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Research Article

QoS-based Scheduling Algorithm for LTE-A

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Abstract: The aim of this study is to propose a novel scheduling algorithm which is classified into two levels. In the first level, the users with Quality of Services (QoS) requirements, such as delay and Packet Drop Rate (PDR) which considered critical issues in wireless networks, are prioritized. In the second level, the QoS users are selected based on real-time queuing algorithm which allocates available resources to users with tightest delay. Furthermore, the proposed scheme improves the overall system throughput since it allocates the Resource Blocks (RBs) to the users with highest expected data rate which results in higher system throughput. However, the proposed scheme is evaluated in terms of delay, throughput and Packet Drop Rate (PDR) and compared with Proportional Fairness (PF) and Maximum Throughput (MT) schemes. The results illustrate that the proposed algorithm outperforms the comparative schemes in terms of delay, PDR and throughput for QoS users while MT algorithm shows the highest overall system throughput.

Keywords: 4G, LTE-A, QoS, resource allocation, scheduling

INTRODUCTION

Due to the increasing demand of high data rate and low latency, the 3rd Generation Partnership Project (3GPP) has proposed Carrier Aggregation technology (CA) in order to support wider bandwidth up to 100 MHz (Vulpe *et al*., 2013). The current data rate which can be supported by LTE (Release 8) is 100 Mbps for downlink and 50 Mbps for uplink. Whereas LTE-A (Release 10) is expected to provide higher data rate up to 1 Gbps for downlink and 500 Mbps for uplink (Zhao *et al*., 2012).

One of the resource management mechanisms is the packet scheduling which has a crucial role in the network performance because it is responsible for distributing the resources among users taking into account QoS requirements (Hajjawi *et al*., 2014). The smallest allocated resource in LTE network is called Resource Block (RB) which utilizes 180 KHz in terms of frequency and 0.5 msec in terms of time as shown in Fig. 1 (Xiaolin *et al*., 2013).

The main issue with scheduling in LTE-A is that there is no firm provision set by 3GPP to control scheduling process. So that packet scheduling becomes an open subject for researchers. Furthermore, most of the recent works which have been proposed for scheduling in LTE and LTE-A networks focus on specific criteria (throughput, delay, fairness or throughput) regardless others. Such schemes are not preferable choice to be practically implemented because the wireless networks have variety of traffics. Here in this paper, QoS user are served with higher quality of services and NQoS users are given a chance to be served.

Following the requirements for such a scheduler, this study proposes a novel scheduling algorithm which prioritizes the users with QoS requirements such as delay and Packet Drop Rate (PDR), which are considered critical issues in wireless networks. Meanwhile, the proposed algorithm concerns about NQoS users and gives them a chance to be served. Moreover, the proposed scheme aims at improving the overall system throughput by allocating RBs to the UEs with highest SNR first which results in higher system throughput. Also the proposed scheme improves the delay performance where in the second stage the proposed algorithm allocates resources to the users with tightest delay.

LITERATURE REVIEW

Several scheduling algorithms have been proposed in order to improve the resource allocation performance for LTE and LTE-A networks. Such as Round Robin (RR) which aims at allocating equal amount of time to all users regardless other QoS requirements (Hindia *et al*., 2015). RR scheduler is fair in terms of time but not in terms of throughput where in the case there are two users who have allocated an equal amount of time and one of them has bad channel conditions and the

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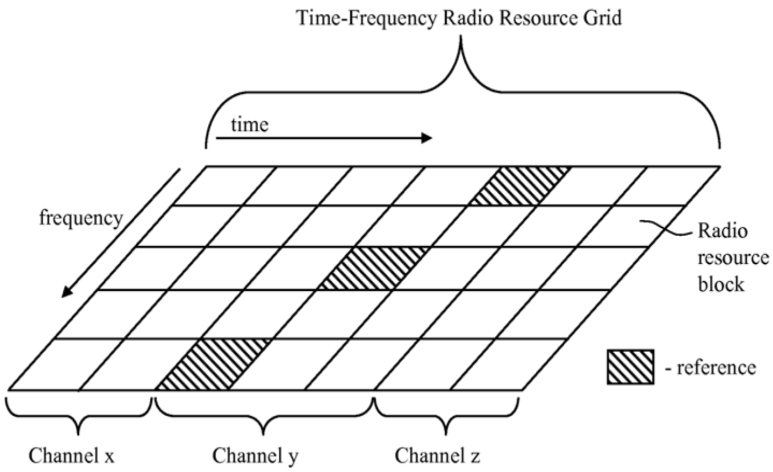

