LTE Performance Evaluation of Scheduling Strategy for Multiple Antenna Technology

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Abstract—**Long Term Evolution (LTE) is aimed to deliver high speed data and multimedia services. Scheduling strategy and MIMO antenna technology are said to be the key elements in improving the performance of the LTE system. The suitable scheduler for each antenna technology by evaluation the performance using Vienna System Level LTE Simulator is presented. This research focuses on four type of scheduling strategy. There are Best CQI, Max Min, Proportional Fair and Round Robin. This paper addresses the scheduling strategy in SISO and MIMO antenna technology in two environments with specific size of users. Due to software limitation, only the downlink part of the LTE network will be considered.**

Keywords: Long Term Evolution (LTE), LTE simulator, scheduling strategy, antenna technology.

I. INTRODUCTION

Long Term Evolution (LTE) is the 4th generation cellular mobile system that is being deployed and specified in 3GPP as a successor of UMTS technologies. Work on LTE began at 3GPP in 2004, with an official LTE work item started in 2006 and a completed 3GPP Release 8 specification in March 2009. Initial deployments of LTE began in late 2009. LTE is a 3GPP standard that expected to provide an uplink speed of up to 50Mbps and a downlink speed of up to 100 Mbps. The system bandwidth will be at range from 1.25 MHz to 20MHz. With this wide option of bandwidth, performance of LTE is also expected to improve in term of spectral efficiency which allows carriers to provide more data and voice services over a given bandwidth [1].

The 3GPP standards body has completed definition of the first release of the Long Term Evolution (LTE) system. LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) as radio access technologies together with advanced antenna technologies [2]. It operates in all IP-based and improves the system capacity, coverage and cost by having simple architecture. LTE can be operated as a scheduled system in all traffic including delay-sensitive services such as VoIP or SIP that needs to be scheduled. Therefore, scheduler should be considered as a key element of the larger system design [1].

This paper will focuses on simulation static UE in LTE downlink with four type of scheduling technique in three antenna technique that are SISO (1x1) and MIMO (2x2 and 4x2). These antenna techniques are varied in two environments. From these simulations, the suitable scheduler can be determined for each antenna technique in different environment.

II. SCHEDULING STRATEGY

Scheduling is a computing process assigned in operating system to give an access to data flow to the system resources [3]. 3GPP does not specify which one is the best scheduler that able to use in LTE because it based on the condition. Therefore, it select best multiplexing for UE based on channel condition and preferably schedule transmissions to UE on resources with advantageous channel condition as in figure 1 below.

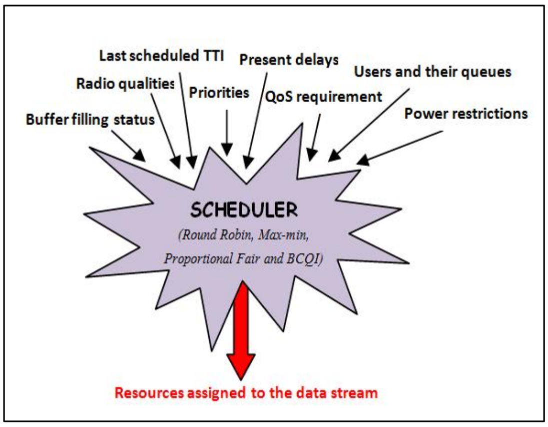

Fig 1: Scheduler with Channel Condition [4].

As mention before, this project focuses on four type of scheduling strategy. The first one is Best Channel Quality Indicator (BCQI). This scheduling strategy assigns the resource blocks to the user with the possible best radio link connection. For the scheduling process, the terminals will start off by sending the Channel Quality Indicator (CQI) to the Base Station (BS). Then, the Base Station will transmit a reference signal or better known as the downlink pilot to the terminals. The measurement of the CQI will be done by the UE using the reference signal received. This includes the value of signal-to- noise interference ratio (SINR). Higher CQI value indicates better channel condition. Based on the

CQI received, the best CQI is selected for scheduling. However, certain delay is involved during this process and this scheduling strategy is not suitable for terminals that are located far from the base station.

