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Analysis of Proportional Fair Scheduling Algorithm for Long Term Evolution (LTE) Uplink

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Abstract

Scheduling is a radio resource allocation schemes for serving users by an algorithm. The amount of resource blocks that will be allocated is 50 by the 10 MHz bandwidth. The simulation scenario defined as a single cell network with several users in which located among 1-4 km. Proportional Fair algorithm will assigns more resource block to a user who has the highest rate than the average rate. This simulation result shows that SNR value implicates the data rate and modulation scheme applied. The increasing of user distance from eNodeB, will decrease SNR and data rate. Thus, the number of resource block allocated will be decreased. While as the increasing of user number, the value of system's BER are tend to constant, maximum normalized throughput are increase, and the level of fairness will tend to constant close to ideal value of 1.

Keywords*: scheduling, Proportional Fair, BER, throughput, fairness*

1. Introduction

The enhancement of LTE (Long Term Evolution) user demands efficient methods for serving a sufficient capacity and good fairness index. Scheduling methods are introduced to provide the efficiency using resource block allocation algorithm. There are several kind of algorithm to do scheduling or assign or allocate those resource blocks. Some resource blocks on certain bandwidth are allocated for active users at each channel. In the LTE uplink channel, requires Single Carrier Frequency Division Multiple Access (SC-FDMA) that users cannot be allocated on separated resource blocks because of its single carrier property. This is the main characteristic of uplink channel that differentiate with the downlink.

In this paper, an analysis of scheduling simulation will be performed in the LTE uplink channel. The scenarios are set on a single cell network with one eNodeB and some active users. The amount of users in scenarios A, B, C, and D are 4, 8, 12, and 16 respectively. The users of each scenarios are located between 1 to 4 kilometers from eNodeB. This user number variation will obtain quite significant parameter value that can be analyzed as showed in [12]. The 50 resource blocks will occupy 10 MHz bandwidth for each time slot (0.5 milliseconds). The scheduling of Proportional Fair algorithm will serve the user with better channel quality first. While the other users whose qualities are lower will have minimum scheduling or less allocation of resource blocks. The Proportional Fair algorithm was chosen because according to [3], it provides balance between fairness index and the system throughput.

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The research questions in this paper, we will see how the channel quality on Line of Sight (LOS) and Non Line of Sight (NLOS) determine the scheduling of resource blocks based on the average quality of each scenarios. The channel quality shown by the Signal to Noise Ratio (SNR) value determines the modulation used i.e. QPSK and 16QAM. While the other parameters to be analyzed are Bit Error Rate (BER), throughput, and fairness.

2. Related Researches

2.1. Scheduling Algorithm

Packet scheduler assigns the number of RB for active users. In SC-FDMA, this assignment is done on condition that the RB assigned to the user must be sequential on the frequency domain. The user's transmission power is equally distributed on each assigned RB [1].

The scheduling algorithm can be described as an algorithm that assigns the RB to user according to some parameters or metrics to obtain a good system performance under certain conditions [2]. There are some type of scheduling algorithm can be used in LTE system those have different proporties. Proportional Fair is an approach that selects user with the best channel level compared to the average channel level. This system supports fairness by prioritizing channels with higher relative quality. A Proportinonal Fair scheduling algorithm provides balance between fairness and the system throughput. It was first presented in Code-Division Multiple Access High Data Rates (CDMA-HDR) [3], but is now used in OFDMA and SC-FDMA based systems as well. Proportional Fair algorithm will choose user-i and can be defined by Equation (1):

$$user(i) = max\,\frac{rate(i)}{\acute{rate}} \quad \text{.......} \quad (1)$$

2.2 Resource Block

In a 3GPP LTE, slot structure is defined as a group of resource block (RB) that occupies 180kHz bandwidth at frequency domain and 0.5 milliseconds time slot at time domain. A RB has 12 subcarriers that each subcarriers occupy 15 kHz at frequency domain, and 7 symbols on 0.5 milliseconds at time domain (Figure 1). While 1 Transmission Time Interval (TTI) consist of two RBs, which TTI is 1 milliseconds in time domain [3]. The initial channel quality determination until scheduling process will be done per TTI. RB is a basic element for scheduling in a LTE system with various applicable scheduling methods to allocate a group of RB to serve active users. In a SC-FDMA, RBs can not be allocated separately because its single carrier property [4].

