization with successive interference cancellation (ZF-SIC). Channel response is inverted in zero forcing equalization (ZFE) such that by applying the inverse of the channel at the receiver, ZFE restores the transmitted signal and remove inter-symbol interference. Mathematically derivation of ZFE:

Given that y_{k1} and y_{k2} are two signals received by two kth mobile stations (users) 1 and 2 respectively with the resulting channel gain given by: $h_{1,1}, h_{1,2}, h_{2,1},$ and $h_{2,2}$ showing the relation between transmit and receive antenna as shown in Fig. 5.

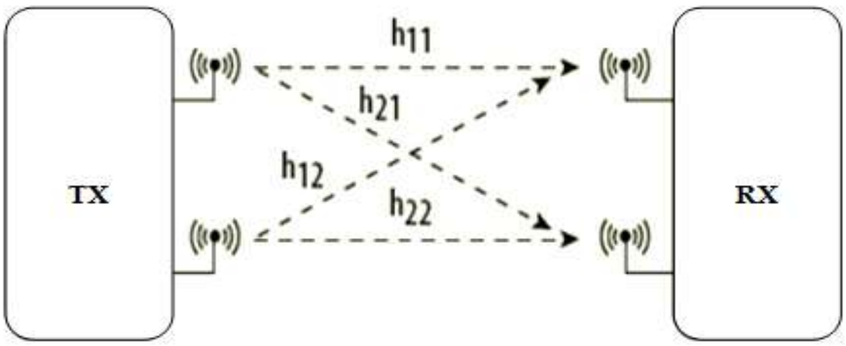


Fig. 5 – Block diagram of MIMO wireless communication

The transmitted signals from first and second antenna are x_1 and x_2 respectively and assuming the noise on receiving antennas 1 and 2 are n_1 and n_2 then the received signals are:

$$y_{k1} = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = \begin{bmatrix} h_{1,1} & h_{1,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1 \tag{7}$$

$$y_{k2} = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = \begin{bmatrix} h_{2,1} & h_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2 \quad (8)$$

The resulting channel matrix from Equations (7) and (8) is given by:

$$\begin{bmatrix} y_{k1} \\ y_{k2} \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{1,1} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (9)$$

Equation (9) can be expressed in a simplified form similar to Eq. (1) as:

$$Y = Hx + n \quad (10)$$

where Y is the received signal matrix, H is the channel gain matrix, x and n is the noise matrix. Now, to solve for *x*, let there be matrix Z such that ZH = 1, that is, Z should be the inverse channel matrix H given by (Kumar et al., 2016):

$$Z = \left(H^H H\right)^{-1} H^H \quad (11)$$

The matrix in Eq. (10) is called pseudo inverse for a general m x n matrix. Therefore:

$$H^H H = \begin{bmatrix} h_{1,1}^* & h_{1,1}^* \\ h_{2,1}^* & h_{2,2}^* \end{bmatrix} \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \quad (12)$$

Next, is to determine the zero forcing (ZF) successive interference cancellation (ZF-SIC). Considering the ZFE described earlier, an estimate of the two transmitted symbols (signal) x_1 and x_2 can be obtained by the receiver given:

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \end{bmatrix} = \left(H^H H\right)^{-1} H^H \begin{bmatrix} y_{k1} \\ y_{k2} \end{bmatrix} \quad (13)$$

Let one of the estimated symbols say $\hat{x}_2$ be taken and its effect subtracted from the received vector y_{k1} and y_{k2}, then the resulting received signal becomes (Kumar et al., 2016):

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} y_{k1} - h_{1,2}\hat{x}_2 \\ y_{k2} - h_{2,2}\hat{x}_2 \end{bmatrix} = \begin{bmatrix} h_{1,1}x_1 + n_1 \\ h_{2,1}x_1 + n_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} \\ h_{2,1} \end{bmatrix} x_1 + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (14)$$

Equation (14) can be further expressed as:

$$r = hx_1 + n \quad (15)$$

The information can be optimally combined from multiple copies of received symbols in receive diversity scenarios by means of maximal ratio combining. Thus, the equalized symbol is given by(Kumar et al., 2016):

$$\hat{x}_1 = \frac{h^H r}{h^H h} \quad (16)$$

where $h^H h = \sum_{i=1}^{N} |h_i|^2$ and it is sum of the channel powers across all receive antennas, and with this, ZF-SIC has been presented (Haider & Thabit, 2015).