Second type of scheduling used is Round Robin. This scheduling is considered a simple scheduler and often used in a system. It is very easy to implement as less computation is done compared to other scheduling strategy. This scheduling strategy will provide fairness to all users. It schedules the users with a fixed pattern where it implements on first come first serve basis. However, this strategy will result in low user throughput since the CQI is not taken into consideration.

Third type of scheduling used is proportional fair. This scheduling strategy is based on balancing two major issues; that are maximizing the total network throughput while conserve the fairness. The total throughput will be lower down to more accepted levels to users with poorer SNRs. This scheduler performs its algorithm by comparing the given rate for each user with its latest average throughput, and selecting the one with the maximum ratio [5].

The last type of scheduling used is Max Min. This scheduling strategy allows obtaining any fairness ranging from the fairest solution, $\alpha \rightarrow \infty$, to $\alpha = 0$ the most unfair but throughput-maximizing solution. It will maximize the minimum user throughput received. But once the chosen rate is being increased, the rate of other UE must lower down its rate [6].

III. ANTENNA TECHNOLOGY

The different forms of antenna technology refer to single or multiple inputs and outputs. The input will be transmitted by a transmitter through a single path to the receiver. There are four different types of single/multiple antenna such as Single Input Single Output (SISO), Single Input Multiple Output (SIMO), Multiple Input Single Output (MISO) and Multiple Input Multiple Output (MIMO) [7].

However, this paper only focuses on SISO and MIMO technology. Antenna technology is the key element of the high performance offered by the standard 3GPP. This standard supports multi-antenna technologies that will improve the performance in any given scenarios [8]. A MIMO system can be configured with an unequal number of antennas at the transmitter and the receiver. Figure below shows types of antenna technologies.

A. MIMO TRANSMIT TECHNIQUES

During scheduling process, Transmission mode is implemented. Table 1 summarizes the transmission mode available. However, this paper only focuses on transmission mode 2, transmit diversity. Transmit diversity will increase the SINR at the receiver without having to increase the data rate. Each transmit antenna transmits the exact same data thus the receiver will receive multiple of the same signal. This transmission mode is said to improves the cell user edge and cover range. To create the diversity effect, an additional antenna-specific coding is applied to the transmit signals before any transmission [9].

TABLE I: TRANSMISSION MODE

TRANSMISSION MODE	DECSCRIPTION
1	Single-antenna port(port 0)
2	Transmit diversity
3	Open-loop spatial multiplexing
4	Closed-loop spatial multiplexing
5	Multi-User MIMO
6	Closed-Loop single-layer precoding
7	Single-antenna port(port 5)

B. SIMULATION SCENARIO

i. Environment Only two selection of environment that is considered in this paper; Urban Macro (medium density area) and Sub-Urban macro (low density area). Both areas are using Cost231 Path Loss Model that also known as the Okumura-Hatta model. It is the most widely used model in radio frequency propagation for predicting the behavior of cellular transmissions in urban and Sub-Urban.

TABLE II: PATH LOSS MODEL

ENVIRONMENT	DESCRIPTION
Urban macro	Urban macrocell pathloss based on the cost231 extended Hata model (ref: 3GPP TR25.996) and cost 231 book.
Sub-Urban. macro	Suburban macrocell pathloss based on the cost231 extended Hata model (ref: 3GPP TR25.996) and cost 231 book.

ii. Parameters The simulation parameters are fixed for each simulation as summarized in Table 4 below. The frequency is set to 2600MHz, which will be used by operator in Malaysia for the LTE operation in 2013. The bandwidth chosen is 5MHz just to reduce the simulation computation time and provide comparison compatibility with WCDMA mobile technology. The TTI is set to 1000s in order to achieve more precise results from the simulation. The traffic model chosen is full buffer where all users in the system always have data to send and receive.

TABLE III: SIMULATION PARAMETER SETTING

ITEM	PARAMETER
Frequency	2600MHZ
Bandwidth	5MHZ (25 RBs)
RB Bandwidth	180kHz
TTI	1000 (1ms per TTI)
Antenna Technology	1x1 (Single Antenna) 2x2 (Transmit Diversity) 4x2 (Transmit Diversity)
eNodeB distance	500 meter
Traffic Model	Full Buffer
UE distribution	Random (fixed for each UE size & eNB number)

IV. METHODOLOGY

Figure 2 shows the flowchart during completing this project. As mention before, this project consists of two parts which is simulation and analysis. In order to execute simulation part, the simulation scenario is first identified and the LTE parameter is set. The simulation will be repeated 4 times according to each scheduling strategy. Upon completion of each scheduling strategy simulation, the result will be automatically stored into specific folder for further analysis.

