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Scheduling Algorithms Implementation for LTE Downlink

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Abstract: The increasing demand for cellular communications leads to the development of Long Term Evolution (LTE). LTE is the evolution for existing 3G mobile networks which offers higher capacity, efficient utilization of radio resources, lower latency. As a core functionality of LTE downlink radio resource management, packet scheduling algorithms plays a vital role. Maximum SNR(Max SNR), Round Robin, Proportional Fair are the conventional scheduling algorithms. The main contribution of Max SNR is towards maximizing system throughput. Round Robin and Proportional algorithms tries to please the fairness among the users. In this paper two new scheduling Algorithms has been proposed in order to give higher capacity than Round Robin and higher fairness than Max SNR.

Keywords*: *LTE, OFDMA, Packet Scheduling, Max SNR, Round Robin, Proportional Fair.

I. INTRODUCTION

LTE release 8 is the standard for Radio Access Network specified by 3GPP [1]. 3GPP, the 3rd Generation Partnership Project is collaboration between groups of telecommunications associations known as organizational partners. LTE is a standard [2] for Radio Access Network (RAN) part of Evolved – Universal Terrestrial Radio Access (E-UTRA). The standard is targeted to support 100Mbps for downlink and 50Mbps for uplink. It uses Orthogonal Frequency Division Multiple Access (OFDMA) for downlink and Single Carrier – Frequency Division Multiple Access (SC – FDMA) for uplink. WCDMA is used for 3GPP Release 6. It is verified that OFDMA is outperforming than WCDMA in both broadcast and unicast services [3].

The efficient use of radio resources has become the challenging task for next generation wireless communication systems. The scarcity of radio resources, diverse Quality of Service (QoS) requirements [4] and wireless channel conditions complicate the scheduling and radio resource management. The main function of the scheduler is to intelligently allocate radio resources to users in order to achieve high system performance in terms of efficiency and fairness. This makes the scheduling algorithm a key component in optimizing the system performance across the physical (PHY) and Media Access Control (MAC) layers [5].

The Two key performance indicators considered are fairness and efficiency. Efficiency is evaluated in terms of system throughput, which is sometimes unfair to users with bad channel conditions. On the other hand, absolute fairness may lead to low bandwidth efficiency. Therefore, a tradeoff between efficiency and fairness is desired.

II. BRIEF INTRODUCTION TO CONVENTIONAL SCHEDULING ALGORITHMS

Max SNR, Round Robin and Proportional Fair are the three conventional scheduling algorithms for High Speed Packet Access (HSPA). For every eNB all the active users are

identified by their unique ID. Active users are changed for every instant because the users are situated randomly but not fixed.

A. MAX SNR Scheduler

In Max SNR Scheduling all the users are ranked with their respective Signal-to-noise ratio (SNR) Values. For every scheduling event, the user with the highest SNR value is selected and allocated number of time cycles depending on service requirements and availability of resources. It is possible for the same user to be rescheduled for the next available resource provided that it still possess the highest SNR value at the next scheduling event. The user selection for every scheduling event depends upon the following criteria:

$$j = \max_{i=1-N} \left(\frac{S}{N}(t)\right)_i \quad (1)$$

Here, j is the selected user for the ith instant, $(\frac{S}{N})_i$ is the SNR ratio of ith user, N is the total number of active users.

B. Round Robin Scheduler

Round Robin (RR) is a well known scheduling strategy in packet data services. RR runs the scheduling in a fixed cycle. All active users are identified by their ID. Each user is allocated an equal and fixed number of time slot(s) in a ring fashion. Transmission service will not be regranted to the same user before all other users had been served as shown below.

$$j = \max_{i=1 to N}(Q_i(t)) \quad (2)$$

Here, N is the total number of active users, $Q_i(t)$ is the user queue length, j is the selected user for the instant. The users are served on first come first serve basis.

C. Proportional Fair Scheduler

The proportional fair tries to please both fairness and total system throughput requirements with the following metric. In order to improve fairness without sacrificing much in terms of throughput, one can incorporate both fairness and throughput in a scheduling scheme as figures of merit. Proportional Fair (PF) is one of many efforts to address this issue. The scheduler selects the user with a maximal priority metric, defined as

$$j = \arg \max_{i \le i \le N} \frac{D_i(t)}{R_i(t-1)} \quad (3)$$

Where i is the user index, j is the selected user, N is the total number of users, $D_i(t)$ is the current supportable data rate by the channel, and $R_i(t-1)$ is the average experienced rate by this user. With this scheme, a user is selected when it has a good channel or high $D_i(t)$, to keep system throughput high. In the meantime, users in bad channels are also considered since their low average rate $R_i(t-1)$ will increase their chance of being selected for the next scheduling event.