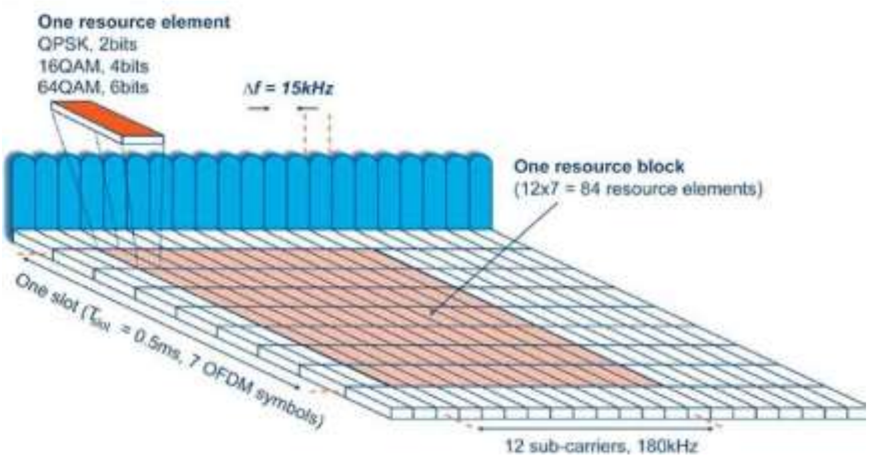

Figure 1. LTE Resource Block Model

The smallest unit in LTE scheduling is an intersection of 180kHz with 1 milliseconds TTI or can be describe as two RBs in a time domain. Scheduling control by eNodeB based on channel quality of user.

3. Scheduling Simulation

The system design is a LTE single cell network with various user number those are 4, 8, 12, and 16 that will be located in various distance with the eNodeB. The specified channel type is a Rayleigh Fading propagation channel where there is a pathloss (LOS and NLOS) caused by distance and multipath fading effect. Figure 2 shows the simple uplink communication between user and eNodeB to determine the resource allocation. SNR estimation of each user channel will be used to determine the channel condition. Then, the scheduling steps are marked by a red arrow.

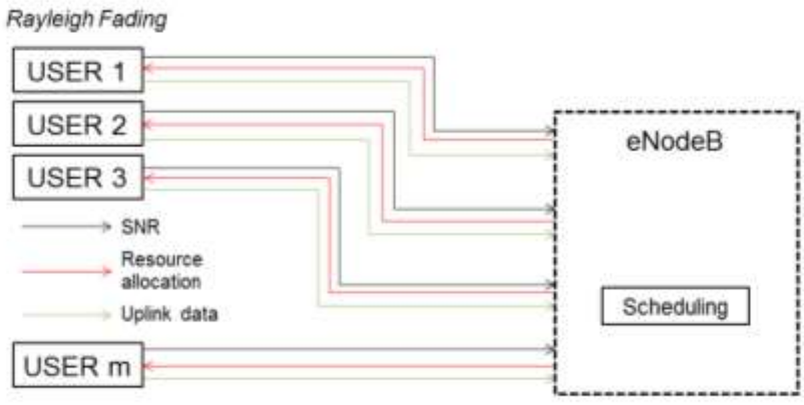

Figure 2. Uplink Communication Scheme

Among the initial parameters, the propagation losses and the SNR will be related to the type of modulation and channel capacity. SNR at some level will determine the type of modulation used where the modulation number will determine BER. While the channel capacity will be used as reference of scheduling or allocation of radio sources. While the simulation is done by the following steps:

