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Resource Allocation Management in LTE System Using Priortized Defict Round Robin (DDR) Scheduling Algorithm

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Abstract— The Long Term Evolution provides a high data rate and can operate in different bandwidths ranging from 1.4MHz up to 20MHz. LTE supports high peak data rates (100 Mb/s in the Down Link and 50 Mb/s in the Up Link), low latency (10ms round-trip delay) and Multiple Input Multiple Output (MIMO) which enhances the throughput and allows seamless integration with an existing systems. However, the resources on LTE network are limited and it has to be allocated in such a way that the highest throughput is attained and fairness is maintained among all types of network connections. As a result of this, allocation of network resources over LTE network has been of major concern over the past few years, so many scheduling algorithms have been proposed. This paper evaluated various scheduling algorithms in Long-Term Evolution (LTE) network and proposed a new scheduling algorithm that improves on the limitation of existing algorithms by making use of Prioritized Deficit Round Robin. In this paper network connection types were categorized into Real-Time (RT) and Non Real-Time connection (NRT); NRT connection is further classified into Urgent NRT (UR) and Non Urgent NRT connections, so as to give fairness to all traffic types. Resource blocks were shared between traffic types using partial sharing system and the deficits (TTI) of old connections were added on to the incoming connections. Network Connection were prioritized such that RT has preemptive power over NRT and UR has preemptive power over Non-Urgent NRT.

Index Terms— Resource Allocation management, Deficit Round Robin, scheduling, LTE, GSM, MIMO

1 INTRODUCTION

Long Term Evolution (LTE) has been designed to support only packet-switched services. It aims to provide seamless Internet Protocol (IP) connectivity between User Equipment (UE) and the packet data network (PDN), without any disruption to the end user's applications during mobility. The term "Long Term Evolution" encompasses the evolution of the Universal Mobile telecommunications System (UMTS) radio access through the Evolved UTRAN (E-UTRAN)

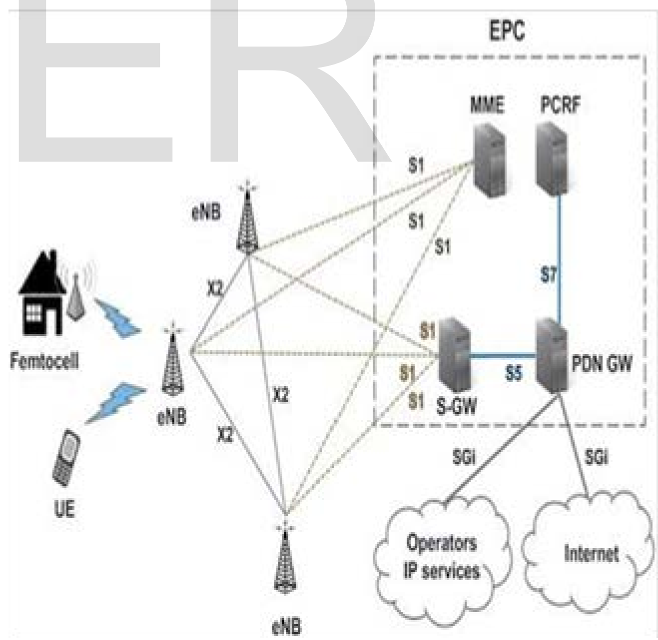

Fig. 1: LTE Network Architecture and Its Interface [1]: [2]

2 RELATED WORKS

In [3] Research on comparison between scheduling techniques in Long Term Evolution discusses the performance of three types of scheduling algorithms namely: Round Robin, Best Channel Quality Indicator (CQI) and Proportional Fair (PF) schedulers representing the extreme cases in scheduling. The scheduling algorithms performances on downlink were measured in terms of throughput and block error rate using a

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MATLAB-based system level simulation. Results indicate that best CQI algorithm outperforms other algorithms in terms of throughput levels. Limitation is on the expense of fairness to other users suffering from bad channel conditions.

In [4]Proposed Deficit Round Robin (DRR) in a research work titled Efficient Fair Queuing using Deficit Round Robin due to the fact that previous schemes for fair queuing that achieved nearly perfect fairness were expensive to implement. Proposed scheme achieves nearly perfect fairness in terms of throughput requirement and is simple enough to implement in hardware. Ordinary round-robin servicing of queues can be done in constant time. Major problem, however, is unfairness caused by possibly different packet sizes used by different flows which is corrected with DRR.