3.4 Simulation parameters and design flowchart

The parameters used for the graphical and numerical analysis that will be used to evaluate the performance of the proposed system using Round Robin for resources allocation and ZF-SIC for coordination in the multi-cell is presented in Table 1.

Table 1: Simulation Parameters (Adam et al., 2017)

Parameters	Values
No of users	≤ 20
Quantum time	2
Burst time/call duration	[2 4 3 1 3 7 2 1 7 8 9 1 6 9 5 6 4 3 6 8]
No. of bits or symbols	10^6
Eb/N0	0:25

No. of transmit antenna	2
No. of receive antenna	2
Bit period	1s
Modulation scheme	BPSK

4. Simulation Results

The essence of the simulations carried out in this work is to evaluate the performance of the proposed system. MATLAB codes were developed to conduct the analysis. The evaluation of the system performance was considered in terms of utility function, implementation of scheduling algorithm and coordination in the multi-cell.

Simulation result is presented in terms of logarithmic utility function employed for elastic generated by applications that are delay-tolerant. The result indicates the degree to which the required quality of service (QoS) for application traffic is achieved, which is defined by the relation between the QoS and the throughput (rate of achieving 100% user satisfaction) as shown in Fig. 6.

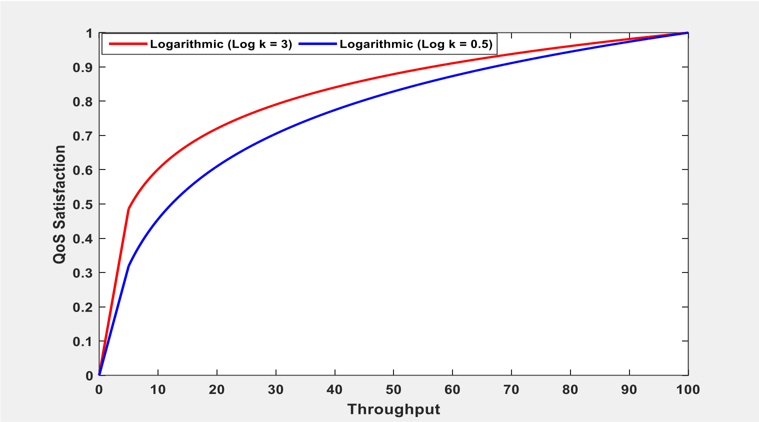


Fig. 6 – Application utilities

Figure 6 shows the QoS in terms of two logarithmic functions with maximum rate of 100 and different rate of increase (k = 3, 0.5), which are typical parameters for delay tolerant applications. The figure compares the QoS satisfaction and the throughput for different rate of increase in the cellular network. The QoS satisfaction curve indicates the link utilization of the system during transmission of data. It can be seen from the simulations curves that when the rate of packet arrival increases, the system aids the packet to minimize the cache (or accumulation) pressure in a way of increasing the outgoing traffic or volume. Thus, from Fig. 6, it can be seen that with k = 3, higher QoS satisfaction (or utility value) was achieved.