III. SYSTEM MODEL

The LTE system is based on a flat architecture, known as "Service Architecture Evolution", with respect to 3G systems [5]. This guarantees a seamless mobility support and a high speed delivery for packet data and signaling. As shown in Fig 1, it is made by a core network, known as the "Evolved Packet Core", and a radio access network, namely the Evolved – Universal Terrestrial Radio Access Network (E - UTRAN). The Evolved Packet Core comprises the Mobility Management Entity (MME), the Serving Gateway (SGW), and the Packet Data Network Gateway (PGW). The MME is responsible for user mobility, intra-LTE handover, and tracking and paging procedures of User Equipments (UEs) upon connection establishment. The main purpose of the SGW is, instead, to route and forward user data packets among LTE nodes, and to manage handover among LTE and other 3GPP technologies. The PGW interconnects LTE network with the rest of the world, providing connectivity among UEs and external packet data networks.

The LTE access network can host only two kinds of node: the UE (that is the end-user) and the eNB.Note that eNB nodes are directly connected to each other (this obviously speeds up signaling procedures) and to the MME gateway. Differently from other cellular network architectures, the eNB is the only device in charge of performing both radio resource management and control procedures on the radio interface.

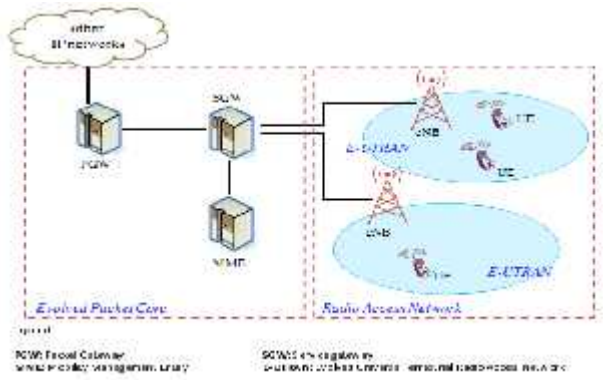


Figure 1: The service Architecture Evolution in LTE Network

In the downlink System simulation of LTE, 19-cell structure with 19 Base Stations (eNB) are located at the cell center, N number of users (UE) are uniformly distributed within the cell radius are considered. Wrap around technique is employed to avoid edge effects [6]. OFDMA has been adopted as multiple access technique. As the signal travels through wireless medium it has path loss and affected by multipath fading.

A. Path loss Model

The path loss from each base station to each user is calculated. A user is made associated with the base station which has minimum path loss from the user among all the path losses from all the eNBs.

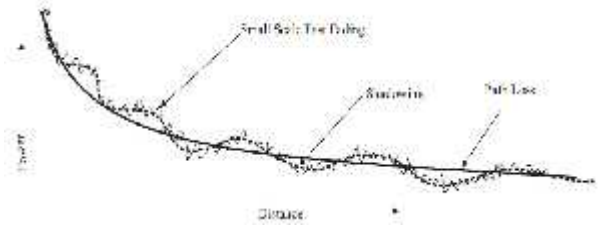


Figure 2: Propagation Path loss

The path loss model considered for the simulation is,

$$P_L(d) = 128.1 + 37.6 * log_{10}(d) + S + 10 * log_{10}(H_k) \quad (4)$$

Where, $P_L(d)$ is the path loss of a user at distance d, S is is the shadowing value and it is log-normally distributed with zero mean and 8dB standard deviation and H_k is the multipath fading coefficient over frequency channel k.

B. Channel Model

In IEEE 802.16a standard, the non-line of sight (NLOS) is assumed. The frequency selective fading can be modeled as Rayleigh fading by using tapped delay line model [6]. The development of frequency selective fading channel leads to a representation of the time-varying channel impulse response as

$$h(\tau,t) = h_0(t)\delta(\tau - T_0(t)) + h_1(t)\delta(\tau - T_1(t)) + h_2(t)\delta(\tau - T_2(t)) \quad (5)$$

Where, $h(\tau,t)$ is the averaging of the received signal from multipath, $h_0(t)$, $h_1(t)$, $h_2(t)$ are the time varying gains, $\delta(\tau - T(t))$ are the impulse response of signal at delays T_{0-2}. The multi path gains are considered from the power delay profile [7].