In [5] Delay-aware proportional fair scheduling in OFDMA Networks considered problem of delay-constrained scheduling over wireless fading channels in OFDMA networks like LTE-Advanced networks. Existing scheduling algorithms were considered and extended to OFDMA networks, and their performance was evaluated. Specifically, the problem of scheduling users on the downlink in TD-LTE networks was addressed, and suitably modified proportional-fair and opportunistic schedulers were proposed. Modifications to the opportunistic and proportional fair schedulers were innovative and simple to implement. Also, they helped to a great extent in improving performance of schedulers within the given QoS metrics of packet drops due to deadline exhaustion.

In [6] Researched on the stratified round robin scheduler: design, analysis and implementation because there are a growing number of Internet-based applications (interactive multimedia) that make quality-of-service (QoS) demands on network. Scheduler works by grouping flows of roughly similar bandwidth requirements into a single flow class, and within a flow class, employing a weighted round-robin scheme with deficit. Since all flows within the class have approximately the same weight, unfairness can be bounded. Limitation shows that worst-case fairness is proportional to N, for special case of a single Packet.

In [7]Proposed Variable Quantum Deficit Round Robin (vqDRR) scheduling for improved fairness in multi-hop networks because scheduling algorithms for WiMAX has been a topic of interest for a long time since inception of WiMAX networks. Objective of this algorithm is to allow a fair share of resources among the users. VqDRR based scheduling mechanism provides Quality of Service while at the same time maintaining fairness among users in a Multi-hop networks. Limitation of this research work is that it does not consider scheduling in Mobile Multi-hop Relay (MMR) networks, while maintaining backward compatibility with the legacy 802.16e.

In [8] Research on Design and Implementation of Low Latency Weighted Round Robin (LLWRR) Scheduling for High Speed Networks. Main focus of this research is high speed packet queuing and scheduling at central node such as base station (BS) or router to handle network traffic. They proposed a novel packet queuing scheme termed as Low Latency Weighted Round Robin (LL-WRR) which is simple and effective amendment to weighted round robin (WRR) for achieving low latency and improved fairness. Limitation is that the computation of coefficient introduces additional complexity in proposed scheme but its overall impact will be very small, since it is computed only at the beginning of WRR cycle and not at every packet arrival and departure.

In [9]Modified Opportunistic Deficit Round Robin Scheduling for improved QOS in IEEE 802.16 WBA networks. They proposed two credit based scheduling schemes, one in which completed flows distributes the left over credits equally to all higher priority uncompleted flows (ODRREDC) and another in which completed flows give away all excess credits to the highest priority uncompleted flow (ODRRSDC). Two proposed schemes were compared with opportunity based Deficit Round Robin (ODRR) scheduling scheme. While the ODRR scheduler focuses on reducing the credits for the flows with errors, their approach also distributes these remaining credits together with the credits from completed flows equally among higher priority uncompleted flows or totally to the highest priority uncompleted flow.

In [10] Proposed a Dynamic Uplink Scheduling Scheme for WiMAX Networks. Due to the rapid growth of new services and to achieve Quality of Service (QoS) requirements, an efficient and reliable scheduling algorithm is needed. This paper proposes dynamic uplink scheduling algorithm for WiMAX networks based on VWRR to allocate the bandwidth to users to maximize the throughput and ensure the constraints of delay, jitter, and load and it was compared with Weighted Round Robin algorithm (WRR) and Modified Deficit Round Robin algorithm (MDRR) over WiMAX networks. Simulation results revealed that the proposed algorithm has a superior performance compared with WRR with respect to throughput, delay, jitter, load and also provide an excellent level of reliability and scalability when increasing the number of served subscriber stations

In view of related literatures, it is obvious that focus of most of the literatures are on deficit round robin but without priority to solve challenges of scarce resources experienced in cellular networks. Hence, this paper propose a new model that makes use of deficit round robin with prioritization on the LTE network.

3 Modelling and Simulation

3.1 Methodology

In order to enhance resource block allocation on the LTE network transmission, there should be a scheduling system to allocate the key element of the NodeB that assigns the time and frequency resources to different elements in the cell, Prioritized Deficit Round Robin (PDRR) scheduling method is used to allocate the resources in Complete Sharing (CS) and Partial Sharing (PS) schemes respectively. This schemes (CS and PS) have been used extensively in GSM Networks where both voice and data are accommodated on the networks via radio channels [11]. In the case of LTE, RBs are used for both voice and data transmission which is quite different from GSM networks. The performance of PDRR on both Complete Sharing and Partial Sharing schemes on the LTE network was evaluated using Matlab to the best throughput, fairness, packet loss ratio (PLR) and delay.

