A TRAFFIC SCHEDULER FOR RADIO RESOURCE MANAGEMENT OF LONG TERM EVOLUTION –ADVANCED (LTE-A)

Mohsin Nazir, Ayesha Haider Ali, Ayesha Afzaal, and Aneeqa Sabah

***Abstract*— The ever increasing subscriber's demand for higher data rates pursued International Telecommunications Union (ITU) to define future mobile communications standard named LTE-A to provide higher data rates up to 1 GBPS. With the development of radio access techniques, the radio resource is becoming insufficient. Therefore, it is turning out to be a vital issue that how should the demands for higher data rates with limited resources is met for the evolving 4G network. In this paper, we present a traffic scheduler to distribute the radio resource in an efficient and fair manner according to the priority and QoS requirements of the incoming traffic. It allocates the system resources according to CQI parameters defined in the standard. Apart from allocating resources it also defines preemption rules for higher priority traffic. The idea is to queue the requests coming from several mobile stations according to their service groups. The purpose of dividing the service classes into groups is to decide whether a particular service group can get resources that were assigned to another service group. The results show the fair distribution of resources satisfying user's requirement and achieving higher system throughput.**

***Index Terms*— Service Groups, QoS, Resource Chunks, LTE-A.**

I. Introduction

The volume of traffic on Internet is growing day by day causing congestion in the network. As a result, there are great chances of packet loss. Moreover, different types of data have different requirements, for example, for voice and video delay and jitter should be less. The service class guarantees the quality to all types of services.

PRB is the smallest user assignment resource unit or the smallest unit for resource scheduling. In this allocation phase, the spectrum/ bandwidth is divided into portions called Resource Chunks (RC) as shown in Figure 1. Variable number of RCs is allocated to different UEs for various applications. RC is basically a group of contiguous PRBs.

To provide high performance the scheduler should know radio channel conditions across all users and all RCs. Due to the scarcity of the radio resource, it is challenging to provide user with seeming less service according to their need. Today's popular mobile internet applications, such as voice, gaming, streaming, and social networking services, have diverse traffic characteristics and consequently different QoS requirements. As the femtocells are dense in nature, thus there are issues regarding formulation of RRM (Radio Resource Management) policies that ensure QoS requirements of individual users. Thus there is a need to develop traffic scheduler which ensure QoS and has the capability of fairly distributing the scarce radio resource among its users, moreover achieving high throughput and increased system performance.

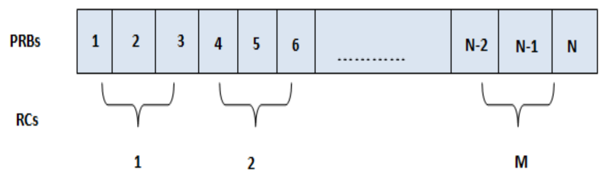

Fig 1: A total of M RCs dividing the total bandwidth into N PRBs.

The work done in [1], explores the issue of contiguous allocation of subcarriers with the help of uplink scheduling with time domain. It uses the Proportional Fair algorithm to achieve fairness. Four algorithms to allocate resources are proposed with the emphasis to gain high throughput and achieve fairness for all the service classes.

The proposed scheduler in [2], provides efficient allocation of radio resources to User Equipments (UEs) according to their Quality of Service (QoS) and channel conditions. The proposed scheduler is divided into Time Domain Packet Scheduling (TDPS) and Frequency Domain Packet Scheduling (FDPS). It also supports multi-bearer UEs in accordance with their buffer size. It divides the RBs into RCs and creates a RB to UE allocation table, makes all possible combinations and chooses the best combination according to metric value.

The scheduling scheme proposed in [3], considers joint and separate user scheduling using carrier aggregation. A non-contiguous carrier aggregation scenario is setup with carriers positioned in the same frequency band and are assumed to have same bandwidth.

Most of the research work [4,5], is directed towards the scheduling of the packets, some consider the fairness only, some emphasize on the allocation of RBs to UEs, others

Mohsin nazir, Ayesha haider ali, Ayesha afzaal, and Aneeqa sabah, Lahore College for Women University, Lahore. Email: mohsinsage@gmail.com

 ISSN – 1999-4974

have the objective of achieving greater throughput. Our work emphasizes not only providing QoS to all service classes fairly but also to achiev high throughput considering most importantly the scarce radio resource. Moreover, we have added the feature of resource preemption to support the incoming traffic with stringent QoS requirements.

The rest of the paper is organized as follows: In section two we will discuss the QoS support in LTE-A. In section three the system model is presented. Section four discussed the preemption rules. Section five discusses the simulation and results.