- Implementation of Round Robin algorithm:

The round robin scheduling algorithm is implemented here. The algorithm is designed to spread resource blocks through all the users in the network. The performance of the round robin algorithm was examined via simulation in MATLAB for the proposed system. The results obtained from the simulation analysis are shown in Fig. 7 to Fig. 10 or different number of users in the system evaluated in terms of waiting time and turn-around time. Table 2 to Table 5 is the numerical analysis assuming number of users = 5, 10, 15, and 20 for a given simulation time. It is important to define the following terms as regards scheduling:

i. Burst time: It is the time required by the process for its execution (defined in the simulation).

ii. Waiting time: this is the time spent by a process waiting in the ready queue.

iii. Turn around time: this is the time interval measured from the time of a process submission to the time the process is completed. That is the difference between when the user completes its task and when it is scheduled

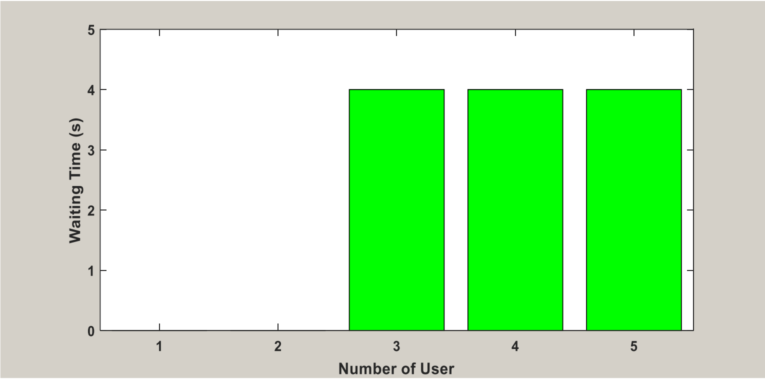


Fig. 7a – Waiting time for five users

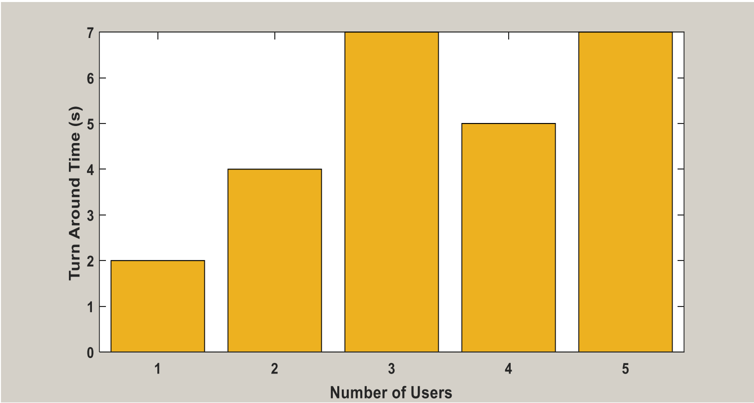


Fig. 7b – Turn around time for five users

Table 2 Performance of round robin scheduler for N = 5

Number of user	Burst time (s)	Waiting time (s)	Turn around time (s)
UE1	2	0	2
UE2	4	0	4
UE3	3	4	7
UE4	1	4	5
UE5	3	4	7

Figures 7 and bare the simulation plots of waiting time and turn around time when the number of users is 5. The numerical analysis of the simulation is shown in Table 2. It can be seen that the scheduled waiting times for UE1 and UE2 are zero whereas UE3, UE4 and UE5 have equal waiting time of 4 s respectively. Thus, the resulting turn around times for UE3, UE4 and UE5 are higher than that of UE1 and UE2. The simulated average waiting time and turn around time in this case is 2.40 s and 5.00 s respectively.