Fig. 1: LTE resource block (Simonsson and Hagerman, 2011)

other has good channel conditions then the throughput of the later one is significantly higher than that of earlier one. Later on Proportional Fairness (PF) was proposed to overcome such a problem (Sesia *et al*., 2009; Hajjawi *et al*., 2015). PF scheme allocates the resources to the users who had the lowest throughput in the previous Transmission Time Interval (TTI) nevertheless other QoS requirements such delay. Another approach namely Maximum Throughput (MT) was proposed in order to improve the overall system throughput (Capozzi *et al*., 2013). MT allocates the resources to the users with highest SNR value which improves the overall system throughput but makes starvation to the users who are located at the cell edge where they have the lowest SNR value. To solve such a problem, Frame Level Scheduler (FLS) was proposed to give attention to the users with tightest delay (Piro *et al*., 2011a). FLS scheme is a two level scheduler which shows an acceptable performance for real time applications which are sensitive to delay. While it doesn't concerns about non-real time applications which results in higher starvation to non-real time users. Musabe and Larijani (2014) proposed a cross-layer scheduling which improves only one real-time application namely VOIP in terms of throughput and delay but it causes a huge starvation for best effort Traffic (FTP). Mushtaq *et al*. (2014) proposed a novel scheduling algorithm which improved the performance for VOIP traffic and compared it with well-known algorithms. The proposed scheme shows better performance in terms of delay sensitivity and Packet Loss Ratio (PLR) whereas it didn't study the non-real time applications. Vulpe *et al*. (2014) proposed an approach which prioritizes the QoS users but it doesn't concern about QoS users with high delay sensitivity which significantly increases the Packet Loss Ratio (PLR). Following the requirements for a scheduler that takes into account both QoS and NQoS users and prioritizes users with tightest delay and the same time improves the overall system throughput, this study proposes a novel scheduling algorithm which overcomes the aforementioned weaknesses.

METHODOLOGY

System model: The proposed algorithm distributes the available resources among users taking into account both QoS and NQoS users. All users are grouped into classes termed as QoS and non-QoS classes. The users who have QoS requirements are allocated more resources. If there is a possibility to serve QoS user with minimum requirements, the users who don't have any QoS requirements are also allocated resources. The proposed algorithm considers the main QoS parameters such delay, data rate and Packet Drop Rate (PDR) and for non-QoS parameters such as users with tolerate delay. In the second stage, users with tightest delay requirements are prioritized to be served within their delay budget. Figure 2 shows the basic diagram of the proposed algorithm.

In the first stage, the proposed model calculates the data rate for each user and allocates the Resource Block (RBs) to the users with highest expected data rate in order to improve the overall system throughput as in (1):

$$R_{i,j}\,(t) = \frac{N_b}{S} \times \frac{N_s}{SL} \times \frac{N_{SL}}{TTI} \times \frac{N_{sub}}{RB} \tag{1}$$

where, N_b is the number of bits in the Symbol (S), N_s is the number of symbols in each Slot (SL), N_{SL} is the number of slots in each Transmission Time Interval (TTI) and N_{sub} is the number of subcarriers in each Resource Block (RB). UEs update their expected achievable SNR to the base station at each TTI which is calculated as in (2):