II. QOS IN LTE-A

In LTE-A, bearer is a packet flow established between the packet data network gateway and the user terminal (UE). The traffic flow between an application and a service can be classified into separate service data flows which are mapped to the same bearer and they get a similar QoS treatment (e.g., scheduling policy and radio resource management). LTE supports two types of bearers [6]:

- Guaranteed Bit Rate (GBR): The GBR bearer will be provided by the network with a guaranteed service rate.
- non Guaranteed Bit Rate (non-GBR): the non-GBR bearer has no such requirement as GBR and may experience congestion.

A scalar value is assigned to each bearer known as a QoS class identifier (QCI). QCI specifies the class of a particular bearer. It indicates the parameters that are pre-configured by the operator according to the type of bearer. Figure 2 shows the packet format of LTE-A. Apart from QCI following are the QoS parameters associated with LTE-A [7]:

- Allocation and Retention Priority (ARP): This parameter is used for call admission control to control the traffic load for a bearer. ARP helps to decide whether a request from the bearer is accepted or rejected.
- Maximum Bit Rate (MBR): This the maximum data rate the bearer should not exceed. It is only for GBR bearers.
- Aggregate MBR (AMBR): This is the total bit rate of a particular group of non-GBR bearers.

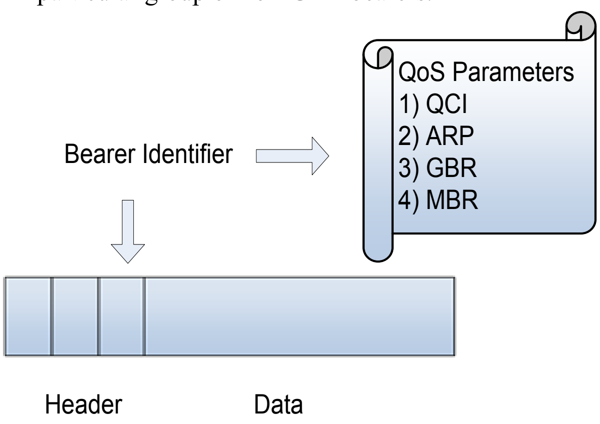

Fig 2: Packet format in LTE-A.

III. SYSTEM MODEL

We will now consider a HeNB with a total capacity/ bandwidth C with K service classes supporting both GBR and non GBR bearers. Different parameters that will be used throughout are explained in the following:

C	Total bandwidth/ system capacity
A_k	Allocated Resource Chunks (RCs) to service group k
R_k	Required RCs of new user belonging to service group k
D_k	Residual RCs for service group k
P_k	Priority of each service group k
G_k	Service group
P_{tot}	Total number of PRBs
R_{tot}	Total RCs assigned to a service group
T_k	Throughput for each service group
T	Total system throughput
n	total number of requests/incoming packets

where $k \in \{1,2,3\}$

As certain traffic class/ flow have stringent QoS requirements for example video, VOIP etc., thus satisfying their requirements is essential to maintain network operations smoothly and achieve higher throughput. Thus, certain rules for resource preemption from lower traffic flows need to be defined. Figure 3 shows the division of service classes/ flows into service groups. The idea is to queue the requests coming from several mobile stations according to their service groups. The purpose of dividing the service classes into groups is to decide whether a particular service group can get resources that were assigned to another service group.

There are total of two service classes one each for GBR and non-GBR bearers respectively. Thus, K=1 for GBR and K=2 for non-GBR bearers. The priority of GBR bearers is always higher than the non-GBR bearers. The rules for preemption define whether a particular service class can lose its assigned resources to satisfy the needs of higher level service class. Thus we have classified the traffic into 3 service groups. Service group 1 and 2 are for non-GBR bearers and group 3 is for GBR bearers.

The priority of service group 1 is the highest, then service group 2 and service group 1 has the lowest priority. Thus,

$P_k = 1$ for service group 1
$P_k = 2$ for service group 2
$P_k = 3$ for service group 3

Group 1 is the lowest priority group thus its resources can be preempted by group 2 and group3. Group 2 also represents the group whose resource can be preempted only by group 1. Group 3 represents the highest priority group whose resources cannot be preempted. The preemption rules are defined in section IV.

A packet scheduler is required that would be capable of scheduling the incoming packets according to their QoS requirements and to ensure fairness among various traffic

ISSN – 1999-4974

flows. Packet scheduling is of great importance to guarantee QoS for various services.