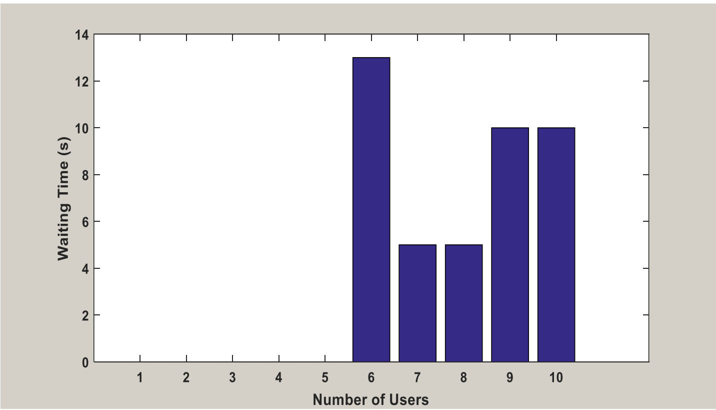


Fig. 8a – Waiting time for 10 users

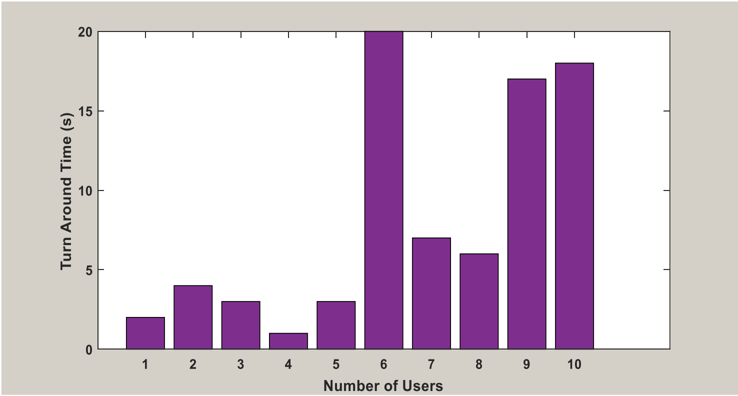


Fig. 8b – Turn around time for 10 users

Table 3 Performance of round robin scheduler for N = 10

Number of user	Burst time (s)	Waiting time (s)	Turn around time (s)
UE1	2	0	2
UE2	4	0	4
UE3	3	0	3
UE4	1	0	1
UE5	3	0	3
UE6	7	13	20
UE7	2	5	7
UE8	1	5	6
UE9	7	10	17
UE10	8	10	18

The simulation plots of waiting time and turn around time for 10 users are shown in Fig. 8a and b. Table 3 is the numerical analysis of the simulation plots. From the table, it can be seen that the scheduled waiting times for UE1, UE2, UE3, UE4 and UE5 are zero whereas UE6, UE7 UE8, UE9 and UE10 have waiting time of 13, 5, 5, 10, and10 s respectively. In terms of the turn around times, UE6 has the highest turn around time followed by UE10 and UE9. The average waiting time was 4.30 s, while the average turn around time was 8.10 s.

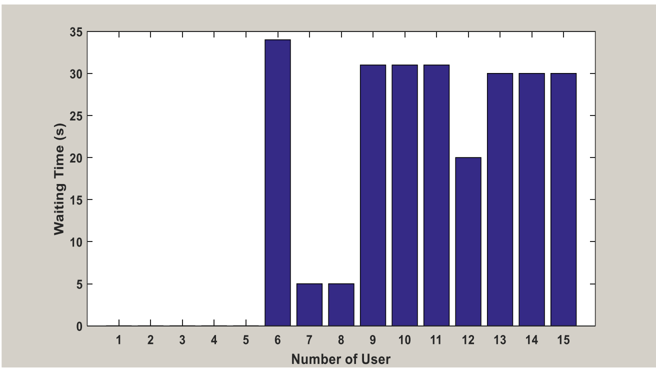
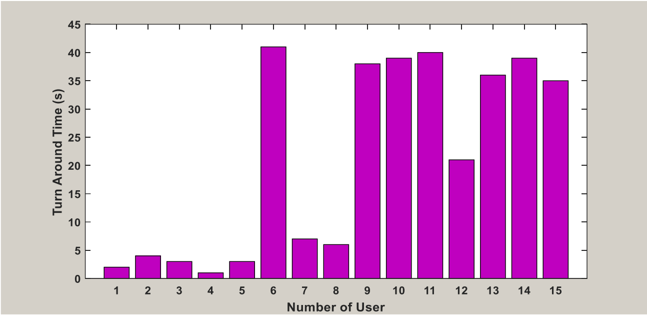