The simulation is then repeated with the rest of simulation scenario. This simulation covering other types of antenna technology, sizes of UE and types of environment. Once finished, the results are analyzed. Each execution will take 40-60 minutes depending on the scenario setting.

In the analysis part, 72 files of simulation results are extracted. All the 72 files have been analysis to get the result. From this, the UE fairness, system throughput and system error rates are calculated. All calculated results are then compared between each scheduling strategies and given a rank based on the highest value to lowest value. The highest value is considered as the best rank and it will be set a weight of 40 while the worst rank weight is 10.

However, for system error rates, the best rank is indicated by the lowest error rate value while the worst rank indicates the highest error rates value. Total result then multiply by the % of performance criteria for each value of UE fairness, system throughput and system error rates. Ranking process will be done again to rank from best to worst scheduler. The step is repeated for each performance criteria required. Final result that is the recommended optimum scheduling strategy is compiled into table for each scenario based on the best rank scheduler.

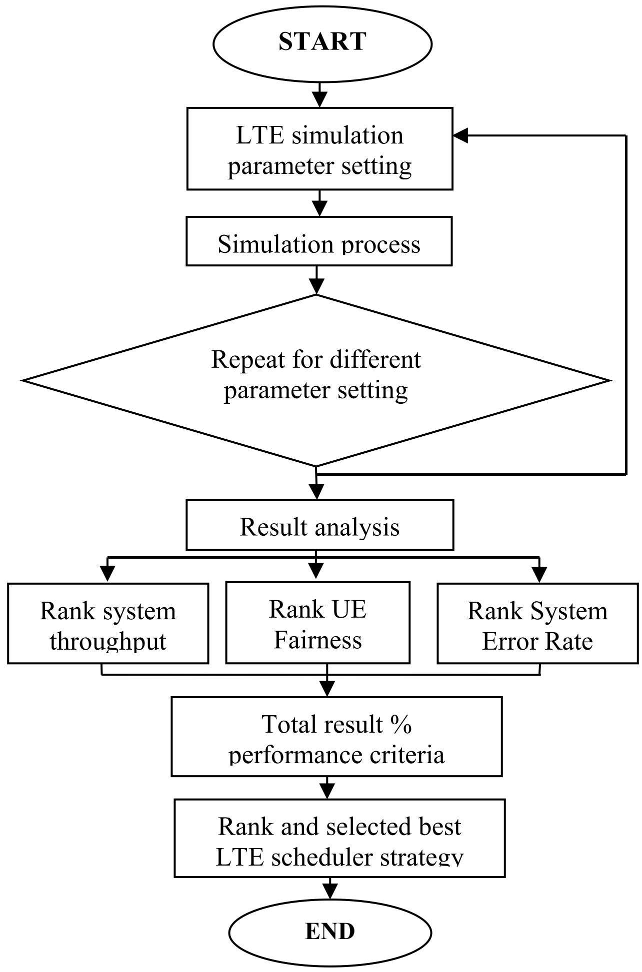

Fig 2: The Flowchart during Completing This Project

V. RESULTS AND DISCUSSIONS

A. RESULT COMPARISON

As mention in introduction in part 1, this project consists of simulation and analysis part. The analysis of UE Fairness, System Throughput and Error Rates in three antenna technologies (SISO 1x1, MIMO 2x2 and MIMO 4x2) have been analyzed in this section. These results are evaluated in three performance criteria in different scenarios.

Figure 3 shows the UE Fairness for antenna technology. From this graph, it can be said that all scheduler display a similar pattern in term of UE size for all three antenna technologies in both environment. For Best CQI scheduler, the highest UE Fairness is obtained at small UE size in all antenna technologies while the other scheduler obtains the highest UE Fairness in a medium UE size. In term of the value of UE Fairness, SISO and MIMO technologies doesn't exhibit the same results. For SISO (1x1), the highest value of UE Fairness is achieve from Max Min or Proportional Fair scheduler while for MIMO (2x2 and 4x2), Max Min scheduler dominates all

UE sizes on both environment. This is parallel with the characteristic of this scheduler where Max Min is a fair scheduler that will minimize the gap be between the minimum and maximum amount of assigned resources to each user what is needs. Otherwise, the resources are split evenly [11]. The value for UE fairness increases depending on the antenna technologies.