A Complete Sharing (CS)

In this work, the traffics are classified into two classes; real time (RT) and non-real time (NRT). Real Time traffic constitutes voice calls, video calls and conferencing and all connections that cannot tolerate delay, most times they are not always as long as NRT connections. They are time sensitive.

Non Real time traffic constitutes internet browsing, chatting on social media and a replay of a television program. NRT connections can accommodate delay thereby making RT connections higher in priority. The NRT is further divided into urgent NRT (UR) and non-urgent NRT (NRT). The CS resources sharing scheme have all the RBs in a central pool and they are all open to access by both RT and NRT without restriction as shown in Fig.2

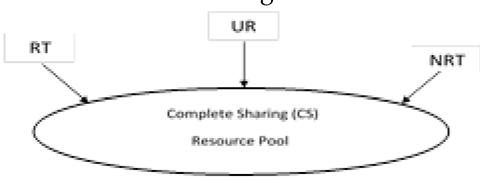
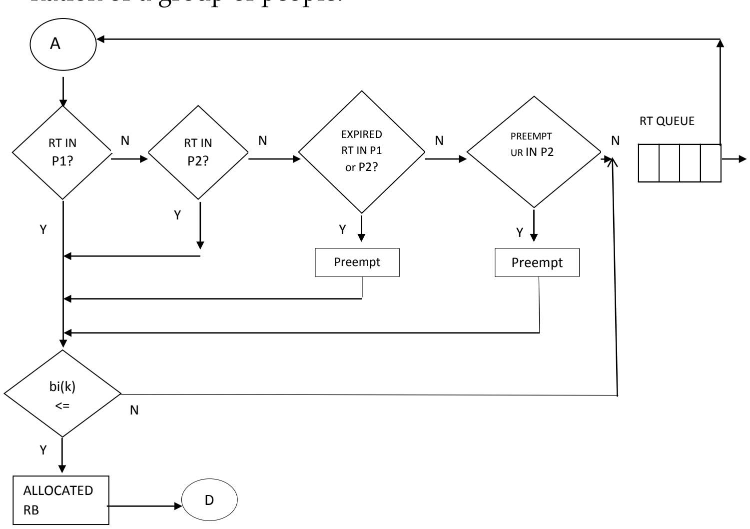


Fig.2: CS Resources Pool

At the initial state of the sharing, the traffics are allocated equal resources based on Round Robin scheme. In the process of allocation if any call arrives and meet the pool used up, it will search for the identity of the user to see if there is any that has lower priority to its own priority. If there is any, it will preempt the call to occupy the RB, else it will be queued. For example, if RT call arrives and meet the pool (RB) engaged, it will search if there is NRT to preempt, else it will be queued. The remaining Transmission Time Interval (TTI) of the lower priority connection will be added to the TTI of the incoming higher priority connection.

B. Partial Sharing (PS)

In Partial Sharing, the resource pool is partitioned into three classes which are real time (RT), non-real +time (NRT) and urgent non real time (UR) as shown in Table 1. Urgent NRT connections are NRT but are time sensitive and they are mostly in short duration but may contain sensitive data or information. They include downloading of Criminal pictures, broadcast of information which deals with the security of a nation or a group of people.