$$SNR_{i,j}(t) = \frac{p_t \times G_{i,j}(t)}{N(N_0 + I)} \tag{2}$$

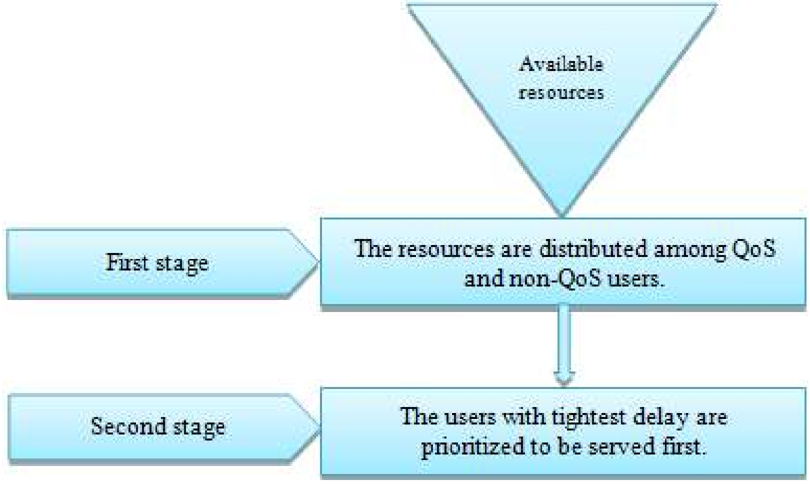

Fig. 2: The basic diagram of the proposed model

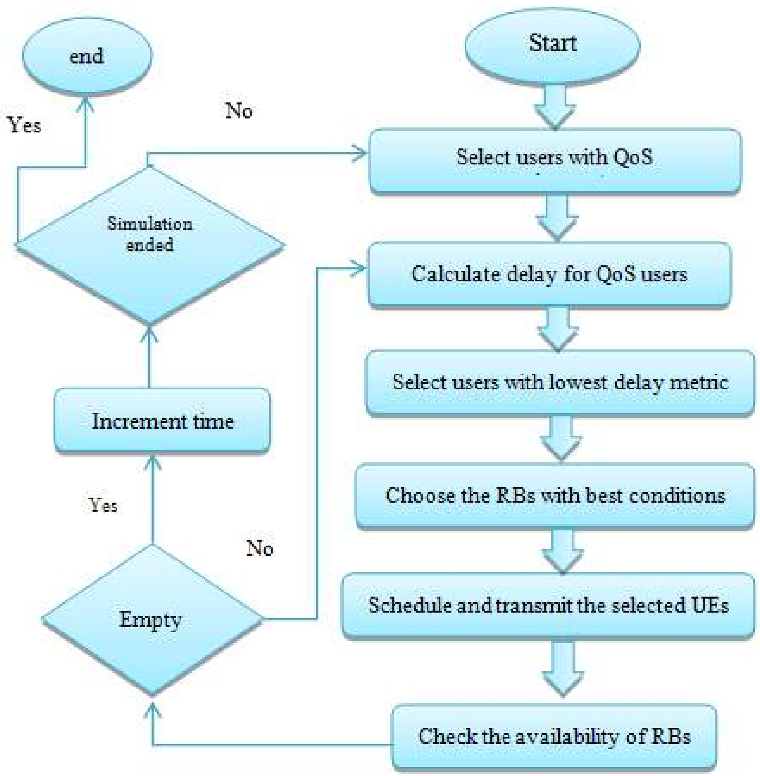

Fig. 3: Illustrates the second stage steps

where, p_t is transmission power, $G_{i,j}\ (t)$ is the channel gain, N is the number of RBs, N_0 is thermal noise measure and I is the cell interference. The first stage is based on following steps:

For each component carrier *c*
  For each user i with QoS requirements
    Compute SINR
    Compute No of RBs
    Compute w
    If user i has QoS requirements
    $\alpha = 1$
    else
      $\alpha = 0$
    end if
    end for
Partition w into w-QoS and w-non-QoS (based on the value of α)
Normalizew QoS with max (w-QoS)
Normalizew non-QoS with max (w-non-QoS)