Figure 4 shows the system throughput for antenna technology. For these performance criteria, the environment also does not have major effect on the System Throughput. The scheduler pattern in System throughput is different as in the UE Fairness. Best CQI display the highest System Throughput value followed by Proportional Fair scheduler for all antenna technologies in all scenarios.. For Max Min and Round Robin, the throughput values are more likely the same in all scenarios. The value of System Throughput is highest in MIMO 4x2. Adding more antennas on the transmitter or receiver can be used to improve throughput between the transmitter and receiver, or both [12]. This is because of multiple data streams are transmitted in parallel from different antennas, linear increase in throughput can be observed with every pair of antennas added to the system [13].

Figure 5 shows the system error rate for antenna technology. From this figure, the Max Min scheduler received the highest error rate in most scenarios even though Max Min provides higher UE Fairness. This is expected as Max Min scheduler objective is maximizing the fairness of recourses without concerning the error rate [5]. Round Robin scheduler displays the most convincing in term of lowering the error rate in all scenarios. It fit with the characteristic of the scheduler itself where less computation is done compared to other scheduling strategy [14]. Error rate for MIMO 4x2 is the lowest compared to the other two antenna technologies in both environments. In term of UE size, small UE size obtained the lowest error. Form this results, it shows that MIMO antenna technologies obtained lower error rate compared to SISO. This is due to the way of the data stream is being transmitted. Higher number of antenna will enhanced the chances of the data to be successfully transmitted [15]. SISO produce higher error rate because of the multipath effects. This multipath effect can cause a reduction in data speed and an increase in the number of errors [16].