In this, channel is modeled using three fading paths, each representing a cluster of multipath components received at around the same delay. The maximum Doppler shift is computed as v*f/c, where v is the mobile speed, f is the carrier frequency, and c is the speed of light. For example, a maximum Doppler shift of 200 Hz (as above) corresponds to a mobile speed of 65 mph (30 m/s) and a carrier frequency of 2 GHz.

Together, the path delays and path gains specify the channel's average delay profile. Typically, the average path gains decay exponentially with delay (i.e., the dB values decay linearly), but the specific delay profile depends on the propagation environment.

C. System Description

Based on the frame structure in the standard, for 5MHz bandwidth 24 Physical Resource Blocks (PRB's) are supported. Each PRB constituted to a grid of 12 sub carriers in frequency domain and 7 or 6 OFDM symbols and is the minimum frequency allocation unit for each LTE user. Each sub carrier of frequency 15KHz, so the bandwidth of each PRB will be 180KHz. The LTE supports many channel bandwidths such as 1.4 MHz to 20 MHz unlike WCDMA supports only 5 MHz However the transmission bandwidth will be measured in terms

of number of PRBs it can use for transmission and are listed in table 1.1 [8-11].

Table 1: Number of PRBs for each channel bandwidth supported by LTE

Channel Bandwidth (MHz)	1.4	3	5	10	15	20
Number of PRB's	6	15	25	50	75	100

For every scheduling drop, PRBs are allocated to the uniformly distributed users according to the specified scheduling algorithm. Each user reported with the specified SINR and is calculated as,

$$SINR = \frac{R_x}{N_0 B + I} \quad (6)$$

Where,

$$R_x = \frac{P_t}{P_L(d)} \quad (7)$$

Here, R_x is the Received Signal Power, $N_0 B$ is the Thermal Noise power over transmission bandwidth, P_t is the transmitted signal power, $P_L(d)$ is the Path Loss. From this the capacity of the system can be defined as

$$C = \text{BW} \times log_2(1 + SINR) \quad (8)$$

The simulation parameters adopted are listed in the below table.

Table 2: Simulation Parameters

Parameter	Value
Carrier frequency	2000 MHz
Cellular layout	Two tier (19 cells)
Inter-site distance	1.732 Km
System bandwidth	5 MHz, 24 PRBs considered
Distance-dependent path loss	128.1 + 37.6 $\log_{10}$ (d), d in kilometers
Lognormal Shadowing	Log Normal Fading with 0 mean,8dB standard deviation
Tx antennas (eNB)	1
Rx antennas (UE)	1
Traffic model	Full buffer
Minimum UE distance from eNB	35m
Scheduling	Max SNR, Round Robin, Proportional Fair, Max Round Robin, Max Throughput Scheduling
Bandwidth per PRB	180 kHz
Number of major PRBs	8
White noise power density	−174 dBm/Hz

IV. SCHEDULING ALGORITHMS

Different wireless users experience different channel conditions at a given time. At any given time there will be high probability that some users will have good radio link condition. By scheduling users, the shared channel resources are used in the most efficient manner and the total system capacity is maximized.

A. Algorithm 1

This scheduling algorithm has been developed to please the system throughput as well as fairness. In this Scheduling scheme users are scheduled in two levels. In the first level, the scheduler gives equal priority to all the users and in the second level, the users with highest SINR will be served. With this scheme fairness is maintained in the first level, higher throughput will be achieved from the second level. User selection will be according to the following criteria.

For first level:

$$j = \max_{i=1 to N}(Q_i(t)) \quad (9)$$

For second level:

$$j = \underset{i=1-N}{max}\left(\frac{S}{N}(t)\right)_i \quad (10)$$

The flow chart for the above scheduling algorithm is depicted below.

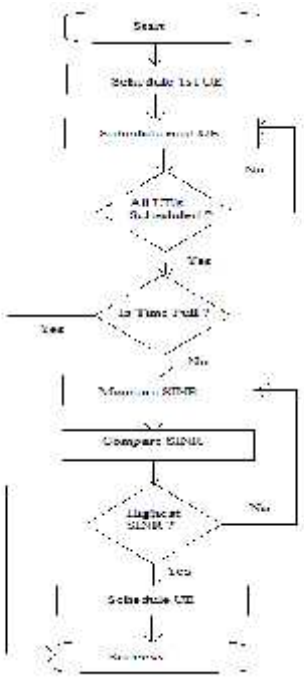


Figure 3: Flow chart for Algorithm 1

B. Algorithm 2

Main objective of this algorithm is to serve all the active users but the user with highest SINR will serve first. So that the Throughput as well as Fairness among all the users will be maintained. The working of this algorithm is as follows:

All the active users are ranked according to their SINR and arranged in the descending order. Resources are allotted in a round robin fashion, the UE having high SINR served first and second highest served second and so on. The served user will again served only when all the users are served in the present time slot. The flow chart regarding the working of above algorithm has shown below.