Table 1: Simulation scenario parameters

Parameter	Value
Cells No.	Single cell
Users locations	Random
Path loss model	Cost 231 model
Base station radius	500 m
Users speed	Up to 3 km/h
Carrier frequency	800 MHz and 2.1 GHz
System bandwidth	10 MHz, 5 MHz each
TTI	1 msec
Scheduling time	Each 1 msec
Number of RBs for	25 each CC

Partition No of RBs into in Nr-QoS and Nr-non-Qos (based on the No of RBs)
Allocate each user with$\alpha\ = 1$nRBs
Allocate each user with non-QoS requirements nRBs
End for

The second stage aims at serving the users with shortest delay first to guarantee higher QoS for real time applications. To start with, the waiting time of the packets which is considered a crucial parameter is calculated as in (3). However, it is defined as the difference in time between current time and the time when the packet entered the queue. Based on this knowledge, the proposed algorithm calculates the packet delay and selects the packets with shortest delay:

$$HOL_j(t) = T_{c,j}(t) - T_{e,j}(t) \quad (3)$$

where, $HOL_j(t)$ is the waiting time of the packet, T_c is the current processing time of the packet and T_e is the time when the packet entered the queue (Ali and Zeeshan, 2012). The difference time between the HOL delay and the packet budget delay (T_b) is calculated as in (4):

$$T_{comparison}(t) = T_{b,j}(t) - HOL_j(t) \quad (4)$$

where, $T_{comparison}(t)$ is the difference time between $T_{b,j}(t)$ and $HOL_j(t)$ which should be positive, $T_{comparison}(t) \geq 0$, otherwise the packet dropped since its delay crosses the budget delay. Figure 3 illustrates the second stage's steps.

Simulation scenario: Both QoS and non-QoS users are randomly distributed in the network with different proportions. The simulation conducted using LTE-Sim simulator which based on C++ (Piro *et al*., 2011b). Moreover, the simulation runs for single cell with a radius of 1 km and the path loss utilized is Cost 231 model. Two CCs are considered with system bandwidth of 10 MHz (5 MHz each CC) and carrier frequency of 800 MHz and 2.1 GHz respectively as shown in Table 1.

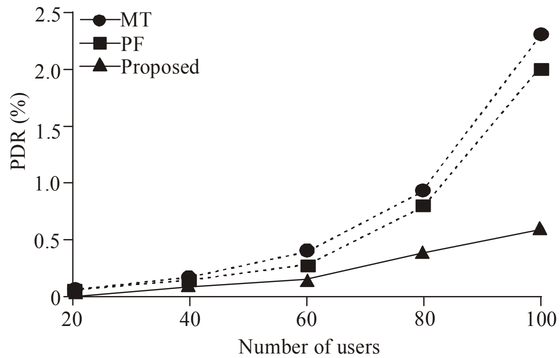

Fig. 4: PDR for QoS users

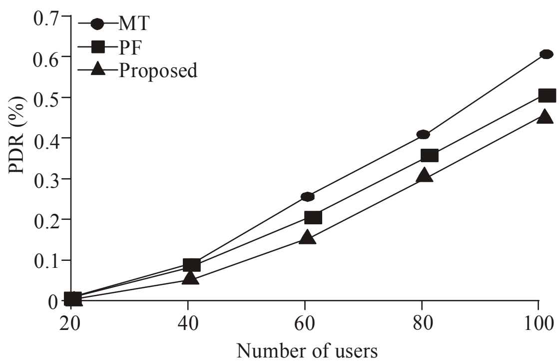

Fig. 5: PDR for NQoS users

RESULTS AND DISCUSSION

The performance of the three comparative schemes is compared in terms of Packet Dropped Rate (PDR), Delay and throughput. The proposed scheme shows the lowest PDR value for users with QoS requirements compared to MT and PF as in Fig. 4. This is because the proposed algorithm prioritizes users with QoS requirements over NQoS ones which reduces the PDR value for the QoS users since they met their requirements. Moreover, the proposed algorithm calculates the delay for all QoS users and serves the users with tightest delay first based on (4). Whereas both MT and PF schemes perform similarly low for QoS users since they don't concern whether the user is QoS or NQoS. For NQoS users, the proposed algorithm slightly outperforms the other schemes since it prioritizes the users with QoS requirements as illustrated in Fig. 5.