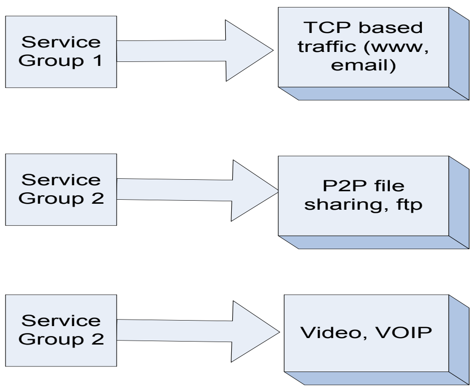

Fig 3: Division of service classes/ flows into service groups.

The HeNB first receives data from various application form a User Equipment (UE) that may be a mobile, a PDA or a laptop etc. It then encapsulates them in the form of packets according to the type of bearer and QoS requirements. Finally the packets are sent to appropriate queues according to certain rules and algorithms.

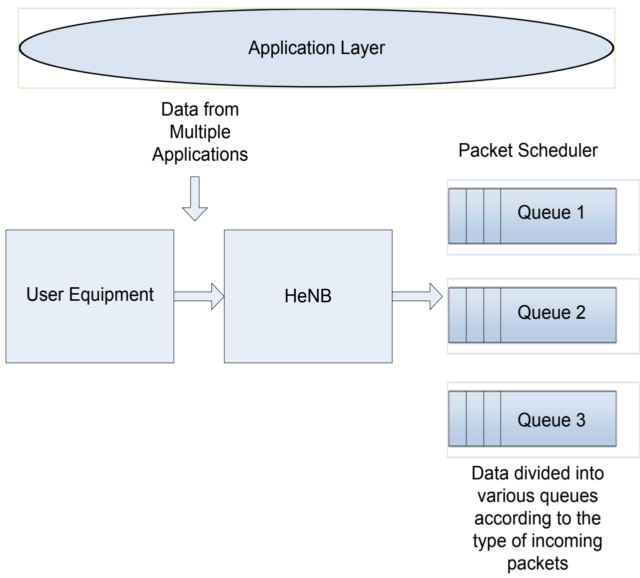

Fig 4: Application level packet scheduler.

The system capacity C is divided into PRBs and these PRBs are then grouped together in RCs to be allocated to a particular service group/ groups. The total number of PRBs in a RC can be calculated by dividing the total PRBs by the total number of requests/incoming packets (belonging to any of the three service groups), that is, one RC is equal to P_{tot} / N. Now the total number of RCs in the system will be divided equally among the three service groups.

The next step is the allocation of RCs to the service groups. The RC allocation algorithm selects the best assignment of RC to a particular service group according to the following steps:

1) Determine the service group of the incoming packet.
2) Assign RCs to the higher priority service groups first and maintain a matrix as shown in Figure 3.
3) Repeat step 1 until all RCs are allocated.
4) If there is still any outstanding request apply preemption rules mentioned in the next section.

As shown in Figure 5, a matrix is maintained for RC allocation to a service group, where $m_{k,N}$ = {0,1}, k$\in$ {1,2,3} and G_1 represents service group 1, G_2 represents service group 2,and G_3 represents service group 3. N= RC number. A 0 shows an unassigned RC for a given service group and 1 shows an assigned RC. Thus we can represent $m_{k,N}$ as:

$$m_{k,N}= \begin{cases} 0, if\ RC_N\ is\ unassigned \\ 1, if\ RC_N\ is\ assigned\ to\ service\ group\ k \end{cases}$$

	RC_1	RC_2	RC_3	RC_4	……	RC_N
G_1	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$	$m_{1,4}$	……	$m_{1,N}$
G_2	$m_{2,1}$	$m_{2,2}$	$m_{2,3}$	$m_{2,4}$	……	$m_{2,N}$
G_3	$m_{3,1}$	$m_{3,2}$	$m_{3,3}$	$m_{3,4}$	……	$m_{3,N}$

Fig 5: Matrix for allocation of RCs to service groups.

For example if we consider the matrix allocation in Figure 6, all the service groups (from G1 to G3) are assigned RCs. The assigned RCs that are allocated to a particular service group are denoted by 1 and unallocated slots are marked by a 0.

	RC_1	RC_2	RC_3	RC_4	……	RC_N
G_1	1	1	0	0	……	0
G_2	0	0	1	1	……	0
G_3	0	0	0	0	……	1

Fig 6: Matrix for allocation of RCs to service groups

Algorithm 1 represents the Service Group G to RC allocation algorithm.

ALGORIT HM 1: RC assignment

1: Let i be the number of users

2: Determine the service group G of the incoming packet

3: Calculate total number of RCs.