3.1 Check the Channel Conditions

It is known in wireless celular systems that users located in different distances have different fading condition. Consequently, users that have high SNR leads to unfair scheduling amongst users [6]. The simulation starts with checking the channel conditions by calculate the SNR of each user with Equation (2) [7] and the user channel capacity with Equation (3). Channel conditions obtained from the calculation are mapped in the matrix (Figure 3) where C represents channel, m represents time, and i represents user number. This matrix contain different values of channel capacity or data rate and will be processed at allocation or scheduling for each time.

$$SNR = 10log\frac{P_r}{N_0} \quad \text{(2)}$$

SNR= signal to noise ratio (dB)
Pr = receiver power (mW)
N0 = noise power

$$C = B \times log_2(1 + SNR) \quad \text{(3)}$$

C = channel capacity
B = Bandwidth (Hz)

$$\begin{bmatrix} C_{1,1} & C_{1,2} & \cdots & C_{1,i} \\ C_{2,1} & C_{2,2} & \cdots & C_{2,i} \\ \vdots & \vdots & \vdots & \vdots \\ C_{m,1} & C_{m,2} & \cdots & C_{m,i} \end{bmatrix}$$

Figure 3. Matrix of Channel Condition

3.2 Scheduling

Scheduling based on Proportional Fair algorithm described in Figure 4 where m is a time, n is a number of resource blocks, and i is a number of user. Proportional Fair assigns the resource blocks to user by selecting the best channel level compared to the average channel level of users. User with the best channel condition will be served by more resource blocks.

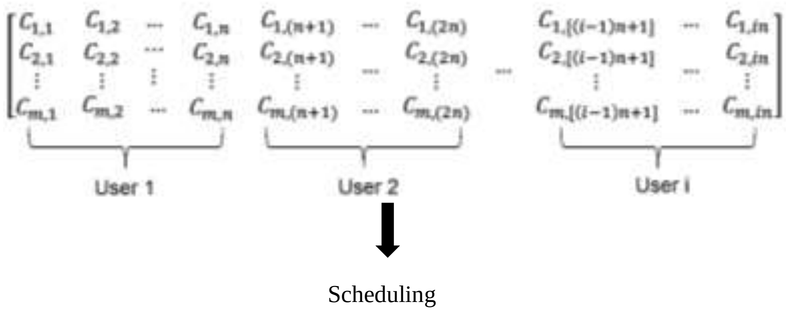

Figure 4. Scheduling Process

3.3 BER

BER is a parameter of channel quality received in a digital transmission systems [8]. The result of BER calculation is converted in a matriks form for each user then summed up for 1 TTI and divided by the number of system RB, so the average of system BER for each scenarios are obtained.

3.4 Throughput

Throughput of users and throughput of the cell area are affected by the methodology selected by the scheduling algorithm[9]. Throughput calculation is a calculation of normalized throughput expressed in Equation (4) [10]. Normalized throughput represents the value of success which requested by users due to the system bandwidth and efficiency. In this case, the system bandwidth simply considered as a resource blocks. Based on the value of throughput normalized obtained, the highest value is selected as a best value of the system.

$$N_i = \frac{D_i}{\frac{1}{K}\sum_{i=1}^{K} D_i} \quad \text{.......(4)}$$

Ni = Normalized throughput each user
Di = Data rate each user
K = user number

3.5 Fairness

The values of fairness are between 0 and 1 or 0% until 100%. Fairness for each scenarios calculated by the Equation (5) [11].

$$\frac{\sum_{i=1}^{K} D_i \vee^2}{K \cdot \sum_{i=1}^{K} D_i^2} \quad \text{....... (5)}$$

$F =$

F = Fairness index
Di = Data rate each user
K = user number

Simulation and parameter calculations are using Matlab R2015a under the following characteristics in Table 1.