MT scheme shows the highest delay for QoS and NQoS users followed by PF as in Fig. 6 and 7. MT allocates the available resources to the users with highest Channel Quality Indicator (CQI) value regardless the users with delay requirements. On other words, it distributes the resources to the users who are close to the base station since they have the highest SNR value. Also PF scheme doesn't concern about delay requirements since it allocates the resources to

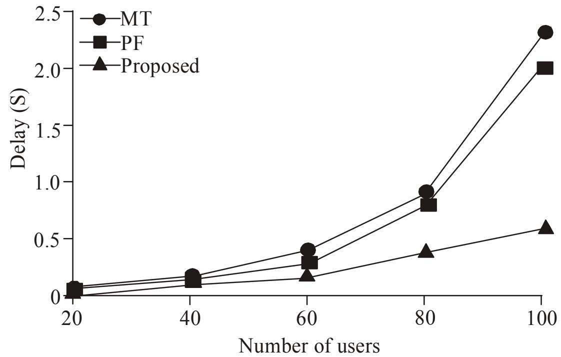

Fig. 6: Delay for QoS users

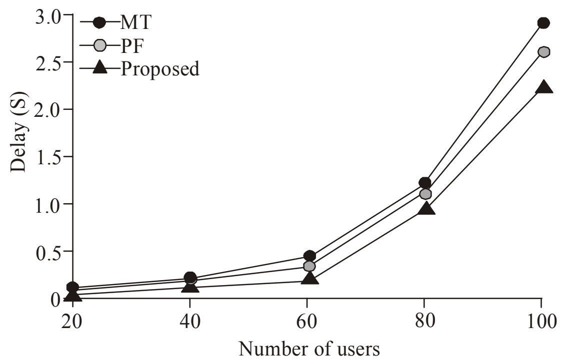

Fig. 7: Delay for NQoS users

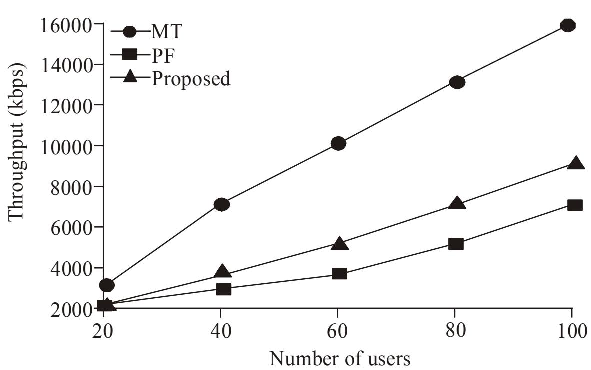

Fig. 8: System throughput

users who had the lowest throughput in the previous TTI. PF algorithm fairly improves the throughput among users which results in higher level of fairness in term throughput than that of MT.

MT scheme outperforms other algorithms for overall system throughput since it distributes the resources to the users with highest CQI value which results in higher overall throughput performance. Whereas PF approach allocates resources to the users who have been starved in the previous TTI. So in the case when PF scheme serves a user who has bad channel conditions, its throughput will be very low, since the Modulation and Coding Scheme (MCS) is low which results in lower throughput as illustrated in Fig. 8.

CONCLUSION

This study has proposed a novel scheduling algorithm for QoS and NQoS users. The proposed model is composed of two levels where in the first level the resources are initially distributed among QoS and NQoS users and in the second level the users with tightest delay requirements are prioritized. The proposed algorithm is evaluated in terms of delay, Packet Drop Rate (PDR) and overall system throughput. The results carried out that the proposed model outperforms the other two comparative schemes in terms of delay and PDR value whereas MT scheme has showed the highest overall system throughput. PF approach has illustrated the lowest performance for all studied parameters.

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