4: Let $m_{i,N}$ be the G to RC assignment status

5: According to P_k determine the priority

 ISSN – 1999-4974

6: Assign RCs to higher priority groups first and update the matrix

7: Repeat step 6 until all RCs are assigned

8: For an outstanding request check the matrix for any available RCs and allocate

9:Constantly monitor changes, update matrix and assign RCs to service group G accordingly

Our objective is to manage resource allocation among various service groups so as to maximize performance while providing QoS guarantees to higher level flows and maintaining fairness among different flows. Thus our objective is the maximization of total system throughput T.

For calculating T we will first calculate the throughput for each service group as follows:

$$T_k = R_{tot}\ x\ P_k\ x\ log_2(1 - SINR) \quad (1)$$

Where T_k is the total achievable throughput of a service group k, R_{tot} is the total number of RCs allocated to a service group, and P_k is the priority of the service group. Signal to Interference and Noise Ratio (SINR) is calculated as follows:

$$SINR=P/Interference + Noise \quad (2)$$

where P=desired signal power
Interference= interference from other HeNBs
Noise= thermal noise

We can now calculate total system throughput as follows:

$$T= \sum^{3}_{n=1} T_k \quad (3)$$

After each request and resource allocation the number of remaining RCs needs to be updated and will be done according to the following:

$$D_k= A_k - \sum_{N=1}^{i} m_{k,N} \quad (4)$$

where k=1 for service group1, k=2 for service group 2 and k=3 for service group 3. N represents the RC number. In the next subsection the preemption rules are defined so as to decide whether an incoming request can preempt the resource to an assigned service group.

IV. PRE EMPTION RULES

Before defining the preemption rules we will consider that total number of RCs assigned to a particular service group, required RCs for a service group and the remaining RCs for a particular service group are denoted by A_k, R_k and D_k respectively. They can be calculated by the matrix values given in Figure 3.

Also group 3 represents the group whose resources cannot be preempted and group 1 and 2 are the ones whose resource can be preempted. Group 3 can preempt resources from group 1 and 2, whereas group2 can only preempt resources for group1. Group 1 is the least priority group and thus cannot preempt resource from any other group. The total RCs assigned to the service group after preemption is updated according to the following equation:

$$A_k= A_k + R_k \quad (5)$$

where k=1 for service group1, k=2 for service group 2 and k=3 for service group 3. N represents the count of total RCs.

Rule 1: for an incoming packet/request belonging to service group 3 whose $D_k < R_k$. If D_k for group 1 is greater than or equal to the R_k for service group 3 then the request is accepted otherwise D_k for group 2 is checked, if D_k for group 2 is greater than or equal to the R_k for service group 3 then the request is accepted otherwise it is rejected. Also the matrix values will be updated accordingly.

Rule 2: for an incoming packet belonging to service group 2 whose $D_k < R_k$. If the R_k for group 1 is greater than or equal to the R_k for service group 2 then the request is accepted otherwise it is rejected.

Rule 3: for an incoming packet belonging to service group 1 if D_k for group 1 is greater than or equal to its R_k then the request is accepted otherwise it is rejected.

Algorithm 2 represents the resource preemption rules, according to which the service group of the incoming packet is determined and according to that the above mentioned rules are applied. K=3 for service group 3 (the highest priority group), k=2 for service group 2 and k=1 for service group1 (the lowest priority group).

V. SIMULATION AND RESULTS

To measure the effectiveness of the proposed scheduling scheme the main simulation parameters are listed in the following table:

Table I. Simulation Parameters.

No. of users	5
Channel Model	Path Fading
Total transmission power	43 dBm
Transmission Time Interval (TTI)	1 ms
Bandwidth	20 MHz
Frame length	1 ms
No. of Service Groups	4

 ISSN – 1999-4974

To compare the effectiveness of the scheduler, all users will receive the same data rate. We have carried out the experiment to depict that our resource allocation is fair and achieves highsystem throughput for higher priority traffic.

For example Group 3 has the highest priority packets and thus should be scheduled first and should have high throughput. Moreover, in case all RCs are allocated this group will have access to the resource reserved for lower priority groups.

The following experiment shows the achieved throughput for all the three service groups.

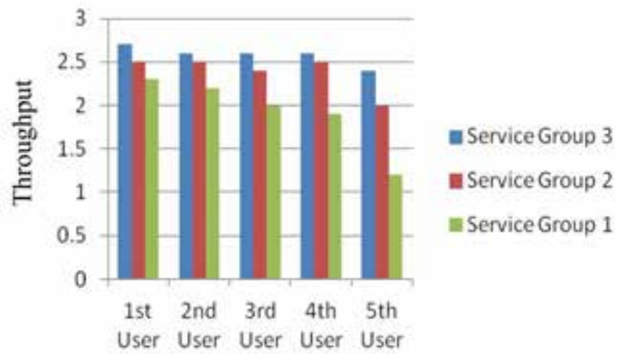

Fig 7: Throughput for each Service Group.