Table 1. Simulation Parameters

Parameters	Value
System	Single cell
Carrier frequency (MHz)	700
Bandwidth (MHz)	10
Efficiency (%)	90
Subcarrier	600
Subcarrier spacing (KHz)	15
RB	50
TTI (ms)	1
Transmitter power (dBm)	43
Antenna gain (dB)	18
User number	4, 8, 12, 16
Modulation	QPSK dan 16 QAM
User distance (Km)	1-4

4. Experiments

4.1 SNR

Path loss or propagation loss will determine the SNR value for the user is inversely proportional, which means the higher the path loss the lower the SNR. Better SNRs are of higher value. SNR LOS condition is higher than NLOS condition at same distance and will decrease with increasing distance between user with eNodeB. This is because, in NLOS experience more decrease signal level due to multipath.

Both LOS and NLOS condition determine the pathloss value that implicate to SNR calculation. The carrier frequency is selected at 700 MHz with FDD. SNR value as a reference is considered since the calculation, scheduling until the final step of performance calculation. The difference SNR value of the user on the various distance with eNodeB is shown in Figure 5. Generally, the LOS condition has a higher SNR than the NLOS condition, which means that users in LOS condition has a higher acceptability and noise resistance than NLOS with the same distance. This is due to LOS condition which has a slight of fading effect so the decreasing of power level are less than NLOS condition. Both in LOS and NLOS condition, the SNR value will be desrease as the increasing of distance because of error cosidered as noise and attenuation influence. According to the equation and calculation, SNR will greater when the noise power was lower. And this is implicates to modulation scheme used by the user and BER which explain in Section 4.4.

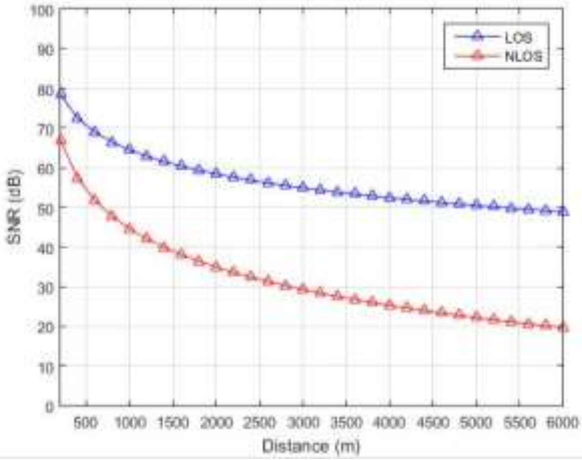

Figure 5. SNR to Distance

Based on the SNR calculation before, the SNR value of each user of scenarios can be determined as in Table 2.

Table 2. SNR User

Scenario	User	User number	SNR (dB)	
			LOS	NLOS
A	4	1	64,4874	44,5932
		2, 3	56,8832	32,4265
		4	52,4462	25,3273
B	8	1, 2	64,4874	44,5932
		3, 4, 5	58,4668	34,9603
		6, 7	55,5442	30,2842
		8	52,4462	25,3273
C	12	1, 2, 3	64,4874	44,5932
		4, 5, 6	59,3819	36,4245
		7, 8, 9	55,5442	30,2842
		10, 11, 12	52,4462	25,3273
D	16	1, 2, 3, 4	64,4874	44,5932
		5, 6	60,4050	38,0614
		7, 8, 9, 10	55,5442	30,2842
		11, 12	54,3844	28,4284

Scenario	User	User number	SNR (dB)	
			LOS	NLOS
		13,14, 15, 16	52,4462	25,3273

Source: Design

4.2 Channel Capacity

SNR brings implication to the value of channel capacity in a proportional way. User with high channel capacity value will have good condition because of high SNR value. Figure 6 shows the channel capacity of users for each scenario in a LOS and NLOS condition. Users in a NLOS condition have lower channel capacity than the LOS condition with difference between 30-50% and this percentage increases as the distance increased for each scenarios. User channel with higher SNR will has high channel capacity or data rate. This channel capacity also considered as the data rate achieved which will determine the scheduling decisions.