Fig. 9a – Waiting time for 15 users



Fig, 9b – Turn around time for 15 users

Table 4 Performance of round robin scheduler for N = 15

Number of user	Burst time (s)	Waiting time (s)	Turn around time (s)
UE1	2	0	2
UE2	4	0	4
UE3	3	0	3
UE4	1	0	1
UE5	3	0	3
UE6	7	34	41
UE7	2	5	7
UE8	1	5	6
UE9	7	31	38
UE10	8	31	39
UE11	9	31	40
UE12	1	20	21
UE13	6	30	36
UE14	9	30	39
UE15	5	30	35

The results of the simulation conducted in terms of waiting time and turn around time when 15 users were on the network are shown in Fig. 9. It can be seen from Table 4 that users UE1 to UE5 have zero waiting time, UE7 and UE8 have 5.0 s waiting time, UE9 to UE11 have 31 s waiting time, UE13 to UE15 have 30 s waiting time, UE6 has 34 s waiting time, and UE12 has 20 s waiting time respectively. Regarding the turn around time, the UE6 has the highest value, which is 41 s, followed by UE11 with value of 40 s. The simulation revealed an average waiting time of 30.50 s and average turn around time 34.80 s respectively.

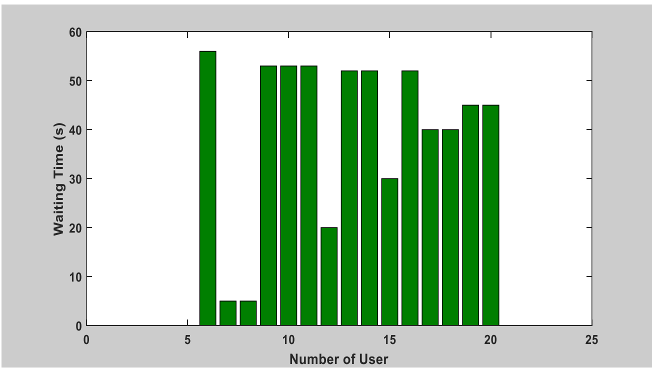


Fig. 10a – Waiting time for 20 users

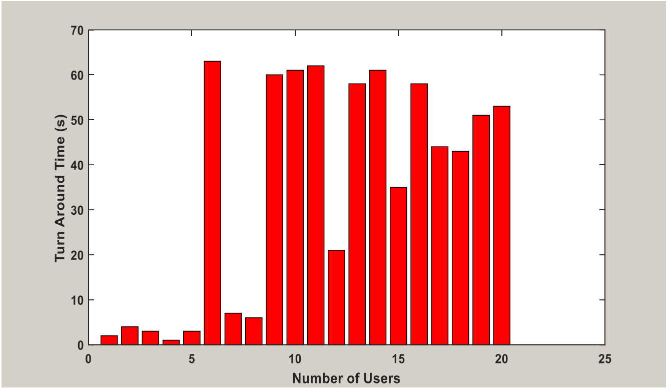


Fig. 10b – Turn around time for 20 users

Table 5 Performance of round robin scheduler for N = 20

Number of user	Burst time (s)	Waiting time (s)	Turn around time (s)
UE1	2	0	2
UE2	4	0	4
UE3	3	0	3
UE4	1	0	1
UE5	3	0	3
UE6	7	56	63
UE7	2	5	7
UE8	1	5	6
UE9	7	53	60
UE10	8	53	61
UE11	9	53	62
UE12	1	20	21
UE13	6	52	58
UE14	9	52	61
UE15	5	30	35
UE16	6	52	58
UE17	4	40	44
UE18	3	40	43
UE19	6	45	51
UE20	8	45	53

The simulation of analysis of round robin scheduling algorithm for 20 users is shown in terms of waiting time and turn around time in Figures 4.4a-b. The numerical performance evaluation of the simulation plots is shown in Table 4.4. It can be seen from the table that UE 6 has the highest waiting time and turn around time respectively. The average waiting time was 30.05 s and average turn around time 34.80 s.