Comparing the throughput for each service group we can see that the throughput for service group 3 is highest as it is the highest priority group. Also the throughput for other service groups is not much degraded due to proposed algorithm for service group to RC allocation.

VI. CONCLUSION

This paper focuses on the resource management problem faced in LTE-A. Resource allocation methods can be utilized to assign some limited resources such as bandwidth and power, in such a manner so as to maximize performance. The proposed scheduler considered achieving QoS for various service groups to achieve high throughput and fairness. The results have shown that the resources are allocated fairly and high throughput is achieved for the prioritized traffic using the resource preemption strategy.

ALGORITHM 2: Resource preemption rules.

for an incoming packet determine the service group
if k=3 then
if $D_k < R_k$ then
if $D_{k-2} \geq R_k$ then
Accept request and update $m_{i,N}$ in the input matrix
else
if $D_{k-1} \geq R_k$ then
Accept request and update $m_{i,N}$ in the input matrix
else
Request rejected
end if
end if
else
if k=2 then
if $D_k < R_k$ then
if $D_{k-1} \geq R_k$ then
Accept request and update $m_{i,N}$ in the input matrix
else
Request rejected
end if
end if
else
if k=1 then
if $D_k < R_k$ then
Request rejected
Else
Accept request and update $m_{i,N}$ in the input matrix
end if
end if
end if

REFERENCES

[1] Suk-Bok Lee, Loannis Pefkianakis, Adam Meyerson, Shugong Xu, and Songwu Lu, “ Proportional Fair Frequency-Domain Packet Scheduling for 3GPP LTE Uplink”, IEEE INFOCOM 2009.

[2] Safdar Nawaz Khan Marwat, Thushara Weerawardane, Yasir Zaki, Carmelita Goerg, and Andreas Timm-Giel, “ Performance Evaluation of Bandwidth and QoS AwareLTE Uplink Scheduler”, Springer 2012.

[3] L. Zhang, Y.Y. Wang, L. Huang, H.L. Wang, and W.B. Wang, “QoS Performance Analysis on Carrier Aggregation Based LTE-A Systems”, Wireless Mobile and Computing (CCWMC 2009).

[4] Hung Pham, Xuan Nhan Vu, and Seung-Hoon Hwang, “Service Class-Aided Scheduling for LTE”, ICACT 2011.

[5] G. Piro, L.A. Grieco, G. Boggia, and P. Camarda,“ QoS provisioning in LTE-A networks with relay nodes”, Proceedings of IFIP Wireless Days Conference 2012 IEEE.

[6] Mehdi Alasti. Behnam Neekzad, Jie Hui and Rath Vannithamby, “Quality of Service in WiMAX and LTE networks”, IEEE Topics in Wireless Communications, 2010, 48(5), pp.104-111.

[7] H. Ekstrom, “QoS control in the 3GPP evolved packet system,” IEEE Communication Magazine, Feb. 2009, pp.76–83.

[8] Pei Li and Weiling Wu, “Traffic load and QoS-oriented packets scheduling for WCDMA communication,”, IEEE ICCC 2006, vol.5, pp.2490-2494.

[9] Yizhe Li, Zhiyong Feng, Shi Chen, Yami Chen, Ding Xu, Ping Zhang and Qixun Zhang, “Radio resource management for public femtocell networks”, EURASIP Journal on Wireless Communications and Networking, SpringerOpen Journal 2011 ,1(1), pp.181-196.

[10] Domenico, Antonio De, Strinati, Emilio Calvanese, "A radio resource management scheduling algorithm for self-organizing femtocells", IEEE Personal, Indoor and Mobile Radio Communications Workshops (PIMRC Workshops), 2010, pp.191-196.

[11] Chung Shue Chen, Franc¸ois Baccelli, and Laurent Roullet, “Joint optimization of radio resources in small and macro cell networks” IEEE 73rd Vehicular Technology Conference Vehicular Technology Conference (VTC Spring) 2011, pp.1-5.

[12] Claudio Stocchi, Nicola Marchetti, and Neeli Rashmi Prasad, “Self-optimized radio resource management techniques for LTE-A local area deployments”, Wireless Vitae, IEEE 2nd International Conference on Computing & Processing 2011, pp.1-5.

 ISSN – 1999-4974