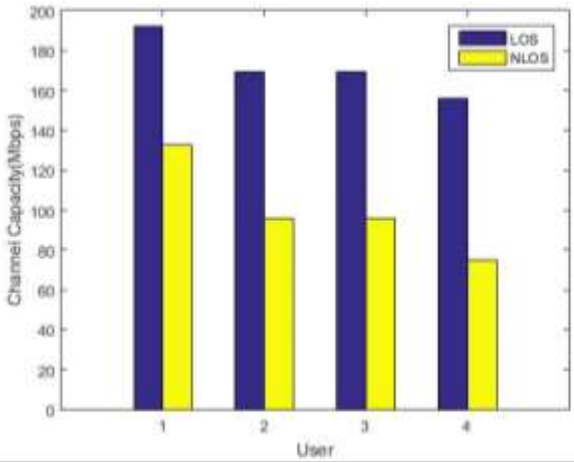

Figure 6(a). Channel Capacity of Scenario A

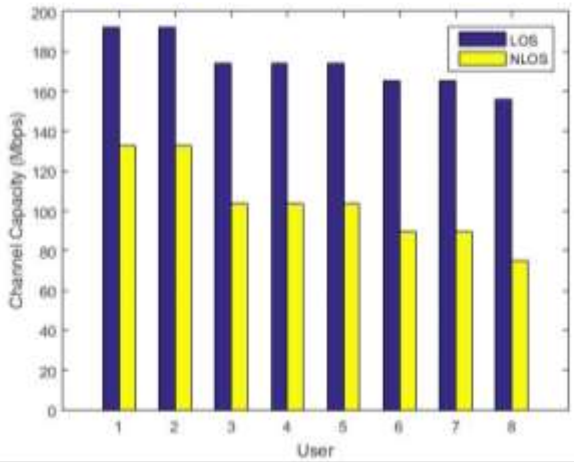

Figure 6(b). Channel Capacity of Scenario B

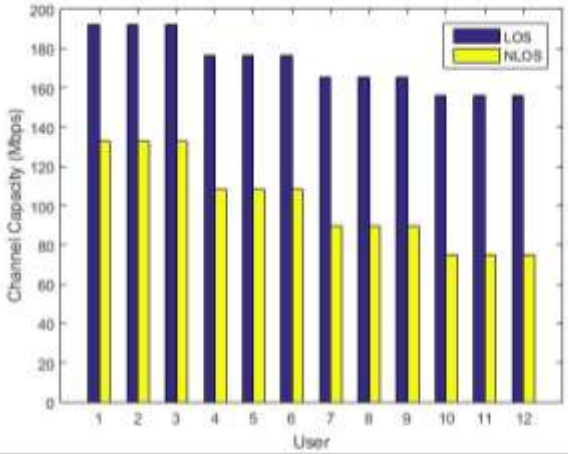

Figure 6(c). Channel Capacity of Scenario C

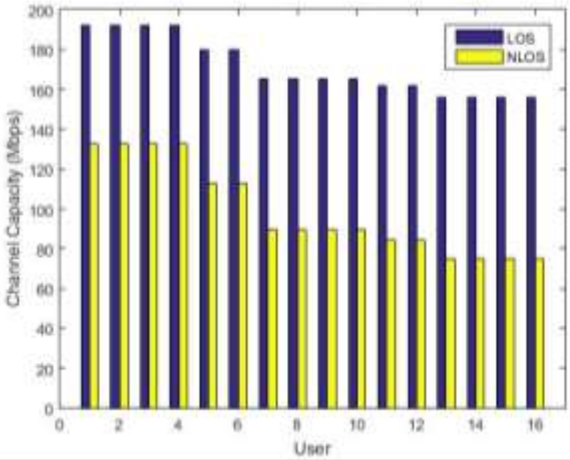

Figure 6(d). Channel Capacity of Scenario D

4.3 Scheduling

Proportional Fair algorithm prioritizes serving for user with the better channel condition level than the average level. This simulation resulting the average number of resource blocks allocated to the user with certain condition. There are 50 resource blocks in a 10 MHz bandwidth system that can be allocated to some active users. Tables below show the results of scheduling that the average of resource blocks allocated are directly proportional with the data rates of each users in a LOS and NLOS conditions.