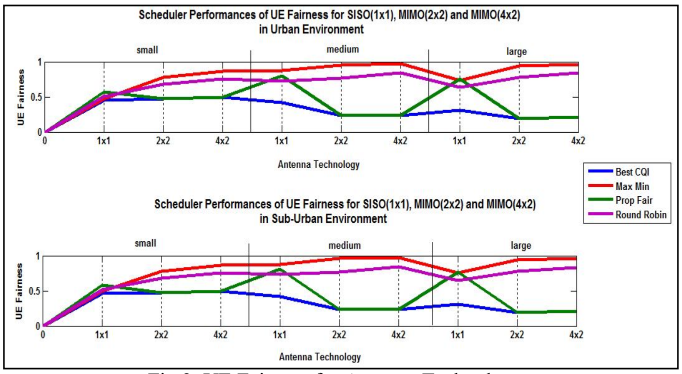

Fig 3: UE Fairness for Antenna Technology

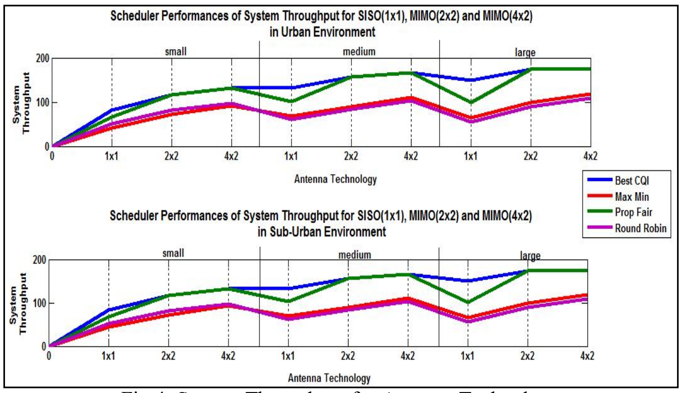

Fig 4: System Throughput for Antenna Technology

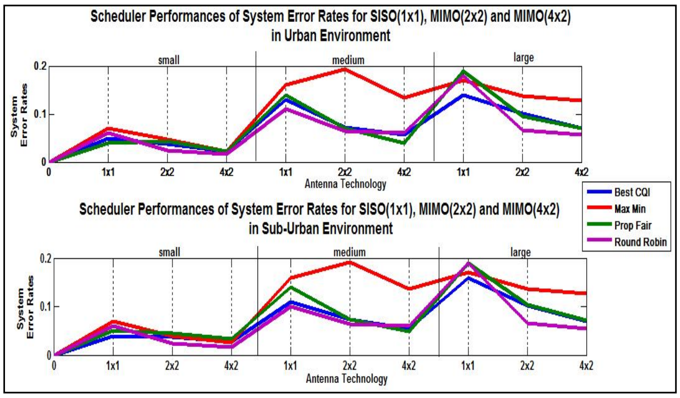

Fig 5: System Error Rate for Antenna Technology

B. RECOMMENDED OPTIMUM SCHEDULER

In order to select the suitable scheduler based on specific performance criteria, a few steps of analysis are performed and the recommended scheduling strategies are tabulated as below.

Table IV shows the recommended Scheduling Strategy for UE Fairness Priority. From this table, for SISO 1x1, Proportional Fair scheduler is best to use in small and large UE size while for medium UE size, Max Min scheduler is the most dependable scheduler. MIMO 2x2 and 4x2 produce the same outcome where Max Min is the most reliable scheduler. For UE fairness priority, it can be conclude that Max Min is the most recommended scheduler in all scenarios. This is expected as Max Min scheduler minimized the gap between the maximum and the minimum throughput to enhance its fairness [14].

Table V shows the recommended Scheduling Strategy For throughput Priority. For throughput priority, all three antenna technologies recommend either Best CQI or Proportional Fair scheduler. It confirms that these two schedulers can provide higher throughput in all scenario. Best CQI increase the cell capacity at the expense of fairness. In other word, in order to achieve higher throughput, fairness must be at a low level [14].

Table VI shows recommended Scheduling Strategy for equal Priority. The recommended scheduler for equal priority is unstable as seen in the table VI except for SISO (1x1). Proportional fair dominates in all scenarios for SISO (1x1). This scheduler can provide equal fairness and throughput while minimize the error rate. For MIMO (2x2 and 4x2) on the other hand, the recommended scheduler is not steady. This instability of this result is expected as the scheduler tries to compromise between the performance criteria required and the scenario involved.

TABLE IV: RECOMMENDED SCHEDULING STRATEGY FOR UE FAIRNESS PRIORITY

recommended scheduler	Urban Macro			Sub-Urban Macro		
	small	med	large	small	med	large
SISO (1X1)	pf	mm	pf	pf	mm	pf
MIMO (2X2)	mm	mm	mm	mm	mm	mm
MIMO (4X2)	mm	mm	mm	mm	mm	mm

TABLE V: RECOMMENDED SCHEDULING STRATEGY FOR THROUGHPUT PRIORITY

recommended scheduler	Urban Macro			Sub-Urban Macro		
	small	med	large	small	med	large
SISO (1X1)	pf	bcqi	bcqi	bcqi	bcqi	pf
MIMO (2X2)	bcqi	bcqi	pf	bcqi	bcqi	pf
MIMO (4X2)	pf	pf	bcqi	bcqi	bcqi	pf

TABLE VI: RECOMMENDED SCHEDULING STRATEGY FOR EQUAL PRIORITY

recommended scheduler	Urban Macro			Sub-Urban Macro		
	small	med	large	small	med	large
SISO (1X1)	pf	pf	pf	pf	pf	pf
MIMO (2X2)	pf	mm	pf	bcqi	bcqi	mm
MIMO (4X2)	pf	pf	mm	bcqi	mm	pf

IV CONCLUSIONS

Scheduler is one of the major factors in determining the performance of the LTE system. The scheduler will assign the resource block to the user. In order to determine the most suitable scheduler for each scenario, a comparative analysis base on the performance criteria (UE Fairness, System Throughput and Error Rate) was performed. Max Min is the best scheduler in providing fairness while Best CQI provides the highest value of throughput in all scenarios. However, the error rates for both schedulers are quite high. Because of this, a system is used where each system has its own percentage of the performance criteria to achieve an optimum scheduler. These percentages represent priorities required from the performance criteria.

As for antenna technology, both MIMO configuration shows impact in improving the UE Fairness, System Throughput and lowering the System Error Rates compared to SISO. However, the values of the performance criteria for MIMO 2x2 and 4x2 are quite similar to each other. This slight different in values are the cause of the different in the recommended scheduler.

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