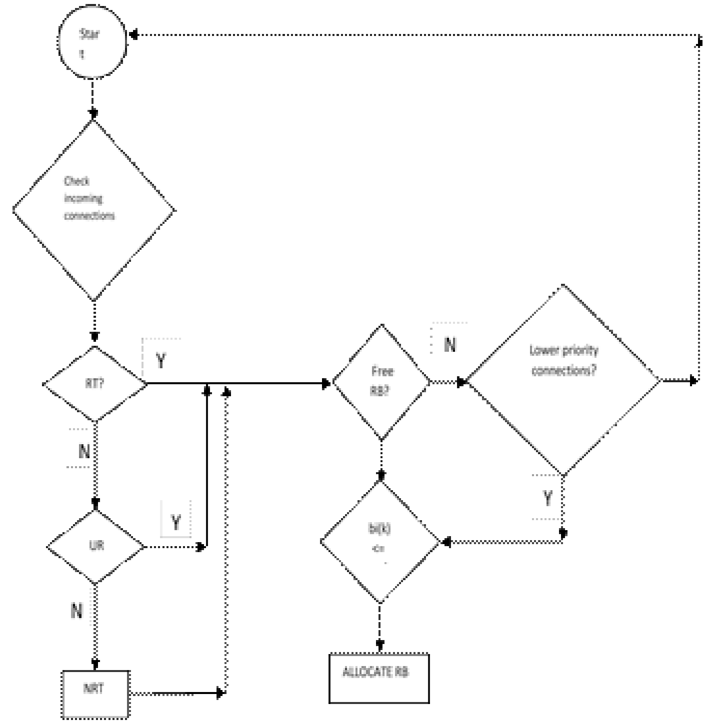


Fig 3: Flow Chart for the Complete Sharing Algorithm

Table 1
Partial Sharing resource pool

Real Time(RT)	Real Time (RT) and Urgent Non Real Time(UR)	Non Real Time (NRT)
P1	P2	P3

The reason for this partition is to give fairness to NRT traffics as well as giving higher priority to Urgent NRT connections (UR) which are time sensitive and contain vital information or data.

C. Deficit Round-Robin (DRR)

The Deficit Round-Robin (DRR) scheduling approach is a queuing algorithm which divides the different data flows into FIFO sub-queues and dequeues from these respective queues in an iterative manner. During each iteration the DRR enabled node uses variables which are corresponding to the sum of the number of allowed bits to transmit and the number of deficit bits from last iteration [4].The deficit variables gives the DRR enable node a higher degree of fairness since it reduces the impact of different packet sizes from different sources. Deficit Round Robin Scheduling Algorithm is described mathematically thus:

Let Qi represent distinct queues Q1 to Qn and CI as the Capacity for each queue i.e. (i = 1, 2, 3… n)

Total queue capacity is given by $C = \sum_i C_i$ (3.1)

The default allocated bit for each queue is given by Q_i^N and are initially set for all services

That shows that for all resource, they are shared equally which implies equal resources for all queues and represented in equation 3.2

$$Q_i^N = Q_j^N \text{ i.e } \left(Q_1^N = Q_2^N\right) \quad \forall i, j \qquad (3.2)$$

For every (∀) iteration K of the round robin cycle, the amount of bits transmitted is bi(k).

The amount of available bits for the next iteration will hence be according to DRR, [4]That is,

$$Q_i^A(k) = D_i(k-1) + Q_i^N \qquad (3.3)$$

The available bits at the next iteration, k+1, is the sum of the default static allowance Q_i^N and the deficit of the previous iteration $(D_i(k))$ which leads to the expression. Therefore, new available bit for the next round of Round Robin is $Q_i^A(k)$

Before a new transmission from the next queue can be allowed, the expression in equation 3.4 must be satisfied:

$$b_i(k) \le Q_i^A(k) \qquad (3.4)$$

The scenario above is for a single traffic. This is true for multiple traffic allocation. That shows for i, j …N

$$b_N(k) = b_i(k), b_j(k), \cdots, b_N(K) \qquad (3.5)$$

and

$$Q_N^A(k) = Q_i^A(k), Q_j^A, \cdots\cdots, Q_N^A(K) \qquad (3.6)$$

Before any transmission could take place for any traffic class, equation 3.7 must be satisfied.

$$b_N(k) \le Q_N^A(k) \qquad (3.7)$$

3.2 The proposed Priotized DRR scheduling algorithm

In this section, a new model for scheduling strategy in LTE called Prioritized Deficit Round Robin (PDRR) is presented. This strategy makes use of deficit round robin with prioritization and carrier sensing. The resource blocks are partitioned to three (P1, P2 and P3) to serve RT, NRT and UR connections as shown in Fig. 2.

The resource blocks are allocated in a round robin manner that is; they are allocated in equal amount to different connections within a fixed transmission time interval after which they can be seized by an incoming connection with lower or higher priority. When there is incoming calls into the system, it will be tested to determine the class of the call, so as to know the next line of action as shown in the flowchart in fig. 3

3.2.1 Real Time Traffic in PDRR Pseudocode

An incoming RT connection checks for free allocatable resource blocks in P1, if there is, allocate the requested resource blocks to the RT connection. Else, check for free resource blocks in P2, if found then it allocates it to the incoming RT connection.