Table 3. Resource Block Allocation of Scenario A

User number	Data rate (Mbps)		RB	
	LOS	NLOS	LOS	NLOS
1	191.926	132.449	14	17
2	169.192	96.081	12	12
3	169.192	96.081	12	12
4	155.926	74.889	11	9

Source: Calculation

Table 4. Resource Block Allocation of Scenario B

User number	Data rate (Mbps)		RB	
	LOS	NLOS	LOS	NLOS
1	191,926	132,449	7	8
2	191,926	132,449	7	8
3	173,926	103,652	6	6
4	173,926	103,652	6	6
5	173,926	103,652	6	6
6	165,189	89,681	6	5
7	165,189	89,681	6	5
8	155,926	74,889	6	5

Source: Calculation

Table 5. Resource Block Allocation of Scenario C

User number	Data rate (Mbps)		RB	
	LOS	NLOS	LOS	NLOS
1	191,926	132,449	5	5
2	191,926	132,449	5	5
3	191,926	132,449	5	5
4	176,662	108,029	4	4
5	176,662	108,029	4	4
6	176,662	108,029	4	4
7	165,189	89,681	4	4
8	165,189	89,681	4	4
9	165,189	89,681	4	4
10	155,926	74,889	4	3
11	155,926	74,889	4	3
12	155,926	74,889	3	2

Source: Calculation

Table 6. Resource Block Allocation of Scenario D

User number	Data rate (Mbps)		RB	
	LOS	NLOS	LOS	NLOS
1	191,926	132,449	4	4
2	191,926	132,449	4	4
3	191,926	132,449	4	4
4	191,926	132,449	4	4
5	179,721	112,922	3	4
6	179,721	112,922	3	4
7	165,189	89,681	3	3
8	165,189	89,681	3	3
9	165,189	89,681	3	3
10	165,189	89,681	3	3
11	161,721	84,139	3	3
12	161,721	84,139	3	3
13	155,926	74,889	3	2
14	155,926	74,889	3	2
15	155,926	74,889	3	2
16	155,926	74,889	1	2

Source: Calculation

4.4 BER

BER value will be calculated based on modulation types those are QPSK and 16QAM as the property which BER value are less than 10-3 for each modulation type [12]. Table 7 shows the calculation result that 16QAM has a higher value than QPSK because 16QAM modulates data with the more bits number than QPSK. It also directly proportional with the SNR value, as the channel with higher SNR will be modulated by 16QAM modulation scheme so it has higher BER value. While in the increasing of user number conditions, system BER tend to constant. BER in LOS condition are less than the value in a NLOS condition for both modulation scheme. So the channel in LOS condition has better performance than channel in a NLOS condition.

Table 7. System BER Performance

Scenario	BER			
	QPSK		16QAM	
	LOS (*10-22)	NLOS (*10-11)	LOS (*10-9)	NLOS (*10-4)
A	0.1092	0.6393	0.2981	0.1306
B	0.0637	0.3593	0.2193	0.0843
C	0.1214	0.6437	0.3213	0.1356
D	0.1296	0.5914	0.3660	0.1430

Source: Calculation

4.5 Throughput

Normalized throughputs which analyzed are directly proportional with the number of average resource block allocation. Table 8 and Figure 7 show the maximum value of normalized throughput reached at 1000 meters for each scenarios. These value are tend to increase as the user number inceased because of the relativity to the average data rate value of the constant resource blocks number and distance range. Throughput values in the Table 11 reach more than one because the data rates of user channel are above the average value. It represents the best value can be reached by the system.