- Implementation of coordination scheme:

In this paper, the multi-cell coordination scheme is implemented in terms of zero forcing equalization with successive interference cancellation (ZF-SIC). The simulation was assumed for a multi-cell system in which communication is established between a transmitting end equipped with two antennas (in a macro-cell) and receiver side with two users each from a femto-cell considering a binary phase shift key (BPSK) digital modulation scheme in Rayleigh fading channel. The resulting simulation curve for bit error rate (BER) against signal to noise ratio in dB using the ZF-SIC is shown in Figure 4.5.

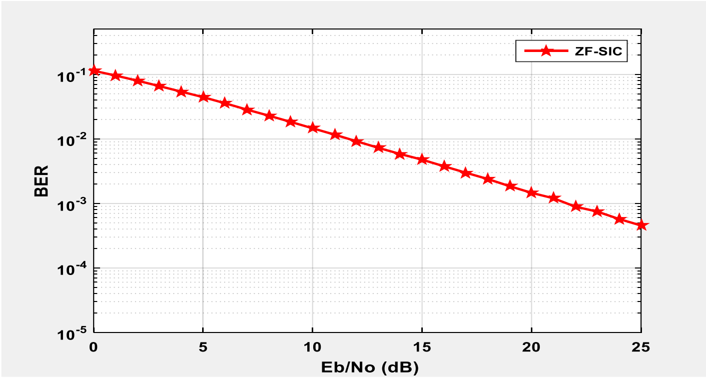


Fig. 11 – Bit error rate curve using ZF-SIC

As shown in Fig. 11, the evaluation of the BER performance of the received signal by users in the network was carried out using ZF-SIC. The achieved BER for signal to noise ratio of 25 dB is 0.000454.

- Performance Comparison

This section presents the performance analysis of the implemented scheduling scheme and coordination technique based on round robin and ZF-SIC for the proposed multi-cell network against similar algorithms such as first come first serve(FCFS) scheduling algorithm and the conventional zero forcing technique for network coordination (or harmonization). Figures 12 and 13 show the performance of round robin and FCFS in terms of waiting time and turn around time. Figure 14 the performance comparison curves of ZF-SIC and ZF equalization techniques for system coordination to ensure QoS.

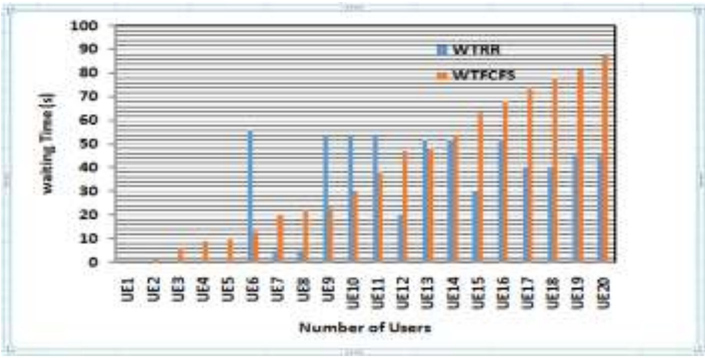


Fig. 12 – Comparison of waiting time

Figure 12 is performance evaluation of the implemented round robin scheduling algorithm together with FCFS scheme to determine which of them performs better in terms of average waiting time of the users. Looking at the figure, it can be seen that for round robin, each users randomly takes a slice time (which is usually called quanta) such that it takes another slice of time when the previous taken one finishes and waits for its turn. Hence, the reason two or more users can have the same waiting time depending on their slice time as shown in the figure. However, for FCFS, the user that came first will be served while other users wait their turns respectively. Thus, it can be seen from the simulation results that waiting time for FCFS increases in sequential other from the first user (UE1) to the last UE20. It can be seen that user (UE20) in network using FCFS will wait longer than UE20 in networking using the round robin algorithm at the same simulation time frame. Generally, the simulation analysis showed that average waiting times of 30.05 s and 38.65 s were obtained with round robin and FCFS respectively.