Else check for RT connections that have exceeded their transmission time interval (TTI) or the ones that have completed their task but their TTI has not expired in P1, if found, some of these connections are dropped to free some resource blocks which can be allocated to the incoming RT connections.

In the case where there is a connection that has completed its task but still has unused TTI, the remaining TTI is added to the TTI of the incoming RT connection.

If there are no RT or UR connections that have completed their task or elapsed TTI, the incoming RT connection preempts an UR connection. If there are no UR in P2, it will also check for NRT in P3, if none then the RT connection will be queued.

In the case where the connection is true. The bits to be transmitted have to be compared to the available bandwidth, if the available bandwidth is smaller to the bits expected to be transmitted, the call has to wait and allow the next connection that is lesser to occupy the RB.

3.2.2 Urgent Non-Real Time (UR) in PDRR

An incoming UR connection checks for free allocatable resource blocks in P2, if there is, allocate the requested resource blocks to the UR connection.

Else check for RT or UR connections that have exceeded their transmission time interval (TTI) or the ones that have completed their task but their TTI has not expired in P2, if found, some of these connections are dropped to free some resource blocks which can be allocated to the incoming UR connections. This is also done for the NRT connections in P3, in the case where there is a connection that has completed its task but still has unused TTI, the connection is preempted and the remaining TTI is added to the TTI of the incoming UR connection.

If there are no RT or UR connection that have completed their task or elapsed TTI in P2 and no UR or NRT connection that have completed their task or elapsed TTI in P3, the incoming UR connection preempts an NRT connection in P3. If there are no NRT in P3 then the UR connection will be queued.

In the case where the connection is true. The bits to be transmitted have to be compared to the available bandwidth, if the available bandwidth is smaller to the bits expected to be transmitted, the call has to wait and allow the next connection that is lesser to occupy the RB.

3.2.3 Non-Real Time Traffic in PDRR

An incoming NRT connection checks for free allocatable resource blocks in P3, if there is, allocates the requested resource blocks to the NRT connection. Else, check for NRT connections that have exceeded their transmission time interval (TTI) or the ones that have completed their task but their TTI has not expired. If found, drop some of these connections to free some resource blocks which can be allocated to the incoming NRT connections.

In the case where there is a connection that has completed its task but still has unused TTI, the remaining TTI is added to the TTI of the incoming RT connection. If there are none then the incoming NRT will be queued.

One of the important advantages of Deficit round robin is the ability to gain the excess resource blocks that was not made use of by a previous connection.

4 Modelling and Simulation

4.1 Simulation Results for Real-Time network connections Fairness

The table 2 shows the number of resource blocks that is being requested by real-time connections and the number of resource blocks allocated by each scheduling algorithms. The parameters in this table are were used to plot the graph in Fig. 4.2

Table 2
Allocation fairness for Real-Time connections

Allocation Fairness /Number of Resource Blocks (RB)	PDRR	CS	PS
Allocation Fairness	0.96429	0.54135	0.89286
Allocated RB	18	13	20

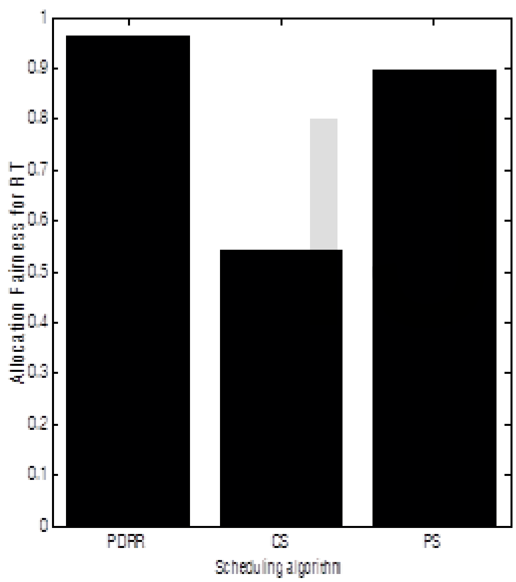


Fig. 4: Allocation fairness for RT connections

PDRR has the highest allocation fairness for RT because it allocates resources to RT based on priority and also allows most RT connections to finish their tasks based on the gained deficits from previous connections. While PS has a slightly lower allocation fairness because although it works like PDRR, it does not make use of deficits. While CS has a low allocation fairness because it RBs are distributed to RT connections and they are cut off immediately their time is complete, which implies that most RT connections will not be able to complete their task and will have to wait for another round of allocation.