Table 8. Maximum Throughput

Scenario	User number	Throughput	
		LOS	NLOS
A	4	1,1187	1,3261
B	8	1,1031	1,2765
C	12	1,1131	1,3080
D	16	1,1228	1,3394

Source: Calculation

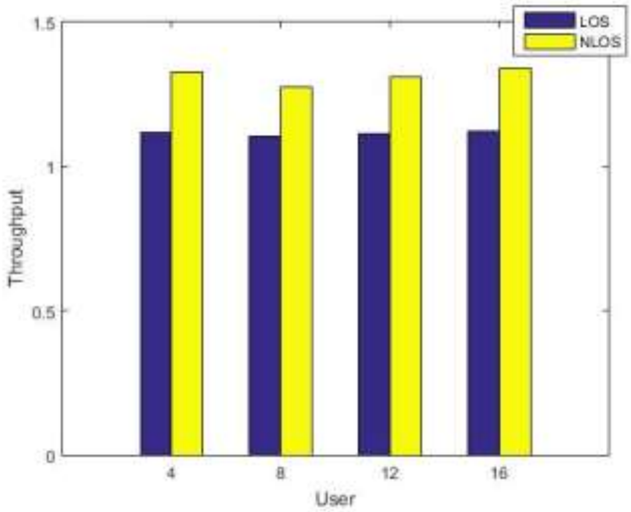

Figure 7. Throughput to User Variation

4.6 Fairness

Fairness value between 0-1 are determined by the data rate value. Fairness level of each scenarios showed at Table 9 and Figure 8 which fairness level at a LOS conditions are higher than NLOS and tend to constant to the variation of user numbers. Fairness value are close to 1 and represent the Proportional Fair algorithm property that calculate the average condition of system. The scheduling depends on channel condition will provide fairness within the resource allocation in proportional number.

Table 9. Fairness Level

Scenario	User number	Fairness	
		LOS	NLOS
A	4	0,9949	0,9618
B	8	0,9952	0,9664
C	12	0,9930	0,9580
D	16	0,9926	0,9525

Source: Calculation

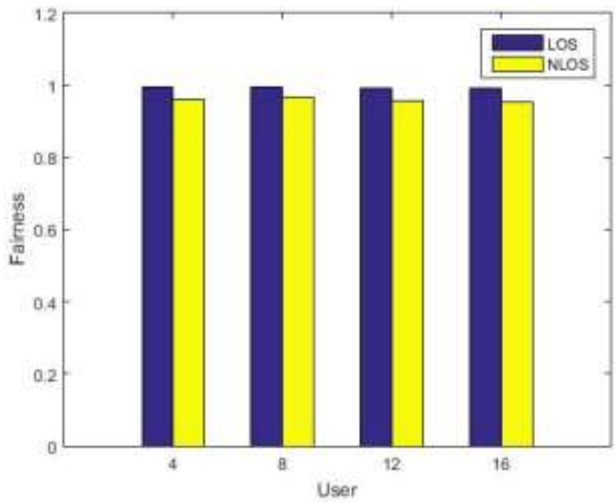

Figure 8. Fairness Level

5. Conclusions

The variation of users distance to the eNodeB have implication on the channel condition shown with SNR and channel condition or data rate. Then the resource blocks allocation tend to decrease as the distance increases but also relative to the LOS and NLOS condition on the same user because of different value of average data rates and channel condition at LOS or NLOS. The Proportional Fair algorithm prioritizes channels with the highest channel capacity for the average channel capacity of a user on a system to serve. This priority means that the user's channel with the best conditions will be allocated higher than any other user regardless of queue or retransmission. Users with the same distance could have different value of channel capacity at LOS and NLOS so it has different number of resource blocks allocated. However the allocation could be relative to LOS and NLOS conditions for users with the same position in the same scenario.

By giving treatment in the form of variations in the number of users on the scheduling with different scenarios BER, throughput, and fairness will show different performances. SNR gives effect to the type of modulation applied to uplink LTE communication that is QPSK and 16QAM. Furthermore this type of modulation will determine BER. Channels with smaller BER values will have better quality. The BER calculation is influenced by the modulation numbers of the different modulation types. BER system and fairness level are tend to constant to the variation of user number because the value of the system will depend on the average value. Normalized throughput and fairness are directly affected by the data rate. The more user number, will decrease the average value of throughput of each scenarios. While the maximum values are constant which reached by user with the best condition. So the maximum normalized throughput tend to increase as the user number increases, it can be interpreted that the Proportional Fair algorithm has a throughput performance that supports multiuser diversity.

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