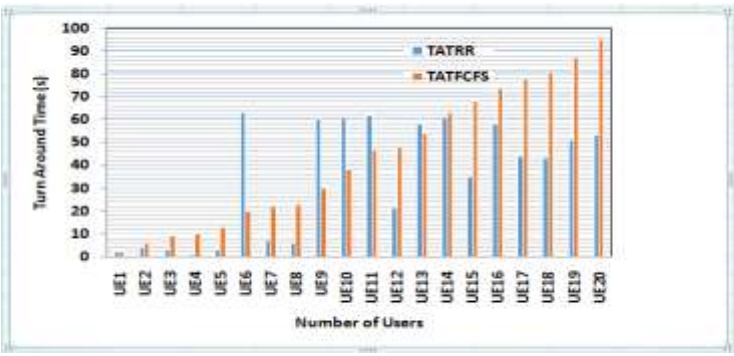


Fig. 13 – Comparison of turn around time

In Fig. 13, the performance analysis of the round robin scheduling algorithm alongside FCFS technique was carried out to determine which of the two schemes outperforms the other in terms of average turn around time of the users. It can be seen from the simulation results that turn around time for FCFS increases in sequential other from the first user (UE1) to the last UE20. It suffices to say that user (UE20) in network using FCFS will require longer time to complete its communication process than UE20 in networking using the round robin algorithm at the same simulation time frame. Generally, the simulation analysis showed that average turn around times of 34.80 s and 43.40 s were obtained with round robin and FCFS respectively.

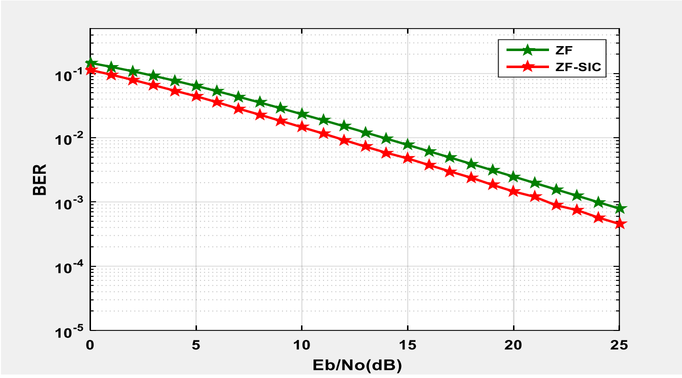


Fig. 14 – Performance comparison of ZF and ZF-SIC

Table 6 shows the numerical summary of the BER performance of the ZF and ZF-SIC schemes with signal to noise ratio changing from 0 to 25 dB.

Table 6 BER performance analysis

	BER	
Signal to Noise Ratio (Eb/No)	ZF	ZF-SIC
0	0.1464	0.1136
5	0.06418	0.0443
10	0.02327	0.01458
15	0.007723	0.004757
20	0.002481	0.001456
25	0.000827	0.000454

Figure 14 is the performance evaluation of ZF and ZF-SIC equalization techniques. It can be seen looking at Table 6 that BER of ZF-SIC was better than that of ZF. This can be attributed to the presence of signal to interference cancellation (SIC). The SIC ensures that the ZF-SIC performance is enhanced to optimize the equalization of signal in the system with minimized propagation error of the transmit data. This means that use of ZF-SIC resulted in high quality of service (QoS) achieved via improved bit error rate.

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