4.2 Simulation Results for Urgent Non Real-Time network connections Fairness

Table 3
Allocation fairness for Urgent Non Real-Time connections

Allocation Fairness /Number of Resource Blocks (RB)	PDRR	CS	PS
Allocation Fairness	0.96241	0.75904	0.78397
Allocated RB	16	21	15

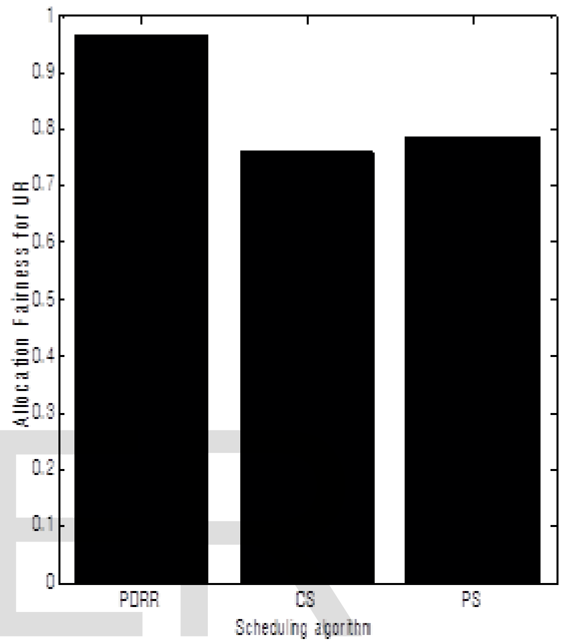


Fig. 5: Allocation fairness for UR connections

PDRR has the highest allocation fairness for UR because it allocates resources to urgent NRT connections which gives advantage to emergency NRT connections that can tolerate little or no delay and also allows most UR connections to finish their tasks based on the gained deficits from previous connections as shown in fig 5. While PS has a slightly lower allocation fairness because although it works like PDRR, it does not make use of deficits. CS has a low allocation fairness because it RBs are distributed to UR connections which can be preempted by an incoming RT connection and they are cut off immediately their time is complete. This implies that, most UR connections will not be able to complete their task and might lead to loss of vital information.

4.3 Simulation Results for Non Real-Time network connections Fairness

Table 4
Allocation fairness for Non Real-Time connections

Allocation Fairness /Number of Resource Blocks (RB)	PDRR	CS	PS
Allocation Fairness	0.64021	0.68571	0.59524
Allocated RB	11	12	10

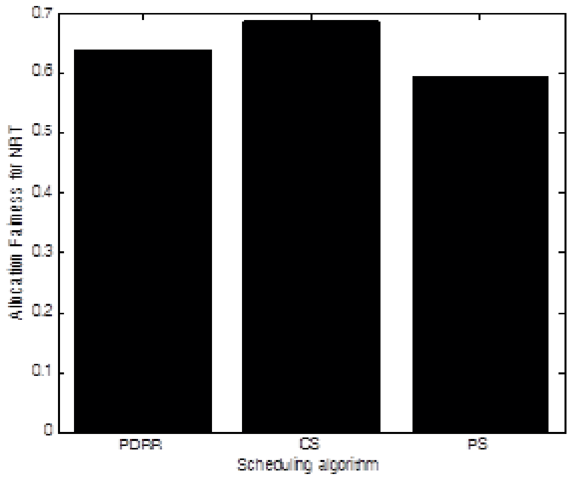


Fig. 6: Allocation fairness for NRT connections

CS has the highest allocation fairness for NRT because most NRT can tolerate delay even if they cannot complete their task in a TTI, they can conveniently continue their task when there is a free RB as shown in fig 6.As an example, browsing on the internet can still tolerate delay while a voice conversation cannot. PDRR has a lower fairness because the partition for NRT RBs in PDRR can make use of by RT and UR connections if there is no free RBs thereby preempting NRT. PDRR has slightly higher allocation fairness for NRT connections in PDRR than in PS because it makes use of deficits which NRT connections can gain from any class of previous connections in fig 7.