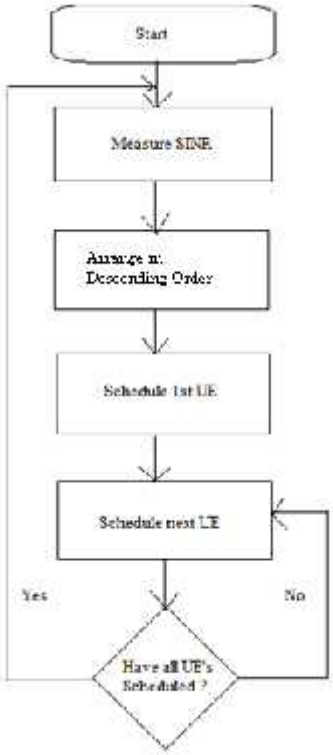


Figure 4: Flow chart for Algorithm 2

C. Scheduling Scheme Evaluation

The Scheduling algorithms have been compared in terms of Average Cell Throughput, System Capacity and fairness coefficient [14]: the fairness coefficient is defined as $= \frac{1}{1+V}$. Where V is the variance of the normalized throughput of multi users. System capacity refers to the overall system capacity and Average cell throughput refers to the average throughput of all the cells.

V. SIMULATION RESULTS

Simulation results show that both the Algorithms achieved high Average Cell Throughput, System Capacity than Round Robin. The Fairness Coefficient of Algorithm 2 and Round Robin

Scheduler are almost same because number of users is less than the number of PRB's. In case of Fairness Both the Algorithms are having high value than Max SNR.

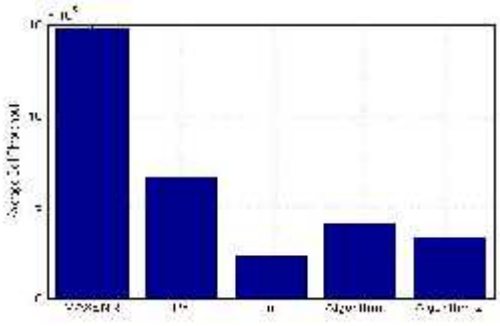


Figure 5: Average Cell Throughput

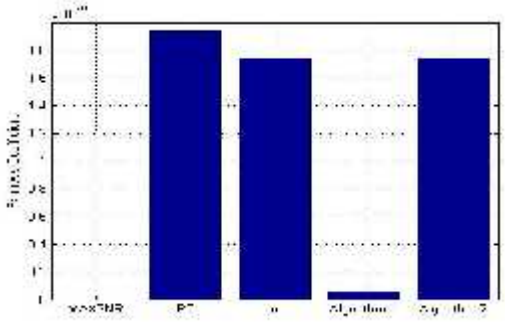


Figure 6: Fairness Coefficient

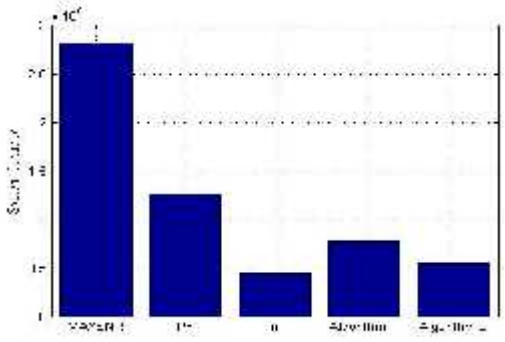


Figure 7: System Capacity

The below table shows the comparative results of all the scheduling algorithms with respect to different parameters.