4.4 Simulation Result for Throughput

The values of the throughput obtained by the scheduling algorithms are shown in the table 5 and the values are used to generate the graph.

Table 5
Throughput for the scheduling algorithms

Scheduling Algorithms	Throughput (Mbps)
Prioritized Deficit Round Robin (PDRR)	228
Partial Sharing (PS)	167
Complete Sharing(CS)	140

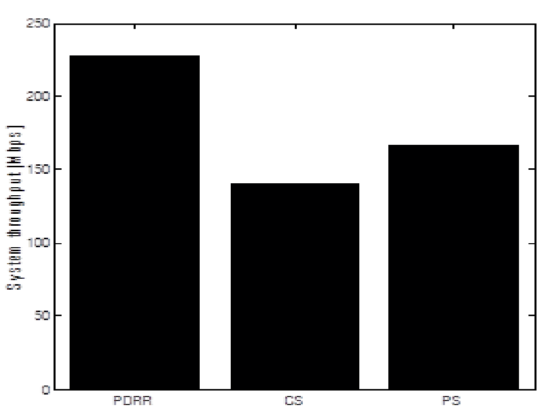


Fig. 7: Throughput for the scheduling algorithms

As shown in the graph in Fig. 7, PDRR has the highest throughput because it is efficient with all classes of calls (RT,NRT and UR).It gives fairness to all call classes and make use of deficits (remaining or unused time) of previous connections. While PS has a lower throughput because though it partitions the resource blocks into classes and priorities, it does not make use of deficits. Unlike PDRR and PS, CS does not partition its resource blocks based on the different types of connections but makes use of a central pool of resources and does not make use of deficits thereby having the lowest throughput and starvation.

4.5 Simulation Results for Number of Allocated Resource Blocks

Table 6
Number of Allocated Resource Blocks

Scheduling Algorithms	RT	UR	NRT
Prioritized Deficit Round Robin (PDRR)	18	16	11
Partial Sharing (PS)	20	15	10
Complete Sharing	12	21	12

As shown in the graph Fig. 8, PDRR has the most efficient allocation of resources for a simulated traffic with RT having the highest followed by UR and NRT which will be very good for real time traffic. It maximizes uses of RBs because the remaining TTI of previous connections are added to the incoming connections. CS has highest number of resource blocks for UR but UR comes only once in a while and therefore should not precede RT connections, RT and NRT has the same number of allocated RBs, it cannot work in a real time scenario. As shown in the graph above PS has highest number of allocated RB for RT because it allocates a fixed portion of RB to incoming connections even though some might not be needed and the RB will be wasted because they cannot be merged with incoming connections thereby leading to high consumption of RBs.

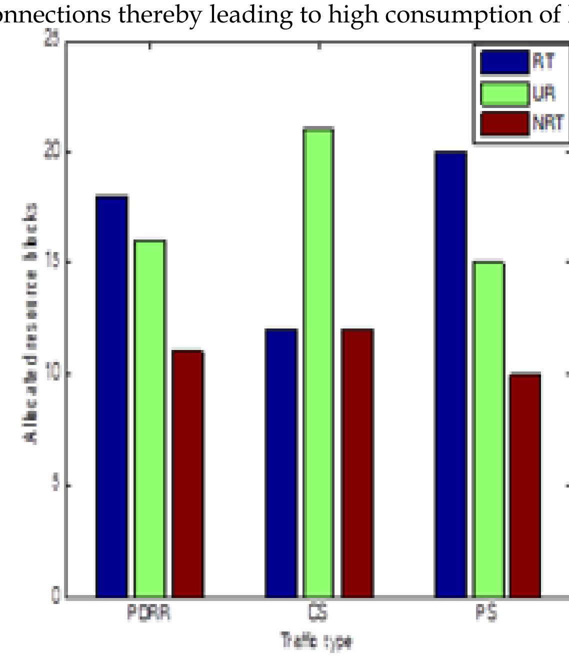


Fig. 8: Resource block allocations for PDRR, CS and PS

4.6 Simulation Results for Packet Loss Ratio

Table 7
Packet Loss Ratio for different scheduling Algorithm

Scheduling Algorithms	Packet Loss Ratio (PLR)
Prioritized Deficit Round Robin (PDRR)	0.7707
Partial Sharing (PS)	0.84141
Complete Sharing	0.86687

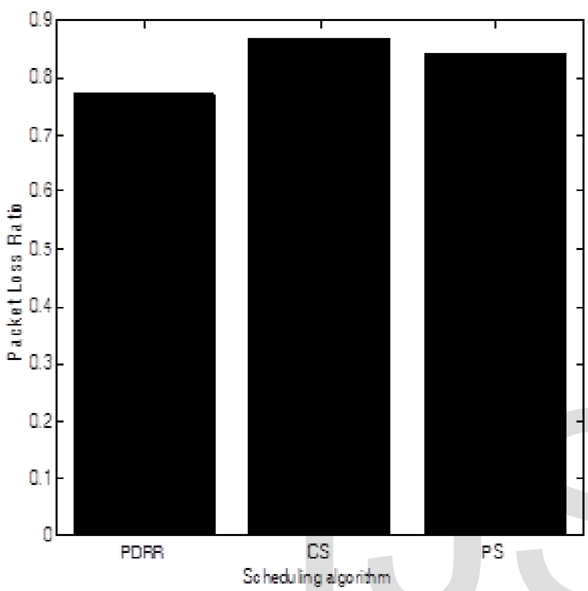


Fig. 9: Packet Loss Ratio for PDRR, CS and PS

Due to high prioritization of PDRR, a flow is more likely to be allowed transmission of a packet (instead of a lower prioritized flow when both have packets ready for transmission) thereby reducing the packet loss. Due to the use of deficits, more time is gained and therefore more packets are processed. PS has a slightly higher PLR because of RBs partitioning for different classes of connections, though, it will still drop packet when their TTI has expired, while CS has the highest PLR because of low prioritization (no partitioning), lower connections will constantly get preempted by higher priority connections, as shown in fig 9

4.7 Simulation Results for Delay.

Table 8
Packet Loss Ratio for different scheduling Algorithm

Scheduling Algorithms	Average Delay (sec)
Prioritized Deficit Round Robin (PDRR)	0.0083897
Partial Sharing (PS)	0.0079748
Complete Sharing	0.0079748

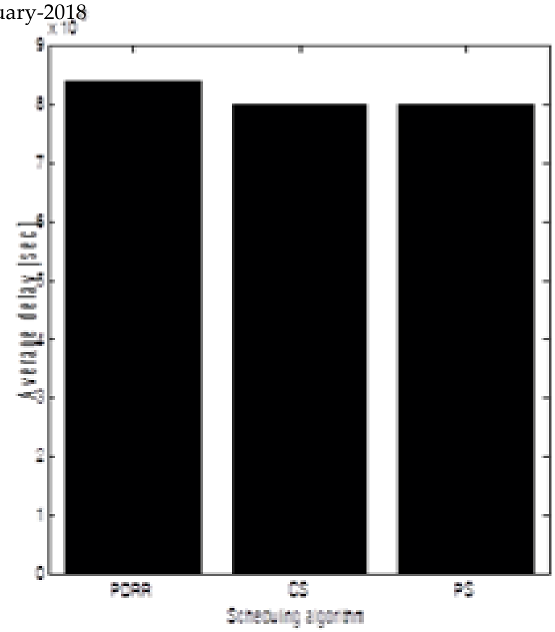


Fig. 10: Average delay in PDRR, CS and PS

Table 7 and Fig 10 showed that PDRR has a high average delay because as an efficient algorithm it has an increased queue capacity and naturally yields more room for packets to be stored, and as more packets can be stored in a queue, the average age of the packets increase, leaving an increased average delay and a potential decrease in packet-loss. The delay statistics should be considered together with the packet-loss. Unlike PDRR, CS and PS have lower average delays which eventually lead to old packets being dropped upon the arrival of new packets.

5 Conclusion

The resources on LTEv network are limited and it has to be allocated in such a way that the highest throughput is attained and fairness is maintained among all types of network connections.As a result of this, the allocation of network resources over the LTE network has been of major concern over the past few years, so many scheduling algorithm have been proposed. in this study, a new model for resorsce allocation was proposed and simulated; therafter, it was compared with two existing scheduling algorithms (complete sharing and partial sharing). The results show that the PDDR performs better than the two algorithms in terms of throughput and allocation fairness, packet loss ratio and average delay which gives maximumthroughput and fairness to all types of network connections. This model should go a long way in maximizing the system's throughput and fairness. Future work will explore different users scenario requiring varios number of network connections.

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