Table 3: Comparison of different parameters for different scheduling algorithms

	MAXSNR	PF	RR	Algorithm	Algorithm 2
Average cell Throughput (10^5)	14	7	2.8	4.5	4
Fairness coefficient	5.8 10^{-}	1.9 $\times 10^{-}$	1.74 $\times 10^{-}$	6.2 $\times 10^{-}$	1.74 $\times 10^{-}$
System capacity	2.8 $\times 10$	1.3 $\times 10$	0.4 $\times 10$	0.8 $\times 10$	0.6 $\times 10$

VI. CONCLUSIONS

LTE is a breakthrough technology with respect to previous generation of cellular networks, as it is based on an all-IP architecture that aims at supporting several high quality services such as video streaming, VoIP, online gaming and everything related to wideband Internet access. Given this ambitious objective, the desired performance can only be achieved by implementing a series of procedures at physical and MAC layers, able to exploit the wireless link capacity up to the Shanon limit.

The two scheduling algorithms are outperforming than the conventional scheduling methods. The radio resources are used in an efficient manner through these algorithms.

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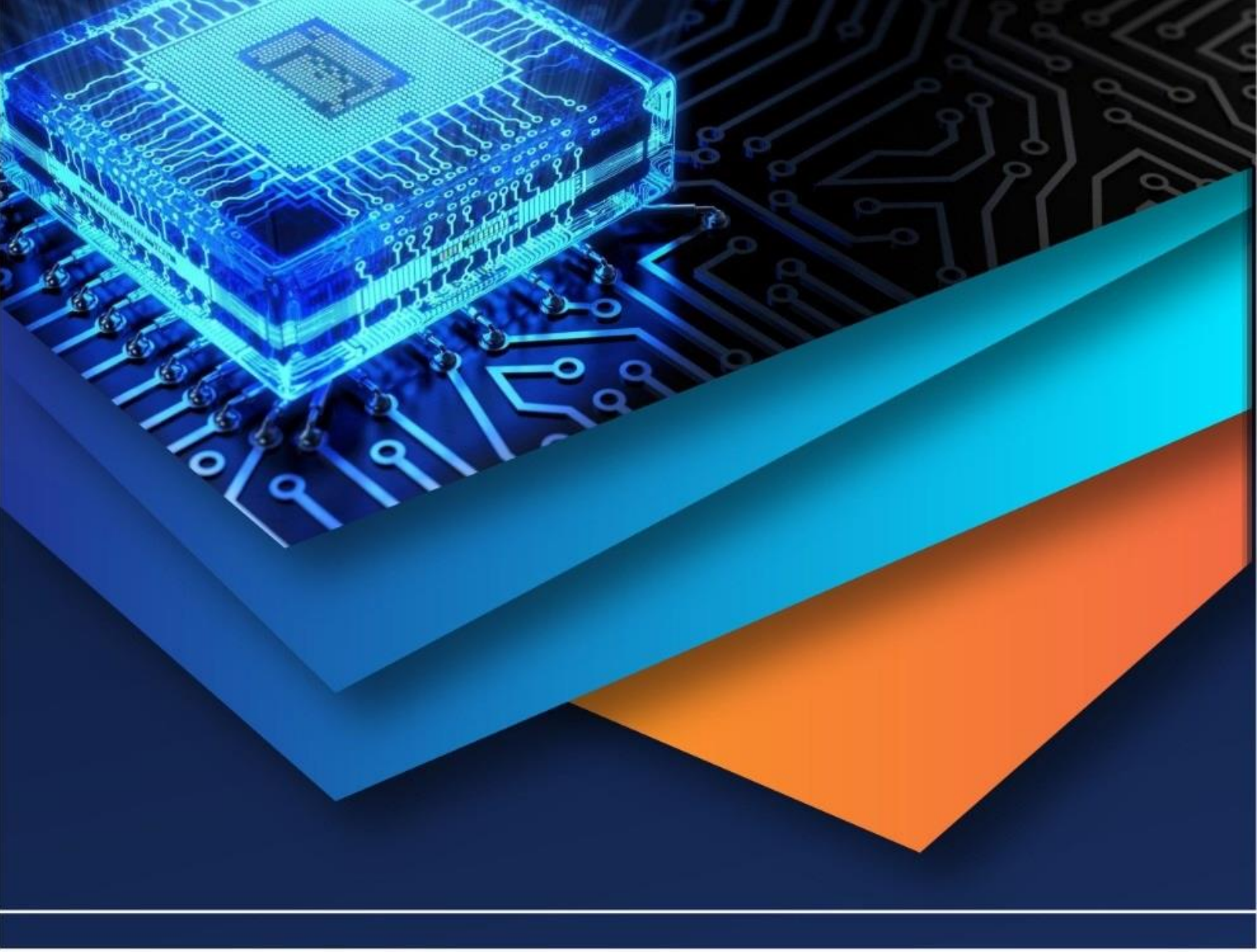
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